Scientific Programme

Monday, August 27

Session 1: Opening Talk & FEL Prize and New Lasing

Chair N.Vinokurov

09:20 – 09:50 Opening of FEL-2007, G.N.Kulipanov
Opening Address by Budker INP Director A.N.Skrinsky

09:50 – 10:10 Guillaume Lambert, Commissariat à l'energie atomique, "First Lasing in Seeding Configuration at 160 nm Using High order Harmonic Generated in gas on the FEL of the SCSS Prototype Accelerator"

10:10 – 10:30 Peter van der Slot, University of Twente, "Lasing of a Cherenkov FEL Driven by a Low Electron Beam Current"

10:30 – 10:50 Giovanni De Ninno, ELETTRA, "First Lasing of the Elettra Storage-Ring Free-Electron Laser in Seeded Configuration"

10:50 – 11:10 Coffee break

Session 2: FEL Prize lectures

Chair E.J. Minehara

11:10 – 11:50 Evgeny Saldin, DESY, 2006 FEL Prize Winner, "Self-Force-Derived Mass of an Electron Bunch"

12:00 – 12:40 Jörg Rossbach, DESY, Hamburg University, 2006 FEL Prize Winner, "Technology Challenges Towards Short-Wavelength FELs"

12:40 Group Photo (Budker INP main entrance)

13:00 – 14:00 Lunch (Budker INP Canteen)

14:00 – 16:10 Monday Poster Session: FEL Theory, FEL applications, FEL operations, FEL projects

Session 3: FEL Theory

Chair L.H. Yu

15:50 – 16:10 Coffee break

16:10 – 16:35 Neil Thompson, Daresbury Laboratory Accelerator Science and Technology Centre, "Short Wavelength Regenerative Amplifier FELs"

16:40 – 16:55 Oleg A. Shevchenko, Budker INP, "Numerical Solution of the FEL Correlation Function Equation"

17:00 – 17:15 Oleg Chubar, Synchrotron Soleil, "Numerical Propagation Simulations and Coherence Analysis of SASE Wavefronts"

17:20 – 17:35 Gianluca Geloni, DESY, "Impact of Longitudinal Space-charge Wake from FEL Undulators on Current-enhanced SASE Schemes"

17:40 – 17:55 Gennady Stupakov, SLAC, "Space Charge Effect in an Accelerated Beam"

Tuesday, August 28

Session 4: High Power FELs

Chair V.N. Litvinenko

09:00 – 09:25 George R. Neil, Jefferson Lab, "High Power FEL Developments – A Review"

09:30 – 09:45 Alexander N. Matveenko, Budker INP, "Electron Outcoupling Scheme for the Novosibirsk FEL"

09:50 – 10:05 Stephen Vincent Benson, Jefferson Lab, "A Comparison of Short Rayleigh Range FEL Performance with Simulations"

10:10 – 10:25 Michelle Diane Shinn, Jefferson Lab, "Extended High Power Operation of the Free-Electron Laser at Jefferson Lab"

10:30 – 10:45 Peter van der Slot, University of Twente, "Modelling Mirror Aberrations in FEL Oscillators Using OPC"

10:50 – 11:10  Coffee break

Session 5: X-ray FELs

Chair J. Rossbach

11:10 – 11:35 Holger Schlarb, DESY, "FLASH Upgraded - Preparing for the European XFEL"

11:40 – 11:55 Tsumoru Shintake, RIKEN SPring-8, "Status of SCSS & X-ray FEL Project in Japan"

12:00 – 12:15 Jens Knobloch, BESSY, "STARS – an FEL to Demonstrate Cascaded HGHG"

12:20 – 12:35 Anne Oppelt, PSI, "Towards a Low Emittance X-ray FEL at PSI"

12:40 – 12:55 Kwang-Je Kim, ANL, "One Angstrom FEL Oscillator using ERL Beams"

13:00 – 14:00  Lunch (Budker INP Canteen)

14:00 – 16:10 Tuesday Poster Session: High Power FELs, Storage Ring FELs, X-ray FELs

Session 6: Storage Ring FELs

Chair M.-E.Couprie

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16:10 – 16:35 Vladimir N. Litvinenko, BNL, "No-nonsense Approach to Storage Ring FEL Physics"

16:40 – 16:55 Marie Labat, Commissariat à l'energie atomique, "Even Harmonic Generation on UVSOR-II Storage Ring"

17:00 – 17:15 Francesca Curbis, ELETTRA, "Seeded Harmonic Generation with the Elettra Storage-Ring Free Electron Laser"

17:20 – 17:35 Y. K. Wu, FEL/Duke University, "A Versatile High Gain Storage Ring FEL Powered by a Distributed Optical Klystron"

Wednesday, August 29

Session 7: FEL Technology I

Chair F. Stephan

09:00 – 09:25 David Dowell, SLAC, "Commissioning Results of the SLAC LCLS Gun"

09:25 – 09:50 Enrica Chiadroni, INFN/LNF, "Direct Measurement of Phase Space Evolution in the SPARC High Brightness Photoinjector"

09:50 – 10:05 Jonathan D. Jarvis, Vanderbilt University, "Development of Nanodiamond-Field-Emission Arrays for Free-Electron Lasers"

10:10 – 10:25 Ilan Ben-Zvi, BNL, "Superconducting Photoinjector for High-Power Free Electron Lasers"

10:30 – 10:45 Alex Lumpkin, ANL, "A Compact Electron Spectrometer for an LWFA"

10:50 – 11:10 Coffee break

Session 8: FEL Technology II

Chair A. Lumpkin

11:10 – 11:35 Hiromitsu Tomizawa, JASRI/SPring-8, "Adaptive 3-D UV-laser Pulse Shaping System to Minimize Emittance for Photocathode RF Gun"

11:40 – 11:55 Frank Stephan, DESY Zeuthen, "Recent Experimental Results from PITZ"

12:00 – 12:15 Rolf Treusch, DESY, "Performance Tests of the Photon Monochromator for Self-seeding at FLASH"

12:20 – 12:35 Bernd Steffen, DESY, "Single-Shot Longitudinal Bunch Profile Measurements at FLASH Using Electro-Optic Detection: Experiment, Simulation, and Validation"

12:40 – 12:55 Yurii Levashov, SLAC, "Magnetic Measurements, Tuning and Fiducialization of LCLS Undulators at SLAC"

13:00 – 14:00 Lunch (Budker INP Canteen)

14:00 – 16:10 Wednesday Poster Session: FEL Technology I & II

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16:10 – 18:00 Excursion to Novosibirsk FEL

Thursday, August 30

Session 9: FEL Operation

Chair P. Michel

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09:25 – 09:50 Siegfried Schreiber, DESY, "Operational Experience of FLASH"

09:50 – 10:05 Pavel V. Molchanov, Belarussian State University, "Experimental Study of Volume Free Electron Laser Using a "Grid" Photonic Crystal with Variable Period"

10:10 – 10:25 Xijie Wang, BNL, "Experimental Studies of Efficiency and Spectral Control in a Laser Seeded FEL Amplifier at the NSLS SDL"

10:30 – 10:45 Vitaly V. Kubarev, Budker INP, "Light Pulse Structure, Spectrum and Coherency of Novosibirsk Terahertz Free Electron Laser"

10:50 – 11:10  Coffee break

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Chair I. Lindau

11:10 – 11:35 Rolf Treusch, DESY, "Research Highlights from FLASH"

11:40 – 11:55 Alexander van der Meer, FOM Rijnhuizen, "FELICE, the Free Electron Laser for Intra-Cavity Eperiments"

12:00 – 12:15 Sergey E Peltek, ICG SB RAS, "FEL Irradiation Use for the Biochip Production Standardization"

12:20 – 12:35 Boris Kapilevich, CJS, "Millimeter Waves Sensing Behind Walls - Feasibility Study with FEL Radiation"

12:40 – 12:55 Peter Weightman, Daresbury Laboratory, "The Scientific Programme of the UK Fourth Generation Light Source: 4GLS"

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Chair S. Werin

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09:50 – 10:05 Oleg A. Shevchenko, Budker INP, "Compact Ring FEL as a Source of High Power Infrared Radiation"

10:10 – 10:25 Goro Isoyama, ISIR, "Re-Commissioning of the Far-Infrared Free Electron Laser for Stable and High Power Operation after the Renewal of the L-Band Linac at ISIR, Osaka University"

10:30 – 10:45 Brian W.J. McNeil, USTRAT/SUPA, "4GLS: a Facility for the Generation of High Brightness, Variably Synchronised Sources from THz into the XUV"

10:50 – 11:10  Coffee break

Session 12: Conference Closing

Chair N. Vinokurov

11:10 – 12:00 World FEL Projects Review (to be confirmed)

Closing remarks

Conference closing

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MOAAU01 First Lasing in Seeding Configuration at 160 nm Using High order Harmonic Generated in gas on the FEL of the SCSS Prototype Accelerator

Guillaume Lambert, Bertrand Carré, David Garzella, Olivier Bernard Gobert, Marie Labat, Hamed Merdji, Pascal Salieres (CEA, Gif-sur-Yvette), S. Inoue (JASRI/SPring-8, Hyogo-ken), Toru Hara, Hideo Kitamura, Tsumoru Shintake, kazuhiko tahara, Yoshihito Tanaka (RIKEN Spring-8 Harima, Hyogo), Oleg Chubar, Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Takanori Tanikawa (University of Hyogo, Hyogo)

Coherent radiation has been observed at 160 nm, 54 nm and 32 nm (respectively fundamental, 3rd and 5th non linear harmonics) by seeding the 5th harmonic of a Ti: Sa laser (800 nm, 50 mJ, 10 Hz, 100 fs) generated in a Xe gas cell inside the FEL of the SCSS (SPring-8 Compact Sase Source, Japan) Prototype Accelerator. In this configuration, the external source is focalized at the beginning of the first in-vacuum undulator section (300 periods, 15 mm of period) in order to interact properly with the electron beam (150 MeV, 0.3 nC, 10 Hz, 1 ps). The details of the experimental set-up will be given. With one undulator section, high amplification levels and shortening of the spectral width compared to the spontaneous emission have been measured. When adding the second undulator section, saturated signal is apparently observed. The measurements are then compared with time dependant simulations using PERSEO and GENESIS included in SRW. Finally, perspectives offered by seeding an FEL with High order Harmonics Generated in gas, following this first experimental demonstration, will be derived for 4th generation light sources in the soft X-ray range.

MOAAU02 Lasing of a Cherenkov FEL Driven by a Low Electron Beam Current

Peter van der Slot, Klaus Boller, Isabel de la Fuente (Mesa+, Enschede)

We have designed and constructed a compact (0.5 x 1.5 m), 100 kV Cerenkov FEL operating at around 20 to 25 GHz*. The electron beam is produced by a gridded thermionic electron gun, which yields a maximum current of about 500 mA. This current is injected into a cylindrical waveguide lined with Al2O3 and about 60 % of the beam is transported through the lined waveguide section. A transported current of only 250 mA was sufficient to observe lasing. The total power generated for an interaction length of 25 cm was about 3 W. Although not designed as an oscillator, reflections at various positions along the waveguide provide a low-Q resonator. The power observed was in good agreement with results obtained with a model of the CFEL when reasonable values are used for beam quality, resonator feedback and liner fluctuations**. Measurement of the tuning with voltage showed excellent agreement with theory, and indicates operation at the fundamental TM01 mode as well as on higher order modes.

* Proceedings of the 2004 FEL Conference, Trieste, Italy, 2004, p314-317

** J. Appl. Phys. 100, 053108 (2006)

MOAAU03 First Lasing of the Elettra Storage-Ring Free-Electron Laser in Seeded Configuration

Giovanni De Ninno, Enrico Allaria, Miltcho B. Danailov, Bruno Diviacco, Emanuel Karantzoulis, Luca Romanzin, Carlo Spezzani, Svetla Tileva, Mauro Trovo (ELETTRA, Basovizza, Trieste), Marcello Coreno (CNR - IMIP, Trieste), Francesca Curbis (ELETTRA, Basovizza, Trieste; Università degli Studi di Trieste, Trieste)

We report the first lasing of the Elettra storage-ring free-electron laser operated in “single-pass” seeded configuration. The external seed was provided by a Ti:Sa laser tuned at 780 and 390 nm, with adjustable repetition rate (10 Hz – 1kHz) and pulse duration (100 fs or 1 ps). We have obtained intense coherent radiation in the spectral range between 130 and 260 nm. Harmonic pulses are characterized by high peak power (orders of magnitudes above spontaneous radiation) and very good stability (fluctuations of few percent). The signal is transform limited. The Elettra optical klystron is made of independent APPLE-type undulators. This allows complete freedom in the choice of light polarization. Presently, all the above features make the Elettra free-electron laser in seeded configuration a unique light source, which is attractive for several user experiments.

MOBAU01 Self-Force-Derived Mass of an Electron Bunch

Evgeny Saldin (DESY, Hamburg)

The properties of Lorentz transformations for energy and momentum in electromagnetic systems are illustrated in a simple example involving a short electron bunch moving in a bending magnet. The famous 4/3 problem in electromagnetic mass is discussed.

MOBAU02 Technology Challenges Towards Short-Wavelength FELs

Jörg Rossbach (Uni HH, Hamburg)

Since the very first proposal of high-gain FELs for the X-ray wavelength regime it was obvious that realization of such a device, potentially rewarding revolutionary science opportunities, would impose extraordinary challenges in terms of accelerator physics and technology. The talk will review the major steps that had to be taken to finally construct an FEL user facility for soft X-rays. Also, a few issues will be pointed out that are to be addressed in order to make full profit of the FEL principle at X-ray wavelengts.

MOPPH001 Quantum Electrodynamics Theory of a Multimode Undulator Oscillator

Sergei Georgii Oganesyan

We have studied the operation of a free electron oscillator (FEO) in a multimode regime. Our device includes a long undulator, two mirrors and a space-uniform e-beam of a Gaussian energy spread. Using the Heisenberg picture and neglecting both the contributions of the electron intrinsic magnetic moment and the positron fields we have derived a set of temporal equations for the operators of the electron and electromagnetic fields. The set correctly describes both the evolution of the modes' fields from a spontaneous noise and the process of amplification. We have neglected the nonlinear losses and studied a non steady-state lasing regime. Namely, applying a perturbation theory for the electron operators and a technique of slowly varying functions for the electromagnetic field operators we have calculated the operators of the electric fields. Using this result we have estimated the oscillator energy flux in the forward direction. It is shown that within the framework of the chosen model the total flux is a sum of fluxes of unlocked modes. We have estimated the oscillator line width, the number of activated modes and, as a result, the power of the FEO that operates in the exponential regime with unlocked modes.

MOPPH002 Generation of Short Pulses by an Undulator Oscillator with an Electron Absorber Placed into Cavity

Sergei Georgii Oganesyan

We have considered the operation of an e electron oscillator, which contains a long undulator, two mirrors, a space-uniform e-beam and an absorber which allows tuning the lifetime of the electrons within the cavity. Our study is based on the quantum electrodynamics approach. Using a Heisenberg picture we have derived two temporal deferential equations for the electromagnetic field operators. The equations describe the electron absorption by the absorber as well as a wide-band spontaneous noise produced by the electron, and the process of the amplification of the activated modes by the electron beam. To maintain a constant value of the system gain we have adopted that there is a pumping mechanism, which compensates the process of the electron absorption and supports the same density of the active medium. We have estimated the oscillator energy flux in the forward direction at a fixed point. It is shown that the device produces a chain of pulses. Since the contribution of losses is omitted the pulse amplitudes exponentially increase in time. The duration of the pulses may be short due to the large number of the locked modes.

MOPPH003 VOLC: Volume Free Electron Laser Simulation Code

Svetlana Sytova (Belarussian State University, Minsk)

First lasing of Volume Free Electron Laser (VFEL) in mm wavelength range was obtained recently*. Multi-wave volume distributed feedback where electromagnetic waves and electron beam spread angularly one to other in a spatially-periodic target is the VFEL distinctive feature**. Mathematical model and numerical methods for VFEL nonlinear stage simulation were proposed*** and implemented in computer code VOLC that means "VOLume Code". It was developed on the basis of multiple Fortran codes created in 1991-2006 years. VOLC allows to simulate different geometries of two- and three-wave VFEL in amplifier and oscillator regimes. Electron beam is modelled by averaging over initial phases of electrons. Dimensionality is 2D (one spatial coordinate and one phase space coordinate) plus time. All numerical results obtained using VOLC are in good agreement with analytical predictions of VFEL theory. Different roots to chaos in VFEL were investigated using VOLC. Some successful simulations of VFEL experimental setup at INP were carried out. A description of VOLC possibilities and representative numerical results are presented.

* V.G. Baryshevsky et al., NIMA483 (2002) 21.

** V.G. Baryshevsky, NIMA445 (2000) 281.

*** K.Batrakov, S.Sytova, Computational Mathematics and Mathematical Physics 45 (2005) 666.

MOPPH004 Measurement and Analysis of CSR effects at FLASH

Bolko Beutner, Winfried Decking, Torsten Limberg, Michael Roehrs (DESY, Hamburg)

The vacuum-ultra-violet Free Electron Laser in Hamburg (FLASH) is a linac driven SASE-FEL. High peak currents are produced using magnetic bunch compression chicanes. In these magnetic chicanes, the energy distribution along an electron bunch is changed by effects of Coherent Synchrotron Radiation (CSR). Energy changes in dispersive bunch compressor chicanes lead to transverse displacements along the bunch. These CSR induced displacements are studied using a transverse deflecting rf-structure. Recent experiments and simulations concerning the charge dependence of such transverse displacements are presented and analyzed. In these experiments an over-compression scheme is used which reduces the peak current downstream the bunch compressor chicanes. Therefore other self interactions like space charge forces which might complicate the measurements are suppressed.

MOPPH005 Improvements of the Parallelized Tracking Code Astra for the Simulation of Dark Current Losses in the FLASH Linac

Lars Fröhlich, Sascha Meykopff (DESY, Hamburg)

At the Free Electron Laser in Hamburg FLASH, the activation of components due to dark current emitted by the gun has become a serious problem. To improve the understanding of dark current transport in the linac, simulations with the Astra tracking code have been conducted. These studies require a big amount of computing time due to the high number of simulated macroparticles. Therefore, the parallelized version of Astra had to be enhanced by features like dynamic load balancing and an improved aperture model. The paper will provide an overview of the new features and discuss possible remedies of the dark current problem based on the simulation results.

MOPPH006 Longitudinal Wake Field for an Electron Beam Accelerated through a Ultra-High Field Gradient

Gianluca Geloni, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

Electron accelerators with higher longitudinal field gradients can produce high-energy beams with compact, cheap setups. Laser-plasma acceleration appears to constitute the more promising breakthrough in this direction, delivering field gradients up to TV/m. Here we describe the impact of longitudinal wake fields on the electron beam, based on solution of Maxwell's equations for the longitudinal field. We consider an acceleration distance much smaller than the overtaking length (the length that electrons travel as a light signal from the tail of the bunch overtakes the head of the bunch), that is the case for laser-plasma devices. We give expressions for impedance and wake function that may be evaluated numerically. We show that the rate of energy loss in the bunch due to radiative interaction is equal to that of coherently radiated energy in the far-zone. A limiting expression is found for a large distance of the electron beam from the accelerator compared with the overtaking length. We derive analytical solutions for a Gaussian transverse and longitudinal bunch shape. We apply our analytical asymptote by studying the feasibility of a Table-Top FEL based on laser-plasma driver. Numerical estimations indicate that the effects of the time-dependent energy change induced by the longitudinal wake pose a serious threat to the operation of this device. (See DESY 06-222)

MOPPH007 Theory of Nonlinear Harmonic Generation in Free-Electron Lasers with Helical Wigglers

Gianluca Geloni, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

Coherent Harmonic Generation (CHG), and in particular Nonlinear Harmonic Generation (NHG), is of importance for both short wavelength Free-Electron Lasers (FELs), in relation with the achievement of shorter wavelengths with a fixed electron-beam energy, and high-average power FEL resonators, in relation with destructive effects of higher harmonics radiation on mirrors. In this paper we present a treatment of NHG from helical wigglers with particular emphasis on the second harmonic. Our study is based on an exact analytical solution of Maxwell's equations, derived with the help of a Green's function method. In particular, we demonstrate that nonlinear harmonic generation (NHG) from helical wigglers vanishes on axis. Our conclusion is in open contrast with results in literature, that include a kinematical mistake in the description of the electron motion. (See DESY 07-058)

MOPPH008 Unaveraged Three-Dimensional Modelling of the FEL

Cynthia Kar Woon Nam, Pamela Aitken, **Brian W.J. McNeil** (USTRAT/SUPA, Glasgow)

A new three-dimensional model of the FEL is presented. A system of scaled, coupled Lorentz-Maxwell equations are derived in the paraxial limit. A minimal number of limiting assumptions are made and the equations are not averaged in the longitudinal direction of common radiation/electron beam propagation, allowing the effects of coherent spontaneous emission and non-localised electron propagation to be modelled. The equations are solved numerically using a parallel Fourier split-step method.

MOPPH009 Undulator Radiation in a Waveguide

Gianluca Geloni, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

We propose an analytical approach to characterize undulator radiation near resonance, when the presence of the vacuum-pipe considerably affects radiation properties. This is the case of the far-infrared undulator beamline at the Free-electron LASer (FEL) in Hamburg (FLASH), that is designed to deliver pulses in the TeraHertz (THz) range. This undulator can be used for pump-probe experiments where THz pulses are naturally synchronized to the VUV pulse from the FEL, as well as the development of novel electron-beam diagnostics techniques. Since the THz radiation diffraction-size exceeds the vacuum-chamber dimensions, characterization of infrared radiation must be performed accounting for the presence of a waveguide. We developed a theory of undulator radiation in a waveguide based on paraxial and resonance approximation. We solved the field equation with a tensor Green's function technique, and extracted figure of merits describing in a simple way the influence of the vacuum-pipe on the radiation pulse as a function of the problem parameters. Our theory, that makes consistent use of dimensionless analysis, allows treatment and physical understanding of many asymptotes of the parameter space, together with their region of applicability. (See DESY 07-031)

MOPPH010 Three-Dimensional Analysis of the Surface Mode Supported by a Reflection Grating

Vinit Kumar (RRCAT, Indore (M.P.)), Kwang-Je Kim (ANL, Argonne, Illinois)

In a Smith-Purcell Free-Electron Laser (SP-FEL), the electron beam interacts with the surface mode supported by a metallic reflection grating to produce coherent radiation. All the previous analyses of SP-FEL had considered the localization of the surface mode only in the direction perpendicular to the grating surface and assumed translational invariance along the direction of grooves of the grating. In this paper, we include the localization of the surface mode along the direction of grooves and study the three-dimensional structure of the surface mode in order to include diffraction effects in the analysis of SP-FELs. Full three-dimensional Maxwell-Lorentz equations are derived for the self-consistent nonlinear analysis of SP-FELs.

MOPPH011 Comparison Between Kinetic and Fluid Description of Plasma-Loaded Free-Electron Laser

Behrouz Maraghechi, Soheib Babaei (AUT, Tehran)

In the kinetic treatment of the plasma-loaded FEL in Ref.* single particle equation of motion, for both beam and plasma electrons in the radiation fields, are used. Therefore, interaction terms between the wiggler and the space-charge wave, in the transverse velocity of electrons, which are important elements in the fluid model, are neglected. A dispersion relation of a plasma-loaded FEL with kinetic theory is found in Ref.* that takes into account the velocity spread of both beam and plasma electrons. In the present analysis, a dispersion relation is obtained, by the fluid theory, with the interaction terms between the wiggler and the space-charge wave in the transverse velocity of electrons taken into account. Since these interaction terms are inherently missing in the kinetic theory the two dispersion relation are compared to find out about the importance of these terms. It was found that although the absence of these terms has considerable effects on the growth rate, the general kinetic dispersion relation may be used to study the temperature effects of a warm beam/plasma on the instability of a free-electron laser with a plasma background.

* S. Babaei and B. Maraghechi, "Kinetic description of plasma-loaded free-electron laser", Phys. Plasmas, to be published.

MOPPH012 Conservation Laws in Quasilinear Theory of Raman Free-Electron Laser

Behrouz Maraghechi (AUT, Tehran), Amir Chakhmachi (AEOI, Tehran; AUT, Tehran)

A quasilinear theory of the free-electron laser, in Raman regime, is presented to establish that conservation laws on number, energy, and momentum are upheld. A high density electron beam is assumed so that the space-charge potential is no longer negligible. A sufficiently broad band spectrum of waves is assumed so that saturation will be due to the quasilinear spread of the beam electrons. Otherwise, for the single mode excitation, saturation will be due to the electron trapping in the space-charge potential. It is shown that the quasilinear slow variation of the background distribution function is in the form of the diffusion equation in momentum space. An expression for the time evolution of the spectral energy density is derived. Conservation laws to the quasilinear order (second order) are derived and are proved to be satisfied. Results of the present investigation may be used to study the quasilinear saturation of free-electron laser in the presence of the space-charge wave.

MOPPH013 Raman Scattering of a Perturbed TM Mode in a Dielectric Loaded Plasma Waveguide

Farzin Mojtaba Aghamir (IPM, Tehran)

The stimulated Raman scattering of a perturbed TM mode in a dielectric loaded partially filled plasma waveguide is considered. The radiation is the result of the scattering of the pump electromagnetic wave, which is EH waveguide mode, off of a space-charge wave. In the analysis, a non linear wave equation for the three-wave interaction is used to investigate the coupling of the space-charge and the waveguide modes. Dispersion relations for electromagnetic modes are solved numerically to study the frequency characteristics of the interaction of the EH waveguide modes with the space-charge modes. Formulas for the spatial and temporal growth rates of the backscattered wave near the electron cyclotron frequency are derived and the effect of the dielectric liner on the growth rates is investigated. The numerical studies show that the presence of the dielectric liner has an effect on the phase matching condition and leads to a rather larger growth rates close to the electron cyclotron resonance.

MOPPH014 Velocity Shot Noise, Space Charge Effects and Coherence Enhancement Schemes in SASE FEL

Avraham Gover, Egor Dyunin (University of Tel-Aviv, Tel-Aviv)

We employ a formulation of the linear transfer matrix of FEL to explore new operating schemes and limiting effects in the high gain regime of FEL. These include analysis of SASE seed radiation injection, pre-bunching schemes, study of the role of velocity shot noise and collective (space charge effects). We propose new schemes for enhancement of the temporal coherence of SASE radiation, and study them by employing the transfer matrix formulation. The numerical computations indicate that X-Ray pulses, spatially and temporally (Fourier transform limited) coherent, are attainable with available high gain FEL parameters. The theoretical model is based presently on single transverse mode excitation (optically guided). Extension to a multi transverse modes excitation model will be outlined.

MOPPH015 Limit for Harmonic Conversion in a Single Cascade of Coherent Harmonic Generation

Enrico Allaria, Giovanni De Ninno (ELETTRA, Basovizza, Trieste)

Harmonic generation is a reliable method for producing coherent high-brightness photon pulses from relativistic electron bunches. The standard process leading to Coherent Harmonic Generation (CHG) is initiated by a powerful seed laser. As a consequence, reaching short wavelengths generally requires a high order frequency conversion. For that reason some of the projects which are presently under development for coherent VUV and soft-Xray emission are based on a series of two or more consecutive "cascades". In these setups, the radiation produced into one CHG stage is used as a seed in a following CHG cascade. The required number of cascades is related to the maximum harmonic conversion which can be obtained in single stages. In this paper the mechanism underlying the CHG, i.e. the bunching creation into the modulator, is studied in detail and the physical limits for the single-stage CHG are investigated. The identification of the limiting parameters may allow the implementation of new methods for enhancing the conversion efficiency. One of these methods, which relies on a simple modification of the standard CHG scheme, has been recently proposed* and shown to be able to significantly improve the system performance. Results are confirmed by numerical simulations using the codes Ginger and Genesis. Expected impact on some of the existing projects for CHG is also presented.

* E. Allaria, G. De Ninno, Phys. Rev. Lett., to be published.

MOPPH016 A Genetic Algorithm for Maximizing the Brightness of an Electron Beam

Alberto Bacci, Cesare Maroli, Andrea Renato Rossi, Luca Serafini (INFN-Milano, Milano), **Vittoria Petrillo** (Universita' degli Studi di Milano, Milano)

The determination of the parameters of a beam line that permit to reach optimum values of beam emittance, current and focussing is a challenging problem, from both experimental and simulation points of view. The whole parameter ensemble characterizing the elements of the beam line constitutes, in fact, a set of quantities linked by non linear relationships that do not allow defining easily an optimized configuration. Usually the optimization of the beam line is made changing the input values by hand. A genetic algorithm can be used to circumvent this difficulty. In the applications we present here, a genetic code is used, for the first time, in series with transport codes and manages their input parameters. The iterations proper of the genetic algorithm lead to a fast and precise convergence on a particularly good solution, estimated by means of an ad hoc function, the "fitness function", defined as a pondered combination of the quantities that have to be optimized. The results obtained by applying the genetic code first to the envelope evolution code Homdyn, and then to the multi-particle tracking code Astra are presented with some comments and conclusions.

MOPPH017 1D Linear Intensity Spiking Evolution in a Single Shot of a SASE FEL

Cesare Maroli, Luca Serafini (INFN-Milano, Milano), **Vittoria Petrillo** (Universita' degli Studi di Milano, Milano)

The analysis is based on the 1D Maxwell-Lorentz equations which are reduced to the usual averaged linear equation in the limit of vanishingly small radiation field A(z,t) and average length lm. It is shown that if this equation is solved with initial shot noise conditions in which the widths of the spikes and the average distance between successive spikes are both uniformly smaller than the cooperation length Lc, it may lead to large amplitude coherent signals. The intensity spiking RMS relative amplitude decreases from the 100% values it has at t=0, down to values of the order or less than 0.1% in time intervals from ten to twenty gain times.

MOPPH018 Particle-in-cell Simulation of Two-stream Smith-Purcell Free-electron Laser

Wexin Liu, Zheng Liang, Ziqiang Yang (UESTC, Chengdu, Sichuan), Kazuo Imasaki, **Dazhi Li** (ILT, Suita, Osaka)

An approach to enhancement of terahertz (THz) Smith-Purcell (SP) radiation from an open rectangular grating driven by two electron beams is presented in this paper. The two electron beams with a velocity separation propagate over the grating. With the help of a two-dimensional particle-in-cell (PIC) simulation, some nonlinear processes from spontaneous emission to superradiant radiation are demonstrated. The optimum voltage ratio is obtained where the SP radiation power achieves the maximum. The simulation results show that the enhancements of radiation power, the shortened saturation time, and the decrease of critical current for spontaneous SPR to superradiant at a proper voltage ratio. The simulation results can correspond to the linear analyses.

MOPPH019 Optimized Designs for CAEP IR Free-electron Laser

Xiaojian Shu, Yuhuan Dou (IAP, Beijing)

The characteristics of CAEP IR free-electron laser are estimated and the optimized designs of the resonator parameters such as radius of output hole, the size of mirror, the resonator length is carried out using our 3D FEL oscillator code. Based on the appropriate parameters, the saturated power, output power, gain and construction of optical modes are calculated.

MOPPH020 FEL with Orotron Type Feedback

Andrey Malkin, **Naum Ginzburg**, Nikolay Peskov, Roman Rozental, Alexander Sergeev, Vladislav Zaslavsky (IAP/RAS, Nizhny Novgorod), Ritoku Ando, Keiichi Kamada (Kanazawa University, Kanazawa)

In microwave electronics orotron is widely used as a source of RF radiation in millimeter and submillimeter wavebands. In this device an electron beam is coupled to a mode of quasi-optical resonator by means of the periodical grating one of the resonator mirror. In our paper we discuss a relativistic modification of such a device. A novel FEL scheme is suggested in which the slow wave structure of orotron is replaced by shallow Bragg corrugation which provides the coupling of the transverse (with respect to direction of

beam propagation) mode of a two-mirror cavity with longitudinally propagating wave. The latter can be excited by the electron beam wiggling in undulator field. Described scheme allows to combine selective properties of an orotron with relativistic frequency conversion of a free electron laser. The transverse mode provides the feedback in the system thus leading to self-excitation, while the propagating wave is responsible for energy extraction in the steady-state regime of operation. The discussed system was investigated both analytically and numerically using direct codes and averaged equations approach.

MOPPH021 Karat Pic-Cod Simulation of Smith-Purcell Radiation from Gratings with Different Profiles

Konstantin Petrovich Artyomov, Viktor Vasilievich Ryzhov (Institute of High Current Electronics, Tomsk), Vladimir Pavlovich Tarakanov (LPI, Moscow)

Particle-in-cell simulation of Smith-Purcell radiation from gratings with lamellar, triangle, "volume" and "flat" profile using PIC-code KARAT is carried out. The paper present some calculation results compared with experimental data obtained on the 6-Mev microtron. It is shown that the maximal SPR yield for different gratings are in agreement with experiment.

MOPPH022 A Description of Guided FEL Radiation Using Dielectric Waveguide Eigenmodes

Erik Hemsing, James Rosenzweig (UCLA, Los Angeles, California), Avraham Gover (University of Tel-Aviv, Tel-Aviv)

An analysis of the radiation field of an FEL in terms of eigenmodes of a linear dielectric waveguide is presented

MOPPH023 Enhancing FEL Power with Phase Shifters

Daniel Ratner (Stanford University, Stanford, Califormia), Alex Chao, Zhirong Huang (SLAC, Menlo Park, California)

Undulator taper is a well-known technique to increase the FEL efficiency past saturation by maintaining the resonant condition. In this paper, we demonstrate that shifting the electron bunch phase relative to the radiation is equivalent to tapering the undulator parameter. Using discrete phase changes derived from optimized undulator tapers for the LCLS x-ray FEL, we show that placing appropriate phase shifters between undulator sections can reproduce the power enhancement of these undulator tapers. The phase shifters are relatively easy to implement and operate, and hence can be used to aid or replace the undulator taper for optimizing the FEL performance.

MOPPH024 Four-dimensional Simulations of FEL Amplifiers

Joseph Blau, David Thomas Burggraff, William B. Colson, Anastasios Kampouridis, Juan Sans Aguilar (NPS, Monterey, California)

A four-dimensional simulation code has been developed for modeling and studying FEL amplifiers. The parallelized program runs on the NPS 128-node cluster computer. It follows the evolution in (x,y,z,t) of the electron and optical beams, for a single pass through an undulator, using the self-consistent Lorentz force and Maxwell wave equations. The output beam from the FEL amplifier is propagated using an expanding coordinate system to the first optical element, where the intensity and mode composition are determined. This new 4D program allows us to study the combined effects of transverse and longitudinal modes, including pulse slippage and optical guiding effects. The undulator can have either a linear or step taper, or it can be a two-stage optical klystron design. The electron beam can be "pinched" at any point using betatron focusing. The seed laser and the electron beam can be tilted or shifted off-axis to study system vibration effects. The program has been benchmarked against well-known theoretical formulas for FEL gain and extraction, and by comparison to existing FEL amplifier experiments. Results of these simulations and comparisons are shown.

This work is supported by the Office of Naval Research and the Joint Technology Office.

MOPPH025 Three-dimensional Theory of the Cerenkov Free-Electron Laser

Heather L. Andrews, Charles A. Brau (Vanderbilt University, Nashville, Tennessee)

We present an analytical theory for the operation of a Cerenkov free-electron laser which includes diffraction of the optical mode in the direction transverse to the electron beam. Because the width of the optical mode depends on the gain, the usual cubic dispersion relation is replaced by a 5/2-power dispersion relation, however, only two of these roots are allowed. These two roots both have positive real parts, indicating that they are slow waves. For a narrow electron beam, the optical mode is much wider than the beam, thus reducing the gain by an order of magnitude from that predicted by the two dimensional theory. In the limit of a wide electron beam, the two dimensional theory is recovered.

MOPPH026 Three-Dimensional Theory of the Smith-Purcell Free-Electron Laser

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau (Vanderbilt University, Nashville, Tennessee)

We present an analytic theory for the operation of a Smith-Purcell free-electron laser (SPFEL) amplifier that includes transverse diffraction of the optical beam. For the case of an infinitely wide electron beam, this theory agrees with previous two-dimensional analyses. When the electron beam is narrow compared to the mode, the gain is substantially reduced by diffraction, while its dependence on the beam current is increased due to gain guiding. A 5/2-power dispersion relation replaces the conventional cubic dispersion relation. Additionally, the constituent waves of the laser mode are found to have different transverse decay rates. The boundary conditions required for operation as an oscillator cannot be satisfied for an infinitely wide grating.

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MOPPH027 Status of the KAERI THz FEL for the Application on Security Inspection

Young Uk Jeong, Pildong Ahn, Hyuk Jin Cha, Byung Cheol Lee, Jungho Mun, Seong Hee Park (KAERI, Daejon), Grigory Kazakevich (Fermilab, Batavia, Illinois)

Terahertz (THz) technology has been considered as a new tool for security inspection due to its safe energy range to human irradiation, foot-print spectral characteristics for most chemicals and bio-materials, and relatively high spatial resolution for imaging. One of the main tasks in the THz inspection technology is to develop a high power and compact source to realize a real-time imaging. We have developed a compact terahertz (THz) free electron laser (FEL). The FEL operates in the wavelength range of 100–1200 micrometers, which corresponds to 0.3–3 THz. THz radiation from the FEL shows much higher power of 100 W when compared to the power level, < 100 mW, of the table-top sources by conventional lasers. The THz FEL beam shows a good performance in pulse-energy stability, polarization, spectrum and spatial distribution. We report the experimental studies of the transmission and reflection-type scanning imaging of baggage and a window dummy. The required power level of the THz sources is estimated for the practical applications of the inspection imaging.

MOPPH028 On NMR probing of the kinetics of a free-electron laser-induced chemical exchange

Sergey Pavlovitch Babailov (Nikolaev IIC, Novosibirsk; ICKC SB RAS, Novosibirsk)

Determination of the quantum yields of photochemical reactions (in particular, molecular photoisomerization reactions) is an efficient application of NMR spectroscopy*,**. We are proposed a combined approach for study the kinetics of photo-induced chemical exchange (PICE) reactions (see Scheme), which involves a free-electron laser (FEL) and NMR spectroscopy**. Scheme hv A↔B Continuous and pulse IR-irradiation of the chemical system in the presence of PICE can be achieved using FEL. Based on the analytical equations derived in the work we consider the time-dependent dynamics of variation of the instant NMR line shape for two-site chemical exchange. If one induce an abrupt increase in the rate constant of chemical exchange (for example, by quickly heating the system or PICE), then the NMR line shape will change with time, ultimately reaching another new steady state. Our calculations show that there are beats and oscillations (on the NMR line shape) damped with time. The information about the time-dependent instant line shapes provides possibility to predict the real kinetics of PICE. Prospective objects are molecular conformers and spin isomers. So, FEL can be used in the setup for PICE studies in combination with a NMR spectrometer.

* S.P. Babailov, E.M. Glebov, et al., Concepts in Magn.Reson., 2006, 8, 571.

** S. P. Babailov, Russ. Chem. Bull., Int. Ed., 2006, 10, 1631.

MOPPH029 Nondestructive Transfer of Complex Molecular Systems into Aerosol Phase by Means of Terahertz Irradiation of Free Electron Laser

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Original investigations of ablation of various substances under the action of submillimeter radiation of the free electron laser (FEL) developed and built at Budker Institute of Nuclear Physics were carried out at the Chemical and Biological user station of the Siberian Center for Photochemical Research. It was shown that ablation can be nondestructive. In order to determine the size distribution of aerosol products, we used the Diffusion Aerosol Spectrometer (DSA) developed at the ICKC SB RAS* and sampling for examination with electron microscope. The arrangement of experiments and equipment involved allowed us to determine the disperse composition of irradiation products within particle size range 3nm – 10mkm. At the present moment we have classified the aerosol products of ablation of the following substances: Crustal minerals, Fullerene-like complexes based on molybdenum; Polymers with different molecular masses, Biological macromolecules**. The most impressive results are obtained under ablation of biological macromolecules. In order to reveal whether the enzymatic activity of ablation products is conserved, we carried out a test for histochemical coloring of the collected aerosol of horse radish peroxidase. The test showed that this complicated enzyme remained active after ablation. We believe that this result is extremely important for biotechnology.

* A.N. Ankilov et al. Atmospheric Res., 2002, 62, 209-237.
** A.K. Petrov et al. Nuclear Inst. and Methods in Physics Res., 2007, 575, 68-71.

MOPPH030 Terahertz Imaging and Radioscopy with 160x120 Microbolometer 90 fps Camera

Boris Aleksandrovich Knyazev, Gennady N. Kulipanov, Nikolay A. Vinokurov (BINP SB RAS, Novosibirsk), Alexander Leonidovich Aseev, **Michael Alekseevitch Dem'yanenko**, Dmitry G. Esaev, I. V. Marchishin (ISP, Novosibirsk)

Uncooled micromolometer camera for IR and THz high-speed imaging has been developed. The 160x120 focal plane array consists of resistive vanadium oxide elements on a silicon nitride bridge. The element size is 48x48 micron at 51 micron array period. We describe device fabrication process and focal plane array operational characteristics. The camera was used as a recorder in quasi-optical systems with Novosibirsk terahertz free electron laser as a radiation source. Radioscopy of the objects, which are of interest for biology and security applications, has been demonstrated. The recording rate up to 90 frames per second has been obtained.

MOPPH031 Spectroscopy and Spectrally Resolved Radioscopy of Biological Substances Using Terahertz Free Electron Laser Radiation

Boris Aleksandrovich Knyazev (BINP SB RAS, Novosibirsk), Alexander M. Gonchar (ICG SB RAS, Novosibirsk), **Vasily V. Gerasimov** (NSU, Novosibirsk)

High average power and monochromacity of terahertz Novosibirsk free electron laser are favorable for the development of time and space resolved spectroscopic and radioscopic techniques for study of highly absorbing substances, in particular, biological ones. To study highly absorbing objects we applied a homemade attenuated total reflection spectrometer, which enables operation in both conventional and imaging mode. By measuring the reflection coefficients for p- and s-polarized radiation, the real (n) and imaginary (k) parts of refractive index can be derived. Using a microbolometer matrix (see the paper by Esaev et al. at this conference), imaging radioscopy of the samples containing amino acids and DNA had been performed. The methods developed were applied also for examination of bones of intact and senescence-accelerated mice that, probably, would lead to study osteoporosis development.

MOPPH032 Development of Metal Mesh Based Quasi-optical Selective Components and Their Application in High-power Experiments at Novosibirsk Terahertz FEL

Sergey Alexandrovich Kuznetsov, Boris Goldenberg, Peter Kalinin, Vitaly V. Kubarev, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

Successful realization of terahertz research programs at the Novosibirsk FEL-facility requires detailed development, designing and optimization of passive quasi-optical selective components, intended for polarization and frequency gating of powerful THz-beams of NovoFEL radiation. Along with desired

selective characteristics such components should be capable of operating over a long period of time under high-power load conditions (a few hundred Watts of average incident radiation power) without noticeable degradation of their properties. It admits to employ in selective components only low absorbing and thermostable materials, such as high conductivity metals and special types of polymers. This report is devoted to development of metal mesh based selective structures, such as polarizing beamsplitters (attenuators) and different frequency filters, and their application in high-power THz-experiments. Possibilities and prospects of two main production technologies are discussed: 1) conventional photolithography destined for manufacturing thin metal structures deposited on low-absorbing thermostable polymer films; 2) LIGA-technique intended for producing thick substrate-free metal structures.

MOPPH033 Diffraction Optical Elements and Optical Systems with a High Power Monochromatic Terahertz Source

Irina Aleksandrovna Polskikh, Alina Fanova, Boris Aleksandrovich Knyazev, Gennady N. Kulipanov, Nikolay A. Vinokurov (BINP SB RAS, Novosibirsk), Hyuk Jin Cha, Young Uk Jeong (KAERI, Daejon), Valery Cherkassky, Lev A. Merzhievsky, Sergey Zhigach (NSU, Novosibirsk)

We have developed reflective diffraction optical elements (DOE) for focusing radiation of terahertz free electron lasers (FEL). Metal-dielectric Fresnel zone plates and metallic kinoform "lenses" were fabricated and tested using FEL radiation. A microbolometer camera (see the paper by Esaev et al. at this conference) sensitive to THz radiation had been applied for recording both terahertz beam caustic and terahertz images. Diffraction efficiency of a kinoform lens appears to be about unity. Quality of images obtained with the kinoform lens was studied. The lens was used as a key element for a Toepler optical system, which were used for studying condense matter non-uniformities and deformations. The experiments were performed at Novosibirsk and KAERI FELs.

MOPPH034 Diagnostics of an Electron Beam using Coherent Cherenkov Radiation

Rodion Tikhoplav (UCLA, Los Angeles, California)

A comparison of coherent Cherenkov and transition radiations as a diagnostic tool for longitudinal distribution of an electron beam is studied in this paper. Two methods will be used for the 7th harmonic bunching experiment at Neptune linear accelerator facility at UCLA. Coherent Cherenkov radiation is produced in an aerogel with an index of refraction close to unity.

MOPPH035 FELs and High-energy Electron Cooling

Vladimir N. Litvinenko (BNL, Upton, Long Island, New York), Yaroslav Derbenev (Jefferson Lab, Newport News, Virginia)

Electron cooling is extremely successful in cooling low and medium energy ions, including protons. ERLs are promising to extend the reach of traditional electron cooling to about 100 GeV/nucleon for heavy ions. Nevertheless, cooling of protons with energies from about 100 GeV (RHIC) to few TeV (LHC) becoming very complicated or even possible. Optical stochastic cooling* has potential to be an instrument of choice, but it has two main shortcomings: a) it requires significant modifications of the lattices of hadron machine and b) in the case of the protons it suffers from very inefficient interaction (radiation) of protons with TEM wave. It was suggested** to combine advantages of electrostatic interaction with broad-band FEL-amplifier in what is now called stochastic electron cooling. Such system will naturally fit into a straight section of modern high energy hadron colliders. In this paper we present description of the cooling process and give examples of FEL-based electron cooler for protons in RHIC and LHC.

* A. Mikhalichenko and M. Zolotorev, Phys. Rev. Lett., 71, p.4146 (1993).
** Ya. S. Derbenev, NIM A441 (2000) 223

MOPPH036 First Experiences with the FIR-FEL at ELBE

Ulf Lehnert, **Peter Michel**, Wolfgang Seidel, Gerald Staats, Jochen Teichert, Rudi Wuensch (FZD, Dresden)

We show the design and the parameters of operation of the long-wavelength (U100) FEL of ELBE. First lasing has been shown in August, 2006. Since then, the laser has undergone thorough commissioning and is available for user experiments since fall, 2006. Besides in-house users the IR beam is available to external users in the FELBE (FEL@ELBE) program witch is a part of the integrated activity on synchrotron and free electron laser science in the EU. At the beginning of 2007 lasing in the full

designed wavelength range from 20µm to 200µm was demonstrated. The laser power typically reaches several W in CW operation but drops for very long wavelengths depending on the size of the used outcoupling hole. However, there exists a serious problem with small gaps in the providable wavelength spectrum. We attribute this behaviour to the transmission characteristics of the overmoded partial waveguide used from the undulator entrance to the first mirror.

MOPPH037 Characterization of a New High-Q Talbot Effect Confocal Resonator for mm-Wave FEL

Oleg (Alon) Faingersh, Jeremy Dadoun, Khona Garb, Avraham Gover (University of Tel-Aviv, Tel-Aviv), Boris Kapilevich, Boris Litvak (CJS, Ariel)

A new FEL resonator for mm- wave range was assembled and characterized before installation into the high voltage terminal of the Tandem electrostatic FEL accelerator. The measured unloaded Q-factor of the new resonator is Q=30,000. Accordingly, the round-trip losses are ~18% for the total length of the resonator about 1.5m The reflector of the new resonator utilizes in one transverse dimension the Talbot effect for imaging and splitting the radiation mode field for the purpose of the laser radiation. In the other transverse dimension optical imaging is realized by means of two confocal mirrors. A 3-wire grid assembly, remotely controlled, provides fine tuning of the laser frequency and control over the resonator out-coupling coefficient. The new resonator includes an integral e-beam profile diagnostics means installed on the safety shield. All e-beam diagnostics and tuning motors are remote controlled in a Lab View environment.

MOPPH038 Experimental and 3D Simulation Studies of the Spectral Characteristics of Electrostatic Accelerator FEL with Space Charge Dominated Transport

Mark Volshonok, Avraham Gover (University of Tel-Aviv, Tel-Aviv), Yuri Lurie (CJS, Ariel)

One of the important properties of the FEL it is the ability to generate high power radiation within a wide frequency range. By varying the acceleration energy of the tandem electrostatic FEL in the range 1.3-1.44 MeV we tuned the FEL lasing radiation between 80GHz to 110GHz. The tuning range is limited by the resonator frequency dispersion one hand and the beam trajectories on the other hand. At low acceleration energies space charge effects make it difficult to keep the electron trajectories in the wiggler confined to the axis. Because of this and because of difficulty to keep optimal e-beam injection parameters into the wiggler, the oscillation threshold is reduced and the tuning range of the FEL is limited. The finite size of the e-beam inside the wiggler also has a reduction effect on the lasing frequency. The measured spectral tuning characteristics of the FEL matches well the results of FEL lasing 3-D simulation (with FEL3D). The electron trajectories and the beam transport were calculated with GPT simulations in the space charge dominated regime.

MOPPH039 Sideband Instability in a Compact THz Free-Electron Laser at KAERI

Young Uk Jeong, Pildong Ahn, Hyuk Jin Cha, Byung Cheol Lee, Jungho Mun, Seong Hee Park (KAERI, Daejon), Grigory Kazakevich (Fermilab, Batavia, Illinois)

Frequency offset of a Sideband instability has been observed in a compact waveguide-mode terahertz (THz) free-electron laser (FEL). The spectra of the FEL pulses were measured by a Fabry-Perot spectrometer having a resolution of 10^(-4) of the central wavelength at a 2-3 THz range. The shift of the sideband was measured to be 0.5-1.2 micrometers depending on the FEL wavelength from 110 to 165 micrometers. An increase of the sideband shift for a longer wavelength can be explained by the change of the wave's group velocity in a plane-parallel waveguide. Mode competition between the sidebands and primary wave was observed by changing the cavity length of the FEL. We could decrease the number of the modes and reduce the linewidth of the spectra by controlling the cavity detuning. We have discussed the complexity of the sideband instability depending on the FEL wavelengths and its gain characteristics.

MOPPH040 A Study of Detection Schemes in Electro-Optic Sampling Technique

Yong Woon Parc, Jung Yun Huang, Changbum Kim, In Soo Ko (PAL, Pohang, Kyungbuk), Yujong Kim (FEL/Duke University, Durham, North Carolina)

Electro-Optic Sampling (EOS) is the ingenious tool for the measurement of the electron beam or Thz radiation. There are two traditional detection schemes: one is the crossed polarizer scheme and another is balanced detection one. A new detection scheme called Near Crossed Polarizer scheme in the EOS technique is developed to increase the Signal to Noise Ratio in the experiment. The new detection scheme is studied

in detail and the 3D scanning result with electron beam in FLASH is compared with the detection scheme. The new detection scheme has an analytical problem which shows two solutions for the relative phase shift for specific measurement of the electron beam. That problem is also studied through the comparative study between simulation and the analyzed data from the TEO setup in FLASH.

MOPPH041 Comparative Study of Electro-Optic Effect between Simulation and Measurement

Yong Woon Parc, Jung Yun Huang, Changbum Kim, In Soo Ko (PAL, Pohang, Kyungbuk), Yujong Kim (FEL/Duke University, Durham, North Carolina)

The short, intense, and low emittance electron beams are crucial to make high quality X-ray beam for X-ray free electron laser (XFEL). Electro-Optic Sampling (EOS) is a promising method to measure the electron bunch length non-destructively. A simulation study is done with the pulse propagation method, which utilizes Fourier transform to investigate the evolution of electromagnetic pulse inside the electro-optic (EO) crystal. The experimental result measured with spatial decoding method at Free electron LASer in Hamburg (FLASH) facility in Deutsches Elektronen-Synchrotron (DESY) is analyzed in terms of the relative phase shift between the horizontal and vertical component of the laser pulse. In this report, the experimental results expressed in terms of the "Relative Phase Shift Γ" are compared with the simulation result. The simulation and the experimental result show similar values within reasonable error. The way to increase the signal level is also proposed.

MOPPH042 Losses in Optical Resonator of Novosibirsk Terahertz Free Electron Laser: Theory and Experiment

Vitaly V. Kubarev (BINP SB RAS, Novosibirsk)

Design of optical resonator of Novosibirsk terahertz free electron laser (NovoFEL)was made on base simple analitical theory discribed in paper*. Direct comparison of the theory and many experiments on NovoFEL is presented.

* Kubarev V.V. Babinet principle and diffraction losses in laser resonators. Quantum Electronics 30(9)824-826(2000).

MOPPH043 Control and Diagnostic System of Novosibirsk FEL Radiation

Stanislav S. Serednyakov, Vitaly V. Kubarev, Evgeniy Makashov, Konstantin S. Palagin (BINP SB RAS, Novosibirsk)

The architecture the main capabilities of control and diagnostic system of the Novosibirsk FEL coherent radiation are described. The client-server model is used for software, controlling this system. The developed software is capable to work both in client and server mode. Also it can control various equipment – from FEL optical cavity mirrors to local equipment of users stations. The mode of control program operation and controlled equipment are determinates by external configuration files. Some results of the system operation are also presented.

MOPPH044 Status of Novosibirsk ERL and FEL

Nikolay Vinokurov, Nikolai Gavrilov, Boris Aleksandrovich Knyazev, Evegeniy I. Kolobanov, Vladimir V. Kotenkov, Vitaly V. Kubarev, Gennady N. Kulipanov, Alexander N. Matveenko, Lev E. Medvedev, Sergey Vladimirovich Miginsky, Leontii Mironenko, Vladimir Ovchar, Vasiliy M. Popik, Tatiana Vladimirovna Salikova, Mikhail A. Scheglov, Stanislav Sergeevich Serednyakov, Oleg A. Shevchenko, Alexander Skrinsky, Vladimir G. Tcheskidov (BINP SB RAS, Novosibirsk)

The Novosibirsk terahertz free electron laser is based on the energy recovery linac (ERL) with room-temperature radiofrequency system. Some features of the ERL are discussed. The results of emittance measurements and electron optics tests are presented. The first stage of Novosibirsk high power free electron laser (FEL) was commissioned in 2003. Now the FEL provides electromagnetic radiation in the wavelength range 110 - 230 micron. The average power is 400 W. The minimum measured linewidth is 0.3%, which is close to the Fourier-transform limit. Four user stations are in operation. The second stage of the ERL, which has four orbits, is under construction.

MOPPH045 Measurement of timing jitter based on HGHG FEL spectrum dynamics

Timur Shaftan, Li-Hua Yu (BNL, Upton, Long Island, New York)

We discuss impact of temporal shift between seed laser and electron beam on the HGHG FEL radiation spectrum. Following analysis of experimental data reveals basic properties of the time jitter in the accelerator-FEL driver at Source Development Lab (BNL).

MOPPH046 Operation of Near-infrared FEL at Nihon University

Ken Hayakawa, Yasushi Hayakawa, Keisuke Nakao, Kyoko Nogami, Toshinari Tanaka (LEBRA, Funabashi), Atsushi Enomoto, Shigeki Fukuda, Kazuro Furukawa, Shinichiro Michizono, Satoshi Ohsawa (KEK, Ibaraki), Manabu Inagaki, Takao Kuwada, Takeshi Sakai, Isamu Sato (Nihon University,)

The near-infrared FEL at Laboratory for Electron Beam Research and Application (LEBRA) in Nihon University has been operated for a variety of scientific applications since 2003. The stability of the FEL power was improved appreciably by the advanced stability of the 125 MeV electron linac. Currently fundamental FEL wavelength ranges from 1 to 6 microns, which is restricted by the electron energy and the optical devices. The higher harmonics in the visible region is also available. The maximum macropulse output energy of 60 mJ/pulse has been obtained at a wavelength of 1725 nm. The short FEL resonator at LEBRA causes relatively high optical energy density on the surface of the resonator mirrors; present copper-based Ag mirrors in use at LEBRA are not durable enough for long term operation. As an alternative way of generating intense harmonics in the visible to near-UV region, second and third harmonic generation by means of non-linear optical devices has been tested for the FELs around 1.5 microns as input fundamental photons.

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MOPPH047 Influence of Terahertz Electromagnetic Radiation on Neurons In-vitro

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Isolated neurons of mollusk in vitro at various stages of network neogenesis were studied earlier. The influence of submillimeter laser radiation (from 70 up to 418 mkm) it was investigated. 40-50 hours after laser irradiation (81.5 mkm) the formation of heterogeneities of the cell surface with the subsequent creation of arbitrarily directed process - like frames is observed in 12-15% of cells which were at the process shaping stage. In neurons which have formed processes, 15-20 hours after the exposition there is disturbance in the processes growth zones. The disturbance of formation of interneuron connections and thickening of processes terminations are observed. Similar alterations of cells are absent at smaller power density, exposition at other wavelengths, and in control neurons (without exposure). There is disturbance of cell adhesion to surface in 70-80% of neurons after irradiation at 418-mkm wavelength. Experiments on high power Novosibirsk teraherz free electron laser have shown influence of such radiation on functional characteristics alive neurons. The alterations observed can be the result of a modification of separate (possibly, individual) molecules of neuron regulation or structure-forming systems.

MOPPH048 ARC-EN-CIEL Project Electron Beam Dynamics

Christelle Bruni, Marie-Emmanuelle Couprie, Alexandre Loulergue (SOLEIL, Gif-sur-Yvette)

ARC-EN-CIEL project is based on the development of fourth generation light source of high brilliance and tunable in the UV-X domain. The project will evolved into three phases leading to different light performances: first and second phases are in single pass configuration with energy of 220 MeV and 1 GeV respectively, while third phase comports recirculation loops at 1 GeV and 2 GeV. For delivering a high brilliance light source with high peak power short pulses, the high charge electron beam should have subpicoseconde duration with low emittance and energy spread. In order to keep optimal slice characteristics for light production, phase space non linearities due to optics aberrations and collective effects should be minimized. In ERL configuration, a critical consequence of collective effects is the Beam Break Up instability, which forms a feedback loop between the beam and the cavities. This contribution aims at presenting the electron beam dynamics for the ARC-EN-CIEL project in single pass and ERL configuration, especially on the conditions for minimizing non linearities and Beam Break Up instability.

MOPPH049 Machine layout of the STARS facility

Michael Abo-Bakr, Wolfgang Anders, Johannes Bahrdt, Rolf Follath, Kathrin Goldammer, Stefan Hessler, Karsten Holldack, Thorsten Kamps, Jens Knobloch, Bettina Christa Kuske, Atoosa Meseck, Torsten Quast (BESSY GmbH, Berlin)

BESSY is proposing STARS, a facility to demonstrate the operation of a two-stage high-gain harmonic-generation free-electron laser (HGHG FEL) in the wavelength range 40 to 70 nm. This paper describes the main facility components: a normal conducting gun, a 325 MeV superconducting CW operated driver linac based on TESLA technology, a single-stage bunch compression scheme and finally a two-stage HGHG cascaded FEL. Design considerations for each component are discussed, and the evolution of electron beam properties from its generation up to the compressed and accelerated bunch delivered to the HGHG FELs undulators is presented.

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MOPPH050 Status of the Undulator System of the Seeded HGHG-FEL Test Bench at MAX-lab

Johannes Bahrdt, Winfried Frentrup, Andreas Gaupp, Kathrin Goldammer, Karsten Holldack, Michael Scheer (BESSY GmbH, Berlin), Mathias Brandin, Filip Lindau, Dmytro Pugachov, Sara Thorin, Sverker Werin (MAX-lab, Lund)

Within the EUROFEL Design Study a seeded HGHG-FEL will be set up at the 400 MeV linac at MAX-lab. The undulators and the dispersive section have been installed. A glass fibre based power meter system for integrated dose measurements as well as a Cherenkov system for a fast detection of electron losses have been integrated. We report on the performance of all components. Simulations on the acceptable radiation doses inside the undulator magnets will be presented. In the first step of commissioning the THz radiation as produced by the bunched electron beam inside the dispersive section will be used for the optimization of the longitudinal and transverse overlap of the electron beam and the laser beam.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 – EUROFEL.

MOPPH051 Nonlinear Harmonic Generation in the BESSY Soft X-Ray FEL

Kathrin Goldammer (BESSY GmbH, Berlin)

Free Electron Lasers do not only radiate at the fundamental frequency, they may also radiate coherently at higher harmonics. This process is referred to as nonlinear harmonic generation or NHG. NHG is of high interest, because it extends the FEL output wavelength of FELs to several harmonics of the FEL resonant frequency. In cascaded High Gain Harmonic Generation (HGHG) FELs, harmonic radiation may be used to improve frequency-conversion and reduce the number of HGHG-stages. BESSY proposes to build a cascaded HGHG FEL with three FEL lines. They cover a wavelength range of 51 nm (Low-Energy FEL) to 1.2 nm (High-Energy FEL) and consist of up to four HGHG-stages. In this paper, we present studies of the BESSY High-Energy FEL harmonic content performed with the upgraded version of the simulation code Genesis 1.3.

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MOPPH052 Output Performance of the STARS HGHG Demonstrator at BESSY

Bettina Christa Kuske, Kathrin Goldammer, Atoosa Meseck (BESSY GmbH, Berlin)

BESSY is planning to construct a free-electron laser facility (STARS) to demonstrate cascaded high-gain harmonic generation (HGHG) FELs. A 325MeV superconducting linear accelerator will drive two HGHG-stages, where the second stage is seeded by the radiation from the first stage. Such a cascading of the HGHG scheme, originally pioneered by L.H. Yu, allows a reduction of the STARS output wavelength down to the few 10nm range. This paper describes the expected performance of the facility, the achievable wavelength range, the harmonic content of the radiation, the potential of super-radiant pulses and first considerations about the stability of the source.

Work funded by the Bundesministerium fuer Bildung und Forschung and the Land Berlin

MOPPH053 Seeding the STARS HGHG Demonstrator with Chirped Radiation

Bettina Christa Kuske, Michael Abo-Bakr, Torsten Quast (BESSY GmbH, Berlin)

For all seeded free-electron lasers aiming at short pulses in the few 10fs range the timing between the fs seed radiation pulse and the electron bunch must be precisely controlled. Due to space charge phenomena in the gun and the bunch compression necessary to reach high bunch currents, beam parameters like the emittance, the current or the energy spread vary significantly along the bunch. Hence, jitter of the bunch w.r.t. the seed results in a jitter of the FEL radiation characteristics. To provide for intrinsic seed-laser to bunch synchronization, a two-cycle setup has been proposed*. In the first cycle, a seed pulse long enough to cover a pilot electron bunch with the maximal expected temporal jitter produces a pulse with highly reproducible characteristics. For the second cycle this pulse is split in two one providing the next gun cathode pulse while the other seeds the second HGHG stage. Critical to the scheme is the seeding of the bunch with a wavelength-chirped laser pulse. This paper evaluates the applicability of this scheme at the BESSY test-facility. GENESIS simulations of the expected performance of STARS, when this self-synchronization scheme is implemented, are presented.

* L.H. Yu, Nuc. Inst. and Meth. in Phys. Research A 528 (2004), p481-485

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MOPPH054 Small-Aperture Vacuum-Chamber Design for STARS

Atoosa Meseck, Johannes Bahrdt, Volker Duerr, Michael Scheer, Godehard Wuestefeld (BESSY GmbH, Berlin)

To demonstrate and investigate the cascaded HGHG-scheme proposed for the BESSY Soft X-ray FEL, BESSY plans to build a test-facility called STARS consisting of two HGHG stages. The radiator in the second stage is planned as an APPLE III device which provides the highest field for a circular beam pipe. The minimum Gap of 7 mm translates into a 5 mm inner diameter of the vacuum chamber. An analysis of the impact of the wakefields and the expected vacuum profile is thus required. Results of this analysis an vacuum measurements are presented.

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MOPPH055 Measurements of the Projected Normalized Transverse Emittance at PITZ

Lazar Staykov, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Levon Hakobyan, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Sven Lederer, Anne Oppelt, Bagrat Petrosyan, Sabine Riemann, Sakhorn Rimjaem, Juliane Roensch, Andrey Shapovalov, Frank Stephan (DESY Zeuthen, Zeuthen), Dieter Richter (BESSY GmbH, Berlin), Klaus Floettmann (DESY, Hamburg), Galina Asova, Konstantin Konstantinov Boyanov, Ivan Tsakov (INRNE, Sofia)

The main objective of the Photo Injector Test facility at DESY in Zeuthen (PITZ) is the production of electron beams with minumum transverse emittance at 1 nC bunch charge. PITZ consists of a photo cathode RF gun, solenoids for the compensation of space charge induced emittance growth and a booster cavity. In order to study the emittance evolution along the beam line three Emittance Measurement SYstems (EMSY's) were installed downstream of the booster cavity. In a first operation periode in October 2006 the emittance was measured for moderate gun gradients of about 40 MV/m. A new gun cavity is presently installed at PITZ and conditioning up to a gradient of 60 MV/m is ongoing. In this work we present recent results from measurements of the normalized projected transverse emittance of the electron beam. The emittance is measured using the so called single slit technique. Data are presented for different gun gradients solenoid strengths and booster phases.

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MOPPH056 Optimization of the PITZ Photo Injector Using a Simplex Method

Lazar Staykov, Mikhail Krasilnikov, Frank Stephan (DESY Zeuthen, Zeuthen)

The Photo Injector Test facility at DESY in Zeuthen (PITZ) was build to develop and optimize electron sources providing high quality electron bunches for SASE FEL operation in the short wavelength region. Main components of PITZ are: a photo cathode laser system providing carefuly shaped laser pulses, a Cs2Te cathode embeded in a 1.3 GHz RF gun copper cavity operated at high gradient, a solenoid for space charge compensation and a booster cavity. The main goal of the optimization is to produce electron beams with a projected normalized emittance of below 1 mm.mrad at 1 nC bunch charge. The optimization process is twofold: it goes through numerical and analytical simulations of the photo injector using ASTRA and envelope equations formalism and experimental verification of the results

obtained from the simulations using electron beam measurements has to be done. The optimization process runs through many parameters of the photo injector such as RF phases, solenoid field, accelerating gradients, laser shape etc. For the experimental determination of the optimum we use three parameters where all the other are fixed at numerically optimized positions. In this contribution we discuss both, the numerical optimization of the PITZ setup using an enhanced simplex method, and a proposal for on-line search of the working point of the injector using the downhill simplex method.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the "Impuls- und Vernetzungsfonds" of the Helmholtz Association, contract no. VH-FZ-005.

MOPPH057 Development of mm-Wave TDR Technique for Direct Estimating of the Quality of the FEL's Resonator Mirrors

Boris Kapilevich, Moshe Einat, Boris Litvak (CJS, Ariel), Oleg (Alon) Faingersh, Avraham Gover (University of Tel-Aviv, Tel-Aviv)

Radiated power of the Israeli FEL is greatly dependent on the quality of input/output mirrors of the quasi-optical resonator, where an interaction between electron beam and EM fields is taken placed. Since they are located in the close proximity to the electron beam transport area, the probability of their damaging is increased and regular diagnostics of mirror's quality is urgently required. However, such a diagnostic is time consuming due to the required vacuum-opening. The time domain reflectometry (TDR) method allows estimating the mirror's quality by means of direct measurements of its power reflectance. We have developed the TDR's experimental set-up in 90-105 GHz permitting to perform such measurements. The key element of this setup is the pulse modulated pin-switch with a rise time of 1-2 ns. The forward and backward signals have been recorded independently using the two separated detectors and Tektronix digital scope. We have investigated the TDR's patterns of various damaged mirrors and conclude that the suggested technique can be recommended for remote diagnostics and estimating their quality without vacuum opening.

Israeli Ministry of Science

MOPPH058 Status of the SPARX Project

Daniele Filippetto (INFN/LNF, Frascati (Roma))

The SPARX project consists in an Soft-X-ray-FEL facility jointly supported by MUR(Research Department of Italian Government), Regione Lazio, CNR, ENEA, INFN and the University of Roma Tor Vergata. It is the natural extension of the ongoing activities of the SPARC collaboration. The aim is the generation of electron beams characterized by ultra-high peak brightness at the energy of 1 and 2 GeV, for the first and the second phase respectively. The beam is expected to drive a single pass FEL experiment in the range of 13.5-6 nm and 6-1.5 nm, at 1 GeV and 2 GeV respectively, both in SASE and SEEDED FEL configurations. A hybrid scheme of RF and magnetic compression will be adopted, based on the expertise achieved at the SPARC. high brightness photoinjector presently under commissioning at Frascati INFN-LNF Laboratory.

MOPPH059 Recent Progress and Future Programs of SPARC-Lab, a High Brilliance Electron-Photon Beam Facility

Luca Serafini (INFN-Milano, Milano)

While the project SPARC is well progressing into its installation phase of the full photo-injector and FEL undulator, aiming at starting soon the first SASE-FEL measurements, future programs for the constitution of a test-facility named SPARC-Lab are well delineated. Such a test-facility will be the Italian site for studying the physics and applications of high brightness electron beams and their interactions with high intensity laser beams, within a collaboration among INFN, CNR, ENEA and several Italian Universities. A wide bouquet of foreseen lines of investigation spans from FEL seeding and HGHG experiments, to plasma acceleration of externally injected ultra-short electron bunches and mono-chromatic and tunable X-ray beam generation by Thomson back-scattering. The former line of activity is already approved an funded through european contracts, while the latter constitutes the back-bone of the PLASMONX project, funded by INFN, based on the acquisition of a 300 TW Ti:Sa laser system synchronized to the SPARC photo-injector. Other planned experiments are IFEL, channeling radiation, quantum FELs. We will describe the status of the design and installation of major components of SPARC-Lab. We will also discuss some of the most relevant applications to be pursued, like advanced X-ray imaging for mammography.

MOPPH060 The Drive-Laser System for CFEL

Weihua Li (CAEP/IAE, Mianyang, Sichuan)

We have developed a solid-state drive-laser system to meet the requirements of the CFEL research.The system can generate 15ps width Gaussian pulses with wavelength 266nm at a repetition rate 54.17MHz.These "micropulses" are contained within a "macropulses" envelope as long as 2 to 6ms,which is emitted from the drive-laser at a rate 3, 6 or 12Hz, "micropulses" energy as large as 2 to 5mJ is achieved.The design specifications, configuration and diode-pumped amplifier of the drive-laser system are also described

MOPPH061 Design of the PAL Test FEL Machine

Mungyung Kim, Jinhyuk Choi, Jung Yun Huang, Heung-Sik Kang, In Soo Ko, Tae-Yeon Lee, Jong-Seok Oh, Sung Ju Park (PAL, Pohang, Kyungbuk), Chang-Mook Yim (POSTECH, Pohang, Kyungbuk)

In a road to the PAL-XFEL, the 1st stage will be to build a test machine, whose design parameters are presented here. It will be a 230 MeV machine that has the target wavelength of visible range. The design details and simulation results are shown in this paper.

MOPPH062 Status of the PAL-XFEL Design

Tae-Yeon Lee, Jinhyuk Choi, Jung Yun Huang, Heung-Sik Kang, Mungyung Kim, In Soo Ko, Jong-Seok Oh, Sung Ju Park (PAL, Pohang, Kyungbuk), Chang-Mook Yim (POSTECH, Pohang, Kyungbuk)

The PAL-XFEL design has been revised since the previous conference. The 2nd bunch compressor has been moved to a higher energy to eliminate the space charge effect and the total linac energy has been increased from 3.7 GeV to 4.0 GeV. Details and reasons of these design revisions are explained.

MOPPH063 Potentialities of ELMI Device for Submillimeter Generation by Stimulated Intercavity Scattering in Planar FEM

Andrey Vasil'evich Arzhannikov, Peter Kalinin, Sergey Alexandrovich Kuznetsov (BINP SB RAS, Novosibirsk), Naum Ginzburg, Nikolay Peskov, Alexander Sergeev, Vladislav Zaslavsky, Irina Zotova (IAP/RAS, Nizhny Novgorod)

Paper describes main features of a project on two-stage generation of submillimeter radiation at the ELMI device. This novel variant of a two-stage scheme based on stimulated intercavity scattering was proposed earlier in the paper*. In accordance with the scheme, at the first stage a sheet electron beam drives a 2D Bragg free electron maser (FEM) of planar geometry to generate 4-mm pump wave. At the second stage this wave undergoes stimulated scattering at the supplementary electron beam to produce submillimeter radiation. A key feature of a proposed scheme is to use two sheet beams with a few kiloampers currents that transported in parallel channels, which are connected by a special waveguide* for synchronization of beam radiation in different channels**. Production of two sheet beams by one accelerator diode with two cathodes is also similar to the process of operation of the multibeam diode described in Ref.**. Two-stage scheme allows us to use high power 4-mm radiation produced in the first channel by the sheet beam moving in an undulator quasi-static magnetic field, as an EM-undulator for the secondary stage FEL operating in Terahertz wave range. In the paper we describe results of theoretical and experimental investigations of various aspects of the two-stage scheme and some testing experiments on units for realization of this scheme at the ELMI device.

* A.V.Arzhannikov et al. Proc. Int.Workshop, N.Novgorod, Vol.1,p.228-232,2006.
** A.V.Arzhannikov et al.Digest Tech.Papers,PPPS-2001, Las Vegas, Nevada, Vol.1, p.561-564,2001.

MOPPH064 A Project of SC ERL at KAERI

Alexey Vladimirovich Bondarenko, Sergey Vladimirovich Miginsky (BINP SB RAS, Novosibirsk), Young Hwan Han, Young Uk Jeong, Byung Cheol Lee, Seong Hee Park (KAERI, Daejon)

A project of an ERL at Korea Atomic Energy Research Institute is described. The ERL will be connected to the existing machine without any modification. It consists of two 180° bents and two straight sections: one is for an FEL, another for a Compton X-ray source. One can choose the regime controlling the lenses. The total ERL is isochronous to avoid any problem with longitudinal beam instability. It will be possible to control both Sx and Sy transormation matrix elements independently to suppress longitudinal beam instability and allow the increase of beam current. Sextuples will be installed in bents to suppress chromatic aberration. This design provides operation in FEL regime with high electron efficiency in the range of electron energies 12–22 MeV.

MOPPH065 Imaging and Spectroscopy at High Power Novosibirsk Terahertz Free Electron Laser: Methods and Experimental Results

Boris Aleksandrovich Knyazev, Evegeniy I. Klobanov, Vladimir V. Kotenkov, Vitaly V. Kubarev, Gennady N. Kulipanov, Alexander N. Matveenko, Lev E. Medvedev, Irina Aleksandrovna Polskikh, Vasiliy M. Popik, Tatiana V. Salikova, Mikhail A. Scheglov, Stanislav S. Serednyakov, Oleg A. Shevchenko, Nikolay A. Vinokurov (BINP SB RAS, Novosibirsk), Alexander M. Gonchar (ICG SB RAS, Novosibirsk), Leonid A. Lukyanchikov (IGD, NOvosibirsk), Michael Alekseevitch Dem'yanenko, Dmitry G. Esaev (ISP, Novosibirsk), Valery Cherkassky, Vasily V. Gerasimov, Lev A. Merzhievsky (NSU, Novosibirsk)

High power and monochromacity of Novosibirsk free electron laser (NovoFEL) are favorable for the development of prospective methods of spectroscopy and imaging in the terahertz spectral region. We have developed, designed, fabricated and examined a number of elements for terahertz optical systems, such as windows, beamsplitters, reflective Fresnel zone plates and kinoform lenses. Using the elements a number of quasi-optical systems for imaging and spectrally resolved terahertz radioscopy were designed and applied for study biological substances and other highly absorbing materials. Attenuated total reflection spectrometer with NovoFEL as a source, which can operate in imaging mode, is under study. Holographic and Toepler systems are used for study condense matter deformation and destruction. A number of imagers have developed for recording of terahertz radiation. A novel 160x120 microbolometer-martix-based 90-fps terahertz camera was applied to obtain high resolution images with very high sensitivity.

MOPPH066 Pre-Wave Zone Effect in Smith-Purcell FEL

Dmitry Valeryevich Karlovets, Alexander Potylitsyn (TPU, Tomsk)

We have developed an approach to study characteristics of Smith-Purcell radiation (SPR) with taking into account pre-wave zone effect*, i.e. radiation field distortion at the finite distance from a grating. It was shown that in the case being considered radiation monochromaticity doesn't satisfy the well-known relation for the far-field zone: FWHM ~ 1/N (N - number of grating periods). At the short distances from a grating corresponding to pre-wave zone (depending on N^2 for SPR) monochromaticity falls down, that should be taken into account in real experimental situations. On the basis of the model developed we propose a new variant of the so-called "transverse" resonator to stimulate radiation in SPR FELs in mm-range**. In such a scheme a grating and a mirror forms the open resonator of cylinder shape that leads to radiation focusing and increasing of the resonator Q-factor.

* D.V. Karlovets and A.P. Potylitsyn, JETP Letters 84, 489 (2006).
** A.N. Aleinik, A.S. Aryshev, E.A. Bogomazova et al., JETP Letters 79, 320 (2004).

MOPPH067 Feasibility of Pre-Bunched FEL Based on Coherent Diffraction Radiation

Leonid Grigorievich Sukhikh, Gennady Naumenko, Alexander Potylitsyn (TPU, Tomsk), Stewart Takashi Boogert, Pavel Karataev (JAI, Egham, Surrey), Alexander Sergeevich Aryshev, Junji Urakawa (KEK, Ibaraki)

The scheme of a prebunched FEL based on coherent transition radiation (CTR) generated in a closed resonator formed by flat mirrors has been investigated in*. We suggest to use coherent diffraction radiation (CDR) from a pre-bunched electron beam passing in vacuum near two semi-paraboloidal targets forming an open resonator. In this case optical characteristics of the targets will be preserved. Simulations showed that paraboloidal targets would focus the CDR, i.e. increase the spectral angular density of radiation due to the pre-wave zone effect**,***. Recently a proof-of-principle experiment confirming the possibility of optical DR focusing by semi-spherical target in the extreme pre-wave zone was carried out at KEK-ATF. The obtained results clearly demonstrated the DR focusing and well agreed with theory. This allows us to be sure that CDR can also be focused by a parabaloidal target providing a much higher quality factor (Q-factor) in comparison with the results*.

* Y. Shibata et al., NIMA, 528 (2004)162
** P.V.Karataev, PLA 345(2005) 428
*** A.P. Potylitsyn and R.O. Rezaev, NIMB 252(2006) 44

MOPPH068 The NCAS-FEL: an FEL Oscillator with High Slippage

Peter van der Slot (Twente University, Enschede), Klaus Boller, Elmer van Geijin (Mesa+, Enschede), Jeroen Jalink, Wim J. van der Zande (Radboud University Nijmegen, Nijmegen)

In normal operation of FEL oscillators with little or no slippage, the cavity length needs to be slightly smaller than the synchronous value due to the lethargy in the gain build-up. If the FEL experiences high slippage, i.e., when the slippage becomes comparable or even larger than the length of the electron pulse, a different cavity detuning may be required. We use the one dimensional Medusa1D code to study the NCAS-FEL* as an example of an FEL oscillator having high slippage. Medusa1d is basically equal to the fully three dimensional Medusa code** with the 3D effects stripped out. It includes multiple wiggler segments, electron beam transport elements, harmonics and a simple oscillator model. Medusa1D can also include 3D effects using the fitting formula of Xie***. The NCAS-FEL is a RF-linac based FEL dedicated for high resolution spectroscopic studies in the wavelength range from 100 micron to 1.5 mm. The design of the NCAS-FEL is currently under way, and we report here initial results of this design and focus on the effects of high slippage on cavity detuning and the development of coherence within the optical pulse.

* Proceedings of FEL 2006, Berlin, Germany (2006) p485 - 487
** Phys. Rev. ST-AB 8, 110701 (2005)
*** Nucl. Instrum. Methods Phys. Res., Sect. A 445, 59 (2000)

MOPPH069 3D Modelling of the ERLP IR-FEL

David James Dunning, James Clarke, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

An Energy Recovery Linac Prototype (ERLP) facility is currently being commissioned at Daresbury Laboratory; it serves as a testbed for technologies to be used in the proposed 4th Generation Light Source (4GLS) facility. As part of the ERLP facility, an infra-red oscillator FEL is due to be commissioned early in 2008. In this paper we present full three dimensional, time-dependent modelling of the ERLP IR-FEL using Genesis 1.3 in combination with a paraxial optical propagation code (OPC). We also discuss how this work will be used to inform commissioning of the FEL.

MOPPH070 Seeded VISA: A 1064nm Seeded FEL at the BNL ATF

Michael P. Dunning, Gerard Andonian, Erik Hemsing, Sven Reiche, James Rosenzweig (UCLA, Los Angeles, California), Marcus Babzien, Vitaly Yakimenko (BNL, Upton, Long Island, New York)

An experimental study of a seeded free electron laser is currently underway at the Accelerator Test Facility at Brookhaven National Laboratory. The seeded FEL will use the VISA undulator and a Nd:YAG seed laser. The study is motivated by the demand for a short Rayleigh length FEL amplifier at 1 micron for high power transmission with minimal damage of transport optics. Planned measurements include transverse and longitudinal coherence, angular distribution, and wavelength spectrum of the FEL radiation. The effects of detuning the electron beam energy will also be studied, with an emphasis on control of the radiation emission angles and increase of the amplifier efficiency. Results of start-to-end simulations are presented with preliminary experimental results.

MOPPH071 Free Electron Lasers in 2007

William B. Colson, Joseph Blau, Darin Smith (NPS, Monterey, California)

Thirty years after the first operation of the short wavelength free electron laser (FEL) at Stanford University, there continue to be many important experiments, proposed experiments, and user facilities around the world. Properties of FELs in the infrared, visible, UV, and x-ray wavelength regimes are listed and discussed.

MOPPH072 The IR-Beam Transport System from the ELBE-FELs to the User Labs

Wolfgang Seidel, Matthias Justus, Karl-Wilhelm Leege, Dieter Proehl, Rainer Schlenk, Armin Winter, Dietrich Wohlfarth, Rudi Wuensch (FZD, Dresden)

In the Forschungszentrum Dresden-Rossendorf, two free-electron lasers (FELs) have been put into operation. They produce laser light in the medium and the far infrared wavelength range (4-200 microns). The IR light is transported to several laboratories in the same building and to the adjacent building of the High Magnetic Field Laboratory (HLD) as well. The latter is up to 70m away from the FELs. Constructional

peculiarities, the large wavelength range (a factor of 50 between the shortest and the longest wavelengths), the high average power in cw regime, and the beam property requirements of the users pose a challenge to the beam line design. The transport system includes vacuum pipes, plane and toroidal gold-covered copper mirrors, exit windows, and diagnostic elements. The designed transport system produces a beam waist at selected spots in each laboratory representing an image of the outcoupling hole. Spot size and position are independent of the wavelength. In the HLD the beam is fed into a circulare waveguide, guiding the radiation to the sample inside of a cryostat. To ensure the desired beam properties, the transport system has been analyzed by means of various ray and wave optical models.

MOPPH073 Thermal and Non-thermal Laser Cutting Utilizing Advanced Industrial Lasers and ERL-FELs

Eisuke John Minehara (JAEA/FEL, Ibaraki-ken)

The JAEA and JLAB energy-recovery free-electron lasers (ERL-FEL) have successfully demonstrated capabilities of a few hundreds fs ultra-fast pulse lasing, 6-9% high conversion efficiency, one GW high peak power, a few kW average power, and wide tunability of infrared wavelength regions. Utilizing the high average and high peak power lasing and energy-recovery linac (ERL) technology, we could realize a more powerful and more efficient FEL than 20kW and 25%, respectively, for nuclear industry, pharmacy, medical, defense, shipbuilding, semiconductor industry, chemical industries, environmental sciences, space-debris cleaning, power beaming and so on very near future. We have performed their thermal and non-thermal cutting and machining experiments and characterized their resultant effects. In order to compare some characteristic differences of thermal and non-thermal laser cutting utilizing advanced industrial laser like fiber, and water-guided ones and the ERL-FELs, we have performed some cutting trials of them. In the presentation, we plan to discuss these differences and how to apply all the lasers to the above applications in the fields.

MOCAU01 Short Wavelength Regenerative Amplifier FELs

Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

In this paper we discuss the possibility of extending the operating wavelength range of tunable Regenerative Amplifier FELs to shorter wavelengths than current design proposals, notably into the XUV regions of the spectrum and beyond where the reflectivity of broadband optics is very low. Simulation studies are presented which demonstrate the development of good temporal coherence in generic systems with a broadband radiation feedback of less than one part in ten thousand.

MOCAU02 Numerical Solution of the FEL Correlation Function Equation

Oleg A. Shevchenko, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

The equation for two-particle correlation function in FEL was derived recently to provide a new way of noise calculations in FELs*. In this paper this equation is solved numerically for the simplest case of narrow electron beam. Time independent solution with saturation is obtained. It is compared with the results of quasilinear theory and results of previous SASE linewidth estimates.

* O.A. Shevchenko, N.A. Vinokurov, NIM A507 (2003) 84-88

MOCAU03 Numerical Propagation Simulations and Coherence Analysis of SASE Wavefronts

Oleg Chubar, Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Olivier Tcherbakoff (CEA, Gif-sur-Yvette), Marie Labat, Guillaume Lambert (SOLEIL, Gif-sur-Yvette; CEA, Gif-sur-Yvette)

Examples of wavefront propagation simulation and coherence analysis of SASE, seeded and started-up from noise, are presented. The calculations are performed using SRW – the wave-optics computer code optimized for synchrotron radiation, and the 3D FEL simulation code GENESIS 1.3. To ensure easy inter-operation and data exchange between the two codes, GENESIS has been integrated into the "emission" part of the SRW, which is dedicated for calculation of initial wavefronts in the form ready for subsequent propagation simulations. In the examples described, after each run of GENESIS in time-dependent mode, the electric field is transformed from time to frequency domain, and the wavefront obtained this way is numerically propagated, using Fourier-optics methods implemented in the SRW, from the exit of the FEL undulator to image plane of a simple interferometer-type optical scheme. Intensity-averaged patterns, obtained after multiple cycles of the SASE (in presence of shot noise and/or

a timing jitter) and the wavefront propagation calculations, allow for straightforward characterization of spatial coherence by visibility of interference fringes. SRW code can also be used for complete optimization of optical beamlines for 4th generation synchrotron radiation sources, which require accurate treatment of wave-optical phenomena in the frequency and time domains.

MOCAU04 Impact of Longitudinal Space-charge Wake from FEL Undulators on Current-enhanced SASE Schemes

Gianluca Geloni, Evgeny Saldin, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg)

In this article we present a description of longitudinal wake fields in X-ray Free-Electron Lasers (XFELs) that is of relevance in relation with Enhanced Self-Amplified Spontaneous Emission (ESASE) schemes. We consider wakes in XFELs, in the limit when the electron beam has gone inside the undulator for a distance longer than the overtaking length (the length that electrons travel as a light signal from the tail of the bunch overtakes the head of the bunch). We find that the magnitude of the resulting energy chirp constitutes a reason of concern for the practical realization of ESASE schemes.

MOCAU05 Space Charge Effect in an Accelerated Beam

Gennady Stupakov, Zhirong Huang (SLAC, Menlo Park, California)

It is usually assumed that the space charge effects in relativistic beams scale with the energy of the beam as the inverse relativistic factor gamma factor squared. We show that for a beam accelerated in the longitudinal direction there is an additional space charge effect in free space that scales as the ratio of the accelerating field to the gamma factor. This space charge field has the same origin as the "electromagnetic mass of the electron" discussed in textbooks on electrodynamics. It keeps the balance between the kinetic energy of the beam and the energy of the electromagnetic field of the beam. We then consider the effect of this field on a beam generated in an RF gun and calculate the energy spread produced by this field in the beam. Work supported by Department of Energy contract DE--AC02--76SF00515.

TUAAU01 High Power FEL Developments – A Review

George R. Neil (Jefferson Lab, Newport News, Virginia)

High power FELs have continued to make significant progress in the last few years. Power advances are taking advantage of the energy recovering linac technology on both superconducting and room temperature machines. In general, the limiting technology has been the injector current capability but there are a number of other technical factors which must be considered to successfully develop a high average power Free Electron Laser. With a number of groups poised to develop 100 mA ERLs, many with FELs, the importance of resolving limiting issues is becoming more critical. The Recuperator at Novosibirsk has the record current of 22 mA and has produced over 400 W of FEL power. Work is underway to extend the power and performance of this pioneering machine. Meanwhile, at Jefferson Lab, the Upgrade FEL achieved 14.3 kW of output while recirculating 8 mA. Numerous efforts are underway to increase the average brightness capabilities injectors: Brookhaven, Los Alamos, and Berkeley National Labs, Cornell University, Advanced Energy Systems, Daresbury Lab, KEK, and FZ Dresden among others have significant injector development programs underway. This talk will review the status of high average power FELs around the world and discuss the technical developments underway in injectors, optics, and other areas to achieve yet higher performance.

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TUAAU02 Electron Outcoupling Scheme for the Novosibirsk FEL

Alexander N. Matveenko, Oleg A. Shevchenko, Vladimir G. Tcheskidov, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

One of the main problems of contemporary high power FELs is the mirror heating. One of the possible solutions of this problem is the use of electron outcoupling*. In this case the mirrors of optical resonator are not transparent and the coherent radiation from an additional undulator in the FEL magnetic system is used. To provide the output of this radiation the electron beam in the auxiliary undulator is deflected from the optical resonator axis. To save bunching it is preferable to use the achromatic deflecting bend. The project of electron outcoupling for the Novosibirsk FEL is described. Simulation results are presented.

- N.G. Gavrilov et al., NIM A304 (1991) 63-65

TUAAU03 A Comparison of Short Rayleigh Range FEL Performance with Simulations

Stephen Vincent Benson, Pavel Evtushenko, George R. Neil, Michelle Diane Shinn (Jefferson Lab, Newport News, Virginia), Joseph Blau, David Thomas Burggraff, William B. Colson, Peter P. Crooker, Juan Sans Aguilar (NPS, Monterey, California)

One approach to attaining very high power in a free-electron laser (FEL) is to operate with a Rayleigh range much smaller than the wiggler length. Previously, 3D simulations of Free-electron laser (FEL) oscillators showed that FEL gain doesn't fall off with Rayleigh range as predicted by one-dimensional simulations*. They also predict that the angular tolerance for the mirrors is much large than simplistic theory predicts. Using the IR Upgrade laser at Jefferson Lab lasing at 935 nm we have studied the performance of an FEL with very short Rayleigh range. We also looked at the angular sensitivity for several different Rayleigh ranges. We find very good agreement between simulations and measured gain and angular sensitivities. Surprisingly the gain continues to rise as the Rayleigh range is shortened and continues to grow even when the resonator becomes geometrically unstable. The same behavior is seen in both the experiment and simulations. We also find that, even for large Rayleigh ranges, the angular sensitivity is much smaller than one might expect. The relative angle of the electron beam and optical mode can change by more than the 1/e^2 divergence without reducing the output power. This is the first demonstration that 3-dimensional effects qualitatively change the performance of an FEL oscillator.

* W. B. Colson et al., "Short Rayleigh length free electron lasers", Physical Review Special Topics: Accelerators and Beams 9, 030703, 2006

This work was supported by U.S. DOE Contract No. DE-AC05-84-ER40150, the Office of Naval Research, and the Joint Technology Office of the Department of Defense

TUAAU04 Extended High Power Operation of the Free-Electron Laser at Jefferson Lab

Michelle Diane Shinn, Stephen Vincent Benson, Jonathan Creel, Kelly Dixon, David Douglas, Fred H. Dylla, Richard Evans, Pavel Evtushenko, Christopher W. Gould, Joe Gubeli, David Hardy, Carlos Hernandez-Garcia, Kevin Jordan, Steven Wesley Moore, Brian Murphy, George R. Neil, Tom Powers, Dan Sexton, Thomas Slachtouski, Richard Lee Walker, Gwyn P. Williams, Shukui Zhang (Jefferson Lab, Newport News, Virginia)

A milestone of the Jefferson Lab (JLab) FEL Upgrade program was to produce for long periods of time an average power output of 10 kW or more in the near-infrared (1-3 microns). In 2004 we produced 10.3 kW during 1 second long macropulses with a 33% duty cycle at 6 microns. Operation at higher duty factors resulted in decreased lasing efficiency and saturation of the output power. Since then we performed tests at shorter wavelengths, with the goal of further optimizing the accelerator and cavity optics. After determining that the cavity optics continued to be a source of our power limits, we implemented cryocooling of the outcoupler to take advantage of the improved thermomechanical properties of sapphire at these temperatures. With this one change, the lasing efficiency remained constant at all beam powers and we briefly produced 14.26 kW of average power at 1.61 microns. Later we operated for about 15 min at powers exceeding 10.6 kW. Some of the details of the test and a discussion of planned improvements will be presented.

This work supported by the Office of Naval Research, the Joint Technology Office, and by DOE Contract DE-AC05-84ER40150.

TUAAU05 Modelling Mirror Aberrations in FEL Oscillators Using OPC

Peter van der Slot, Klaus Boller, Jaap Karssenberg (Mesa+, Enschede)

Thermal distortion in mirrors used in high average power FEL oscillators, like the JLAB FEL and the 4GLS VUV-FEL, will influence the mode quality and affect the FEL performance. In order to quantify these effects, these distortions needs to be characterised. Mirror aberrations are generally described using Zernike polynomials and also in case of thermal distortions, it has been shown that these polynomials can be used to describe the mirror distortion*. The Optical Propagation Code (OPC)** is a general optical propagation package in the paraxial approximation, that works together with gain codes like Medusa and Genesis 1.3 to model FEL oscillators. We have extended OPC to include phase masks, that can either be generated by an external program or internally using Zernike polynomials. This allows OPC to model mirror aberrations. We will present a few examples, illustrating the capabilities of OPC.

* Nucl. Instrum. Meth. A407 (1998)401

** J. Appl. Phys. 100, 093106 (2006)

TUBAU01 FLASH Upgraded - Preparing for the European XFEL

Holger Schlarb (DESY, Hamburg)

Since 2005, the Free electron LASer in Hamburg, FLASH, has delivered a high brilliance photon beam to users in a wavelength range between 13 nm and 40 nm. To meet the user demands for 4 nm wavelengths, sub-50fs timing stability, and better pointing stability, the accelerator will be continuously upgraded within the next few years. The upgrade to an energy of 1.3 GeV, the transverse and longitudinal intra-train feedback system, and a 3rd harmonic cavity at 3.9 GHz are key prototype tests for the European XFEL. FLASH also serves as a test bench for an entirely new approach to accelerator facility synchronisation involving optical pulses distributed in length stabilized fibres. Increased stabilization of the electron beam peak current and its arrival time should provide the possibility to reliably seed the electron bunch with higher laser harmonics. In this paper, an overview of the planned upgrade for FLASH will be presented with respect to its usefulness for the European XFEL. The status of the XFEL project will also be briefly summarized.

TUBAU02 Status of SCSS & X-ray FEL Project in Japan

Tsumoru Shintake (RIKEN Spring-8 Harima, Hyogo)

Staus of SCSS project after the first lasing last year will be reported. The X-ray FEL, which uses 8 GeV C-band, is under construction, whose status will be reported.

TUBAU03 STARS – an FEL to Demonstrate Cascaded HGHG

Jens Knobloch, Michael Abo-Bakr, Wolfgang Anders, Johannes Bahrdt, Rolf Follath, Kathrin Goldammer, Stefan Hessler, Karsten Holldack, Thorsten Kamps, Bettina Christa Kuske, Atoosa Meseck, Torsten Quast (BESSY GmbH, Berlin)

BESSY plans to build the BESSY Soft X-ray FEL facility, a second generation FEL for the VUV and soft x-ray range. The TDR was evaluated by the German Science Council and recommended for funding subject to the condition that cascaded high-gain harmonic generation (HGHG) be demonstrated beforehand. To this end, BESSY is proposing the demonstration facility STARS for a two-stage HGHG FEL. For efficient lasing from 40 nm to 70 nm, a 325 MeV driver linac is required. It consists of a normal-conducting gun, superconducting TESLA-type modules modified for CW operation and a bunch compressor. The two-stage HGHG cascade employs variable gap undulators, with the final amplifier being an APPLE-III device for full polarization control. A beamline with user experiment completes STARS, which is planned to remain operational even after the BESSY FEL comes online. This paper summarizes the layout of STARS, the main parameters and the expected performance.

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TUBAU04 Towards a Low Emittance X-ray FEL at PSI

Anne Oppelt, Andreas Adelmann, Alexander Anghel, Rene Johan Bakker, Micha Dehler, Romain Ganter, Christopher Gough, Sladjana Ivkovic, Felix Jenni, Christof Kraus, Frederic Le Pimpec, Simon Christian Leemann, Kevin Li, Peter Ming, Benedikt Stephan Clemens Oswald, Martin Paraliev, Marco Pedrozzi, Jean-Yves Raguin, Leonid Rivkin, Thomas Schietinger, Volker Schlott, Lothar Schulz, Andreas Streun, Frank Stulle, Detlef Vermeulen, Fuqiang Wei, Albin Friedrich Wrulich (PSI, Villigen)

The Paul Scherrer Institute (PSI) in Switzerland aims at building a compact and cost-effective X-ray FEL facility for the wavelength range 0.1 - 10 nm. Based on the generation of very low emittance beams, it consists of a low-emittance electron gun (LEG) followed by high-gradient acceleration, and advanced accelerator technology for preserving the initial low emittance during further acceleration and bunch compression. In order to demonstrate the feasibility of the concept and the emittance preservation, a 250 MeV test facility will be built. This machine has been designed to be used as injector for the X-ray FEL at a later date. The accelerator design of the 250 MeV linac will be presented in the paper together with the status of the LEG and high gradient acceleration.

TUBAU05 One Angstrom FEL Oscillator using ERL Beams

Kwang-Je Kim, Yury Shvydko (ANL, Argonne, Illinois), Sven Reiche (UCLA, Los Angeles, California)

An oscillator X-ray FEL for 1-Å is feasible with ERLs. We have studied a 1-Å FEL using electron beams extrapolated from the "high coherence" mode of the proposed Cornell ERL, using the electron energy = 7 GeV, the undulator parameter K=1.4, and period length=1.88 cm. With a 30-m undulator the small signal

gain is about 20%, sufficient for "lasing" if one round trip reflectivity is greater than 90%. The gain will be higher for a higher bunch current achievable with further optimization of the gun. The peak power of the circulating optical beam at saturation is about 20 MW and its bandwidth 10-6. The increased energy spread of the electron beam due to the FEL interaction does not pose problem for the recirculation optics. Two possible schemes for optical cavity are possible. One is a cavity of regular triangle with three crystal reflectors. Another is to use a cavity consisting of two Bragg reflectors at near-backscattering configuration and a grazing incidence mirror in between. Parasitic diffraction in backscattering of a cubic crystal provides a convenient out-coupling mechanism. The fraction of parasitic diffraction can be set to a small, desired value while keeping the high reflectivity in the main diffraction by suitably orienting the crystals away from the exact backscattering geometry. The mirror serves also the important function of focusing the x-ray beam.

Work supported by U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC01-06CH11357

TUPPH001 Positron Source Based on laser Compton Scattering Gamma Ray

Dazhi Li, Kazuo Imasaki (ILT, Suita, Osaka), Sho Amano, Shuji Miyamoto, Takayasu Mochizuki (NewSUBARU/SPring-8, Hyogo)

Positron generation from a laser Compton scattering gamma ray is presented. When the gamma ray bombards a target, the positron is generated due to the reaction of pair production, and it can be applied as the positon source of a collider. In our experiment, a 17 MeV gamma ray is produced in the way of laser Compton scattering and it induces positrons and electrons in a Pb target. The positron flux and energy spectrum were measured.

TUPPH002 High Order Mode Coupling Impedace of Nonrelativistic Beam in Superconducting RF Gun Cavity

Vladimir Volkov (BINP SB RAS, Novosibirsk)

High Order Modes (HOM) excitation in superconducting RF (SRF) gun cavity can play a negative rule in obtaining of high quality beam especially for large charge bunches of 2.5 nC and small emittance of 1 mm mrad. This problem is considered on base of the theory for HOM coupling impedances of nonrelativistic beam for both TM and TE modes used in Superconducting RF gun cavities. The numerical calculation has been done for a 3.5 cell SRF gun like developed in Rossendorf.

TUPPH003 Transverse Coherence of the 4GLS VUV-FEL

Neil Thompson, Marion Bowler, David James Dunning (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Mark David Roper (STFC/DL, Daresbury, Warrington, Cheshire), Brian W.J. McNeil (USTRAT/SUPA, Glasgow)

The proposed 4th Generation Light Source (4GLS) at Daresbury Laboratory in the United Kingdom includes a low-Q cavity (also called a regenerative amplifier) FEL to generate variably-polarised, temporally-coherent radiation in the photon energy range 3-10eV. In this paper we report on work to optimise the design of the cavity geometry such that the far-field transverse coherence of the output beam is maximised.

TUPPH004 Simulations of the Jefferson Lab IR Upgrade FEL with a Short Rayleigh Length

Joseph Blau, David Thomas Burggraff, William B. Colson, Peter P. Crooker, Juan Sans Aguilar (NPS, Monterey, California)

Simulations are used to study the IR Upgrade laser at Jefferson Lab lasing at 935 nm. We model the performance of the FEL with very short Rayleigh length (much less than the wiggler length). Simple FEL theory predicts that the gain and extraction should fall off dramatically at short Rayleigh lengths, but our simulations predict that the gain actually increases, and the extraction stays roughly constant as the Rayleigh length is decreased. This has been confirmed by recent experimental studies at Jefferson Lab. We also simulate the sensitivity of the Jefferson Lab FEL to tilting and shifting of the electron beam and cavity mirrors, as well as mirror distortions, for several different Rayleigh lengths. Basic cold-cavity theory predicts that a very short Rayleigh length FEL should be very sensitive to such vibrations and distortions, but our simulations show that the system is surprisingly stable, tolerating vibrations and distortions many times greater than the simple theory predicts. This has been partially confirmed by

recent experiments at Jefferson Lab.

This work is supported by the Office of Naval Research and the Joint Technology Office.

TUPPH005 Short Rayleigh Range Experiments using the IR Upgrade FEL at Jefferson Lab

Stephen Vincent Benson, Pavel Evtushenko, George R. Neil, Michelle Diane Shinn (Jefferson Lab, Newport News, Virginia)

Operation of a free-electron laser (FEL) with a very short Rayleigh range presents many experimental difficulties. Among these are mirror figure errors, mirror vibrations, Rayleigh range calibration, and radius of curvature stability. We present the methods used to address these issues and propose some possible future approaches to produce routine operation at short Rayleigh range.

This work was supported by U.S. DOE Contract No. DE-AC05-84-ER40150, the Office of Naval Research, and the Joint Technology Office of the Department of Defense.

TUPPH006 FEL Potential of the High Current ERLs at BNL

Dmitry Kayran, Ilan Ben-Zvi, Vladimir N. Litvinenko, Eduard Pozdeyev (BNL, Upton, Long Island, New York)

An ampere class 20 MeV superconducting Energy Recovery Linac (ERL) is under construction at Brookhaven National Laboratory (BNL)*. This ERL prototype will be used as a test bed to study issues relevant for very high current ERLs. High average current and high performance of electron beam with some additional components make this ERL an excellent driver for high power far infrared Free Electron Laser (FEL). A possibility for future up-grade to a two-pass ERL is considered. We present the status and our plans for construction and commissioning of the ERL. We discus a FEL potential based on electron beam provided by BNL ERL.

* Litvinenko, V.N. et al. High current energy recovery linac at BNL. Proc. 26th International Free Electron Laser Conference and 11th FEL Users Workshop (FEL 2004).

Work performed under the auspices of the U.S. Department of Energy.

TUPPH007 Spatial Coherence Measurement of UVSOR-II Free Electron Laser

Marie Labat (CEA, Gif-sur-Yvette), Guillaume Lambert (CEA, Gif-sur-Yvette; RIKEN Spring-8, Hyogo), Masahito Hosaka (Nagoya University, Nagoya; UVSOR, Okazaki), Oleg Chubar, Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Masahiro Katoh, Akira Mochihashi, Miho Shimada (UVSOR, Okazaki), Kazutoshi Fukui (University of Fukui, Fukui)

The interaction between a very high brightness electron beam and a relativistically intense optical laser pulse produces X rays via coherent Thomson back scattering with FEL collective amplification. The phenomenon is, however, very selective, so that the characteristics of both electron and laser beam must satisfy tight requirements in terms of beam current, emittance, energy spread and laser amplitude stability within the pulse. The three-dimensional equations governing the radiation phenomena have been studied in both linear and non linear regime and solved numerically for the particularly interesting values of wavelengths of 1 Ang, 1 nm and 12 nm. The performance of the collective Thomson source has been compared with that of an equivalent static undulator. A set of scaling laws ruling the phenomenon is also presented. The possibility of using an electron beam produced via LWFA in the bubble regime is investigated.

TUPPH008 Beam Dynamics Studies on the UVSOR-II Free Electron Laser

Marie Labat (CEA, Gif-sur-Yvette), Guillaume Lambert (CEA, Gif-sur-Yvette; RIKEN Spring-8, Hyogo), Masahito Hosaka (Nagoya University, Nagoya; UVSOR, Okazaki), Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Masahiro Katoh, Akira Mochihashi, Miho Shimada (UVSOR, Okazaki)

In the Coherent Harmonic Generation Free Electron Laser configuration, an external laser source is seeded inside a first undulator. The interaction between the electron beam and this seed induces energy modulation of the bunch, further converted into a density modulation, producing coherent radiation in a second undulator. The energy modulation enhances the energy spread of the electron bunch, converted by the machine optics into a modification of its longitudinal distribution. In the case of a storage ring FEL, the electrons are re-circulating: the same bunch keeps interacting with the seeded laser, and relaxation of the distribution is only allowed in between two laser injections. Such specific dynamics has

been studied on the CHG FEL of UVSOR-II storage ring (Japan). The electron beam stored at 600 MeV is seeded using a 2.5 mJ, 1 kHz, 1.2 ps Ti:Sa laser at 800 nm wavelength, allowing radiation at 266 nm (third harmonic). A Streak Camera is used to record the evolution of the longitudinal profiles as a function of the repetition rate and average power of the seeding laser, leading to bunch lengthening and distortion dynamical analysis. It appeared that because the heating induced by the interaction remains local, the refreshment process of the electronic distribution is modified. The experimental results are compared to simulations using SYNC.

TUPPH009 SASE FEL Simulations for the European XFEL with the Codes Simplex and Genesis

Vitali Khachatryan (CANDLE, Yerevan), Winfried Decking, Andranik Vasili Tsakanian (DESY, Hamburg)

Numerical simulation studies of the FEL process have been carried out for the European XFEL project. The impact of the electron beam spatial and angular offsets at the entrance of the undulator as well as quadrupole misalignments on the FEL performance have been investigated using the FEL simulation codes SIMPLEX and GENESIS. A comparison of results obtained by the two different software tools is presented. The choice of the optimal beta function for the undulator beam lines has been investigated as well. A reduction of the number of quadrupoles in the undulator beam line is considered.

TUPPH010 Gamma Laser on the Base of Diffraction Scattering an Intense 4.3 GeV Electron Beam on a Crystal

Aleksandr Aganyants (YerPhI, Yerevan)

Difficulties of creating gamma lasers are generally known. Difficulties of creating gamma lasers are generally known. However such gamma laser as a phenomenon of nature has unexpectedly manifested in our experiments on the Yerevan synchrotron. A nonlinear increase in gamma ray emission depending on the electron beam intensity had been shown in the foregoing. New striking results will be presented, among them: swelling a gamma beam profile or growth of the spatial coherent length of electron-photon interaction in crystal and tending produced photons to coalescence at their interaction with substance. New data give evidence: gamma laser takes place when electron beam touches the crystal.

TUPPH011 Analytical Studies of Transverse Coherence Properties of X-ray FELs

Evgeny Saldin, **Evgeny Schneidmiller**, Mikhail Yurkov (DESY, Hamburg)

We describe analytically the process of formation of transverse coherence in X-ray SASE FELs.

TUPPH012 Compact X-ray Free-Electron-Laser Based on an Optical Undulator

Luca Serafini, Alberto Bacci, Cesare Maroli, Andrea Renato Rossi (INFN-Milano, Milano), Paolo Tomassini (INFN-Pisa, Pisa), **Vittoria Petrillo** (Universita' degli Studi di Milano, Milano)

The interaction between a very high brightness electron beam and a relativistically intense optical laser pulse produces X rays via coherent Thomson back scattering with FEL collective amplification. The phenomenon is, however, very selective, so that the characteristics of both electron and laser beam must satisfy tight requirements in terms of beam current, emittance, energy spread and laser amplitude stability within the pulse. The three-dimensional equations governing the radiation phenomena have been studied in both linear and non linear regime and solved numerically for the particularly interesting values of wavelengths of 1 Ang, 1 nm and 12 nm. The performance of the collective Thomson source has been compared with that of an equivalent static undulator. A set of scaling laws ruling the phenomenon is also presented. The possibility of using an electron beam produced via LWFA in the bubble regime is investigated.

TUPPH013 Production of Ultra-short Radiation Pulses in Frequency Doubler

Evgeny Saldin, Evgeny Schneidmiller (DESY, Hamburg), **Mikhail Yurkov** (JINR, Dubna, Moscow Region; DESY, Hamburg)

Typically beam formation system of driver linac for SASE FEL produces electron beams with small local energy spread. This feature opens up extra possibilities for implementation of different FEL schemes. One of them is an effective frequency doubler*. It consists of an undulator tuned to the fundamental harmonic, dispersion section, and undulator tuned to the second harmonic. The first stage is a conventional soft X-ray SASE FEL. Its gain is controlled in such a way that the maximum energy modulation of the electron beam at the XFEL exit is about equal to the local energy spread, but still far away from saturation. When electron bunch passes through dispersion section this energy modulation leads to effective compression of the particles. Then bunched electron beam enters the 2nd harmonic undulator, and produces the radiation at the 2nd harmonic. Recently SASE FEL FLASH in Hamburg demonstrated unique mode of operation generating sub-10-fs radiation pulses**. In this paper we study an option of frequency doubler for FLASH operating in the femtosecond mode of operation.

* J. Feldhaus et al., NIM A 528 (2004) 471.

** W. Ackermann et al., "Operation of a free electron laser from the extreme ultraviolet to the water window", Nature Photonics, in press.

TUPPH014 Generation of X-ray FEL Light Using Laser Wakefield Accelerated Electron Beams

Oleg A. Shevchenko, Nikolay Vinokurov (BINP SB RAS, Novosibirsk), Antoine Rousse (LOA, Palaiseau)

We consider a new class of high gain FELs based on femtosecond electron bunches with extra high current density produced by Laser Wake Field Acceleration (LWFA). The FELs of this kind can be used for generation of high power femtosecond x-ray pulses. We present the results of simulations of FEL operation with some reasonable beam parameters which will be obtained in future. We focus our attention on the advantages which can be gained from the unique possibility of the use of femtosecond hundred-kiloamperes bunches, generated by LWFA. We also consider the impact of the relatively poor electron beam properties on FEL characteristics.

TUPPH015 Diffraction Effects in the Coherent Transition Radiation Bunch Length Diagnostics

Grigory Kazakevich, Valeri Lebedev, Sergei Nagaitsev (Fermilab, Batavia, Illinois)

Diffraction effects in the Coherent Transition Radiation (CTR) bunch length diagnostics were considered for the A0 Photoinjector and the ILC injection module. The effects can cause a noticeable distortion of the measured CTR spectra dependently on the experimental setup and the bunch parameters. The distortion results in the the errors of the bunch length determination. Presented calculations show possible errors in determination of the bunch length in assumed experiments based on the CTR spectra measurements at A0 Photo injector and the ILC injection module.

TUPPH016 Start-to-End Simulations of PAL XFEL Test Facility (PTF)

Yujong Kim (FEL/Duke University, Durham, North Carolina), Jinhyuk Choi, Jung Yun Huang, Changbum Kim, In Soo Ko, Tae-Yeon Lee, Jong-Seok Oh, Sung Ju Park (PAL, Pohang, Kyungbuk)

To deliver coherent, ultra-bright, ultra-fast photon beams in the hard X-ray region, a linac based PAL XFEL facility will be built at Pohang Accelerator Laboratory in the near future. To develop needed accelerator and FEL technologies for the PAL XFEL project, we will build a small scale PAL XFEL Test Facility (PTF) with about 350 MeV S-band linac. As an R&D work for the PTF and PAL XFEL projects, In this paper, we describe start-to-end (S2E) simulations from the cathode to the end of undulator of the PTF project.

TUPPH017 Experimenatl Optimization of Photoemission Mode RF Gun and 270 MeV Linac for Duke FEL Facility

Yujong Kim, Jingyi Li, Stepan F. Mikhailov, Ping Wang, Y. K. Wu (FEL/Duke University, Durham, North Carolina)

At Duke Free Electron Laser Laboratory, a 270 MeV S-band linac injector has been operating for more than ten years with an RF photocathode gun. This RF gun was driven by a short pulse (1 ns) nitrogen laser to

allow direct single bunch injection into the storage ring based Duke FEL facility. With a newly commissioned booster synchrotron between the linac and the storage ring based FEL facility, a higher power, longer-pulse (5 ns) Nd:YAG laser has been used to replace the original nitrogen laser. In this paper, we describe our experimental optimization of the S-band RF gun with the new Nd:YAG laser and the 270 MeV S-band linac to improve beam transverse emittance, energy spread, and stable top-off operation of Duke FEL facility.

TUPPH018 Development of Ultra-short Pulse, Single Coherent Spike for SASE X-ray FELs

Pietro Musumeci, Claudio Pellegrini, Sven Reiche, James Rosenzweig (UCLA, Los Angeles, California)

There is a large interest in the production of high power, ultra-short, one femtoseconds or less, coherent X-ray pulses, for atomic physics and other applications. However the present design of X-ray SASE FELs leads to an X-ray pulse about 100 times longer. Several methods to reduce the bunch length to the 10-1 fs region have been proposed. These methods are based on electron bunch manipulation to cut the lasing part of the bunch to a fraction of the total length, thus reducing the X-ray pulse length. We are considering here a different method, using ultra-short, very low charge electron bunches, with a length of the order or shorter than the FEL cooperation length. In this case the X-ray pulse length after amplification in the undulator is a few times the electron bunch length. Our simulations show that in an LCLS-like case we can obtain coherent, Fourier transform limited, X-ray pulses, consisting of a single spike, with a FWHM of about 0.1 um, corresponding to about 300 as, a peak power of about 5 GW, and an intensity of about 10 uJ.

TUPPH019 Simulations for the LCLS Injector

Cecile Limborg-Deprey, Yuantao Ding, David Dowell, Paul Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Zhirong Huang, Richard Iverson, Patrick Krejcik, Henrik Loos, Alan Miahnahri, John Schmerge, James Leslie Turner, William White, Juhao Wu (SLAC, Menlo Park, California)

The commissioning of the LCLS Injector has started this year. The electron beam quality for producing high power SASE X-rays is very challenging to reach. In this paper, we will describe comparisons between simulations made with multi-particle tracking code and electron beam measurements performed on the LCLS injector.

SLAC is operated by Stanford University for the Department of Energy under contract number DE-AC03-76SF00515.

TUPPH020 Calculation of the Performance of an X-ray FEL at 6GeV Based on HGHG

Li-Hua Yu, Timur Shaftan (BNL, Upton, Long Island, New York)

We calculate the performance of an x-ray FEL at 6GeV based on HGHG principle.

TUCAU01 No-nonsense Approach to Storage Ring FEL Physics

Vladimir N. Litvinenko (BNL, Upton, Long Island, New York)

Storage Ring FELs (SR FELs) have subtleties that lead to significant differences from traditional linac-driven FELs. In particular: a) The dynamics of SR FELs is strongly influenced by the reuse of the same electron beam, resulting in significant modifications of electron beam properties in all three dimensions; b) SR FELs have "soft" saturation mechanism, which differs from other FELs. At the same time, the SR FEL community is very small. Physicists with general expertise in FELs who review SR FEL papers may miss SR FEL subtleties. As a result, a number of wrong concepts appeared in publications on SR FELs and went unnoticed for years. Fortunately, the low gain in all existing SR FELs provides for a unified and compact description. This paper presents such a 3-D description of SR FELs (an extension of the approach developed in early works of Vinokurov) with clear identification of the processes, the characteristics and the range of possible parameters. The main theoretical concepts and processes are illustrated with experimental figures and techniques. A number of analogies and contrasts between SR and linac-driven FEL are provided. This paper could become a useful tool for weeding out present and future misconceptions in SR FEL theory and experiments.

TUCAU02 Even Harmonic Generation on UVSOR-II Storage Ring

Marie Labat (CEA, Gif-sur-Yvette), Guillaume Lambert (CEA, Gif-sur-Yvette; RIKEN Spring-8, Hyogo), Masahito Hosaka (Nagoya University, Nagoya; UVSOR, Okazaki), Marie-Emmanuelle Couprie (SOLEIL, Gif-sur-Yvette), Masahiro Katoh, Akira Mochihashi, Miho Shimada (UVSOR, Okazaki)

In the Coherent Harmonic Generation Free Electron Laser configuration, the electrons act as a non-linear medium radiating harmonics of a seed source (e.g., a laser). In the two-step seeding scheme, the seed field forces an energy modulation on the electron bunch in a modulator, converted into a density modulation as the electron beam travels through a dispersive section. Finally, in the radiator, the microbunched electron beam can emit coherently at the fundamental and the harmonics of the seed source. In this paper, successful even harmonic generation is reported on the CHG UV-FEL of UVSOR-II storage ring (Japan) at 600 MeV, using a 2.5 mJ, 1 kHz, 1.2 ps Ti:Sa laser at 800 nm. Second and fourth harmonics were generated using planar configuration of the undulators, and second harmonic was generated in helical configuration, in addition to already observed and studied third coherent harmonic. Such preliminary results allow attractive perspectives to understand further even harmonic generation process, still discussed among the FEL community: in single pass non-guided FELs, with planar undulators even harmonics are expected to vanish on-axis, a spectral selection that could be avoided with helical undulators.

TUCAU03 Seeded Harmonic Generation with the Elettra Storage-Ring Free Electron Laser

Francesca Curbis, Enrico Allaria, Miltcho B. Danailov, Giovanni De Ninno, Bruno Diviacco, Emanuel Karantzoulis, Carlo Spezzani, Svetla Tileva, Mauro Trovo (ELETTRA, Basovizza, Trieste), Marcello Coreno (CNR - IMIP, Trieste)

We have recently demonstrated that the Elettra storage-ring free-electron laser is well suited for producing intense VUV harmonic radiation in seeded "single-pass" configuration. After reviewing the experimental setup, we present here the temporal and spectral characterization of the harmonic pulse with respect to several adjustable parameters, such as the seed power, repetition rate (10 Hz +/- 1 kHz) and pulse duration, the seed pulse-electron bunch temporal detuning and the strength of the dispersive section between undulators. Measured peak power in the working wavelength range (i.e., 260-130 nm for the reported experiments) is several orders of magnitude above spontaneous synchrotron radiation. We also show that measurements are in very good agreement with 3D numerical simulations. The obtained results make the Elettra storage-ring free-electron laser in seeded "single-pass" configuration an ideal test facility for next generation linac-based FELs and, at the same time, a ready-to-use light source for user experiments.

TUCAU04 A Versatile High Gain Storage Ring FEL Powered by a Distributed Optical Klystron

Y. K. Wu, Jingyi Li, Stepan F. Mikhailov, Victor Popov (FEL/Duke University, Durham, North Carolina), Nikolay A. Vinokurov (BINP SB RAS, Novosibirsk)

In this work, we report the recent research results of a distributed optical klystron based storage ring FEL at Duke University, the DOK-1 FEL. The DOK-1 FEL is a hybrid system, comprised of four wigglers: two horizontal and two helical. This new FEL has demonstrated the highest FEL gain among storage ring based FEL oscillators using the distributed optical klystron configuration. The enhanced FEL gain of the DOK-1 FEL opens the door for storage ring based FELs to operate in the VUV region toward 150 nm. We have also realized controlled polarization switches of the FEL beam by a non-optical means through the manipulation of a buncher magnet. The DOK-1 FEL is a promising light source capable of rapid polarization switch in UV and VUV. The versatility of the DOK-1 FEL extends to many areas, including the ability of being operated as a multi-color light source for generation of coherent harmonic radiation.

This work is supported by the medical FEL grant F49620-001-0370 from the Air Force Office of Scientific Research and by U.S. Department of Energy grant DE-FG05-91ER40665.

WEAAU01 Commissioning Results of the SLAC LCLS Gun

David Dowell, Ron Akre, John Castro, Paul Emma, Josef Frisch, Sasha Gilevich, Gregory R. Hays, Philippe Hering, Richard Iverson, Patrick Krejcik, Cecile Limborg-Deprey, Henrik Loos, Alan Miahnahri, John Schmerge, James Leslie Turner, James Welch, William White, Juhao Wu (SLAC, Menlo Park, California)

The beam quality and operational requirements for the Linac Coherent Light Source (LCLS) currently being

constructed at SLAC are exceptional, requiring the design of a new s-band RF photocathode gun for the electron source. Two guns (Gun1 and Gun2) have been fabricated and tested at high RF power. Gun1 was installed March 17, 2007 and began providing beams for the LCLS injector commissioning on April 5, 2007. Gun2 is reserved as a backup gun. The results and analysis of the gun's performance in the LCLS injector will be presented.

*SLAC is operated by Stanford University for the Department of Energy under contract DE-AC03-76SF00515

WEAAU02 Direct Measurement of Phase Space Evolution in the SPARC High Brightness Photoinjector

Enrica Chiadroni, David Alesini, Marco Bellaveglia, Manuela Boscolo, Michele Castellano, Alberto Clozza, Luca Cultrera, Giampiero Di Pirro, Alessandro Drago, Adolfo Esposito, Massimo Ferrario, Daniele Filippetto, Valeria Fusco, Alessandro Gallo, Giancarlo Gatti, Andrea Ghigo, Maurizio Incurvati, Carlo Ligi, Luigi Pellegrino, Ruggero Ricci, Claudio Sanelli, Mario Serio, Francesco Sgamma, Bruno Spataro, Franco Tazzioli, Sandro Tomassini, Cristina Vaccarezza, Mario Vescovi, Carlo Vicario (INFN/LNF, Frascati (Roma)), Luca Giannessi, Marcello Quattromini, Concetta Ronsivalle (ENEA C.R. Frascati, Frascati (Roma)), Simone Cialdi, Andrea Renato Rossi, Luca Serafini (INFN-Milano, Milano), Luciano Catani, Alessandro Cianchi (INFN-Roma II, Roma), Massimo Petrarca (INFN-Roma, Roma), Alberto Bacci (INFN/LASA, Segrate (MI)), Mauro Migliorati, Andrea Mostacci, Luigi Palumbo (Rome University La Sapienza, Roma), Pietro Musumeci, James Rosenzweig (UCLA, Los Angeles, California)

The characterization of the transverse phase space for high charge density relativistic electron beams is a fundamental requirement in many particle accelerator facilities, in particular those devoted to fourth-generation synchrotron radiation sources, such as SASE FEL. The main purpose of the SPARC initial phase was the commissioning of the RF photoinjector. At this regard, the evolution of the phase space has been fully characterized by means of the emittance meter diagnostics tool, placed in the drift after the gun exit. The large amount of collected data has shown not only that we can achieve the SPARC nominal parameters, but has also allowed for the first time a detailed reconstruction of the transverse phase space evolution along the drift, giving evidences of the emittance compensation process to occur as predicted by theory and simulations. In particular the peculiar behavior of a flat top longitudinal electron distribution compared to a gaussian distribution has been studied giving important insights for the correct matching with the following linac based on the double emittance minimum effect.

WEAAU03 Development of Nanodiamond-Field-Emission Arrays for Free-Electron Lasers

Jonathan D. Jarvis, Heather L. Andrews, Charles A. Brau (Vanderbilt University, Nashville, Tennessee)

We present progress in the measurement and simulation of achievable current density and transverse emittance from nanodiamond gated-field-emission arrays (FEA). Arrays of 10-100 nanodiamond tips have been produced using an inverse mold technique. In addition, diamond coated silicon tip arrays are being fabricated. The transverse emittance of these arrays is measured using a pepperpot and phosphor screen, as well as a moving pinhole and wire. Simulations of emittance growth in beamlets traveling through FEA unit cells have been performed. The results are being used to optimize electrode geometry design so that transverse emittance is minimized at the cell exit.

Office of Naval Research, grant NOOOO14-06-0572

WEAAU04 Superconducting Photoinjector for High-Power Free Electron Lasers

Ilan Ben-Zvi, Andrew Burrill, Rama Calaga, Xiangyun Chang, Ranjan Grover, Dmitry Kayran, Jorg Kewisch, Vladimir N. Litvinenko, Gary McIntyre, Damayanti Naik, David Pate, Eduard Pozdeyev, Triveni Rao, John Smedley, Robert J. Todd (BNL, Upton, Long Island, New York), Michael Cole, Michael Falletta, Douglas Holmes, John Rathke, Tom Schultheiss, Robert Wong (AES, Medford, NY), Alan Murray Melville Todd (AES, Princeton, New Jersey)

One of the frontiers in FEL science is that of high power. In order to reach power in the megawatt range, one requires a current of the order of one ampere with a reasonably good emittance. The superconducting laser-photocathode RF gun with a high quantum efficiency photocathode is the most natural candidate to provide this performance. The development of a 1/2 cell superconducting photoinjector designed to operate at a current of 0.5 amperes and beam energy of 2 MeV and its photocathode system are the subjects covered in this paper. The main issues are the photocathode and its insertion mechanism, the power coupling and High Order Mode damping. This technology is being developed at BNL for DOE nuclear physics applications such as electron cooling at high energy and electron ion colliders.

Work performed under the auspices of the U.S. Department of Energy.

WEAAU05 A Compact Electron Spectrometer for an LWFA

Alex Lumpkin, Robert Crowell, Kwang-Je Kim (ANL, Argonne, Illinois)

The use of a laser wakefield accelerator (LWFA) beam as a driver for a compact Free-Electron Laser (FEL) has been proposed recently. A project is underway at Argonnne National Laboratory (ANL) to operate an LWFA in the bubble regime and to use the quasi-monoenergetic electron beam as a driver for a 3-m long undulator for generation of sub-ps UV radiation. The Terawatt Ultrafast High Field Facility (TUHFF) in the Chemistry division provides the 20 TW peak power laser. Towards this goal, a compact electron spectrometer whose initial fields of 0.45 T provide energy coverage of 30-200 MeV has been selected to characterize the electron beams. The system is based on the Ecole Polytechnique design* used for their LWFA and incorporates the 5-cm long permanent magnet dipole, the LANEX scintillator screen located at the dispersive plane, a Roper Scientific 16-bit MCP-intensified CCD camera, and a Bergoz ICT for complementary charge measurements. Test results on the magnets, the 16-bit camera, and the ICT will be described, and initial electron beam data will be presented as available.

*Y. Glinnec et al., "Broadrange Single Shot Electron Spectrometer", Report dated July 6, 2006, Ecole Polytechnique.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

WEBAU01 Adaptive 3-D UV-laser Pulse Shaping System to Minimize Emittance for Photocathode RF Gun

Hiromitsu Tomizawa, Takao Asaka [on leave], Hideki Dewa [on leave], Hirofumi Hanaki [on leave], Toshiaki Kobayashi [on leave], Akihiko Mizuno [on leave], Shinsuke Suzuki [on leave], Tsutomu Taniuchi [on leave], Kenichi Yanagida [on leave] (JASRI/SPring-8, Hyogo-ken), Futoshi Matsui [on leave] (Industrial Technology Center of Fukui, Fukui City)

We developed an adaptive 3-D shaping (both temporal (1D) and spatial (2D)) short pulse (80 fs~40 ps) UV-laser system as an ideal light source for yearlong stable generation of a low emittance electron beam with a high charge (1~2 nC/pulse). In its current form, the laser's pulse-energy stability has been improved to 0.2~0.3% (rms; 10 pps, 0.4 TW in femtosecond operation) at the fundamental wavelength and 0.7~1.4% at the third-harmonic generation. Such improvement reflects an ability to stabilize the laser system in a humidity-controlled clean room. The pulse-energy stability of a mode-locked femtosecond oscillator has been continuously held to 0.3% (p-p) for 10 months, 24 hours a day. In addition, the ideal spatial and temporal profiles of a shot-by-shot single UV-laser pulse are essential to suppress emittance growth in an RF gun. We apply a deformable mirror that automatically shapes the spatial UV-laser profile with a feedback routine, based on a genetic algorithm, and a pulse stacker for temporal shaping at the same time. The 3D shape of the laser pulse is spatially top-hat (flattop) and temporally a square stacked pulse. Using a 3D-shaped laser pulse with a diameter of 0.8 mm on the cathode and pulse duration of 10 ps (FWHM), we obtain a minimum normalized emittance of 1.4 mm mrad with beam energy of 26 MeV.

WEBAU02 Recent Experimental Results from PITZ

Frank Stephan, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Sven Lederer, Anne Oppelt, Bagrat Petrosyan, Sabine Riemann, Sakhorn Rimjaem, Thomas Scholz, Lazar Staykov (DESY Zeuthen, Zeuthen), Dieter Richter (BESSY GmbH, Berlin), Klaus Floettmann (DESY, Hamburg), Galina Asova [on leave], Konstantin Konstantinov Boyanov [on leave] (INRNE, Sofia), Andrey Shapovalov [on leave] (MEPhI, Moscow), Juliane Roensch (Uni HH, Hamburg), Levon Hakobyan [on leave] (YerPhI, Yerevan)

The Photo Injector Test facility at DESY in Zeuthen (PITZ) was built to develop and optimize electron sources for superconducting linac driven, high power, short wavelength FELs. A 1.5 cell L-band gun cavity characterized at PITZ has provided beam for FLASH since 2004. A spare RF gun has been characterized at PITZ and delivered to Hamburg as well. To meet the stringent requirements on beam quality for the European XFEL, a substantial upgrade program is ongoing at PITZ. In a first operation period during October 2006, projected normalized transverse emittances in both transverse planes between 1.2 and 1.5 mm mrad for a bunch charge of 1 nC were measured. These results are in good agreement with simulations. A major step towards even lower emittance is the increase of the electric field at the photo cathode from 40 MV/m to 60 MV/m. With the upgrades ongoing now, simulations predict a projected normalized transverse emittance of 1.2 mm mrad and better for 1 nC bunch charge in the running period scheduled for summer 2007. This contribution will give an overview of the experimental results obtained at PITZ in the operation periods of October 2006 and summer 2007 (e.g. transverse and longitudinal phase space measurements, dark current and cathode properties). The main steps of the further upgrade program at PITZ will be mentioned as well.

The work is supported by the European Community, contract numbers RII3-CT-2004-506008 and 011935, and by the "Impuls- und Vernetzungsfonds" of the Helmholtz Association, contract number VH-FZ-005.

WEBAU03 Performance Tests of the Photon Monochromator for Self-seeding at FLASH

Rolf Treusch, Ulrich Hahn, Jens Viefhaus (DESY, Hamburg), Henrik Kloppenburg Bechtold, Jan Hartvig, Henrik Juul, Vagn Toft (Aarhus University, Aarhus), Rolf Follath, Gerd Reichardt, Friedmar Senf, Frank Siewert (BESSY GmbH, Berlin), Soeren Vronning Hoffmann (ISA, Aarhus), Christian Knoechel (LBNL, Berkeley, California), Ruben Reininger (UW-Madison/SRC, Madison, Wisconsin)

A single pass FEL amplifier can produce extremely intense and fully coherent radiation at short wavelengths if it is seeded by a coherent light beam resonant with the magnetic structure and collinear with the electron beam. Since at the present time a single pass SASE FEL is the only source of sufficiently intense, tunable radiation in the soft X-ray region, it has been proposed to use such a source in combination with a narrow-band monochromator for seeding an FEL amplifier*. By means of such a "Self-Seeding", the soft X-ray free electron laser FLASH at DESY will be modified so that it can provide coherent radiation in space and time in a wavelength range from about 60-6nm (~20-200eV). In this presentation, we will focus on the performance of the photon monochromator beamline which was setup and tested at the synchrotron radiation storage ring ASTRID in Aarhus, Denmark. The optical, mechanical and vacuum design will be described along with results on the resolving power of the monochromator which have been obtained scanning across rare gas resonance lines at various energies. Based on these results we will conclude that the monochromator is mechanically very stable and reproducible and behaves according to its specifications with resolving powers between 10000 and 20000, i.e. bandwidths of a few meV only.

* J. Feldhaus, E.L. Saldin, J.R. Schneider, E.A. Schneidmiller, and M.V. Yurkov, Opt. Commun. 140, 341 (1997)

WEBAU04 Single-Shot Longitudinal Bunch Profile Measurements at FLASH Using Electro-Optic Detection: Experiment, Simulation, and Validation

Bernd Steffen, Vladimir Arsov, Ernst-Axel Knabbe, Bernhard Schmidt, Peter Schmüser (DESY, Hamburg), Giel Berden, Alexander van der Meer (FOM Rijnhuizen, Nieuwegein), Steven Jamison (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Allan MacLeod (UAD, Dundee), William Allan Gillespie, Paul Jonathan Phillips (University of Dundee, Nethergate, Dundee, Scotland)

At the superconducting linac of FLASH at DESY, we have installed an electro-optic experiment for single shot, non-destructive measurements of the longitudinal electric charge distribution of individual electron bunches. The profile of the electric bunch field is electro-optically encoded onto a stretched Ti:Sa laser pulse. In the decoding step, the profile is retrieved from a cross-correlation of the encoded pulse with a 35 fs laser pulse, obtained from the same laser. At FLASH, sub-100 fs electron bunches have been measured during FEL operation with a resolution of better than 50 fs. The electro-optic encoding process in gallium phosphide as well as the decoding step in a frequency doubling BBO crystal were numerically simulated using bunch shapes simultaneously measured with a transverse-deflecting rf structure as input data. In this contribution, we present electro-optically measured profiles and compare them with the simulation.

WEBAU05 Magnetic Measurements, Tuning and Fiducialization of LCLS Undulators at SLAC

Yurii Levashov, Vsevolod Kaplounenko, Achim Weidemann, Zachary Wolf (SLAC, Menlo Park, California)

A new Magnetic Measurement Facility (MMF) has been built at Stanford Linear Accelerator Center (SLAC) to measure, tune and fiducialize undulators for Linac Coherent Light Source (LCLS) project. Climate controlled MMF utilizes two magnetic measurement benches and a large Coordinate Measurement Machine (CMM) and provides a throughput of one undulator segment a week. Magnetic measurement, tuning and fiducialization process is being presented and first tuning results are discussed.

US DOE Contract DE-AC02-76SF00515. This work was performed in support of the LCLS FEL project at SLAC

WEPPH001 Femtosecond CPA-based Laser Research & Development Program for Photoinjectors

Olivier Bernard Gobert, David Garzella, Stéphanie Grabielle, Jean-François Hergott, Philippe Hollander, Delphine Jourdain, Fabien Lepetit, Michel Perdrix, Olivier Tcherbakoff (CEA, Gif-sur-Yvette), Thomas Oksenhendler (FASTLITE, Palaiseau), Giovanni Daniele Rovera (LNE-SYRTE, Paris)

High Brightness, electron Linac-based light sources call for synergy with conventional high energy laser sources. Indeed, photoinjectors R&D needs lasers R&D. The Ti:S lasers based on Chirped Pulse Amplification (CPA) techniques can supply the requested light features for operating with such accelerator systems, provided that one can shape and control the laser pulses in the temporal and spatial domain. In the EUROFEL European program framework, the investigations performed by the LUCA/PLFA team at the Saclay Laser Interaction Center are twofold : - Temporal and spatial shaping of fs UV laser pulses. Temporal beam shaping is performed through an amplitude and phase modulation in the pulse spectral domain by means of an active programmable system. Transverse pulse shaping is achieved with a passive optical system based on aspheric optics. A combination of both techniques allows one to obtain "beer can" shaped photoelectron bunches easily. -Investigations in laser/LINAC synchronization and timing distribution. Optical experimental techniques are used to measure the drift and the jitter at the output laser system whose oscillator repetition rate is locked on a Rb atomic clock. In the present paper the major numerical studies and experimental results are presented. Further considerations on the benefits and the limits brought by these experimental techniques will be discussed.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 – EUROFEL.

WEPPH002 Longitudinal and Spatial shaping of UltraViolet Femtosecond laser pulses: Theoretical Investigations and Experimental Results

Olivier Bernard Gobert, David Garzella, Stéphanie Grabielle, Jean-François Hergott, Philippe Hollander, Delphine Jourdain, Fabien Lepetit, Michel Perdrix, Olivier Tcherbakoff (CEA, Gif-sur-Yvette), Thomas Oksenhendler (FASTLITE, Palaiseau)

The search for minimized emittance high charge electron bunches calls for increased efforts in controlling the temporal and spatial features of photoinjector drive lasers. In the EUROFEL framework, the LUCA/PLFA team in Saclay (SLIC) is investigating the longitudinal and transverse shaping of ultrashort laser pulses. The main goal is to obtain properly shaped UV (@266 nm) ps laser pulses. Temporal pulse shaping is performed through amplitude and phase modulation in the spectral domain with an acousto-optic programmable dispersive filter (Dazzler). Square and parabolic shapes are achieved either by modulating an IR laser pulse (@800 nm) before UV up-conversion, or by a direct manipulation of the UV pulse. Analogies and differences between the two procedures are here underlined through theoretical and experimental studies. Transverse shaping is obtained by using a passive optical system based on aspheric optics, leading to a homogeneous flat-top transverse distribution. The major results on a UV pulse are shown. Moreover, preliminary experimental studies, introducing the use of a deformable mirror and the effects of spatial phase modulation on the laser pulse are also presented here, together with a theoretical analysis. Combined longitudinal and transverse shaping allows us to obtain "beer can" shaped laser pulses easily, and thus photoelectron bunches of the same shape.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 – EUROFEL.

WEPPH003 Magnetic Measurements of the FLASH Infrared Undulator

Oliver Grimm, Yorck Holler (DESY, Hamburg), Alexander Chesnov, Evgeny Matushevsky, Nikolay Morozov, Dmitrij Petrov, Evgeny Syresin (JINR, Dubna, Moscow Region), Jörg Rossbach (Uni HH, Hamburg)

The FLASH free-electron laser at DESY, Hamburg, will be equipped with an infrared electromagnetic undulator during the current shut-down, providing radiation in the range 1-200 um. It will be used both for electron beam diagnostics purposes and as a powerful source synchronized to the VUV and soft X-ray pulses of the FEL. The undulator was constructed at the Joint Institute of Nuclear Research (JINR). This paper summarizes the extensive magnetic measurements that where performed both at JINR and DESY prior to installation of the undulator.

WEPPH004 Numerical Calculations of the Radiation Emitted from the FLASH Infrared Undulator

Oliver Grimm, Vitali Kocharyan (DESY, Hamburg), Jörg Rossbach (DESY, Hamburg; Uni HH, Hamburg)

The results from the magnetic measurements with the FLASH infrared electromagnetic undulator reported in a companion paper where used as input for calculations of the expected radiation spectrum. Especially the behaviour of the device at small first harmonic wavelengths, i.e. small excitation currents, is important for beam diagnostics, as here the high intensity in a narrow band is a distinct advantage over broad-band sources to detect small bunch structures. The field quality is reduced at small currents due to imperfections in the yoke construction and limited compensation by correction windings. A determination of the lower limit for useful operation of the device follows from these calculations.

WEPPH005 Magnet Sorting for the European XFEL Hybrid Undulator - Comparing Study

Yuhui Li, Bart Faatz, Joachim Pflueger (DESY, Hamburg)

Current permanent magnet material quality is insufficient to obtain field qualities in undulators, which satisfy FEL requirements. Therefore position and orientation of magnets have to be carefully chosen in order to obtain mutual cancellation of field errors. In this paper we compare two different sorting schemes, simulated annealing and a straight forward paring method. They are applied to a 5m prototype structure built for the European XFEL facility. The algorithms of these two methods are described in detail and the sorting results and the expected field qualities are carefully compared

WEPPH006 Study of Undulator Deformation Tolerance for the European XFEL

Yuhui Li, Bart Faatz, Joachim Pflueger (DESY, Hamburg)

The undulators for the European XFEL use NdFeB type permanent magnets. Even for perfect magnet material, the undulator quality degrades due to mechanical limitations, such as girder deformation, and temperature variation. Since the beam orbit can always be corrected, the main effect will be a variation in slippage between electrons and photon beam along the undulator. A careful estimation of the error budget is needed to avoid cost driving hardware efforts. We modeled deformation, gap variation and temperature error and used GENESIS to simulate the effect on the performance of the European XFEL.

WEPPH007 MCP-based Photon Detector with Extended Wavelength Range for FLASH

Lutz Bittner, Josef Feldhaus, Ulrich Hahn, Mathias Hesse, Ulf Jastrow, Vitali Kocharyan, Paul Radcliffe, Evgeny Saldin, Evgeny Schneidmiller, Kai I. Tiedtke, Rolf Treusch, Nicole von Bargen, **Mikhail Yurkov** (DESY, Hamburg), Viatcheslav Lokhmatov, Evgeny Syresin (JINR, Dubna, Moscow Region), Oleg Brovko, Dmitry Kharlamov, Evgeny Matyushevskiy, Alexey Shabunov (JINR/LHE, Moscow)

Experimental experience gained at the extreme ultraviolet SASE FEL FLASH (DESY, Hamburg) has shown that successful operation of the facility strongly depends on the quality of the radiation detectors. Here key issues are: wide wavelength range (6 to 100 nm for FLASH), wide dynamic range (from the level of spontaneous emission to the saturation level), and high relative accuracy of measurements which is crucial for detection of a signature of amplification and characterization of statistical properties of the radiation. In this report we describe MCP-based radiation detector for FLASH which meets these requirements. Key element of the detector is wide dynamic range micro-channel plate (MCP) which detects scattered radiation from a target. With five different targets and MCPs in combination with optical attenuators present detector covers operating wavelength range from 6 to 100 nm, and dynamic range of the radiation intensities, from the level of spontaneous emission up to the saturation level of SASE FEL.

WEPPH008 Measurements of Projected Emittances at FLASH

Katja Honkavaara (Uni HH, Hamburg), Florian Loehl, Eduard Prat (DESY, Hamburg)

FLASH is a SASE FEL user facility at DESY (Hamburg) operating with photon wavelengths in the range from vacuum ultraviolet to soft x-rays. Although the slice emittance is a more appropriate parameter to characterize the SASE process, the projected emittance provides a useful measure of the electron beam quality. At FLASH the projected emittance is measured at three location along the linac: in the injector (130 MeV), after the collimator (full electron beam energy), and in the undulator section. The transverse beam shape is measured with OTR monitors and wire scanners. The multi-monitor method is used to

determine the emittance. In this paper we describe the measurement set-up and procedure and report recent results and planned upgrades.

WEPPH009 Recent Measurements of the Longitudinal Phase Space at PITZ

Juliane Roensch, Jörg Rossbach (Uni HH, Hamburg), Dieter Richter (BESSY GmbH, Berlin), Galina Asova, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Levon Hakobyan, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Sven Lederer, Bagrat Petrosyan, Sabine Riemann, Sakhorn Rimjaem, Thomas Scholz, Lazar Staykov, Frank Stephan (DESY Zeuthen, Zeuthen), Kilian Rosbach (Humboldt University Berlin, Berlin)

The Photo Injector Test facility at DESY in Zeuthen (PITZ) was built to test and optimize electron guns for short wavelength Free-Electron Lasers (FELs) like FLASH and XFEL at DESY in Hamburg. For a detailed analysis of the behaviour of the electron bunch, the longitudinal phase space and it projections can be measured behind the gun cavity. The electric field at the photo cathode was increased from 40 MV/m to 60 MV/m, to optimize the transverse emittance. The momentum distributions for different gradients and gun phases will be presented. The determination of the field balance from the momentum distribution will be discussed. In order to study emittance conservation, a booster cavity and additional diagnostics were installed. The evolution of the longitudinal phase space in the booster cavity will be investigated. Measurements of the momentum distribution and longitudinal distribution behind the booster cavity will be discussed.

This work has partly been supported by the European Community, contracts RII3-CT-2004-506008 and 011935, and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract VH-FZ-005.

WEPPH010 Investigations on an Optical Transmission Line for Time Resolved Measurements Using Reflective Optics

Juliane Roensch (Uni HH, Hamburg), Juergen W. Baehr (DESY Zeuthen, Zeuthen), Kilian Rosbach (Humboldt University Berlin, Berlin)

The Photo Injector Test facility at DESY in Zeuthen (PITZ) was built to test and optimize electron guns for short wavelength Free-Electron Lasers (FELs) like FLASH and XFEL at DESY in Hamburg. An optimization of the photoinjector is only possible with high resolution diagnostics. The improvement of the temporal resolution of the system for the measurement of the longitudinal bunch distribution and longitudinal phase space is a major concern. The current system contains a Cherenkov radiator or an optical transition radiator (OTR), an optical transmission line of about 30 m length, which consists of refractive optics* and a streak camera. Especially the optical transmission line contribute to the temporal resolution, due to dispersion. Although useful results could be reached with the current system, it suffers from loss of light due to the use of a narrow bandwidth optical transmission filter. In order to reduce dispersion effects the refractive optics is aimed to be replaced by reflecting optics. Detailed investigations about the choice of mirrors for an optimized pulse transport with a high longitudinal and transverse resolution will be discussed. The existing optical transmission line contains several sub-branches with special conditions to be fulfilled*. It has to be discussed how to match the ideal model to these requirements.

* J.Baehr, J.Roensch "Optical system for measurement of Electron Bunch length and longitudinal phase space at PITZ: extension and methodical investigations" Dipac07. Venice, Italy

Community, contracts RII3-CT-2004-506008 and 011935, and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract VH-FZ-005.

WEPPH011 Photocathode Laser Pulse Diagnostics at PITZ

Marc Hänel, Juergen W. Baehr, Sergey Korepanov, Mikhail Krasilnikov, Frank Stephan (DESY Zeuthen, Zeuthen), Yevgeniy Ivanisenko (DESY Zeuthen, Zeuthen; KhNU, Kharkov)

The main objective of the Photo Injector Test facility at DESY in Zeuthen (PITZ) is the development of electron sources that meet the requirements for existing and future FELs such as FLASH or the European XFEL. The goal is the minimization of the transverse emittance of the produced electron bunches. In this respect one of the key issues is the cathode laser system, which should provide longitudinal and transversal flat-top pulses with an excellent long-term stability. In this work we present the full system of laser diagnostics that is currently used at PITZ to monitor the laser pulse parameters.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract no. VH-FZ-005.

WEPPH012 Investigations on the Thermal Emittance of Cs2Te Photocathodes at PITZ

Sven Lederer, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Bagrat Petrosyan, Sakhorn Rimjaem, Thomas Scholz, Lazar Staykov, Frank Stephan (DESY Zeuthen, Zeuthen), Dieter Richter (BESSY GmbH, Berlin), Galina Asova (DESY Zeuthen, Zeuthen; INRNE, Sofia), Juliane Roensch (DESY Zeuthen, Zeuthen; Uni HH, Hamburg), Levon Hakobyan (DESY Zeuthen, Zeuthen; YerPhI, Yerevan), Konstantin Konstantinov Boyanov (INRNE, Sofia), Andrey Shapovalov (MEPhI, Moscow)

The main objective of the Photo Injector Test facility at DESY in Zeuthen (PITZ) is the production of electron beams with minimal transverse emittance. The lower limit of this property of electron beams produced with a photocathode in an RF-gun is determined by the thermal emittance. To understand this crucial parameter for high performance FEL's, measurements under RF operation conditions for Cesium Telluride (Cs2Te) photocathodes are done. Results for various accelerating gradients and the dependence on the laser spot size in the cathode plane are presented and discussed in this work.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract no. VH-FZ-005.

WEPPH013 Status and Perspectives of the PITZ Facility Upgrade

Sakhorn Rimjaem, Galina Asova, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Levon Hakobyan, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Sven Lederer, Anne Oppelt, Bagrat Petrosyan, Sabine Riemann, Thomas Scholz, Lazar Staykov, Frank Stephan (DESY Zeuthen, Zeuthen), Dieter Richter (BESSY GmbH, Berlin), Klaus Floettmann (DESY, Hamburg), Kilian Rosbach (Humboldt University Berlin, Berlin), Konstantin Konstantinov Boyanov (INRNE, Sofia), Andrey Shapovalov (MEPhI, Moscow), Juliane Roensch (Uni HH, Hamburg)

The Photo Injector Test facility at DESY in Zeuthen (PITZ) has been established to develop and optimize electron sources that cover requirements of FEL facilities such as FLASH and the European XFEL. A major upgrade of the facility is ongoing in steps, in parallel to the commissioning of the extended setup and first experiments. The new setup towards the final design mainly includes a photo cathode RF gun, a post acceleration booster cavity and several diagnostic systems. In order to fulfil the high brightness electron source characterization, the diagnostic systems will consist of three emittance measurement systems, two high-energy dispersive arms, an RF deflecting cavity and a longitudinal phase space tomography module as well as bunch length diagnostics. In this paper, results of the commissioning of the new RF gun, which has been installed and conditioned at PITZ in spring and summer of 2007, the current PITZ status and details of the future facility upgrade will be presented.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract no. VH-FZ-005.

WEPPH014 Performance of the FERMI FEL Photoinjector Laser

Miltcho B. Danailov, Alexander Demidovich, Rosen Ivanov, Paolo Sigalotti (ELETTRA, Basovizza, Trieste)

The photoinjector laser system for the FERMI FEL has been installed at the ELETTRA laser laboratory. It is based on a completely CW diode pumping technology and features a two stage pulse shaping system, a time-plate type third harmonic generation scheme and aspheric shaper based beam shaping. The paper will present experimental results describing the overall performance of the amplifier system as well as of the main sub-system listed above. The data demonstrates that all the initially set parameters were met and some largely exceeded. Special attention is dedicated to the pulse shaping allowing both flat-top and increasing ramp UV temporal shapes. A scheme for extraction and shaping of the laser heater pulses using the same laser system is also presented.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 EUROFEL

WEPPH015 Modeling of a Laser Heater for Fermi@Elettra

Simone Spampinati, Simone Di Mitri (ELETTRA, Basovizza, Trieste)

To cure the microbunching instability in the FERMI@elettra FEL a laser heater is proposed. The one-dimensional model of the instability predicts a large energy modulation building up the electron beam travels through the linac. According to analytical studies and simulations the longitudinal Landau damping provided by the laser heater is expected to help in suppressing the formation of such a modulation. The efficiency of the beam heating is studied as function of the transverse laser-electron beam mismatch in the laser heater undulator in case of a realistic transverse beam profile.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 EUROFEL

WEPPH016 The SPARC FEL Undulator System: Magnetic and Mechanical Characterizations

Elio Sabia, Franco Ciocci, Giuseppe Dattoli, Andrea Doria, Emilio Giovenale, alessandro Lo Bue, Marcello Quattromini, Giuseppe Ronci, Mauro Sassi, Luigi Semeraro (ENEA C.R. Frascati, Frascati (Roma)), Dirk Doelling, Hans-Udo Klein, Peter Arthur Komorowski, Detlef Krischel, Martin Meyer-Reumers (ACCEL, Bergisch Gladbach)

Strict tolerances are required on the magnetic field quality of the SPARC undulators in order to met the condition of saturation in about 12 meters of magnetic length and to ensure the design performances, which foresee the simultaneous operation at the fundamental and at higher harmonics. The undulator sections have been realised at ACCEL instruments and have been passed different tests aimed at characterizing the requirements of magnetic field and mechanical precision. We describe the various magnetic and mechanical test performed either at ACCEL and at the ENEA Frascati Labs. In particular we will report on a) Quality of the magnetic field, namely phase error, roll-off of the transverse magnetic field components along the beam axis and minimization of the errors of the field integrals and integrated multipoles calculated along the transversal beam axis, and their dependence on the gap b) Mechanical issues connected with the proper identification of the geometrical and magnetic axes and with the control of the gap tuning We will in particular comment on the issues associated with he proper understanding of the phase advance and how this parameter is related to other quantities of paramount importance as ΔK/K . Furthermore we will also discuss the observed undulator harmonic content using an appropriate Fourier analysis of the experimental data.

WEPPH017 UV Performances of Pulsed Laser Deposition Grown Mg Photocathodes

Luca Cultrera, Giancarlo Gatti, Franco Tazzioli (INFN/LNF, Frascati (Roma)), Carmen Ristoscu (INFLPR, Bucharest - Magurele), Paola Miglietta, Alessio Perrone (INFN-Lecce, Lecce)

We report a detailed description of the laser cleaning procedure and emission performance measurement on a Pulsed Laser Deposited Mg film. During the tests performed after the end of each cleaning operation we have evidenced an increase of Quantum Efficiency (QE) in time. Then the QE apparently stabilizes at a remarkably higher value. The study of this phenomenon is important because it determines both the working QE value and the lifetime of the cathode. Moreover, the stability of the QE has been revealed for a time scale of several days after each laser cleaning process, in our vacuum conditions.

WEPPH018 A High Brightness X-band Split Photoinjector Concept and Related Technological Challenges

Massimo Ferrario, David Alesini, Mauro Migliorati, Luigi Palumbo, Bruno Spataro (INFN/LNF, Frascati (Roma)), Luca Serafini (INFN-Milano, Milano), James Rosenzweig (UCLA, Los Angeles, California)

Future light sources based on high gain free electron lasers, require the production, acceleration and transport up to the undulator entrance of high brightness (low emittance, high peak current) electron bunches. Wake fields effects in accelerating sections and in magnetic bunch compressors typically contribute to emittance degradation, hence the photo-injector design and its operation is the leading edge for high quality beam production. The state of the art photoinjector beam brightness can be in principle brought above the 10^15 A/m^2 threshold with an X-band gun and a proper emittance compensation scheme. We discuss in this paper an optimized design of a split X-band photoinjector, a convenient matching scheme with the downstream linac, based on the SPARC project experience, and the further technological developments required to reach such an appealing goal.

WEPPH019 Determination of the Wakefield Budget for the FERMI FEL Undulator System

Alberto Andrea Giacomo Lutman (DEEI, Trieste), Cristian Bontoiu, Paolo Craievich (ELETTRA, Basovizza, Trieste)

The FERMI project aims to achieve very high-brightness photon beam pulses of minimum bandwidth. These goals can be marred by the presence of large wakefields generated along the length of the undulator small-gap vacuum chamber. Estimations of the induced energy-spread caused by the resistive wall and surface roughness wakefields along the length of the vacuum chamber of the FERMI FEL undulator are

presented. The energy spread and losses induced by the resistive wall wakefield are determined for three possible transverse geometries of the vacuum chamber, namely circular, rectangular and elliptical cross-section, while the energy spread and losses induced by the surface roughness wakefields are obtained for the circular cross-section case. In this last case in-house surface profile measurements are used to provide realistic estimates.

WEPPH020 Design and Components Development for the Optical Timing and RF Distribution System

Yuji Otake, Masanobu Kitamura, Hirokazu Maesaka (RIKEN Spring-8 Harima, Hyogo), Toru Fukui, Naoyasu Hosoda, Toru Ohata, Takashi Ohshima (JASRI/SPring-8, Hyogo-ken), Mitsuru Musha (University of electro-communications, Tokyo)

At RIKEN, an accelerator as a light source for X-FEL is under construction. Timing and rf phase control accuracy of several ten femto-seconds is required to the timing and LLRF system of the accelerator. However, realizing this accuracy is very difficult with a present electronic circuit. Therefore, we are trying to obtain this accuracy by laser technology. This system comprises; a. an optical comb generator, having 5712 MHz, 1 ps width pulse train, as which has LN crystal installed into an optical fabriot-periot cavity and a phase locked ring fiber laser, b. a DFB laser locked to an acetylene absorption spectrum (1538 nm), c. an optical fiber timing and rf distribution system, which has a function of m for 25 km by a Michelsonμelectrical length regulation controlled within 25 interferometer, d. an electronic circuit-less optical trigger system, to have precise beam timing, which uses the comb pulses passing through EO crystal modulated by the transverse electric field of an electron beam. Its picked up comb pulse is converted by SHG to about 800 nm light for a pump-probe experiment. In this paper, we describe a basic idea of the system, and some results of components development.

WEPPH021 Wide Band Seeding and Wavelength Compression

Tsumoru Shintake (RIKEN Spring-8 Harima, Hyogo)

Seeding with optical laser and compressing wavelength in chicane bunch compressor has been studied theoretically. Overlapping laser beam with in comming electron beam in free space, with oblique crossing, we may apply energy modulation on relativisitic electron beam. When we use forth harmonic YAG-laser, 255 nm, and compressing 20 times, we have 13 nm density modulation period. Passing in undulator, which resonates to the compressed wavelength, the super-radiation mode beam will be generated. In contrast with SASE-FEL, this type of radiation source does not require high quality beam, ease to operate and coherent.

WEPPH022 Feasibility Test of Shottoky Effect-Gated Photocathode RF Gun

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We proposed Shottoky effect-gated photocathode RF gun using z-polarization of laser source. Radically polarized laser propagation modes exist theoretically and were recently generated practically. Focusing a radically polarized beam on the photocathode, the z-polarization of laser is generated at the focusing point. The generated Z-polarization can exceed an electrical field of 1GV/m easily with fundamental wavelength from compact femtosecond laser systems. According to our calculations, the z-field of 1GV/m needs 100MW at peak power for fundamental wavelength (790nm) and 25MW for SHG. In the field of 1GV/m, the work function of copper cathode reduces ~2 eV. The quantum efficiency will be ~10-4 at SHG by the Shottoky effect associated with the 1GV/m. This Shottky effect can be used as a gate of photo-emission process. In our design of Shottoky effect-gated Photocathode, the fundamental is used as gate pulse and SHG as laser source for photo-emission process. The same single laser pulse can also gate its emission by itself. To keep normal incidence on the cathode, we developed modified-Cessegrain-type incident optics combining with axicon lens pair. In the first test run, we are preparing z-polarizer for SHG to generate radial and azimuth polarizations. Comparing photo-emission process with these polarizations, we make clear the feasibility of this new concept of photocathode.

WEPPH023 Beam Properties from S-band Energy Compensated Thermionic RF Gun and Linac for KU-FEL

Toshiteru Kii, Kai Masuda, Hideaki Ohgaki, Satoshi Sasaki, Takumi Shiiyama, Heishun Zen (Kyoto IAE, Kyoto)

Energy degradation arising from back-bombardment effect was quite serious problem for using a thermionic RF gun as injector of FEL device. Thus we have developed energy compensation technique, which keeps cavity voltage as constant by controlling input RF power to the RF gun. We have successfully extracted electron beam with constant energy from the thermionic RF gun with the energy compensation technique*. However, PFN tuning of the Klystron modulator and time-varying beamloading would affect macro-pulse properties; energy spread, emittance, phase mismatch between RF gun and accelerator, etc. Thus we have estimated effects to the beam properties by using the 1D thermal conduction model** and PARMERA, and also evaluated these properties experimentally. The estimated and measured results were not so serious for KU-FEL system. We will discuss the comparison between the experimental results and the calculation results in this conference.

* N. Okawachi, et al., Proc. of the FEL 2006, pp.664-667 (2006)
** T. Kii, et al., Nucl. Instr. and Meth. A 483 310-314 (2002)

WEPPH024 Numerical Evaluation of Oscillator FEL with Multi-Bunch Photo-Cathode RF-gun in Kyoto University

Hideaki Ohgaki, Toshiteru Kii, Kai Masuda, Satoshi Sasaki, Takumi Shiiyama, Heishun Zen (Kyoto IAE, Kyoto), Ryunosuke Kuroda (AIST, Tsukuba, Ibaraki), Masao Kuriki, Nobuhiro Terunuma, Junji Urakawa (KEK, Ibaraki), Yoshio Kamiya, Masakazu Washio (RISE, Tokyo)

An infrared FEL (4-13 micro-m) facility to develop new energy materials is constructed in Institute of Advanced Energy, Kyoto University. The electron beam of 40 MeV has been successfully accelerated by a linac system which consists of a 4.5-cell thermionic RF gun*. However, due to severe back-bombardment effect, there still needs several efforts to extend the macro-pulse duration to obtain a stable FEL. Upgrade from the present thermionic RF gun to a photocathode RF gun has been planned in KU-FEL**, because a photocathode RF gun is free from the back-bombardment and can generate a high brightness electron beam. A multi-bunch photo-cathode RF gun system has been developed*** and will be installed into the KU-FEL linac. Thus a design work on the new linac system from the gun to the FEL has been performed by using PARMELA and GENESIS. The evaluated peak current is about 4 times and the expected FEL gain is about 10 times as high as those with the present system. The required laser system will be discussed in this conference, as well.

* H. Ohgaki, et al., NIM A, vol.528, pp.366-370 (2004).
** H. Ohgaki, et al., Proc. of the FEL 2004, pp.454-457 (2004).
*** K. Hirano, et al., NIM A, vol. 560, pp.233-239 (2006).

WEPPH025 Progress in the FEL Lasing in Kyoto University

Satoshi Sasaki, Toshiteru Kii, Kai Masuda, Hideaki Ohgaki, Takumi Shiiyama, Heishun Zen (Kyoto IAE, Kyoto)

We have constructed an infrared (4 ~ 13μm) FEL facility for advanced energy researches in Kyoto University. The numerical studies on the expected FEL gain, which was based on the experimental measurements both of the undulator and of the electron beam parameters, were carried out*. However, g-parameter of the mirror cavity was located close to the unstable region. In order to obtain a stable FEL, we calculated the FEL gain taking into account the duct shape, the tilt angle, and the offset of the mirror, then for the first lasing the mirror parameter was optimized. At the present stage, we have installed the undulator and the mirror cavity. A spectrum of the spontaneous emission was measured, which was consistent with the result of spectrum calculation obtained with measured magnetic field of the undulator. In this conference, we will present the result of the mirror optimization, and measurement of the spontaneous emission. The status of the experiment on FEL lasing will also be addressed.

* M. Nakano, et al., Proceedings of the 2006 FEL conference, (2006)

WEPPH026 Design Study of the Triode-Type Thermionic RF Gun

Takumi Shiiyama, Toshiteru Kii, Kai Masuda, Hideaki Ohgaki, Satoshi Sasaki, Heishun Zen (Kyoto IAE, Kyoto), K. Kanno, Eiji Tanabe (AET Japan, Inc., Kawasaki-City)

We use a 4.5-cell RF gun with a thermionic cathode as the injector for our KU-FEL facility, having taken its advantageous features compared with photocathode guns, such as high averaged current, low cost and

easy operation, while we suffer from the limited macro-pulse duration and peak current by the back-bombardment effect. To mitigate these adverse effects, we proposed the triode-type thermionic RF gun with an additional small cavity providing the accelerating phase nearby the cathode independent of the main cavity phase*. Results from PIC simulations show that the back-bombardment power can be reduced drastically by more than 80%, and in addition the peak current of the output electron beam will be improved greatly by supplying a moderate RF power of tens kW to the RF triode structure. The RF system of up to 100 kW capabilities has been prepared and tested. Also the prototype design of the triode-type thermionic RF gun was completed. The cavity parameters, namely the quality factor, shunt impedance, and the coupling coefficient with the RF feed coaxial cable were designed taking into account both the available maximum field on the cathode and the phase and amplitude stability against the expected variations of the beam loading and cavity temperature. We will also present PIC simulation prediction on the output beam characteristics promising the first FEL lasing.

* K. Masuda, et al., Proceedings of the 2006 FEL conference, (2006)

WEPPH027 Beam Diagnostics for the First Lasing of the KU-FEL

Heishun Zen, Toshiteru Kii, Kai Masuda, Hideaki Ohgaki, Satoshi Sasaki, Takumi Shiiyama (Kyoto IAE, Kyoto)

Mid-IR FEL (4-13 micro m) device for energy science has been constructed in Institute of Advanced Energy, Kyoto University and the electron beam of 40MeV has been successfully accelerated*. The transverse phase space distribution and the corresponding emittance of the electron beam were measured by using a tomographic method**. As the result, normalized emittance was around 3 pi mm mrad. An FEL gain calculation*** shows that the peak current of 10A is the minimum value for the FEL amplification, and that of 40A is required to achieve the FEL saturation. Therefore the bunch compression experiment has been carried out to shorten the micro-bunch length by 2 ps in KU-FEL. The 180 deg. arc section was used for the bunch compression. We will report the result of the emittance measurement and of the bunch compression experiment in the conference.

* H. Ohgaki, et al., NIM A, vol.528, pp.366-370 (2004). \

** H. Zen, et al., Proc. of the FEL 2006, pp.592-595(2006)

*** M. Nakano, et al., Proc. of the FEL 2006, pp.660-664 (2006).

WEPPH028 Development of a Compact Cherenkov Free-Electron Laser Operating Terahertz Wave Range

Nozomu Miyabe, Makoto R. Asakawa (Kansai University, Osaka), AKIRA IKEDA, Mitsuhiro Kusaba, Yoshiaki Tsunawaki (OSU, Daito, Osaka)

We designed a compact Cherenkov Free-Electron Laser(CFEL) device capable of delivering mW-level output power at frequencies of up to THz from 10GHz to 1 THz. CFEL has the advantage of generating higher frequencies at lower electron beam energy. Due to lower electron beam CFEL device is compact. Our CFEL device consists of a waveguide partially filled with two lined parallel dielectric slabs through which a relativistic electron beam propagates. We call this structure "double-slab". In our device, the electron beam is generated using the Spindt cathode. We used a super conducting magnet to compress and guide the electron beam along the dielectric slabs. Assuming a dielectric slab thickness of 0.65mm,length of 11cm and electron beam energy 50keV ,the output power generated by the device was numerically calculated to be mW-level at 46GHz. Currently , we are conducting the POP experiment at millimeter wave range.

WEPPH029 Development of the Longitudinal Phase-Space Monitor for the L-band Electron Linac at ISIR, Osaka University

Ryukou Kato, Tetsuya Igo, Goro Isoyama, Shigeru Kashiwagi, Yutaka Morio (ISIR, Osaka)

The correlation between longitudinal positions of electrons in a bunch and their energies has a critical effect on the temporal evolution of SASE, and various methods are being developed to measure the longitudinal phase-space profile. We are developing a system to measure the longitudinal phase-space distribution of electrons by a combination of a bending magnet, a profile monitor, and a streak camera at the Institute of Scientific and Industrial Research (ISIR), Osaka University. In the preliminary experiments using a profile monitor utilizing optical transition radiation (OTR), it was confirmed that the monitor had higher momentum resolution than the presently used momentum analyzer consisting of a slit and a current meter*. However, we could not obtain the sufficient number of photons to obtain the phase-space image since, in addition to a low photon yield, the angular distribution of OTR emitted by the electron beam in the energy region of 10 – 20 MeV, with which THz-SASE and THz-FEL experiments are conducted at

this laboratory, is too large to concentrate it efficiently on a streak camera. In order to increase the number of photons, we try to use silica aerogel as a radiator of the profile monitor by following the example of PITZ**. We will present an outline of the phase-space monitor we are developing and its experimental results.

* R. Kato et al, FEL'06, Berlin, Germany, August 2006, THPPH041, p.676, http://www.jacow.org.

** J. Roensch et al, FEL'06, Berlin, Germany, August 2006, THPPH019, p.597, http://www.jacow.org

WEPPH030 Development of a Precise Timing System for the ISIR L-Band Linac at Osaka University

Shigeru Kashiwagi, Tetsuya Igo, Goro Isoyama, **Ryukou Kato**, Yutaka Morio, Shoji Suemine (ISIR, Osaka)

We are developing a free electron laser (FEL) in the infrared region and also conducting SASE experiment in the same wavelength region using the L-band linear accelerator at the Institute of Scientific and Industrial Research (ISIR), Osaka University. In order to conduct such studies, stable operation of the linac is critical, so that we have developed a highly precise and flexible timing system for stable generation of the high intensity electron beam with the energy region of 10-30 MeV. In the timing system, a rubidium atomic clock producing 10 MHz rf signal is used as a time base for a synthesizer which is used as the master oscillator for generating the acceleration frequency of 1.3 GHz. The 1.3 GHz signal from the master oscillator is directly counted down to produce the clock signal of the timing system at 27 MHz and the four rf signals for the linac and laser used in the beam line. The start signal for the linac is precisely synchronized with the 27 MHz clock signal. To make an arbitrary delayed timing signal, a standard digital delay generator is used to make a gate signal for a GaAs rf switch, which slices out one of the 27 MHz clock pulses to generate the delayed timing signal. Any timing signal can be made at an interval of 37 ns and the timing jitter of the delayed signal is less than 2 ps (rms). We will report the new timing system and its performance in detail.

WEPPH031 Development of A Low Emittance DC Gun for Smith-Purcell BWO FEL

Kittipong Kasamsook, Kazushi Akiyama, Hiroyuki Hama, Fujio Hinode, **Masayuki Kawai**, Toshiya Muto, Ken-ichi Nanbu, Takumi Tanaka, Mafuyu Yasuda (Laboratory of Nuclear Science, Sendai)

An electron DC gun capable for producing very low emittance beam is under developed at Laboratory of Nuclear Science, Tohoku University. The DC gun employs a high voltage of 50 kV to extract electrons, which is suitable to drive Smith-Purcell backward wave oscillator free electron laser (BWO FEL). A result of numerical simulation using a 3-D finite deference time domain (FDTD) method shows the BWO FEL oscillation at the terahertz wavelength region maybe achieved by using the electron beam with an emittance around 0.1 mmmrad. Average power is expected to be more than 100 W per square mm. In addition to which a very small cathode of LaB6 single crystal is employed for the gun, the geometrical structure is optimized to produce the lower emittance beam. A numerical calculation of the elctro-static model for the DC gun to solve equilibrated beam envelope predicts a normalized beam emittance of 0.2 mmmrad will be realized at the beam current of a couple of hundreds mA. Particularly by applying special bias voltage between the cathode and the wehnelt, the transverse distribution of electrons is possibly becoming to be an ideal Kapchinskij-Vladimirskij (K-V) beam, so that the space charge effect will be minimized. The paper will present the status of the development of the low emittance DC gun and various simulation result of the terahertz BWO FEL oscillation.

WEPPH032 Electron-Linac Based Femtosecond THz Radiation Source at PAL

Heung-Sik Kang, Jinhyuk Choi, Young-Gyu Jung, Changbum Kim, Hyung-Gyun Kim, Sung-Chul Kim, In Soo Ko, Wol Woo Lee, Byoung Ryul Park, Hyung Suck Suh, In-Ha Yu (PAL, Pohang, Kyungbuk)

A 60-MeV electron linac for intense femto-second THz radiation is under construction at PAL, which is the beamline construction project to be completed by 2008. To get intense femto-second THz radiation up to 100 cm-1, the electron beam should be compressed down to below 100 fs. The linac will use an S-band photocathode RF-gun as an electron beam source, two S-band accelerating structures to accelerate the beam to 60 MeV, a chicane-type bunch compressor to get femto-second electron bunch, and an optical transition radiation (OTR) target as a radiator. The PARMELA code simulation result shows that the 0.2 nC beam can be compressed down to a few tens of femto-seconds, and even the higher charge of 0.5nC to about one hundred femto-seconds. Also, the linac will be able to provide a femto-second electron beam for electron pulse radiolysis and compton-scattering experiment for fs X-ray.

WEPPH033 Stabilization of a Klystron Voltage at 100 PPM Level for PAL XFEL

Jong-Seok Oh, Sung-Duck Jang, Sei-Jin Kwon, Yoon-Gyu Son, Jae-Hak Suh (PAL, Pohang, Kyungbuk), Eui-Ho Song (CNU, Changwon)

The PAL XFEL needs a stable electron beam. The stable charging of PFN (pulse forming network) of a klystron-modulator is essential to provide the stable acceleration field for an electron beam. For PAL XFEL, stabilization of klystron voltage pulses at 100 PPM level is required. Short-term stability is determined by a minimum resolution of a charging system. Long-term stability is determined by a thermal stability due to the temperature drift. This paper shows details of hardware R&D and test results to achieve the target stability.

WEPPH034 Fourier and Non-Fourier Models for Photoemission

Florea Scarlat, Anca Mariana Mihalache, Ecaterina Mitru, Mihai Oane (INFLPR, Bucharest - Magurele)

This paper is a theoretical study on the photoemission properties of metallic photocathodes in the high intensity ultrashort laser pulse regime, using Fourier and non-Fourier models. First of all the Fourier-model was used. Next an analysis of the electron gas heating phenomenon and how this phenomenon leads to coupled heat equations (two temperature models). The authors also try to show that it is possible to use, in the second approximation, a non-Fourier model instead of two temperature models, using a single temperature hypothesis (the electron gas temperature equals with the lattice temperature). The distributions for thermal fields and photocurrents function of space, time, laser-intensity, incident angle and relaxation time are also represented.

WEPPH035 Femtosecond and Attosecond Bunches of Electrons Upon Field Emission in a Combined Quasi-Static and Laser Electric Field

Vitaly Arkadyevich Papadichev (LPI, Moscow)

Obtaining short pulses of particles and of electromagnetic radiation is of interest for investigating fast processes in physics, chemistry, biology and medicine. A new method of modulating an electron beam is proposed to obtain electron bunches of 50-as to 20-fs duration. For this purpose, two electric fields – quasi-static and the variable field of a laser with wavelength in the 0.25 – to 10 microns range – simultaneously act on a single-spiked or multi-spiked cathode*. Current from 0.01 to 100 A from one spike having a curvature radius of 1 micron corresponds to a maximal intensity of total electric field of 70 to 280 MV/cm. A regime of device operation was determined for which the emitting surface of a copper cathode is not damaged. Obtaining a single bunch or a sequence of bunches with a repetition rate up to1330 THz was considered. Using multi-spiked cathodes permits to obtain bunches with current up to 10 kA.

* V.A.Papadichev, A method to obtain modulated electron beam, Patent RU 2269877 C1, 22.10.2004, published 10.02.2006, Bull. 4.

WEPPH036 Accelerating and Transporting Attosecond and Femtosecond Bunches of Electrons

Vitaly Arkadyevich Papadichev (LPI, Moscow)

Dynamics of short bunches of electrons obtained upon field emission in quasi-static electric field and a variable electric field of a laser has been studied*. The equation of longitudinal motion of electrons was numerically integrated. When the forces of space charge have little effect, grouping part of the beam permits to obtain bunches of about 200-as duration when using carbon dioxide laser and about 6-as with a neodymium laser. Analytical models were used to evaluate the influence of the space charge of the bunch on the longitudinal motion of electrons in it. It has been shown that the proper choice of the intensities of both fields can compensate such an influence. There have been considered methods of lateral focusing of the beam taking into account possible initial angular divergence and space charge effects. Evaluations show that the formation of plasma on the cathode should not noticeably influence the parameters of the electron bunches in a train during 10 ps to 1 ns depending on the tip radius.

* V.A.Papadichev, Femtosecond and Attosecond Bunches of Electrons Upon Field Emission in a Combined Quasi-static and Laser Electric Field, submitted to this Conference.

WEPPH037 Coherence of Space Charge Vibrarion and Parameters of Electron Guns

Sergey Vladimirovich Miginsky (BINP SB RAS, Novosibirsk)

Space charge effect always determines the motion of particles in electron guns. Coherence of space charge vibration leads to oscillation of the emittance along a gun or a charge affected beamline. This phenomenon is closely related to a technique known as emittance compensation. These phenomena together with others (non-coherent) have been considered in the paper. The optimal parameters of guns and the expected emittance of the beam from the optimal ones have been estimated and scaled.

WEPPH038 Low Power Consuming Hybrid Bending Magnet at the XFEL Beam Dump

Fredrik Hellberg, Håkan Danared, Anders Hedqvist (MSL, Stockholm), Winfried Decking, Bernward Krause, Alexander Petrov, Joachim Pflueger, Michael Schmitz (DESY, Hamburg)

At the end of the European XFEL the electron beam is separated from the photon beam and directed towards the beam dump with a bending magnet.* This dipole magnet is designed to bend 10-25 GeV electrons by 1 degree/m and is 10 meter long in total. By integrating permanent magnet material into a conventional electromagnet, this so called hybrid magnet with a 1 T bias magnetic field consumes no power at the nominal energy of the XFEL, 17.5 GeV. The magnetic field can be increased or decreased by magnet coils to obtain 1 degree/m deflection for all energies between 10 and 25 GeV. In case of component failures a passive safety system is needed to prevent the electron beam from reaching the experimental hall. The bias field of the permanent magnet not only saves power, but also works as a safety system for the XFEL. Here a proposal for such a hybrid configuration is presented together with its characteristics. The magnet is designed to use small amount of permanent magnet material and to consume less power than a conventional electromagnet.

*European XFEL Technical design report, edited by M. Altarelli et. al.,DESY 2006.

WEPPH039 The Optical Replica Synthesizer in FLASH

Volker Ziemann, Gergana Vasileva Angelova (UU/ISV, Uppsala), Atoosa Meseck (BESSY GmbH, Berlin), Evgeny Saldin, Holger Schlarb, Bernhard Schmidt, Evgeny Schneidmiller, Mikhail Yurkov (DESY, Hamburg), Nicolas Javahiraly, Peter van der Meulen (FYSIKUM, AlbaNova, Stockholm), Joern Boedewadt, Shaukat Khan, Axel Winter (Uni HH, Hamburg)

During the shutdown in spring 2007 the optical replica synthesizer, a novel device to diagnose ultra-short electron bunches, is assembled in the FLASH accelerator. We report on the status of the construction work with emphasis on the two electro-magnetic undulators needed for micro-bunching and replica-pulse generation.

WEPPH040 Room Temperature Activation and Operation of a Cesium Dispenser Photocathode

Nathan A. Moody, David Lizon, Dinh C. Nguyen (LANL, Los Alamos, New Mexico), Kevin Jensen (NRL, Washington, DC), Donald Feldman, Patrick Gerard O'Shea (UMD, College Park, Maryland)

Many high power FEL designs rely upon photocathodes as a laser-switched electron source. Operational requirements are severe: sustained high current emission, high quantum efficiency (QE), and long lifetime in a contaminated vacuum system. Dispenser cathodes have long served as thermionic emitters and the concept has recently been extended to photoemission. The constituents of high QE cathodes degrade over time and must be replenished to achieve lifetime requirements of most FELs. A cesium dispenser photocathode consists of a porous cathode substrate that acts as a diffusion barrier above a cesium reservoir. Previous designs have used chromates or metallic alloys as the cesium source inside the reservoir. An alternative approach is being pursued for LANL's normal conducting RF gun: elemental cesium is inserted (via ampoule) directly behind the diffusion barrier and provides a high purity source without high temperature activation. The cesium is released after the cell has been evacuated and baked. Based on operating temperature and background gas in the electron gun, we determine the diffusion rate required to maintain a monolayer of cesium at the cathode surface. We then model cesium diffusion through the porous barrier and adjust thickness and porosity to accommodate this rate. Theoretical predictions as well as experimental results will be presented.

We gratefully acknowledge the support of the Joint Technology Office and the Office of Naval Research

WEPPH041 7th Harmonic Buncher Experiment at Neptune Laboratory

Pietro Musumeci, Rodion Tikhoplav, Sergei Tochitsky (UCLA, Los Angeles, California)

Since typically FEL undulator magnets have period length in the cm range, and the normalized magnetic field strength K is maintained close to unity to guarantee a good coupling, a very high energy electron beam is needed to access the far UV and x-ray region of the electromagnetic spectrum. One way to reduce the beam energy necessary for short wavelength light sources consists of exploiting the FEL harmonic interaction. An experiment aimed at demonstrating the efficiency of harmonically coupled schemes is proposed for the Neptune Laboratory at UCLA. We plan to inject the 12.4 MeV beam from the split photoinjector in an already available undulator with period = 3.3 cm and K = 1.8. The FEL resonant wavelength with these parameters is 74.2 um. A copropagating high power 10.6 um CO2 laser bunches the beam via 7th harmonic FEL/IFEL interaction. Preliminary calculations show that even though the interaction is weakened by the high harmonic number, it is required to use only 5 -10 MW of power in order to induce full bunching on the beam in the 10 period long undulator.

WEPPH042 Bunch Length Monitors for Feedback in teh LClS Injector

Josef Frisch, Ron Akre, Thomas Borden, Michael Cecere, Paul Emma, Robert Fuller, Karen Dayle Kotturi, Patrick Krejcik, Jay Langton, Henrik Loos, Douglas McCormick, Timothy M. Montagne, Sheng Peng, Hamid Shoaee, Steve Smith, Juhao Wu (SLAC, Menlo Park, California)

The 250MeV Linac Coherent Light Source injector RF system requires feedback to meet its stability requirements. This feedback uses the beam energy and bunch length after the first bunch compressor to control the phase and amplitude of the preceding accelerator section. It is desirable that the energy and bunch length signals be available non-invasively, at the full 120Hz beam rate of the machine. The beam transverse position in the bunch compressor chicane provides a direct measure of the energy. Relative changes in bunch length are measured using coherent millimeter wave radiation sampled at different wavelengths.

Work Supported by DOE Contract DE-AC03-76SF00515

WEPPH043 The UCSB MM-FEL Injection Locking System

Gerald Ramian, Susumu Takahashi (UCSB, Santa Barbara, California)

An Injection locking system has been implemented on UCSB's Millimeter Wave FEL at 240 GHz. It it is based on a VDI varactor multiplier source and a Keating quasi-optical isolator. Its purpose is to stabilize lasing and suppress mode beating by always forcing lasing to occur at a single frequency on one specific longitudinal mode. Theoretical and experimental results are presented.

WEPPH044 Experimental Characterization of Timing Jitter Amplification by a Magnetic Chicane Bunch Compressor

Xijie Wang, James Murphy, Yuzhen Shen, Takahiro Watanabe (BNL, Upton, Long Island, New York), Renkai Li [on leave], Renkai Li (BNL, Upton, Long Island, New York; TUB, Beijing)

Magnetic chicane bunch compressor has been widely adopted to compress the electron beam bunch length and increase the electron beam peak current. Great attention has been paid to the coherent synchrotron radiation (CSR) effect during the bunch compression. There is little experimental study on timing jitter amplification caused by the time of flight inside a magnetic chicane bunch compressor. The sources of the timing jitter amplification are fluctuations in klystron amplitude and RF phase sampled by the electron beam. Recently we initiated an experiment at the NSLS SDL to investigate the timing jitter amplification during the bunch compression. Two techniques will be employed for our studies. First we will compare the electron beam energy jitter to deduce the timing jitter amplification. In the second technique, a beam position monitor (BPM) will be used to measure the timing jitter by comparing to a 2.856 GHz reference signal. The preliminary experimental results will be presented in this talk.

This work is supported by the Office of Naval Research under contract No. N0002405MP70325 and U.S. Department of Energy under contract No. DE-AC02-98CH1-886.

WEPPH045 Femtosecond-level Timing Instabilities on CPA-based Laser Systems

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An essential feature for operating accelerator-based light sources is the Timing and Synchronization system. This is necessary in photoelectron bunches generation, in order to synchronize the drive laser with the RF of the accelerating cavity, or in the seeding of an external laser in an undulator. A unique Timing Standard is also required by the end-users for setting up time resolved pump-probe experiments. These various needs call for sub-ps synchronization level. The LUCA/PLFA team at the Saclay Laser Interaction Center (SLIC) developed an experimental setup to lock the repetition rate of the oscillator of the CPA-based laser system on a Rb atomic clock. An analysis of the temporal characteristics of the system without this stabilization is presented, showing the influence of the environmental parameters (temperature, atmospheric pressure and humidity) on the oscillator rate. The results obtained with the stabilization system on, are then presented and analyzed using classical methods (Allan variance and phase power spectral density). In order to investigate experimentally the temporal jitter and drift which can appear inside the laser system, a Fourier Transform Spectral Interferometry experiment has been set up. This experiment should give us an accuracy of tens of fs. Detailed results and analysis will be presented.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 – EUROFEL.

WEPPH046 A Superconducting RF Photo-Injector for Operation at the ELBE Linear Accelerator

Jochen Teichert, Andre Arnold, Hartmut Buettig, Dietmar Janssen, Matthias Justus, Ulf Lehnert, Peter Michel, Karsten Moeller, Petr Murcek, Christof Schneider, Rico Schurig, Friedrich Staufenbiel, Rong Xiang (FZD, Dresden), Peter vom Stein (ACCEL, Bergisch Gladbach), Thorsten Kamps (BESSY GmbH, Berlin), Vladimir Volkov (BINP SB RAS, Novosibirsk), Axel Matheisen, Birte van der Horst (DESY, Hamburg), Juergen Stephan (IKST, Drsden), W.-D. Lehmann (IfE, Dresden), Guido Klemz, Ingo Will (MBI, Berlin)

For the ELBE superconducting linear accelerator at Forschungszentrum Dresden-Rossendorf (FZD) a radiofrequency photoelectron injector with a superconducting cavity (SRF gun) is under development. The SRF gun combines the excellent beam quality which can be delivered by RF photoinjectors with the possibility of continuous wave operation. The superconducting niobium cavity of the injector consists of 3½ cells and contains a Cs2Te photocathode which is normal-conducting and cooled by liquid nitrogen. The RF frequency of the cavity is 1.3 GHz. The final electron energy will be about 9.5 MeV and the average electron current will be 1 mA. In the past years the SRF photo injector has been designed and fabricated. Several critical subsystems have been tested. For the cavity, the results of the RF measurements will be shown. An UV driver laser system has been developed which fulfils the different requirements (77 pC at 13 MHz, 1 nC at 500 kHz) for the future operation at ELBE. A photo cathode preparation system was developed and installed. The equipment is now in operation and the first series of Cs2Te photo cathodes have been produced.

WEPPH047 Electro-Optic Spectral Decoding for Single-Shot Characterisation of the Coherent Transition Radiation Time Structure at FLASH

Vladimir Arsov, Ernst-Axel Knabbe, Bernhard Schmidt, Peter Schmüser, Bernd Steffen (DESY, Hamburg)

Characterisation of the longitudinal profiles of ultrashort electron bunches is of primary importance for controlling the lasing process of SASE FEL. Non-destructive, single-shot techniques, are preferable. Presently the most promising ones are the Electro-Optic (EO) laser diagnostics and the THz spectroscopy of coherent transition radiation (CTR). Whereas the former are applied directly in the electron beam line, the latter offer possibility to detect shorter temporal structures, but outside the tunnel. Therefore it is important to know the transfer function of the CTR beam line. We present a single-shot EO detection of temporal CTR profiles, generated from electron bunches, kicked to an off-axis screen at DESY's VUV-FEL (FLASH). The THz radiation is transported through a 20 m long line from the accelerator tunnel to an experimental station outside. The measurements are performed in air and in vacuum with 0.5 mm ZnTe and 0.175 mm GaP crystals in crossed-polarisers detection scheme. Pulses with less than 1 ps FWHM have been measured.

WEPPH048 XPS Studies of Cs2Te Photocathodes

Sven Lederer, Jang Hui Han, Siegfried Schreiber (DESY, Hamburg), Hermann Duerr, Mike Sperling, Antje Vollmer (BESSY GmbH, Berlin), Frank Stephan (DESY Zeuthen, Zeuthen), Paolo Michelato, Laura Monaco, Daniele Sertore (INFN/LASA, Segrate (MI))

Cesium Telluride (Cs2Te) photocathodes are used as sources for electron beams because of their high quantum efficiency (QE) and their ability to release high peak current electron bunches in a high gradient RF-gun. Starting from a high QE level of about 10% the quantum efficiency of these cathodes decreases during operation in a photo-injector to below 0.5%. To understand this behaviour, XPS investigations on the chemical composition were performed at BESSY. In this contribution we compare two fresh cathodes from INFN with one used under normal operation at FLASH and one used at PITZ at a higher than usual RF-gradient of 60 MV/m.

WEPPH049 Test of a Wiresanner in the Diagnostic Section of PITZ

Hans-Juergen Grabosch, Juergen W. Baehr, Jang Hui Han, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Velizar Miltchev, Anne Oppelt, Bagrat Petrosyan, **Martin Sachwitz**, Lazar Staykov, Frank Stephan (DESY Zeuthen, Zeuthen), Galina Asova, Galina Asova [on leave] (DESY Zeuthen, Zeuthen; INRNE, Sofia)

The Photo Injector Test facility at Zeuthen (PITZ) has been established to optimize electron beams of high brilliance needed for short wavelength FELs. In a first step one wire scanner station, developed and used in the undulator section of FLASH at DESY, was tested in the diagnostic section of PITZ. Measurements of the beam-profile and the beam-position were performed to test the useability of such type of wire scanner at PITZ. The obtained results are presented and discussed. The test has shown that wire scanners of this type can be used successfully as complementary measurement device for beam-profile measurements at PITZ. In the final state of extension of PITZ , two wire scanners are foreseen as standard diagnostic tools.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the Helmholtz Association, contract no. VH-FZ-005.

WEPPH050 Proposal for an Automatized Beam Position Alignment System Using BPM's and Rotating Steerers

Thomas Scholz, Galina Asova, Juergen W. Baehr, Charles H. Boulware, Hans-Juergen Grabosch, Levon Hakobyan, Marc Hänel, Sergiy Khodyachykh, Sergey Korepanov, Mikhail Krasilnikov, Bagrat Petrosyan, Sabine Riemann, Lazar Staykov, Frank Stephan (DESY Zeuthen, Zeuthen), Dieter Richter (BESSY GmbH, Berlin), Sven Lederer (DESY, Hamburg), Konstantin Konstantinov Boyanov (INRNE, Sofia), Andrey Shapovalov (MEPhI, Moscow), Juliane Roensch (Uni HH, Hamburg)

The Photo Injector Test facility in Zeuthen (PITZ) is dedicated to improve the performance of high brilliant electron beams. The electron beam is emitted from a CsTe-photocathode placed in a normal conducting 1.5 cell L-band RF gun. The electron beam is further accelerated to 15 up to 30 MeV by a booster cavity. For an optimized acceleration it is important that the beam passes the booster on the symmetry axis. This should be done with a controlling system consisting of two beam position monitors (BPM) and two rotatable steerer magnets to align the beam. A software analyzes the information given by the BPM's and controls the steerer settings to adjust the beam in a feedback loop up to a certain preset limit. Integration of this tool into the PITZ control system has been provided. This contribution will describe the method of calculation, the algorithm, the graphical user interface as well as first experimental results.

This work has partly been funded by the European Community, contract no. RII3-CT-2004-506008 and 011935 and by the 'Impuls- und Vernetzungsfonds' of the Helmholtz Association, contract no. VH-FZ-005.

WEPPH051 Development of a Beam Current Transformer for the X-FEL Project in SPring-8

Atsushi Higashiya, Hirokazu Maesaka, Yuji Otake (RIKEN Spring-8 Harima, Hyogo)

The SCSS prototype accelerator has been constructed at SPring-8. The output signal of the current transformer (CT) for measuring an electron beam current in SCSS prototype accelerator has a few megahertz noise emitted from the thyratron of klystron modulator, a ringing signal caused by the weak field of the electron beam. The long period undulation of an electrical ground level at the CT output also occurred by a large electric current generated by the klystron modulator, and flown into the ground. As a result, it is difficult to measure the beam current correctly. Therefore, we devised a new CT monitor in order to improve the problem as mentioned above. The improvement points are below. The thyratron noise was

reduced by contacting between the ground of the CT case and the outer surface of a CT signal cable. The ringing signal was suppressed by intercalating dumping resistance material into the space between the case and the ferrite core of CT. We think that the undulation of ground level could be common mode noise and devised how to modulate the undulation. In this paper, we introduce the improvement points, and the obtained waveform of the CT signal as result.

WEPPH052 In-situ Undulator Field Measurement with the SAFALI System

Takashi Tanaka, Hideo Kitamura (RIKEN Spring-8 Harima, Hyogo), Takamitsu Seike (JASRI/SPring-8, Hyogo-ken)

Although the in-vacuum undulators (IVUs) have many advantages over out-vacuum undulators, magnetic measurement after assembling vacuum components, i.e., final verification of magnetic performance, is not an easy task. In addition, remeasurement after installation in the accelerator beamline is not trivial. The situation is more severe for cryogenic permanent magnet undulators (CPMUs), an extension of IVUs. We have recently developed a magnetic measurement system to measure the field inside the vacuum chamber. With optical laser beams introduced into the vacuum chamber, the alignment of the Hall probe positions is dynamically carried out, which ensures a high stability and accuracy of the measurement. This system is called SAFALI for Self-Aligned Field Analyzer with Laser Instrumentation. The SAFALI system has been applied to field measurement of two different undulators. One is an IVU installed in Swiss Light Source in 2001 and had been operated for about 3 years. The other is a CPMU prototype to demonstrate the principle of CPMU. The purpose of the measurement of the former is to investigate the radiation damage during operation, while that of the latter is to check the performance variation according to the temperature change of magnets. In the conference, details of the SAFALI system are given together with the results of the field measurements.

WEPPH053 Non-Destructive Single-Shot 3-D Electron Bunch Monitor with Femtosecond-Timing All-Optical System for Pump & Probe Experiments

Hiromitsu Tomizawa, Hirofumi Hanaki [on leave] (JASRI/SPring-8, Hyogo-ken), Tetsuya Ishikawa [on leave] (RIKEN Spring-8 Harima, Hyogo)

We are developing a 3-D electron bunch monitor based on EO sampling, using yearlong stable femtosecond laser source of SPring-8 RF gun. Our developing single-shot bunch monitor can characterize the 3-D (both longitudinal (1D) and transverse (2D)) distribution and position of an electron bunch with femtosecond resolution. This non-destructive monitor can be used as an electron energy chirping monitor in a dispersive region for X-FEL commissioning. The probe laser for spectral decoding EO sampling is prepared as radically polarized and completely linearly chirped broad-bandwidth (~500nm) supercontinuum. EO-probe is made of 8 EO-crystals with assembling each EO-optical axes along radial beam axes. The probe lineally chirped laser is longitudinally sifted in 8 transverse sectors for spectral decoding. We are planning to use organic polymer film as a femtosecond resolution EO-probe instead of crystals. This 3-D bunch monitor with spectrograph detects and analyzes the wake filed of electron bunches as longitudinally spectral decoding and transversely multi-pole expansion. In addition, we are developing all-optical system for femtosecond-timing pump & probe experiments. The EO-sampled probe laser pulse will use as a femtosecond-timing signal pulse. This signal pulse is amplified with a NOPA (noncollinear optical parametric amplifier), using an SHG of Yb fiber laser as a pump laser.

WEPPH054 Coherent THz Light Source Using Very Short Electron Bunches from a Thermionic RF Gun

Toshiya Muto, Kazushi Akiyama, Hiroyuki Hama, Fujio Hinode, Kittipong Kasamsook, Masayuki Kawai, Ken-ichi Nanbu, Takumi Tanaka, **Mafuyu Yasuda** (Laboratory of Nuclear Science, Sendai)

To develop a narrowband coherent Terahertz (THz) light source, a project for producing very short electron bunch has been progressed at Laboratory of Nuclear Science, Tohoku University. Coherent synchrotron radiation is another promising source for generation of high-power THz light. Passing through a conventional undulator with a field period length of ~ 10 cm, the very short electron bunch at the energy around 15 MeV can produce coherent THz radiation. The electron beams of which the bunch length is less than 100 femto-second will be generated by a combined injector system of a thermionic RF gun and a bunch compressor. We have developed an independently-tunable-cells (ITC) RF gun consisted with two uncoupled cavities in order to manipulate the longitudinal phase space. It was found out that the ITC-RF gun is possibly quite suitable to produce such a very short bunch employing a magnetic bunch compressor. In theoretical investigation at the moment, a bunch length of less than 50 fs has been achieved in the numerical tracking simulation. Employing Lienard-Weichert potential, we have

performed a 3-D simulation of the coherent THz radiation. The paper will describes the latest status of development of the ITC RF gun and tracking simulations for the bunch compressor as well. Characteristics of the coherent THz radiation resulted from the simulation will be also reported

WEPPH055 Experimental Investigation of Smith-Purcell Radiation From Gratings of Different Profile

Gennady Naumenko, Vladimir Cha, Dmitry Valeryevich Karlovets, Yuriy Popov, Alexander Potylitsyn, Leonid Grigorievich Sukhikh (TPU, Tomsk), Boris Kalinin, Gennady Saruev (INPR, Tomsk)

Smith-Purcell radiation (SPR) is widely considered as the spontaneous mechanism for FEL. There are a few theoretical SPR models, which predict large difference between radiation intensity from relativistic electrons for grating with different profile. To choose the most effective grating we carried out the absolute coherent SPR intensity measurements on the 6.2 MeV electron beam. The coherent SPR spectra and angular distributions were investigated. Gratings with lamellar, triangular and so-called "flat" gratings were studied. It was shown the grating consisted of the conductive strips is more preferable target for SPR generation.

WEPPH056 Gain and Coherence Enhancement for SASE FEL using Laser pre-modulated Electrons

Yen-Chieh Huang, Han-Lung Chang, Chia-Hsiang Chen, Wei-Chen Cheng, An-Chung Chiang (NTHU, Hsinchu), Wai-Keung Lau, Gwo-Huei Luo (NSRRC, Hsinchu)

SASE FEL built up from shot noises exhibits noisy temporal and spectral structures at the output. We propose to use a laser to modulate the electron density at low beam energy and improve the emission characteristics of the SASE FEL at high beam energy. In this scheme, a laser beat wave is incident on the photocathode of an electron gun to generate periodically bunched electrons at the beat-wave frequency. The density modulated electrons can generate superradiance at the harmonics of the beat frequency in all types of single-pass FEL, including Smith-Purcell FEL, Cherenkov FEL, and undulator FEL. The bunching frequency can be further increased by a factor of 10-100 by compressing a chirped, density-modulated, low-energy electron pulse in an alpha magnet, which is subsequently accelerated to high energy for SASE FEL. Computer simulation using particle-in-cell codes, including ASTRA, ELEGANT, and GINGER, shows significant improvements on the gain and coherence of SASE FEL. We will report our detailed study and experimental progress in the conference.

WEPPH057 Universal Beam Envelope Equation for an Intense Beam in Linac

Chun-Xi Wang (ANL, Argonne, Illinois)

We report a universal beam envelope equation that governs the transverse evolution of a high-intensity relativistic beam in a constant graident linac. This dimensionless and parameter-free envelope equation is particularly useful for investigating beam evolution from space-charge dominated regime to the final emittance dominated regime.

Work supported by U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. W-31-109-ENG-38.

THAAU01 Experience and Plans of the JLAB FEL Facility as a User Facility

Michelle Diane Shinn (Jefferson Lab, Newport News, Virginia)

Jefferson Lab's IR Upgrade FEL building was planned from the beginning to be a user facility, and includes an associated 600 sq. m area containing seven laboratories. The high average power capability (multikilowatt-level) in the near-infrared (1-3 microns), and many hundreds of watts at longer wavelengths, along with an ultrafast (~ 1 ps) high PRF (10's MHz) temporal structure makes this laser a unique source for both applied and basic research. In addition to the FEL, we have a dedicated laboratory capable of delivering high power (many tens of watts) of broadband THz light. After commissioning the IR Upgrade, we once again began delivering beam to users in 2005. In this presentation, I will give an overview of the FEL facility and its current performance, lessons learned over the last two years, and a synopsis of current and future experiments.

This work was supported by U.S. DOE Contract No. DE-AC05-060R23177, the Office of Naval Research, the Army Night Vision Laboratory, the Air Force Research Laboratory, and the Joint Technology Office

THAAU02 Operational Experience of FLASH

Siegfried Schreiber, Bart Faatz (DESY, Hamburg), Katja Honkavaara (Uni HH, Hamburg)

Since summer 2005 the free electron laser FLASH at DESY is operating as a user facility. It produces 10 fs long laser like pulses from the vacuum ultraviolet to the soft X-ray wavelength range. Many successful user experiments have been carried out with this world wide unique facility. In this paper we report on operational issues of the facility.

THAAU03 Experimental Study of Volume Free Electron Laser Using a "Grid" Photonic Crystal with Variable Period

Pavel Valerievich Molchanov, Vladimir Grigorievich Baryshevsky, Nikolai Anatolievich Belous, Victor Alexandrovich Evdokimov, Alexandra Gurinovich, Alexander Sergeevich Lobko, Andrey Valentinovich Oskin, Pavel Fedorovich Safronov (Belarussian State University, Minsk)

Electrodynamical properties of a crystal-like artificial periodic structure (photonic crystal) formed by a periodically strained metallic threads were studied both theoretically and experimentally*,**. In the present paper operation of Volume Free Electron Laser using a "grid" photonic crystal with variable period is experimentally studied. Dependence of the generation threshold on photonic crystal length is investigated along with the frequency characteristics of generated radiation.

* Baryshevsky V.G. et al. NIM section B. Vol252 (2006) P.92-101
** Baryshevsky V.G. et al. Proc. of the 28th FEL Conference PP.331-338

THAAU04 Experimental Studies of Efficiency and Spectral Control in a Laser Seeded FEL Amplifier at the NSLS SDL

Xijie Wang, David Harder, James Murphy, Yuzhen Shen, Thomas Tsang, Takahiro Watanabe (BNL, Upton, Long Island, New York), Renkai Li [on leave], Renkai Li (BNL, Upton, Long Island, New York; TUB, Beijing)

The Source Development Laboratory (SDL) at the National Synchrotron Light Source (NSLS) of the Brookhaven National Laboratory (BNL) is a laser linac facility dedicated to the linac based light sources R&D and its applications. In the last couple years, the SDL has been engaging in experimental demonstration of the critical FEL amplifier technologies for high average power applications; especially to investigate various schemes of improving the FEL efficiency. In the laser seeded FEL amplifier experiments, we have achieved 4 orders of magnitude gain over the seed laser, and experimentally demonstrated FEL efficiency improvement using both undulator tapering and detuning, we are now working on improving the electron beam quality with the goal of realizing 1 mJ FEL output. We will present the latest experimental results on the FEL spectral control using the seed laser chirp.

This work is supported by the Office of Naval Research under contract No. N0002405MP70325 and U.S. Department of Energy under contract No. DE-AC02-98CH1-886.

THAAU05 Light Pulse Structure, Spectrum and Coherency of Novosibirsk Terahertz Free Electron Laser

Vitaly V. Kubarev, Evegeniy I. Kolobanov, Vladimir V. Kotenkov, Gennady N. Kulipanov, Alexander N. Matveenko, Lev E. Medvedev, Vladimir Kirillovich. Ovchar, Konstantin S. Palagin, Tatiana V. Salikova, Mikhail A. Scheglov, Stanislav S. Serednyakov, Nikolay A. Vinokurov (BINP SB RAS, Novosibirsk)

Light pulse structure and spectrum of Novosibirsk free electron laser were studied by direct independent methods. Super fast Schottky diode was used in time domain experiments. Method of vacuum Fourier spectroscopy was applied for spectral investigations. Observation of spectral stability of each light pulse was made by grating monochromator with Schottky diode. Influence of cogerency on harmonic powers is also shown.

THBAU01 Research Highlights from FLASH

Rolf Treusch, Josef Feldhaus (DESY, Hamburg)

The Free electron LASer in Hamburg (FLASH) has started regular user operation in summer 2005, providing XUV radiation pulses with pulse energies in the 10 - 100 μJ range and pulse durations of 10 - 50 fs. The science programme at FLASH covers a broad range of novel applications including fundamental studies on atoms, ions, molecules and clusters, creation and characterisation of warm dense matter, diffraction imaging of nanoparticles, spectroscopy of bulk solids and surfaces, investigation of surface reactions and

spin dynamics, and the development of advanced photon diagnostics and experimental techniques. So far, 16 science projects have been pursued involving approximately 200 scientists from 11 countries. Some of the research highlights will be presented.

THBAU02 FELICE, the Free Electron Laser for Intra-Cavity Eperiments

Alexander van der Meer, Britta Redlich (FOM Rijnhuizen, Nieuwegein)

We present the status and first results of the commissioning of the new beam line FELICE, an extension of the IR User Facility FELIX. The primary purpose of this beam line is to enhance the capabilities of the facility for different types of action spectroscopy of (bio)molecules, ions, clusters and complexes in the gas-phase. FELs such as FELIX are particularly suited for this type of research and the majority of the beam time delivered is nowadays devoted to it. Despite the large number of successful experiments, it soon became clear that for certain experiments even the output of FELIX is not sufficient, especially in the FIR. As the absorption cross sections of the gas samples are inherently low, a very significant boost is possible by making use of the intra-cavity power. FELICE is designed to cover the wavelength range from 3 to 100 microns at a micropulse repetition rate of 1 GHz. It runs interleaved with FELIX at a macropulse repetition rate of up to 10 Hz. The 4-mirror resonator, extending through the radiation shielding, provides an additional focus at either one of two experimental setups: a versatile molecular beam machine and an FTICR ion trap. For the wavelength range above 35 microns, the resonator will be equipped with an insertable, partial waveguide. At this moment, an intermediate stage has been reached in which FELICE can operate in the 6–35 micron range.

THBAU03 FEL Irradiation Use for the Biochip Production Standardization

Sergey E Peltek, Tatiana N. Goryachkovskaya, Tatyana N. Kusnetsova, Viatcheslav A Mordvinov (ICG SB RAS, Novosibirsk), Vasiliy M. Popik, Mikhail A. Scheglov (BINP SB RAS, Novosibirsk), Alexander S Kozlov, Sergey B. Malyshkin, Alexander K. Petrov (ICKC SB RAS, Novosibirsk)

The teraherz emission of the Budker INP Free electron laser was applied to the development of the scientific base for the biochip production standardization. The complementary pairings of hydrogen bonds of DNA nucleotides are the base of biochip applications. The technique is based on the method of soft nondestruction ablation developed by authors, which means the transfer of molecules to aerosol phase form solid substrate under action of the teraherz emission. The teraherz emission excites nonvalency of molecular bonds. Ablation of horseradish peroxidase biomoleculs was carried out and nondestruction of biomelecules was verified by using of an aerosol spectrometer and an electrophoresis in polyacrylamide gel. By hystochemical staining technique there was verified that peroxidase has retained its enzymatic activity. The molecular design of model biochip oligonucleotides and polymerase chain reaction analysis of ablation product were developed. The prototype of two different biochips on high resistance silicon substrate were manufactured. Requirements to the coating and immobilization of oligonucleotide probes on silicon substrate were developed. The first experiment on nondestruction ablation under teraherz emission of oligonucleotides from model biochip was achieved.

THBAU04 Millimeter Waves Sensing Behind Walls - Feasibility Study with FEL Radiation

Boris Kapilevich, Moshe Einat, Michael Kanter, Boris Litvak, Asher Yahalom (CJS, Ariel), Avraham Gover (University of Tel-Aviv, Tel-Aviv)

The existing through-wall imaging (TWI) systems operate in 1 – 10 GHz, basically, in order to reduce an attenuation caused by building material. However, the spatial resolution is drastically degraded when the operating frequency is relatively low. On the other hand, a majority of building materials demonstrate increased losses as the frequency increases. As a result, higher RF power from the source is required. The Israeli mm-wave FEL provides unique opportunity to solve the above TWI problem permitting to deliver output power 100-1000W at 85-105 GHz. Design of TWI system operating on mm-waves needs comprehensive study of constitutive parameters of different building materials. This paper describes systematic measurements of effective attenuation constant of typical building materials such as concrete bricks, wood, tiles, sand, gypsum, etc. on mm-waves using powerful FEL radiation. Since the Rayleigh criterion for surface roughness cannot be satisfied for some of measured materials, scattering and depolarization effects lead to increasing measured attenuation in comparison with bulky material. Additional experiments were performed to estimate a contribution of these effects into the measured attenuation.

THBAU05 The Scientific Programme of the UK Fourth Generation Light Source: 4GLS

Peter Weightman (STFC/DL, Daresbury, Warrington, Cheshire)

This talk will describe the proposed UK Fourth Generation Light Source (4GLS) and the prototype facility that is nearing completion at the Daresbury laboratory. The 4GLS design is based on a 600 MeV Energy Recovery Linear Accelerator (ERL) optimised to deliver high brightness radiation at energies below 100 eV. The ERL drives three free electron Lasers (FEL's): an IR-FEL tunable over 2.5 to 200 mkm, a VUV-FEL tunable over 3 to 10 eV and a X ray FEL tunable over 10 to 100 eV. The source will also generate both high average power (2.6 kW) and high peak power (100 MW) sources of terahertz radiation. The emerging scientific programme for 4GLS will also be described with an emphasis on proposals to exploit its capabilities in the VUV, infrared and terahertz regions of the electromagnetic spectrum. There are particularly exciting prospects for research programmes that exploit various combinations of the 4GLS light sources in pump probe experiments

FRAAU01 Source of Radiation on ARC-EN-CIEL Proposal

Marie-Emmanuelle Couprie, Oleg Chubar, Marie Labat, Guillaume Lambert, Olivier Marcouillé (SOLEIL, Gif-sur-Yvette)

The ARC-EN-CIEL project proposes a panoply of light sources for the scientific community. The phase 1 (220 MeV superconducting Linac, down to 30 nm) and phase 2 (1 GeV, down to 1 nm) choice to provide 30-100 fs HGHG radiation and their Non Linear Harmonics seeded with the High order Harmonics generated in Gas is further confirmed with the suceesfull demonstration experiment of such a scheme at SPA. New optimizations of the undulatros lead to in vacuum undulators of period 26 mm for the modulator, and APPLE-type radiators of period 30 mm, close to the standard SOLEIL insertion devices. New calculations have been carried out using PERSEO TD and GENESIS coupled to SRW for further propagation of the FEL wavefront to the beamlines. In addition, THz radiation from the magnets of the compression chicanes will be provided and has been calculated using SRW. ARC-EN-CIEL Phase 3 incorporates ERL loops, for hard X ray spontaneous emission above 10 keV from short period in vacuum undulators (20 mm period typically), one Soft-X ray spontaneous emission beamline using an variable polarisation undulator, and an FEL oscillator in the 10-60 nm spectral range. Recent calculations and optimisations will be presented.

FRAAU02 Status of the FEL Test Facility at MAX-lab

Sverker Werin, Mathias Brandin, Filip Lindau, Sara Thorin (MAX-lab, Lund), Michael Abo-Bakr, Johannes Bahrdt, Kathrin Goldammer (BESSY GmbH, Berlin), Dmytro Pugachov (DESY, Hamburg; MAX-lab, Lund), Anne L'Huillier (Lund University, Lund)

An FEL test facility is built on the existing MAX-lab linac system in collaboration between MAX-lab and BESSY. The goal is to study and analyse seeding, harmonic generation, beam compression and diagnostic techniques with the focus of gaining knowledge and experience for the MAX IV FEL and the BESSY FEL projects. The test facility will in the first stage be using the 400 MeV linac beam to generate the third harmonic at 90 nm from a 266 nm Ti:SA seed laser. The optical klystron is installed and magnetic system, gun and seed laser systems are currently being finalised. Start-to-end simulations have been performed and operation modes for bunch compression defined. The linac and beam transport system is already in operation. We report the status and layout of the project, the issues to be addressed, the solutions for bunch compression and operation. We also report on the prospects of extending the seeding to HHG laser systems.

This work has been partially supported by the EU Commission in the Sixth Framework Program, Contract No. 011935 – EUROFEL and by the Swedish Research Council.

FRAAU03 Compact Ring FEL as a Source of High Power Infrared Radiation

Oleg A. Shevchenko, Alexander N. Matveenko, Nikolay Vinokurov (BINP SB RAS, Novosibirsk)

Ring FELs* were proposed mainly to improve the quality of radiation of x-ray FELs. Their main advantage is the absence of mirrors. It appears that this advantage is also useful for high power FELs. Another reason to build infrared ring FEL is the proof-of-principle for shorter wavelength FELs. Therefore we considered the scheme of infrared ring FEL which requires ERL with beam energy 50 MeV. Using extensive simulations we developed requirements for electron beam parameters and magnetic system of ring FEL. In spite of rather compact design such FEL may provide more than 10 kW average power.

* N.A. Vinokurov, O.A. Shevchenko, NIM A528 (2004) 491-496

FRAAU04 Re-Commissioning of the Far-Infrared Free Electron Laser for Stable and High Power Operation after the Renewal of the L-Band Linac at ISIR, Osaka University

Goro Isoyama, Tetsuya Igo, Shigeru Kashiwagi, **Ryukou Kato**, Yutaka Morio (ISIR, Osaka)

We have been developing a far-infrared FEL since late 1980s based on the 40 MeV, L-band electron linac at the Institute of Scientific and Industrial Research (ISIR), Osaka University. The first lasing was obtained at 32~40 um in 1994 and since then we progressively modified the FEL system and continued experiment in between to expand the wavelength region toward the longer wavelength. We finally obtained lasing at 150 um in 1998. We could not obtain power saturation because the macropulse duration is 2 us, though the RF pulse is 4 us long, due to a long filling time of the acceleration tube of the L-band linac and the number of amplification times is limited to 50 only. The linac was constructed approximately 30 years ago and it was not suitable for stable and high power operation of FEL, so that we suspended the development of the FEL. In 2002, we had an opportunity to remodel the linac largely for higher stability and reproducibility of operation. We also added a new operation mode for FEL in which the macropulse duration can be extended to 8 us. I took time to remodel the linac and commission it, but finally the operation mode for FEL is being commissioned and we are resuming the FEL again after the long suspension. We will report the progress and the current status of the re-commissioning of the FEL.

FRAAU05 4GLS: a Facility for the Generation of High Brightness, Variably Synchronised Sources from THz into the XUV

Brian W.J. McNeil (USTRAT/SUPA, Glasgow), James Clarke, David James Dunning, Neil Thompson (STFC/DL/ASTeC, Daresbury, Warrington, Cheshire), Brian Sheehy (Sheehy Scientific Consulting, Wading River, New York)

The proposed 4th Generation Light Source (4GLS) at the UK's Daresbury Laboratory is now in its Technical Design phase. The facility will employ three FELs along with conventional lasers and spontaneous synchrotron radiation sources to provide users with a uniquely flexible range of pump-probe options from THz into the XUV regions of the spectrum. A summary of the current design and operating parameters with particular emphasis on the FEL systems are presented

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