SURIYA, A SOURCE OF FEMTO-SECOND ELECTRON AND PHOTON PULSES

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Abstract

A new facility, SURIYA, is being constructed at the Fast Neutron Research Facility (FNRF), Chiang Mai University (Thailand), to generate femto-second electron bunches. These bunches can be used either directly, or to create coherent far infrared radiation or femto-second X-ray pulses. A 20 MeV linear accelerator has been installed and is presently equipped with a conventional electron source. A newly designed rf-gun is under rf-testing and is expected to be installed in 2002. Layout and status of the SURIYA project will be presented.

1 INTRODUCTION

Construction and installation is underway at the Fast Neutron Research Facility, Chiang Mai University, of the SURIYA facility to produce intense, coherent, polarized far infra-red radiation in the wavelength range from 50 µm to a few 1000 µm. This source will provide high intensity, broad band radiation in this wavelength regime far in excess to that available from black body radiators or synchrotron light sources. In Fig. 1 the expected radiation brightness of coherent transition radiation (CTR) from a 30 µm (rms) electron bunch is compared with that available from a synchrotron light source (SR) and a black body radiator.

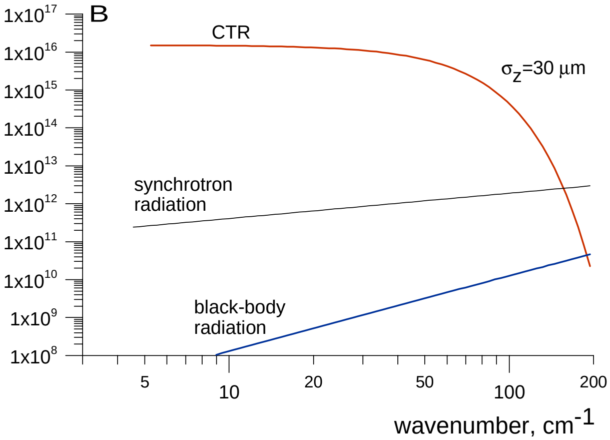

Figure 1: Radiation brightness B(ph/s/mm^2/100%BW) vs. wave number for CTR, SR and black body radiation.

Because the radiation is broadband and comes in ultra-short pulses (< 100 f-sec, rms), this source also provides characteristics, which are not available from FEL's in this wavelength regime. This radiation can be used for basic and applied research in many fields including material science, studies of high-Tc materials, polymer dynamics and structure, biological molecules, phonon and surface physics, metrology standards etc [1,2,3]. A 1994 report by a subcommittee of the American Academy of Science suggests that a "compelling" reason for the establishment of a new national facility to produce radiation can be made only for the wavelength range from 10 µm to 1000 µm [4].

The source under construction at the FNRF is similar to that at the SUNSHINE facility at Stanford University [5-8] producing coherent FIR radiation with intensities far exceeding those from black body radiators. At SUNSHINE, electron bunches as short as 120 f-sec (rms) are produced routinely at microbunch intensities of the order of 100 pC [8]. Such high intensities together with coherence and ultrashort pulse lengths provide new research opportunities, which cannot be pursued with conventional sources. In addition to the research potential of such a source, its components provide a broad training ground for the education and training of graduate students toward master and Ph.D. theses. This is due to the application of many basic physical principles from a variety of fields like mechanics, optics, electronics, component controls, data acquisition, ultra high vacuum technology, magnetics, beam dynamics, and computer simulation.

Specifically, studies can be expanded into radiation production in the form of undulator-, transition-, stimulated transition-, Cherenkov-, Smith-Purcell or diffraction radiation. If desired, a Free Electron Lasers, or a single pass FEL can be added in this wavelength range. By head-on collision of a laser beam with the electron beam ultrashort, quasi- monochromatic soft or hard x-ray pulses can be produced by the process of Thompson backscattering. Through the interaction of the electron beam with crystals ultra short pulses of x-rays can be generated as channelling radiation, as parametric x-rays or resonant transition radiation to name just a few. The research and educational potential associated with such a source fits well the objectives of the Fast Neutron Research Facility at Chiang Mai University.

2 METHOD TO PRODUCE FEMTO SECOND ELECTRON BUNCHES

The particular design of the rf-gun (Fig. 2) exhibits a small correlated particle distribution in phase space as derived from numerical PARMELA [9] simulations and shown in Fig. 3 with most of the particles concentrated in the first 10 psec. A more detailed discussion of the rf-gun design is given in another contribution to this conference [10]. The thin phase space distribution allows for efficient bunch compression in an α-magnet (Fig. 2). An energy filter within the α-magnet allows to select the useful part of the beam.

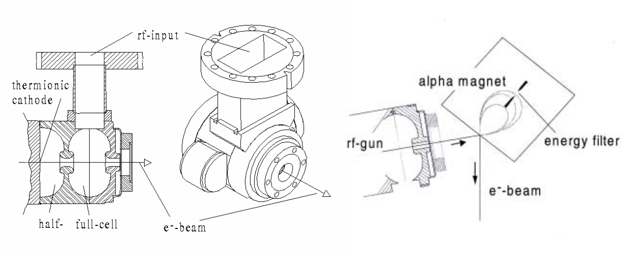

Figure 2: Rf-gun (left) and α-magnet with energy filter (right) [5].

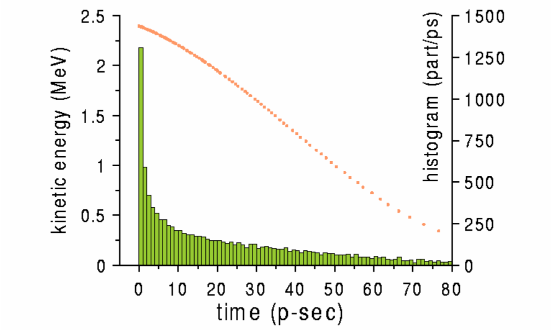

Figure 3: Particle distribution (PARMELA) in energy-time phase space at the rf-gun exit with histogram [11].

High-energy particles, emerging first from the rf-gun will travel a longer path through the α-magnet than lower energy particles, thus leading to bunch compression. After further acceleration in a linac the beam is guided to the experimental stations.

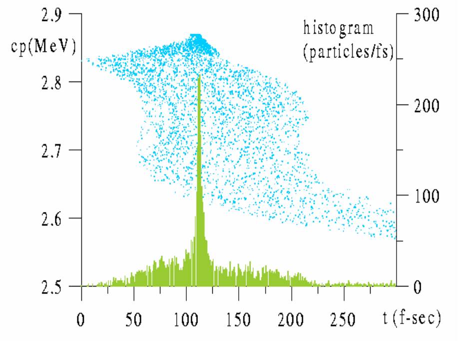

Figure 4: Particle distribution at the experimental station after optimum compression (PARMELA simulation)[11].

From this electron source we expect to obtain bunches as short as 34 fs or 10 µm (rms), which is shorter by at least a factor of 3 compared to the SUNSHINE source [6,12]. As a consequence, the coherent far infrared spectrum available is extended by a factor x3 and thereby covers the wavelength regime from about 30 µm to several mm, or in terms of wave numbers from 10 to 300 cm^{-1} and beyond as shown in Fig. 5.

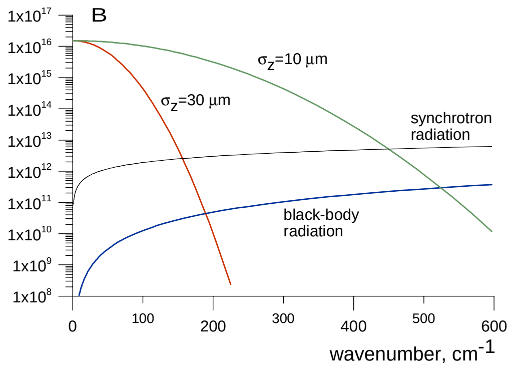

Figure 5: Expected coherent radiation spectrum from the new rf-gun.

3 INSTALLATION STATUS OF SURIYA

The FNRF has obtained a 20 MeV RF linear accelerator from the Chiang Mai Hospital. This system includes all related components to accelerate an electron beam. The installation of the linac including all of its sub-systems and conventional electron source has been completed (Fig. 6). All features related to medical-radiation therapy treatment and not used at SURIYA have been removed. The control electronics has been fully updated to remove therapy related interlocks and replace them with a system guided by research requirements.

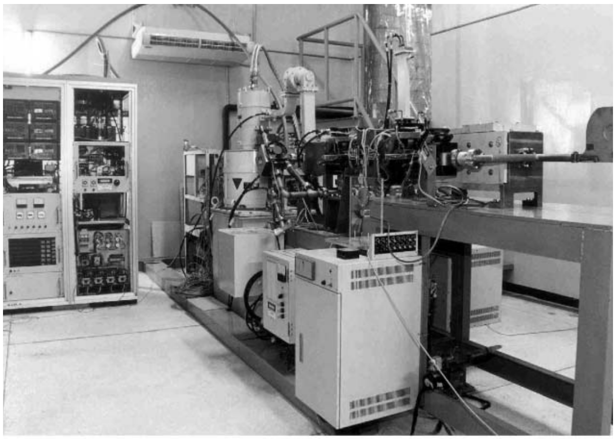

Figure 6: Rf-linac installed at the SURIYA project.

At the SURIYA project laboratory, all personnel and machine protection systems have been installed and tested. An international standard security and safety protocol has been incorporated into the operation of the machine, which includes access door interlocks and panic buttons for automatic beam shut-off in case of personnel access to a restricted area. Beam-on warning lights, high voltage signs and audible sirens are implemented and appropriate locations to notify of machine operating status and radiation hazards. Operator and user training programs are being developed for operational and radiation safety.

In a collaboration with Stanford/SLAC (USA) and LNLS (Brazil) a new rf-gun has been developed [10,11] through numerical studies with PARMELA [10]. This new gun has been optimized for most efficient bunch compression reaching bunch lengths of 34 fs or 10μm (rms), which is three time shorter than those obtained at the SUNSHINE facility. All major parts of the newly designed rf-gun have been machined in Thailand and are presently under rf-evaluation and fine-tuning. This rf-gun will be installed in 2002. A second klystron and modulator is ready for installation as the rf-source for the rf-gun.

Design of an α-magnet can be separated into two main parts: poles and coils design. To match rf-gun requirements, the α-magnet is designed for a maximum field gradient of 450 G/cm. Computer designs of α-magnet and coil have been completed (Fig. 7) and are under construction. We plan to complete the full system of the α-magnet by the end of 2001.

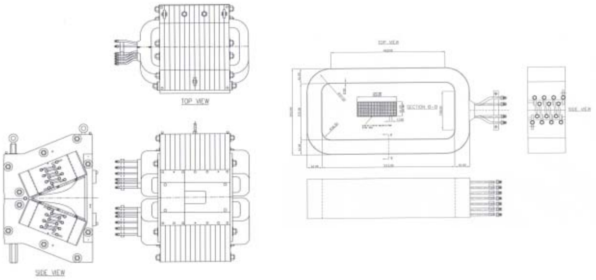

Figure 7: Assembly drawing and coils of the α-magnet

The whole facility is installed in a below ground well shielded enclosure which became available from an earlier neutron beam activity. The final floor plan of the SURIYA facility is shown in Fig. 8 with rf-gun, α-magnet, 20 MeV linac, beam line, radiation station and beam dump.

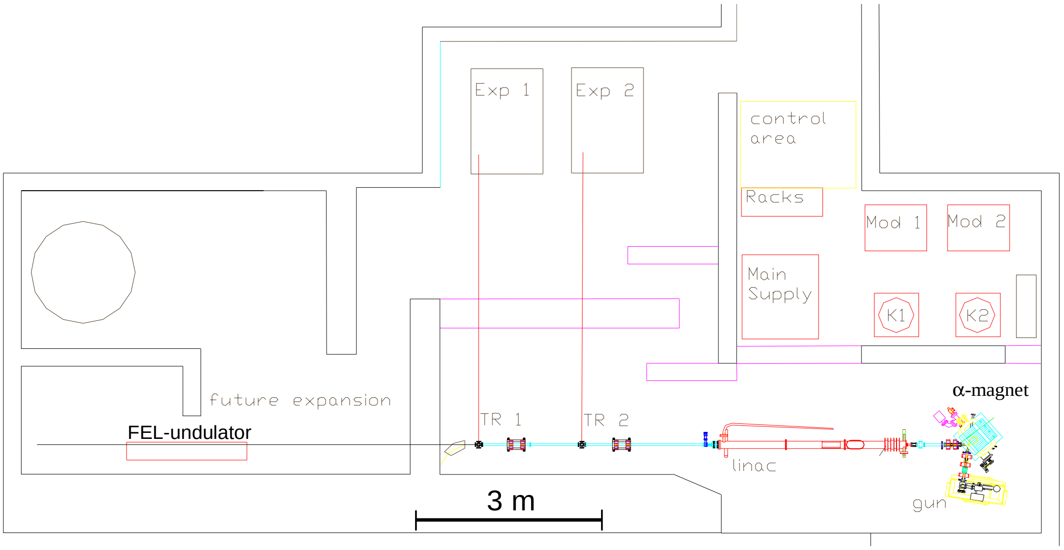

Figure 8. Floor plan of the SURIYA facility with accelerator, experimental stations, equipment and control area and space for future expansion to add, for example, a FEL undulator.

4 ACKNOWLEDGEMENTS

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5 REFERENCES

[1] L. Thrane et. al., "THz Reflection Spectroscopy of Liquid Water", Chem. Phys. Lett. 240 (1995) 330.

[2] J.R. Birch et. al., "An Improved Experimental Method for Reflection Dispersive Fourier Transform Spectrometry of Very Heavily Absorbing Liquids", Infrared Physics 21 (1981) 229.

[3] W.F. Passchier et. al. " A New Method for the Determination of Complex Refractive Index Spectra of Transparent Solid in the Far-Infrared Spectral Region", J. Phys. D: Appl.. Phys. 10 (1997) 509.

[4] "Free Electron Lasers and Other Advanced Sources of Light", Committee on free electron lasers and other advanced coherent light sources, Nat. Res. Council, National Academy Press, Washington, D.C. 1994

[5] H. Wiedemann et. al., " Femto-Second Electron Pulses from a Linear Accelerator", J. Nucl. Mat. 248 (1997) 374.

[6] P. Kung et al. "Generation and Measurement of 50 fs(rms) Electron Pulses", Phys. Rev. Lett. 73 (1994) 967.

[7] C. Settakorn et.al.,"Coherent Far-Infrared Radiation From Electron Bunches", Proc. Of the First Asian Particle Accelerator Conference (APAC98) Tsukuba, Japan, 1998

[8] C. Settakorn, “Generation and Use of Coherent Transition Radiation from Short Electron Bunches”, PhD Thesis, Stanford University, 2001

[9] L.M. Young and J.H. Billen, "Technical Report No. LA-UR - 96-1835: PARMELA", Los Alamos National Laboratory

[10] S. Rimjaem et. al., these proceedings

[11] S. Rimjaem, R. Farias, C. Settakorn, T. Vilaithong, H. Wiedemann, "Femto-Second Electron Bunches from an Rf-Gun", (submitted to Phys. Rev. ST-AB)

[12] M. Borland, "A High-Brightness Thermionic Microwave Electron Gun", Ph.D. Thesis, Stanford University 1991.