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SUMMARY OF WORKING GROUP A (WG-A): LINAC-BASED LIGHT SOURCES

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INTRODUCTION

The WG-A program was broken into 6 sessions with 21 invited and contributed talks. A discussion was scheduled at the end of each pair of sessions and a set of questions had been developed to help focus the discussions in the working group. The sessions are listed below along with highlights from the discussions in each section.

MORE ON NEW FACILITIES

Presentations

1. **Dong Wang (SINAP) :** *The Shanghai Hard X-ray Free Electron Laser Project*
2. **Tor Raubenheimer (SLAC) :** *Progress on the LCLS-II and the High Energy Upgrade of LCLS-II*
3. **Chang-Ki Min (PAL):** *PAL-XFEL and its time-resolved experiment with sub-20-fs timing jitter*

There was no focused discussion on the new facilities although the tour on Friday took us through the Shanghai Synchrotron Radiation Facility (SSRF) and the Soft X-ray FEL (SXFEL) at SINAP.

MACHINE OPTIMIZATION

Presentations

1. **Daniel Ratner (SLAC):** *Report on an ICFA BD mini-workshop on "Machine learning for particle accelerators"*
2. **Lars Fröhlich (DESY):** *Automated Optimization of Machine Parameters at the European XFEL*
3. **Zeng Li (SINAP):** *The Feasibility of Neuron Network-Based Beam-Based Alignment*
4. **Haeryong Yang (PAL):** *FEL optimization through BBA with undulator spectrum analysis and undulator optics matching*

Focus Questions and Discussion:

1. What are the optimization strategies used in tuning a single pass, linac-based FEL for user operation?
2. Will artificial intelligence play a role in tuning and optimizing FEL sources?
3. What are the main differences between the optimization strategies in 3rd and 4th generation light sources?

Machine preparation is time consuming, automatic optimization reduces the preparation times and frees operators from repetitive annoying procedures. It reduces the possibility of errors and may help in retrieving conditions that are operator independent. Furthermore, the **tighter tolerances in 4th generation facilities may prevent them from relying simply on "design models"** because the real system is only partially known and diagnostics do not provide a complete picture. In this case, **automatic optimization becomes essential** to achieve the maximum performance in a reasonable time.

Artificial intelligence techniques are starting to be used to create more accurate "models." Some examples of applications include reconstruction of machine conditions by analysing large amount of stored data and running virtual machines to train optimizers. **In the next generation photon sources, automatic optimizations and machine learning with AI is also playing a role in the design phase** (see CompactLight design study, A. Latina in WG-C). **Interesting cases of non-trivial unexpected behaviors are being "discovered" by optimizers** with advanced algorithms, as the taper optimization (D. Ratner report WG-A). This is **very promising** for the future.

SCHEMES FOR PRODUCTION OF ULTRASHORT PULSES IN EUV AND X-RAY FELS

Presentations

1. **James Mac Arthur (SLAC) on behalf of A. Marinelli, J. Duris, & XLEAP team:** *X-ray Laser-Enhanced Attosecond Pulses*
2. **Xi Yang (BNL) (presented by Luca Giannessi):** *Generation of atto-second pulses in FELS: Ultrashort pulse generation and superradiance*
3. **Neil Thompson (STFC/DL/ASTeC):** *Free-Electron Laser R&D in the UK - steps towards a national XFEL facility*

Focus Questions and Discussion:

1. What are the main challenges and desiderata in the generation of ultrashort pulses in FELs?
2. What are the strategies for temporal synchronization of ultrashort (sub-fs) FEL pulses and of the light properties?

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In hard-Xray coherent diffraction imaging, **fs or sub-fs pulses are highly desirable** for single molecule imaging. Pulses below 10-15 fs are also needed in XUV-Soft xrays FELs in the study of non-linear processes and electron dynamics. **Techniques to achieve these conditions have been proposed and demonstrated.** However synchronization may indeed be an issue. **Seeded FELs provide fs synchronization** with external lasers. SASE is affected by the e-beam arrival time jitter, but **e-SASE can lock a single spike to an external laser.** Synchronization networks with resolution in the sub-fs range in new facilities is demonstrated in tests (F. Kaertner, plenary) and installed in new facilities. **Diagnostics are required to fully benefit of such short pulses.** High resolution diagnostics are being developed including optical streaking, TCAV's, …

LONGITUDINAL COHERENCE IN SOFT AND HARD X-RAY WAVELENGTH RANGES

Presentations

1. **Enrico Allaria (ELETTRA):** *EEHG experiment at FERMI*
2. **Kwang-Je Kim (ANL):** *An X-Ray FEL Oscillator for Novel Sciences*
3. **Evgeny Schneidmiller (DESY):** *Harmonic lasing in XFELs: theory and experiment*
4. **Shan Liu (DESY):** *Simulations and performance study of an optimized longitudinal phase space for the hard X-ray self-seeding at the European XFEL*

Focus Questions and Discussion:

1. Seeded FELs have many nice properties with respect to SASE sources, as improved stability and longitudinal coherence. What are the available options to extend the wavelength range of seeded FELs to shorter wavelengths, covering the soft and hard X-ray spectral range?
2. What are the main differences between self-seeding and external seeding from the point of view of the light properties?

The coherence of an XFELO looks promising and **<u>outperforms all presently available alternatives.</u>** A critical technology is the X-ray cavity which would benefit the XFELO as well as RAFEL configurations.

A recurring question is: **what is the lower wavelength limit for external seeding? I**t is believed that the main limitations from **microbunching instability and IBS** but the answer depends on R&D critical experiments that are going to give an indication about the best way to proceed. These include:

- EEHG test at SXFEL and FERMI
- Slippage enhanced-SASE configurations at CLARA and PSI
- Harmonic seeding studies at many facilities
- Further developments of Self seeding

It seems likely that the best solution may be some combination of these techniques that is optimized for the different wavelength regimes.

ELECTRON BEAM COLLECTIVE EFFECTS - MODELLING AND SIMULATION CODES

Presentations

1. **Martin Dohlus (DESY):** *Fast simulation code including collective effects*
2. **Kaiqing Zhang (SINAP):** *Eliminating the microbunching instability-induced sideband in a soft x-ray self-seeding FEL*
3. **Bas van der Geer (Pulsar Physics, Eindhoven):** *GPT-CSR: a new simulation code for CSR effects*
4. **Peter Williams (STFC/DL/ASTe):** *A Staged, Multi-User X-Ray Free Electron Laser & Nuclear Physics Facility based on a Multi-Pass Recirculating Superconducting CW Linac*

Focus Questions and Discussion:

1. What are the main challenges in the understanding and mitigating the microbunching instability in linac based accelerators?
2. How well do the present simulations codes reproduce the detailed FEL performance?
3. What be included in the ideal FEL simulation code suite?

There was no time for a formal discussion but the following comments were extracted from the questions and short discussion following the talks. Simulation codes do need to be **optimized** to deal with various aspects of **physics problems involved in the beamline: gun codes/linac codes/FEL codes/Photon codes. However the boundaries between systems are not completely separated**. Some problems require crossing these boundaries. Examples include:

- **EEHG and narrow bandwidth affected by microbunching instability**
- Phase space folding is missing in most FEL codes although detailed comparisons between codes have not seen large discrepancies.

One concern that was noted is that in dealing with the **interfaces between plasma acceleration and "linac" and "FEL"** codes, it is important to represent tails or details in phase space from the FEL/accelerator perspective.

MULTI-USER SIMULTANEOUS OPERATION

Presentations

1. **Aymeric Robert (SLAC) (on behalf of Diling Zhu):** *Results from the diamond grating multiplexing study at LCLS (January) to feed 3 experiments simultaneously*

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2. **Giuseppe Penco (ELETTRA):** *Two-bunch operation with ns temporal separation at FERMI*
3. **Bart Faatz (DESY):** Optimizing of electron beam distribution at European XFEL and FLASH

Focus Questions and Discussion:

1. What are the ultimate challenges and limitation in simultaneously serving multiple beamlines in FEL facilities?
2. Can we start thinking to experiments with multiple FEL pulses from independent FEL lines?

Again, there was no time for a formal discussion but the following comments were extracted from the questions and short discussion following the talks. All the **upcoming facilities are planning** or operating simultaneous **multi-beam operation.** Different ways to generate and handle multiple bunches and beam splitting to different experiments were presented. In some cases, multi-pulse operation could even be dedicated to a single experiment, e.g. extending the capabilities of pump-probe investigations.

One thing stressed is the importance of moving toward a 2/1 oversubscription rate for a healthy "acceptance statistics." It is expected that this should change quickly (from the present 4:1) with the new facilities coming into operation and with simultaneous use of multiple FEL lines. It should be noted that the **efficiency of multiple FEL lines is not 100%** (2 FEL lines with 1 linac or beam splitting do not correspond to 200% equivalent beam time). The schedule becomes more rigid and last minute changes in the user's requests make it harder for beam sharing. Good question from Aymeric Robert: **What is the "Definition of success?" Experiments often require very different setups -> Do not lose flexibility.**

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