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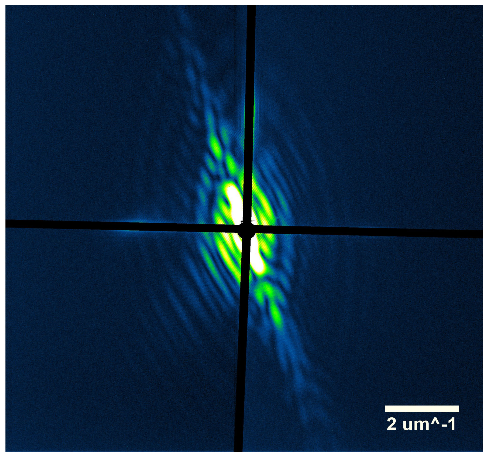

Seeding and Self-seeding at New FEL Sources

ICTP, Adriatico Guesthouse

Trieste, Italy

10-12 December 2012

Seeding and Self-seeding at New FEL Sources
Trieste, Italy
10-12/12/2012

PROGRAM

Monday, 10 December 2012

Kastler Hall

8:30 9:00	Registration	
9:00 9:15	A. Franciosi: Welcome	
Chair: L. Giannessi		
9:15 9:55	F. Parmigiani	*Science driven requirements for seeded FEL*
9:55 10:25	E. Allaria	FERMI: *EUV Soft X-Ray FELs with HGHG*
10:25 10:40	*coffee break*	
Chair: W. Fawley		
10:40 11:10	G. Stupakov	*Intra-beam scattering and the ultimate seeding wavelength in EEHG*
11:10 11:40	W. Zhang	*A Seeded Extreme-UV Free Electron Laser System at Dalian*
11:40 12:10	M.E. Couprie	*Use of various seeding light sources for seeding FELs*
12:10 12:30		*Open discussion*
12:30 14:10	*lunch*	
Chair: G. Dattoli		
14:10 14:40	G. Geloni	*Self-seeding methods at the European XFEL*
14:40 15:10	S. Reiche	*Electron Beam Requirements for Seeded FEL*
15:10 15:40	F. Ciocci	*FEL experiments at SPARC*
15:40 16:00	*coffee break*	
Chair: J. Rossbach		
16:00 16:30	G. Penn	*Coherence requirements for various seeding*

		schemes
16:30 17:00	V. Miltchev	*Recent results of HHG-seeding experiment at FLASH*
17:00 17:30	A. Zholents	*A proposal for a mode-locked hard x-ray free-electron laser*
17:30 18:00	*Open discussion*	
19:30:	*Dinner at the Restaurant "Tavernetta al Molo", Riva Massimiliano e Carlotta 11, Grignano*	

Tuesday, 11 December 2012

Kastler Hall

Chair: R. Schoenlein

09:00 09:30	H. Tomizawa	*Seeding and Self-seeding Options at SACLA*
09:30 10:00	J. Welch	*Seeded Beams at LCLS*
10:00 10:30	D. Wang	*Seeded FEL studies at SINAP*

10:30 10:45 coffee break

Chair: G. Penco

10:45 11:15	A. Lutman	*Experimental results for the HXR self seeding scheme*
11:15 11:45	B.W.J.McNeil	*Improving temporal coherence and generating shorter pulses in the FEL*
11:45 12:15	Open discussion	
12:15 12:30	L. Giannessi: Closing remarks	
12:30 14:00	*lunch*	
14:00 14:30	Bus transfer to FERMI	
14:30 16:30	Visit to FERMI User Experimental Hall and Control Room	
16:30 17:00	Bus transfer to Trieste city center or to Adriatico Guesthouse	

Wednesday, 12 December 2012

Denardo Hall

9:00 12:30 Follow-up meeting: *Possible FEL physics - Beam physics experiments, which can be implemented specifically on FERMI and future possible extensions of FERMI FEL beam lines*

Intra-beam scattering and the ultimate seeding wavelength in EEHG

Gennady Stupakov, SLAC

Echo Enabled Harmonic Generation (EEHG) has a promise of generating extremely high harmonics of the seed laser in soft x-ray FELs. An important question is: what is the physics limitation of the maximally achievable harmonic number in the EEHG seeding? While it is realized that higher harmonics require stricter tolerances on the magnetic system, laser parameters and control of beam properties, these tolerances do not impose a definite limit on the maximal harmonic number. In this talk, I will argue that the physical mechanisms that set such a limit are the intra-beam scattering and incoherent synchrotron radiation in the seeding system.

A Seeded Extreme-UV Free Electron Laser System at Dalian

Weiqing Zhang[1], Qing Guo[1], Chunlei Xiao[1], Dongxu Dai[1], Xueming Yang[1]*, Dong Wang[2], Zhentang Zhao[2]
[1]State Key Lab of Molecular Reaction Dynamics, Dalian Institute of Chemical Physics, CAS, Dalian, China and [2] Shanghai Institute of Applied Physics, CAS, Shanghai, China
Email: weiqingzhang@dicp.ac.cn, xmyang@dicp.ac.cn

Fundamental research in basic energy science is very important to the development of clean energy sources as well as the optimization of fossil energy use, because energy uses and productions are essentially chemical and physical processes. The development of new light sources, such as table laser running at visible range, synchrotron radiation at X-ray, for studying energy systems has been a key in this field. Extreme VUV light sources have been very useful for efficiently detecting and ionizing important molecular species in one photon excitation. However, strong light sources in the EUV region are difficult to obtain with commercially available laser systems using non-linear optics scheme. Although EUV synchrotron radiation is a good tool for near CW type experiment in this wavelength range, time-resolved dynamics studies of molecular energy processes usually need powerful pulsed EUV laser sources. Recently development in the FEL science, especially the seeded high gain high harmonic technique (HGHG)[1,2], have provided us an excellent chance to acquire strong EUV light sources for experimental studies in basic energy science. This type laser source could provide strong laser light that is several orders more intense than current available light sources and is useful for efficient detection of molecular and radical species. Such EUV light source is basically a femtosecond pulsed laser that is excellent for ultrafast dynamical experiments.
A project to build a new seeded free electron laser, operating at extreme UV range between 50nm and 150nm, at Dalian has been recently funded by the National Science Foundation of China. This is a collaborative project by the Dalian Institute of Chemical Physics (DICP) CAS and the Shanghai Institute of Applied Physics (SINAP) CAS. A conceptual design[3] of FEL will be present at this workshop. The FEL uses a 300 MeV electron beam with picosecond duration from normal conducting S band Linac. The electron beam is then modulated at the first short undulator by a seed laser. The high harmonic in the extreme UV range is generated and amplified in a region of several undulators downstream. The designed EHV FEL will produce about 100uJ per pulse with a repetition rate of as high as 50 Hz. User experimental stations in the studies of molecular beams and surface dynamics will also be built at the same time[3]. This will ensure immediate usage of the FEL light source once it is completed. Related research plans using this light source will be also presented.

Ref

[1] L.H. Yu, M. Babzien, I. Ben-Zvi, et al., Science, 289, 932 (2000).
[2] L.H. Yu, L. Dimauro, A. Doyuran, et al., Phys. Rev. Lett. 91, 074801 (2003).
[3] Conceptual Design Report of "An Extreme-UV Coherent Light Source at Dalian"(2012)

Use of various seeding light sources for seeding FELs

Marie-Emmanuelle Couprie, SOLEIL

The Self-Amplified Spontanenous Emission (SASE) mode is currently employed for short wavelength Free Electron Lasers (FELs) because of lack of mirrors in the whole spectral range. SASE presents a limited temporal coherence, conveying « spikes » in the temporal and spectral distributions, because the emission starts with noise. For single pass sources, the injection of an external laser source tuned on the fundamental wave of the undulator (seeding) can improve the temporal coherence in relation to SASE, reduce the gain length and limit the intensity fluctuations. Using conventional lasers limits the wavelength of the seed to the UV (frequency doubled or tripled laser) and does not permit in principle to reach very short FEL wavelength, requiring up-frequency conversion. Coherent sources at short wavelength can also be considered as seeds. High order Harmonics generated in Gas (HHG) produced by focusing an intense laser in a gas (jet or cell) provide nowadays sources with transverse and longitudinal coherence down to a few nm in trains of attosecond pulses in a femtosecond envelop. They have been successfully employed to seed Free Electron Lasers at short wavelength. Indeed, seeding has been recently performed with High order Harmonic in Gas (HHG) seed on SCSS Test Accelerator in Japan at 160 nm in the frame of a French Japanese collaboration. Studies on the seed level were carried out. A further step has been achieved with the 60 nm HHG seeding. HHG seeding has also been conducted at SPARC and is under test at S-FLASH. Tuneability is here provided thanks to the tuneability of the generating laser coupled to stepping from one harmonic to the other. A more easily tuneable seeding source can also be considered, such as the radiation recently demonstrated with the kagome hollow-core photonic crystal fiber filled with noble gas. The emission of a resonant dispersive wave in the DUV spectral region process accompanies the soliton-effect self-compression of the pump pulse down to a few optical cycles. Pulses are diffraction-limited, of tens of femtosecond duration and provide energies larger than 50 nJ and fs-duration with a continuously tunability from below 200 nm to above 300 nm. One could also consider high order harmonics generated in solid targets. Short wavelength seed can also be combined to various up-frequency conversions scheme employed in Free Electron Lasers.

Self-seeding methods at the European XFEL

Gianluca Geloni, Vitali Kocharyan and Evgeni Saldin, European XFEL

In this contribution we will review proposals to enable self-seeding capabilities at the European XFEL. We will discuss both plans involving the baseline undulator system of the European XFEL, as well as ideas for possible future upgrades.

Electron Beam Requirements for Seeded FEL

Sven Reiche, Paul Scherrer Institute

Variations and jitter in electron beam parameters acts differently on the performance of SASE and seeded FELs. SASE are self-tuning and exhibits mostly arrival time and wavelength jitter, while the pulse energy is mostly preserved. This is reserved for seeded FEL, imposing more stringent tolerances for the electron beam quality than SASE FELs. In addition a multi stage approach requires a better control of the electron beam parameters along the bunch. The impact of various jitters on the FEL performance for laser-based seeded and self-seeded FEL is discussed.

FEL experiments at SPARC

F. Ciocci, ENEA C.R. Frascati

The SPARC experimental activity on high gain FEL is reported, within the framework of the SPARC LAB activities. The future upgrades of the device are discussed as well as the planned activities and scientific collaborations.

The seeding activity at SPARC is discussed and a possible scheme for self -seeding operation is presented. In particular a tunable DUV light source based on Kagomè crystal fiber is described as a development of SPARC FEL source.

Coherence requirements for various seeding schemes

Gregory Penn, LBNL

The impact of external laser quality on the quality of the radiation produced by a seeded FEL is fairly well understood. Less appreciated is the impact of longitudinal variations in the electron beam on longitudinal coherence. The mechanisms for this dependence are explored, and tolerances on the electron beam to achieve fully coherent radiation are calculated for various seeding schemes. The most challenging requirement is for a very flat slice energy profile, which is made more challenging for small-gap undulators due to the effect of resistive wall wakefields. Strategies to minimize both beam energy variations and their impact on the output of the FEL are explored, and simulations of examples for soft x-ray FELs are presented.

A proposal for a mode-locked hard x-ray free-electron laser

R. Lindberg and A. Zholents, Argonne National Laboratory

Mode-locking in a free-electron laser (FEL) modifies the FEL output, resulting in an x-ray frequency comb comprised of a large number of frequency lines in the spectral domain, and a sequence of ultra-short x-ray micro-pulses with a fixed and well-defined temporal separation in the time domain. First proposed by Thompson and McNeil [1], the idea of FEL mode-locking quickly attracted the attention of scientists and FEL designers [2, 3]. In this paper we propose a new approach that seems to be easier to implement, and can possibly be employed at the LCLS with few modifications. The first part of the new scheme relies on modulating the FEL gain by introducing a modulation in the peak electron beam current, which can be achieved in a very similar way as that proposed for Enhanced Self-Amplified Spontaneous Emission [4]. The second part of the scheme utilizes the idea of hard x-ray self-seeding [5, 6], in which the x-ray light produced by the electron bunch in the first FEL is used to provide a monochromatic seed for operation of the downstream FEL after passing through a diamond monochromator. In this case, a sequence of electron micro-bunches produces the light required for the monochromatic seed field which, when amplified by the same electron micro-bunches in the downstream undulator, results in a phase-locked x-ray pulse train with the output characteristics comparable to that of a mode-locked laser.

References

[1] N.R. Thompson and B.W.J. McNeil, Phys. Rev. Lett. **100**, 203901 (2008).
[2] E. Kur, D. J. Dunning, B.W.J. McNeil, J. Wurtele and A. Zholents, New Journal of Physics, **13**, 063012(2011).
[3] D. Xiang, Y. Ding, T. Raubenheimer, J. Wu, Phys. Rev. ST Accel. Beams **15**, 050707 (2012).
[4] A. Zholents, Phys. Rev. ST Accel. Beams **8**, 040701 (2005).
[5] G. Geloni, V. Kocharyan, E. Saldin, J. Mod. Opt. 58, 1391–1403 (2011).
[6] J. Amann, et al., Nature Photonics, 2012; DOI: 10.1038/nphoton.2012.180.

Seeding and Self-seeding Options at SACLA

Takashi Tanaka and Hiromitzu Tomizawa, Spring-8 - SACLA

SACLA, the 2nd X-ray FEL facility in the world, has started user operation this March. The machine has been stabley operated and a number of experimental results have been already obtained. In addition, several upgrade programs are in progress at SACLA and the top priority is put on the seeded FEL. In the hard x-ray region, we have investigated several configurations for the self seeding, including the scheme using the thin diamond single crystal, which has been demonstrated successfully in the LCLS. The results of numerical study are presented. Besides the seld-seeding, we are also exploring the seeding FEL by means of the HHG and HGHG scheme especially in the soft x-ray region, which will be covered in the dedicated beamline to be constructed at SACLA in a couple of years. Recent results of the seeding expriments with an external HHG laser, which has been carried out in the test accelerator operating in the EUV region, are presented as well.

Seeded Beams at LCLS

James Welch, SLAC

I will talk about recent seeding developments at LCLS, the current status, and prospects for future developments. Topics will include, self-seeding using various bragg planes, using two bragg planes at the same time, long-bunch self-seeding, taper studies, and chirped seeded beams. I will also discuss the effect of electron energy jitter on the seeded beam.

Seeded FEL studies at SINAP

Dong Wang, Shanghai Institute of Applied Physics, Chinese Academy of Sciences

There are two seed FEL projects at SINAP right now, one in operating(SDUV) and one under construction(SXFEL). SDUV(Shanghai Deep UV FEL) is a dedicated test bench in Free Electron Laser principles especially in seeded schemes. The SXFEL is a seeded FEL facility in soft X-ray regime. This talk will focus on seeded FEL experiments at SDUV and briefly describe the progress on SXFEL.

Experimental results for the HXR self seeding scheme

Andrea Lutman, SLAC

I will present the experimental results for the HXR self seeding scheme, proposed by the colleagues of DESY*, and implemented at the LCLS. A reduction of the bandwidth by a factor 40-50 times was observed in respect to SASE at 8.3 keV in the low charge 40 pC mode. The statistical properties of the self-seeded photon beam will be presented comparing experimental results and simulations, particularly the effect of the machine jitters will be discussed.

**G.Geloni, V.Kochrayan and E.L. Saldin DESY 10-133, arXiv:1008.3036(2010)*

Improving temporal coherence and generating shorter pulses in the FEL

Brian McNeil, University of Strathclyde

There is significant scientific interest in reducing pulse durations and improving the temporal coherence of the output from short-wavelength (X-ray) FELs. In this talk I will review some of the methods that researchers in the UK have proposed towards these goals. It is hoped that some of these options may shape any future UK Light Source and ensure that the next generation of designs will provide users with a unique class of world-leading sources that can generate high-power pulses with the spatial and temporal resolution of the atom (x-ray, attosecond pulses at multi- GW powers). In order to assist this research, a broad-bandwidth 3D simulation code 'Puffin' has been developed and its capabilities will briefly be described.