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Summary of the workshop

Current development of Free Electron Lasers

Lund 18-19 October 1998

Including:
Workshop program &
List of participants

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Summary of the workshop

Current development of Free Electron Lasers

Lund 18-19 October 1998
Biskopshuset
DESY and MAX-lab

The workshop was started on an initiative from Jochen Schneider at DESY and sponsored by the European Round Table for Synchrotron Radiation and Free Electron Laser. The aim was to present an overview of the status of Free Electron Lasers in general with some more weight on the two directions: European and X-ray/VUV. For the initiated people the intention was to give an update of the status of a number of projects and the current development, for those not so familiar with the FEL technology the intention was to give an introduction especially to the concepts of SASE FELs but also to give an appetiser to start thinking in the lines of FELs.

Close to 40 participants from mainly Europe joined the meeting which was held in Gamla Biskopshuset (the Old Bishops manor) in Lund. The program started with a section giving an introduction to Linac based FEL facilities, and the prospects for these as the next generation of synchrotron radiation sources by Jochen Schneider. The general "problem" of generating the necessary electron beams for these machines was treated by Jörg Rossbach.

The following sessions were divided roughly into wavelength sections. Each session was followed by a discussion with an appointed "provocateur" to keep people arguing (see the summaries below). In the VUV section Steve Milton described the FEL development at APS and Josef Feldhaus the VUV FEL at DESY.

Storage ring and IR-FELs were treated by Marie-Emanuelle Couprie from LURE and Jean-Michel Ortega from CLIO.

Before going to the X-ray session there were five brief contributions from a variety of European FEL activities.

In the X-ray session Roger Carr talked on the LCLS project at SLAC and Jörg Rossbach and Jochen Schneider on Techniques and Applications for the TESLA X-FEL at DESY.

Copies of the Overheads are published as an Appendix in a separate volume!

Fragments from the presentations

Jochen Schneider talked on **LINAC driven FELs: The next generation of synchrotron radiation sources**. The synchrotron radiation community consists of 20.000 scientists that use 30 SR facilities worldwide. Only the american laboratories have several thousands of publications from this work. The brightness of the sources have increased 3 orders of magnitude every ten years. A number of 3rd generation X-ray sources are in operation: ESRF, APS and SPring8, but they have limitations: The average brilliance is getting close to the theoretical limit, spatial coherence is limited and the pulselength can not be shorter than 50

ps. The X-ray SASE FEL, like TESLA, will gain 10^6 in average brilliance and will be fully spatially coherent. This will open up for a number of new experiments: phase contrast imaging, speckle spectroscopy etc. The TTF will be a part of EXPO 2000 in Hamburg.

Jörg Rossbach talked on **The production of high density electron bunches for X-ray and VUV-FELs**. The FEL scales the power as the square of the number of particles, which has to be concentrated in a point-like bunch. The phase space density is enourmous, and the damping rings at DESY are hopeless. The way lies in RF photo guns. There are problems with space-charge and coherent SR. With this in mind bunch compression schemes need to be developed.

Stephen Milton talked on **The FEL development at APS**. The goal is to study SASE and pursue demenstration experiments and study new beam characteristics. The schedule is to begin SASE experiments at 500 nm in January '99. The upgraded goal is 120 nm with peak 228 MW peak power. A number of undulator sections later aimed at APS will be available. A BNL photocathode RF gun system will be used and the injection LINAC for APS.

Josef Feldhaus talked on **The VUV-FEL as DESY**. The TESLA Test Facility will make a SASE proof of principle experiment. The TTF uses a photo Rf-gun and superconducting LINAC sections and planar undulators with built-in focusing. A large effort is set in to the diagnostics of the FEL light. Techniques of seeding are studied to overcome some of the instabilities.

Marie-Emanuelle Couprie presented an **Overview on Storage ring based FELs**. The technique and the laboratories were introduced. Dhe also described the implementation in coming projects at ELETTRA and SOLEIL. The development has gone from ACO in 1983 to DUKE and NIJI-IV, which both lased below 230 nm this year. Problems and techniques of mirror degradation were discussed as well as prospects of Coherent harmonic generation, using either external laser or an FEL. Results from micro and macro temporal structures, detuning curve were presented together with optical cavity and saturation damping phenomena.

Jean-Michel Ortega made a presentation on **Infra Red FEL in Europe**. He elaborated on the wavelength region and the ability to lase. Far IR (>100 μm) have very few machines. Mid IR FELs are all RF LINAC based. They give short pulses, high peak power and large tuning ranges. 7 facilities provide > 100h/year to users (Stanford, DUKE, Vanderbilt, Jefferson, CLIO, FELIX, FELI) and have produced > 250 publications. Several programs for > 100 μm have started but there are limits on the spectral range. Cavity tuning and two colour operation of IR FELs was discussed. What makes a user facility, it's ancillary equipment and beamlines was described followed by applications at CLIO and FELIX.

Bernd Schweizer presented **The Darmstadt cw Free Electron Laser facility**. It is based on the S-Dalinac with recirculation. He showed laboratory layout and experimental sites. The electron energy is 25-50 MeV, the wavelength 3-10 μm and the repetition rate 10 MHz (cw). Applications in soft tissue ablation were also described.

Alexander van der Meer talked on **Commissioning the Long-wavelength FEL at FELIX**. The FEL has shown lasing up to 300 μm. A waveguide is installed in the undulator chamber.

Richard Neutze presented **What can a hard X-ray FEL do for biology?** The next generation of X-ray sources will provide extremeley intense fs pulses. By simulating the molecular dynamics of a protein interacing with such a pulse it is possible to quantify the structural information.

Allan Gillespie talked on **Ultrafast electron and photon beam diagnostics for free-electron lasers**. Measurement of the FEL optical micropulse and pulse effects were shown. He also described different techniques, such as DOG (Differential Optical Gating). The method has been synchronisation to FELIX from which results were shown.

Abderrahmane Tadjeddine described **Vibrational spectroscopy of the solid-liquid interface byvisible IR SUM (SFG) and difference (DFG) frequency generation using the CLIO-FEL**. The principles of SFG and it's advantages were shown. A FEL is used because of large tunability, high power and its temporal structure.

Roger Carr talked on **The LCLS X-ray FEL project at SLAC**. The LCLS will use the SLAC LINAC, operate in SASE mode and produce wavelength from 1.5 to 15 Å. It was propsed in 1992 and the design is done by a collaboration SLAC-LANL-LLNL-UCLA. The parameters and characteristics were described in detail (see transparencies).

Jörg Rossbach gave a presentation of the **Technical aspects of the TESLA X-FEL project**. He gave some criteria on how the energy was chosen and discussed the pulse characteristics. The idea of the fan-shaped experimental hall was presented, where the spent beam is fed into ordinary undulators. Data on all important parameters both on the accelerator and the photon beam were also shown.

Jochen Schneider presented **Applications of the TESLA X-FEL**. He made a comparison of the available flux and brilliance. Different applications such as pump-probe experiments, laser induced microexplosions, combination with neutron scattering and radiation damage in protein crystallography were analysed. The DESY CDR with the scientific case of a superbrilliant X-ray FEL facility is available for those interested.

Summary of the discussions

VUV FELS

Steve Milton started out the discussion by posing a few questions to stimulate the audience:
- Who are we building VUV FELs for?
- What do the user really desire: wavelength, coherence, peak or average power?
- Which wavelength range?
- Seeding operation will it give the stability?

In the discussion that followed the following points could be heard:
Comparing to an ordinary laser. At a few 100 nm the FEL capabilities exceed the common lasers. An ordinary laser in this range is not easy to tune while the FEL can be tuned one order of magnitude in wavelength by using *one* undulator and with several undulators an even larger range can be covered.
In short the advantages are: tunability below 120 nm, high peak power < 120 nm.
The focusability at saturation of the FEL is very good as it operates in single mode. The TEM 00 mode gives highest gain and is thus the preferred mode.

It was also discussed how to achieve the tunability:
Linear energy variations can give a factor of 10 change in wavelength but one must adjust the focusing to match the changes. It is difficult to keep the lasing by a few 1% energy change. In principle it can be done, but in practise it is very difficult.

The stability of the laser might pose a problem. The electron beam energy is stable to 1 ‰. The bandwidth of the beamline can in some sense correct the fluctuation in wavelength.
A superconducting accelerator opens up other techniques. It will not respond to changes in beamloading as it is a much "slower system". The filling time is 1 μs in a normal conducting LINAC and 1 ms in a super conducting.

What wavelength regions should one aim at:
As it is uncertain which experiments that will be performed one can only point out potentially interesting regions:
- water window (~2-4 nm)
- Photoionisation (~100 nm range)

A discussion about the science that is likely to be performed gave hints into different directions. It is expected that 1/3-1/4 of current SR-users are interested to use a VUV FEL facility. A new tool must give opportunities for new ideas. One comment was "Something exciting , not seen before must happen!". It can also be assumed that there will be unexplored non linear physics spectroscopy to be done. One can also think in terms of more specific samples, pulsed fields and pressure waves.

To really sell the VUV FEL one should discuss highly specific applications:
- Very low densities/concentrations of samples
- Specialised environments
- Disposable samples, which also raises ideas and questions in sample destruction issues.

IR FELs

Jörg Rossbach posed the question if there is anything challenging left with IR FELs. There is always the challenge of finding money for a project of course, but it was also indicated that a special point is to go to long wavelength and find an application. This means in the range > 60 um. One way could be to first firmly find users and then extend *their* wavelength region of interest.

The discussion turned into if there are intensive activity in the world. The Stanford biomedical/chemical program is totally subscribed. And the groups at Brookhaven are very active.

To compete one has to define the key performance and use that an IR FEL can give or do not possess. There are a number of medical applications up to 10 um. The facilities are in a way inefficient as they only house one user at a time. The lasers should, though, be able to have a large flexibility in pulse formers.

One important point is whether there are any industrial applications?

Jefferson lab has 2-3 projects running. The possible areas are: change properties of polymers using near UV, isotope separation, choose the right structure of Si. In this context a note: "is a 1 KW CW source possible?".

Coming back to the first question about challenge the topic of compact FELs came up. What is the definition of compact? A general idea was that it is not the accelerator and undulator that primarily have to be compact. The equipment surrounding the machine in practise contribute even more to the size of the machine. I one could change the shielding, the RF etc. reductions in size could be achieved. Another idea was to focus of not producing any neutron, then the shielding could be reduced. The same applies for beam stability.

The IR FELs might have a "***need for speed***". This means that for a subject to take-off it needs some speed in the development and activity, and then at a certain point it takes-off…

X-ray

Roger Carr took a provocative stand on the LCLS, his own machine. How is it possible to defend the LCLS which, including user stations, will cost 100 M$ with only 1-2 users active at a time? Is the SASE physics enough to defend such a project? Are there users out there?

The discussion came to focus on new things that could be done by such a light source. Or may be more that nobody really knows about the enormous possibilities for new science it will give.
There is the idea of confining so much energy (no mass) that the density is enough to create mass. If one could really face a Ribosome this single result would be worth all the money. But in general nobody knows before hand, the LCLS will just give new possibilities.

Somebody raised the question for any preference for circular or planar polarisation?
The answers were: both or ask YOUR users or no real difference for crystallography.

A short time was spent with addressing the subject of quality. The SASE FEL produces "instable spikes", and the question is how to get around this problem. Will the quality fall by use of a monochromator. One would need to develop low Z grating to make it work.

Why should we develop all this? The high energy physics will develop everything in 10 years. So far the SR community has not contributed very much to the development of accelerator technology, could it now contribute to the development? So far the SR community never had large machine groups and the users spread in different subjects while the high energy people have "organisations".

A large cost is to reach saturation, but can it be done earlier? In practise 40 m is not a large cost, you don't gain any large amount of money by reaching saturation earlier. On the other hand spontaneous powers go down and so cost. Technically it would be very good.

To make better use of the beam from the SASE FEL, the spent beam should be put into a storage ring.

Final program

Current development of Free Electron Lasers

Lund 18-19 October 1998

Sunday 18 October

9.00	Welcome	**Nils Mårtensson, MAX-lab**
To warm you up.		***Chairman: Nils Mårtensson***
9.15	LINAC driven FELs: The next generation of synchrotron radiation sources	**J.R. Schneider,DESY**
10.00	The production of high density electron bunches for X-ray and VUV-FELs	**J. Roßbach, DESY**
10.45	COFFEE 	
VUV		***Chairman: Wolfgang Gudat***
11.15	The FEL development at APS	**S. Milton, APS**
11.45	The VUV-FEL at DESY	**J. Feldhaus, DESY**
12.15	DISCUSSION: VUV-FEL	**Provocateur: Steve Milton**
13.00	LUNCH at **Restaurang Kulturen** 	
Storage ring and IR		***Chairman: Ingolf Lindau***
14.15	Overview on storage ring based FELs	**M.-E. Couprie, LURE**
15.00	IR FEL in Europe	**J.-M. Ortega, LURE**
15.30	COFFEE 	
Reports from European FEL activities		***Chairman: Jörg Rossbach***
16.00	**Commissioning of the long-wavelength FEL at FELIX**	Alexander van der Meer, FELIX
	The Darmstadt CW Free-Electron-Laser facility	Bernd Schweizer, TU Darmstadt
	What can a Hard X-ray FEL do for Biology?	Richard Neutze, Dep. of Biochemistry, Uppsala
	Measurement of optical and electron pulse shape in an FEL	W.A. Gillespie, Univ. of Abertay, Dundee, UK
	Non linear optical spectroscopy of interfaces using CLIO	Abderrahmane Tadjeddine, LURE
17.30	DISCUSSION: IR-FEL	**Provocateur: Jörg Rossbach**
19.00	WORKSHOP DINNER at **Restaurang Stäket**, Stora Södergatan 6 	

Monday 19 October

X-ray		**Chairman: Lenny Rivkin**
9.00	The LCLS X-ray FEL project at SLAC	**R. Carr, SLAC**
9.45	Technical aspects of the TESLA X-FEL project	**J. Rossbach, DESY**
10.00	Applications of the TESLA X-FEL	**J. R. Schneider, DESY**
10.15	COFFEE 	
10.45	DISCUSSION: X-ray FEL	**Provocateur: Roger Carr**

Summary		***Chairman: Jochen Schneider***
11.30	SUMMARY OF DISCUSSIONS AND THE WORKSHOP	**R. Carr** **J. Rossbach** **S. Milton**

Afternoon	INFORMAL VISITS TO MAX-lab. Please sign up at the secretary!

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	TOTAL:	36	25	29			