Preparation of the European XFEL Project at DESY

The XFEL Project group

Introduction

Preparations for the realization of the European X-ray laser project XFEL are moving ahead with the goal to commence construction in the fall of 2006. The main focus is on issues concerning the detailed technical and scientific planning of the facility, the industrialization of the main components, the plan approval process and the international project organization.

Project parameters

In preparation of the technical layout of the accelerator and electron beam distribution, of the undulators and photon beam distribution, and of the civil construction parameters were defined, both for accelerator and FEL radiation. The electron accelerator is laid out to reach 20 GeV. Key parameters of the accelerator and electron beam parameters are given in Table 1. They can slightly vary for other electron energies. The nominal electron energy for FEL radiation at 0.1 nm has been set to 17.5 GeV. An important parameter for the experiments is the repetition rate of the electron bunch acceleration. Figure 1 depicts the corresponding electron acceleration time pattern. For stability reasons operation of the accelerator with completely filled bunch trains is desirable. Schemes are investigated to select single electron bunches out of trains and to deflect them to either of the electron beamlines or to the commissioning dump.

Parameter	Unit	Value
Electron energy for 0.1 nm FEL radiation	GeV	17.5
Accelerating gradient	MeV/m	22.9
Bunch charge	nCb	1
RF pulse repetition rate	Hz	10
Electron bunch repetition rate during RF pulse	MHz	5
Max. number of electron bunches per RF pulse		3250
Duration of electron bunchtrain	µs	650
Average electron beam power	kW	570
Normalized slice emittance (rms)	mm mrad	1.4
Electron energy spread (rms)	MeV	< 1

Table 1: Main parameters for XFEL electron acceleration for operation at 0.1 nm radiation.

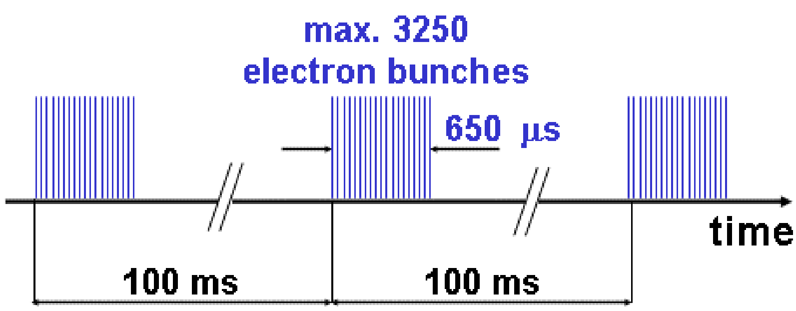

Figure 1: Time pattern of XFEL electron acceleration

With the parameters for electron acceleration and performance of the electron beams it is possible to simulate FEL radiation parameters for the various settings of the FEL undulators. The definition of FEL undulators was made according to the needs for the experiments and operability of the different photon beamlines. SASE 1 and SASE 2 are designed to generate hard X-ray FEL radiation at 0.1 nm in the fundamental line. SASE 1 is optimized for lasing at 0.1 nm operating at this wavelength at a gap value of 10 mm. SASE 2 offers in addition the possibility of changing the FEL wavelength from 0.1 to 0.4 nm by gap tuning. It is therefore laid out to reach 0.1 nm radiation at a larger gap of 19 mm. SASE 3 uses the spend beam of SASE 1 to provide FEL radiation from 0.4 to 6.4 nm using both gap and electron energy tuning. Input from the user community will be required n order to decide whether or not this device shall be realised as an APPLE-type undulator providing helical or linear polarized radiation or with a linear magnetic structure. In addition to the three FEL undulators, 2 undulators for hard X-ray spontaneous radiation will be installed. If required, one of them could be replaced by an FEL device optimized for soft X-ray radiation from 1.6 to 6.4 nm at 17.5 GeV electron energy thus enabling the entire photon wavelength range from 0.1 to 6.4 nm at a constant electron energy of 17.5 GeV. Parameters for the different undulators can be found in the activity report of the undulator group. Figure 2 identifies the different undulators in the electron and photon beam distribution scheme.

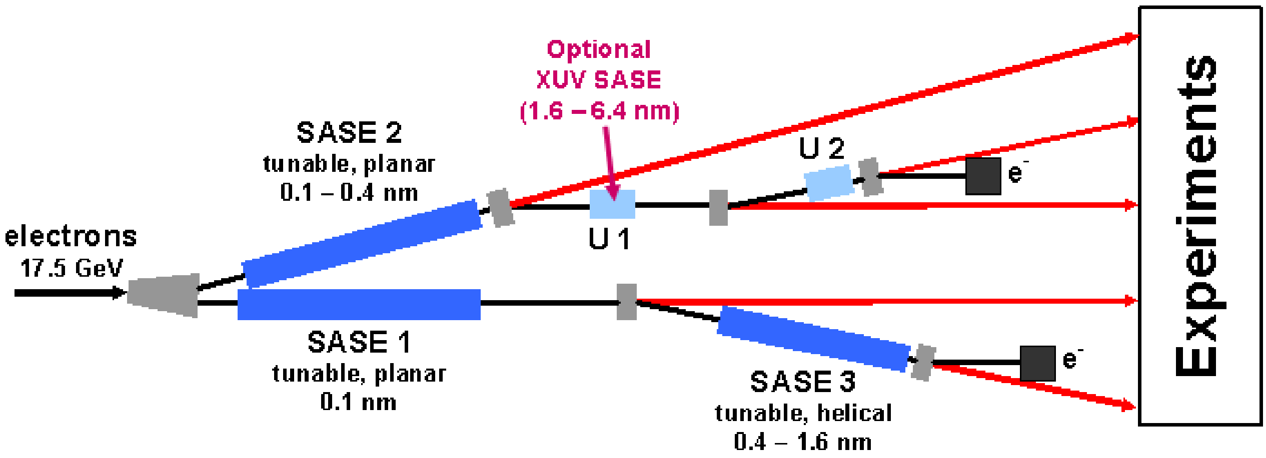

Figure 2: Electron and photon beam distribution including undulators for FEL and spontaneous radiation.

For the above electron beam and undulator parameters FEL radiation properties have been simulated. The results of these simulations are summarized in table 2.

Parameter	Unit	SASE 1	SASE 2		SASE 3		
Electron energy	GeV	17.5	17.5	17.5	17.5	17.5	10.0*
Wavelength range	nm	0.1	0.1	0.4	1.6	0.4	6.4
Photon energy range	keV	12.4	12.4	3.1	0.8	3.1	0.2
Peak power	GW	20	20	80	130	80	135
Average power	W	65	65	260	420	260	580
Photon beam size (FWHM)	µm	70	85	55	70	60	95
Photon beam divergence (FWHM)	µrad	1	0.84	3.4	11.4	3.4	27
Coherence time	fs	0.2	0.22	0.38	0.88	0.34	1.9
Spectral bandwidth	%	0.08	0.08	0.18	0.3	0.2	0.73
Pulse duration	fs	100	100	100	100	100	100
Photons per pulse	#	10^{12}	10^{12}	1.6×10^{13}	1.0×10^{14}	1.6×10^{13}	4.3×10^{14}
Average flux	#/s	3.3×10^{16}	3.3×10^{16}	5.2×10^{17}	3.4×10^{18}	5.2×10^{17}	1.4×10^{19}
Peak brilliance	B	5.0×10^{33}	5.0×10^{33}	2.2×10^{33}	5.0×10^{32}	2.0×10^{33}	0.6×10^{32}
Average brilliance	B	1.6×10^{25}	1.6×10^{25}	7.1×10^{24}	1.6×10^{24}	6.4×10^{24}	2.0×10^{23}

* XFEL STI Report (Jan 2005) and TDR supplement (DESY report 2002-167, DESY, 2002)

Table 2: FEL radiation parameters for FEL undulators SASE 1, SASE 2 and SASE 3. Electron parameters for these simulations are given in table 1.

Ongoing R&D-Projects

The technical and scientific projects relating to the preparation for the construction of the XFEL facility are being continued in the project group. The following list illustrates some examples:

- For the High-Frequency (rf) System, the prototype of a multi-beam klystron manufactured by a second industrial supplier (CPI/USA) was delivered and successfully tested at DESY. The klystron of another supplier (Toshiba/Japan) can only be delivered in 2006, since tests conducted at the supplier's facility yielded results that did not meet the specifications. An increased engagement of DESY-Zeuthen has been agreed regarding the modulators.

- There exist a number of important activities in the area of electron beam stabilization.

  Several projects related to the low-level rf system (in collaboration with Polish institutes) aim at the realization of the extremely tight tolerance requirements on the high-frequency phase and amplitude that apply in the bunch compressor sections. Simultaneously, simulation studies are being used in order to examine to what extent the requirements could be relaxed as a result of an optimized design of the compressor system.

  Good progress is being made in the development of a highly precise time reference system (the goal is a synchronization in the range of some 10 fs). The cooperation with MIT (USA) is proving to be extremely productive in this context.

  The development of a beam position and beam energy stabilization system is being carried out as a Swiss contribution to the project preparations (PSI Zürich is responsible for this work). A first workshop on this topic took place at DESY in mid-November.

- Concerning photon beam distribution and experiments the activities have been concentrating on the following areas.

  The design of the undulator mechanics has been reviewed and a new design was created that enables a mechanical stability required for 0.1 nm FEL radiaton. A call for tender for a prototype undulator has been issued. This process will also allow the qualification of vendors. It is expected to receive the first undulators for test measurements in 2008. The achievements in this area are reported in more detail in the undulator section.

  In the area of photon beam transport work has concentrated on the development of online monitors enabling to measure FEL radiation parameters on a shot-by-shot basis. Vacuum sections filled with residual gas are promising candidates since such monitors do not suffer from damage and allow for high transmission. Furthermore the discussion with mirror vendors has started on the possibility to produce very long (~1m) mirrors with sufficient quality in roughness and figure error in order to preserve the brilliance of FEL radiation.

  For the experiments we have started designing the experimental hall. Further work is needed to collect the requirements of the experiments and to convert these into an experiments layout. An important area of development is that of area detectors for FEL applications. During 2005 contacts were established to German and European laboratories with active detector development groups. The DESY groups (FH) have also been involved in this discussion. A preliminary list of the requirements of 2D detectors for three different kind of applications has been established. These requirements are currently discussed with the user community and also with detector builders.

In addition to these technical projects, the project group is currently busy with the preparation of an updated technical design report (TDR). A first draft version for the accelerator, infrastructure and civil construction is scheduled to be ready at the beginning of 2006.

Plan Approval Procedure

The technical definition and construction planning of the XFEL facility were completed in December of 2004. The compilation of the numerous documents (justification of the project, justification for the choice of the site, the technical description of the facility, its construction, installation and operation as well as a large number of expert reports) has taken place. As an illustration for the planning status, Figure 3 shows the simulation/visualization of the XFEL campus

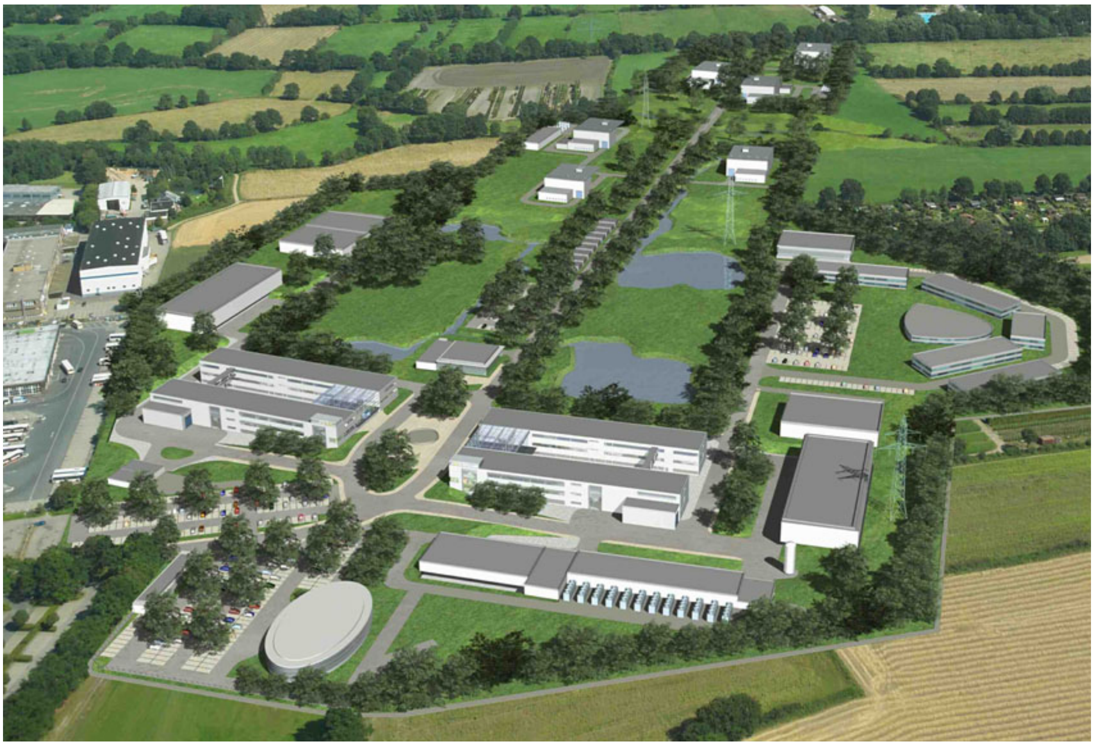

Figure 3: A simulation/visualization of the XFEL campus of the XFEL south of the city of Schenefeld, as viewed from a helicopter.

south of the city of Schenefeld, as viewed from a helicopter. Figure 4 shows a side view of the experimental hall as viewed from the incoming (underground) photon tunnels.

The application for plan approval was filed on April 27th, 2005 with the Plan Approval Authority (Landesbergamt Clausthal-Zellerfeld) and presented for public inspection on May 17th, 2005.

The deadline for raising objections to the project expired on June 30th, 2005. A total of 85 objections were received (one of which contains a collection of 203 signatures), as well as 43 comments from public interest agencies. A relatively large number of the objections relate to the tunneling of private property and the necessary relocation of a garden plot located in the Hamburg district called "Osdorfer Born."

The objections were categorized and organized by subject matter. This was followed by internal formulations of the individual responses to the questions and objections that had arisen. This task served as a preparation for the (non-public) discussion of the project on the date set by the Plan Approval Authority ("Erörterungstermin").

The meeting took place from October 25th-26th, 2005. The project management as well as all parties that had submitted comments or objections were invited to the meeting. The meeting took place under the direction of the Plan Approval Authority. The discussion focused on topics such as alternatives to the routing, questions of land requirements, the loss of close-by recreational space, as well as the potential impact on the environment.

Figure 4: A side view of the experimental hall as viewed from the incoming (underground) photon tunnels.

The meeting took place in a constructive, focused and objective atmosphere. Depending on the time required by the Plan Approval Authority to consider the various arguments and objections, it seems possible that plan approval of the XFEL facility can occur early in 2006.

International Organization

The organizational structure of the international committees established for the preparation of the XFEL as an international facility is shown in Figure 5. At the beginning of 2004, under the impulse of BMBF, a Memorandum of Understanding (MoU) was established and it was signed by representatives, besides Germany, of Denmark, France, Greece, Great Britain, Italy, Poland, Russia, Sweden, Switzerland, Spain and Hungary. As stipulated in the MoU an *International Steering Committee* (*ISC-XFEL*) was installed in order to direct the preparation phase for the creation of the new European facility. Representatives from the Netherlands, Slovakia, China[1] and the European Commission participate in the meetings of ISC-XFEL as observers.

By signing, the signatory states express their interest in the new facility and in the preparation for an inter-governmental agreement for the construction and operation of the European XFEL Facility. A precondition for this agreement are detailed plans for the technical design and the operations of the XFEL, for the timing and financial schedule of the project, and the future organizational structure.

The steering committee (ISC) has set up two working groups, one on “Scientific and Technical Issues” (STI) and one on “Administrative and Funding Issues“ (AFI). Both groups have presented an intermediate report at the end of 2004 in which the scientific, technical and legal requirements of the research facility were further specified.

AFI has set up two sub working groups, one on “Legal Frame Issues“ (LFI) and one on “Full Costing Issues“ (FCI). The mandate of AFI comprises studies on and the recommendation of suitable organizational structures (legal entities) for the realization of the project. First drafts of an

[1] China will sign on November 24, 2005

international agreement (convention) and of the Articles of Association, including possible supplemental agreements that satisfy the objectives cited above, have been developed by LFI and put down on paper in AFI.

The MoU provides that the ISC creates a European Project Team, hosted by DESY. The objective of the European Project Team for the preparation of the European XFEL is to produce and submit to the ISC all the necessary documents (Technical Design Report, Administrative Report, text of an inter-governmental Convention, etc.) on which consensus be reached, for the foundation of a Limited Liability Company (GmbH) for the European XFEL facility, which can then be submitted for approval by the participating countries. Current planning envisions the completion of the documents by July 15, 2006, with the aim to undertake the notarized GmbH foundation immediately following the signing of the agreement, and to break ground for the construction of the facility in the fall of 2006 STI and AFI, each in their respective area of competence, are responsible for advising the Project Team and the ISC by reviewing the early drafts of the documents which will be presented in early 2006 by the XFEL Project Team.

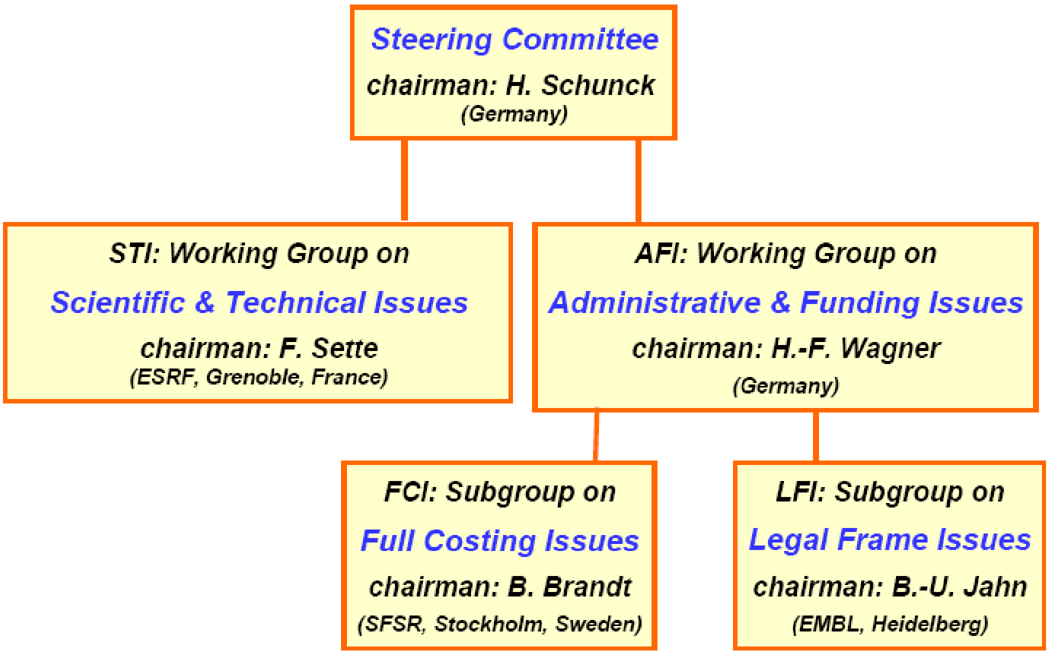

Figure 5: The organizational structure for the preparation of the XFEL as an international facility

In January of 2005, ISC reached a decision to first initiate a search for an experienced project manager for the European Project Team as prescribed in the MoU. Since then, Prof. Massimo Altarelli has been appointed as Leader of the European Project Team and assumed his position at DESY in September. The existing XFEL Project Team at DESY has been integrated into the European Project Team for the preparatory phase. The structure of the European Project Team in preparation for XFEL is illustrated by the following scheme:

Area of Responsibility in the European Project Team	*Member of the European Project Teams*	*Member of the DESY Project Group*
European Project Team Leader	Massimo Altarelli	
Accelerator Complex Responsible	Reinhard Brinkmann	
User Operation Responsible	Appointment in progress	Thomas Tschentscher
Technical Service Responsible	Andreas Schwarz	
Administration and Finance Responsible	Karl Witte (Appointment being finalized)	Thomas Delissen

Figure 6: The organizational structure for the preparation of the XFEL as an international facility.

AFI-FCI (Full Costing Issues) has addressed the methods for a comprehensive cost structure and submitted a corresponding final report to AFI in September of 2005. The report illustrates the common basic principles of determining the costs for the XFEL project, as they will be applied for the cost estimate in the TDR, and establishes the framework conditions.