IRUVX-PP
Final report
Status 2013-05-08

Summary description of the project context and objectives

Free Electron Lasers (FELs) are the most advanced accelerator-based light sources, combining the exceptional spectral range (from the far infrared through the visible and ultraviolet to hard X-rays) of synchrotron radiation sources with the femtosecond pulse duration and coherence of conventional lasers. The FEL concept is particularly exciting for the extended ultraviolet and X-ray region where it outperforms other light sources by far. The bright, femtosecond FEL pulses allow investigating the geometric and electronic structure of virtually any kind of matter on an atomic length and time scale. FELs are therefore expected to have a revolutionary impact on the science we do with light, potentially as profound as the revolutions created by the laser and synchrotron radiation, affecting a wide range of scientific disciplines ranging from physics and materials sciences to chemistry and biology.

The first free electron lasers were built in the 1970s and produced infrared and later visible and ultraviolet light. In order to make FELs work for shorter wavelengths, in particular for X-rays, the technology was further developed during the 1990s culminating in the first demonstration of a single-pass FEL in the vacuum ultraviolet (VUV) in 2001/2 at DESY, Hamburg. These developments opened the door to real X-ray free electron lasers, and DESY proposed to construct a large FEL facility for hard X-rays based on this concept. The project was extensively supported by the German government and resulted in the present European XFEL which is now under construction in Hamburg. The test facility at DESY was extended and converted to what is now known as the FLASH facility; it covers the extended ultraviolet and soft X-ray spectral region including the so-called water window and has been in routine user operation since 2005.

The successful proof-of-principle experiments at DESY in 2001/2 triggered also a number of other new FEL projects worldwide: The Linac Coherent Light Source (LCLS) at SLAC, Stanford, USA, was funded and demonstrated for the first time perfect, stable operation at hard X-ray wavelengths in 2009. While LCLS made use of the existing linear accelerator, a completely new X-ray FEL was built in Japan; first lasing was achieved in 2011, user operation is scheduled for 2012. Also Korea has just started the construction of a new X-ray FEL in Pohang. In Europe several other research centres in France, Germany, Italy, Sweden, Switzerland and the UK proposed to build FEL facilities. So far, only the FERMI@Elettra project near Trieste, Italy, has been realised and just started operation in the VUV, and the SwissFEL project at PSI, Villigen, Switzerland, is far advanced and expects a positive funding decision within 2012.

In contrast to synchrotrons, FELs can only provide a small number of beam lines. While a synchrotron has tens of experimental stations that can truly work in parallel, each FEL provides only a single laser beam, just as a conventional laser, which can be switched to a few different experiments. On the other hand, the scientific applications of FELs are as diverse as those of synchrotrons and conventional lasers, thus requiring a number of complementary beam lines and a large variety of experimental stations. The demand of the European FEL user community is much larger than the available beam time, and it is constantly growing owing to the great success of the first operational FELs, FLASH and LCLS. Consequently, a set of several, more or less complementary FEL light sources are required in Europe in order to exploit the scientific potential of FELs in an efficient way and to consolidate Europe's leadership in this field. This set of FEL facilities as a whole may be considered as the European research infrastructure of free electron lasers, consisting eventually of the European XFEL in Hamburg and a number of national facilities that are in general constructed and operated by single research centres.

The implementation of such a European research infrastructure of FEL light sources is a great challenge. First, the potential user communities need to be informed and organised and a concerted action of all stake holders is needed to secure the required funding of the individual facilities. Second, the construction and operation of a FEL facility require cutting-edge technology and continuous technical development in several areas such as accelerators, femtosecond synchronisation with optical lasers, high data rate detectors and acquisition, and X-ray optics. This research and development cannot be done by a single laboratory in a reasonable amount of time; therefore it is necessary to collaborate with other partners and industry. Finally, due to the technical complexity and the continuous progress, the number of experts is limited and a joint programme for training and exchange of personnel is needed.

In order to cope with these challenges and to make sure that the scientific potential of free electron lasers can be fully exploited in Europe, it would be of great advantage to create a European distributed research infrastructure with open access based on scientific excellence, as defined by ESFRI, because it would provide the required long-term European strategy and coordination. It would also enable a more efficient collaboration with industry by providing a single point of contact and a long-term strategy. This is important for the development and commercialisation of cutting edge technologies required for the construction of the new facilities. In return, this collaboration is also a unique chance for European companies to stay at the forefront of technological developments and remain competitive in the global market.

These ideas led to the EUROFEL Design Study project which was funded by the European Commission under FP6 from 2005 - 2007. All interested parties in Europe (16 institutions) including research centres and relevant University institutes participated in this project to develop the most critical technology needed for the construction and operation of the novel FEL user facilities. During this time the first ESFRI roadmap was established which included two FEL projects: the European XFEL as a single-site facility and IRUVX-FEL (now called EuroFEL) as an additional consortium of national FEL facilities.

The main goal of the IRUVX-PP project was the preparation of a future EuroFEL consortium. The key questions were: How can we make sure that the scientific potential of free electron lasers can be fully exploited in Europe? How can we exploit the complementary features and expertise of the individual member facilities and maximise the benefits for both the member facilities and the users? What are the areas in which the partners should collaborate, what are the specific activities and the benefits for the stakeholders, and what kind of structure should the consortium have in order to achieve the best results?

The main objective of the IRUVX-PP project was to work out a consortium agreement defining the interaction of the individual facilities, the management structure of the consortium, the user policies and procedures for an optimised and transparent access of users to the EuroFEL facilities. It should also comprise means that facilitate exchange and development of human resources and take user needs into account in the construction and operation of the facilities. Web-based tools were to be developed to enable efficient communication between the individual member facilities and to make the distributed facility as a whole visible and conveniently accessible for the European research community.

A further key objective was the identification of critical technical issues that are of importance for the EuroFEL consortium, and to organise long-term collaborations and the transfer of knowledge between the EuroFEL members as well as with neighbour communities and the private sector. This would allow substantial savings in resources and production times and enable full scientific exploitation of the new facilities from the start. Moreover, it would lead to high standards and continuous technical developments enabling the consortium to assume and maintain a leading role worldwide.

Finally, it was considered important to strengthen this collaborative approach during the preparatory phase by coordination activities and joint technical work in all areas that are of common interest and immediately beneficial for the construction and operation of each individual FEL facility.

Description of the main S&T results/foreground

The project included technical and non-technical work. Work package WP1 focused on the legal and governance structure of the future consortium and integrated the results of the other non-technical work packages, WP2 to WP6, into a formal consortium agreement. This work was strongly supported by the Steering Committee of IRUVX-PP and a special task force, both including representatives of all project beneficiaries. These groups discussed and analysed in detail the mission and the activities of the future consortium as well as suitable legal forms and governance models.

WP2 dealt with user access and user needs. Important aspects were the development of a virtual user office and to make sure that the user needs were adequately taken into account in the activities, the statutes and the governance of the consortium.

WP3 to WP6 provided the basis for optimum usage of limited resources and distributed complementary expertise of the partners. WP3 organised long-term collaborations and knowledge transfer between the members of the consortium, WP4 worked on concepts for the training and assignment of limited human resources, and WP5 supported communication and knowledge transfer through web-based tools. It prepared a consortium website which will provide extensive information for the research community and access to the virtual user office prepared by WP2. WP6 addressed efficient long-term collaborations with industry.

The largest benefit for the user community will come from the complementary technical infrastructure that the consortium can provide, including a wide wavelength range and a selection of other photon beam parameters, a sufficient amount and variety of high quality beam lines and instrumentation for a wide range of research applications, and optimum support of users. The two technical work packages, WP7 and WP8, addressed these issues directly. Indirectly, the user community also benefits from a strong consortium due to the combined world-class expertise and the timely, forefront technical developments it can realise.

WP1 Construction of the IRUVX-FEL Consortium

WP1 created, together with the Steering Committee and a task force, the institutional and management structure of the future EuroFEL Consortium and drafted a complete consortium agreement defining the interaction between the individual member facilities and with external stakeholders such as the user community, other research infrastructures and industry, the policies of the Consortium regarding user access, intellectual property and other areas, and a description of the core Consortium activities including their benefits and implementation. After investigating various options, it was agreed to adopt the legal form of the European Research Infrastructure Consortium (ERIC) as defined by the EU Regulation 723/2009.

In order to ensure sufficient flexibility in the implementation, the agreement was drafted in two parts, allowing later modification of procedures if required without the need of a formal amendment of the Statute:

(1) The basic Statute containing only the provisions related to:
- the purpose of the Consortium and the basic principles of its policy in the scientific, technical, financial and administrative areas;
- the Consortium governing organs and advisory bodies;

- the usual rules concerning duration, withdrawal, dissolution, liability, amendments, disputes etc.

(2) The Internal Regulations and Implementing Procedures defining all the detailed procedures related to the practical implementation of the Statute's provisions:
- the membership criteria for new parties;
- the core activities of EuroFEL;
- the organisational structure;
- the scientific and technical advisory committee;
- the user access;
- joint technical developments;
- joint training activities;
- communication and dissemination;
- relationship with industry;
- intellectual properties;
- financing of the Consortium;
- procurement procedures.

WP2 User Needs and Policies

WP2 made several studies in order to evaluate the needs of the user community at all levels. These studies included a review of science cases and their requirements, a report of a user group with several years of experience at the FLASH facility and an evaluation of existing access policies and panels at European synchrotron radiation facilities. Based on these studies, a concept for the integration of the user needs was worked out indicating how they could be adequately taken into account at various levels, from practical procedures related to user access to activities of the EuroFEL consortium and its governance. In addition, a novel Umbrella access tool was developed on this basis as a prototype, properly taking into account the existing IT environment and allowing a common access point for users and unique user identification for all facilities.

Due to the fact that a significant number of user groups make use of several research infrastructure facilities for their research, including the new FEL facilities, synchrotron radiation and neutron sources, it was clear from the beginning that island solutions had to be avoided and new features must be attractive for all partners. Furthermore, the introduction of any novel, common EU-wide tools would affect to some extent the autonomy of the individual facilities and thus have to find unanimous agreement.

The intense discussions within WP2 and with interested partners resulted in the Umbrella concept with the following key requirements:

- *Keep proven functionalities:* In practically all cases the new FEL facilities are constructed on sites where synchrotron and/or neutron facilities are already in operation with a large overlap between the respective user communities. Well-advanced web-based user office (WUO) systems are in place at these facilities with a wealth of applications. The new system had to be designed such, that these applications are maintained and new functionalities added to them (Umbrella concept).
- *Parallel implementation:* Because of the large number of users in the photon / neutron communities (of the order of 30’000 in Europe) it is organisationally not possible to swap all WUOs to the Umbrella system in one step. Instead, Umbrella was developed first as prototype system for the FEL facilities and further facilities can join as they

want. This required, however, designing the system such that a parallel operation between old and new systems is possible.

- *Slim structure:* The manpower at the existing WUOs is limited and there is no possibility for additional personnel in the context of the Umbrella system. Consequently, the new Umbrella system should not require additional and ideally even less operating resources, except for the introduction phase.
- *Confidentiality:* As these facilities are at the forefront of the scientific research, competition and confidentiality between users and also facilities plays an important role. The proposed solutions had to take this into account already in the design of the tools.
- *Open for future developments:* Research at the photon / neutron facilities is currently experiencing a revolution in detector development. These new detectors offer novel and exciting scientific opportunities but at the same time produce data volumes (petabytes scale) which are far beyond the present range. This will introduce a basic change in the way measured data are analysed and any new system will need to take this into account.

The solution developed in WP2 is the Umbrella system with the following main characteristics:

- *Unique user identification:* In order to protect confidentiality, the identity of a user has to be guaranteed on the European level. In order to keep at the same time the administrative load as low as possible, a multi-level authentication is provided ranging from a Google-type handshake to in-person identification at a local facility user office.
- *Shibboleth as underlying layer:* Authentication is a hot topic in many fields, e.g. in building access control or in the banking sector. Basing the new tools on a professional system provides the advantage that new developments in authentication techniques can be automatically taken over. Because of its superior security features (SAML2) and because of its widespread use in the commercial and academic sectors it was decided to choose *Shibboleth* as underlying layer. The present configuration, however, where a person identifies him/herself by entering username + password + affiliation is not suited in this case, as affiliation is not a stable identifier. In addition, unique identification is not provided. It was, therefore, decided to employ a special pan-European federation with one identity provider (see below), where the existing user offices at the partner facilities take over the role of in-person identification.
- *Hybrid databases:* The confidentiality aspect was taken into account by a hybrid structure of the respective databases. Only that information is stored centrally, which is necessary for the proper functioning of the tools. All other information is kept at the local WUOs. Compared to more straight-forward topologies this increases the synchronisation requirements; it lowers, however, significantly any data-protection requirements.

This led to the following structure:

- The *European Authentication and Authorization* (EAA) system. This is the basis of the Umbrella system. The central part of the hybrid system provides the user identification with access to username and password information. The remaining user information including any authorisation information is stored at the local WUO, where the user has registered. Personal address modifications are entered by the user himself.

The EAA includes a pan-European affiliation database, also with central and local elements.

- The *European User Umbrella* (EUU) system. One unique authentication via EAA is provided for various important applications. The EUU consists of a bundle of applications which base in this way on the EAA:
    - *Coaching:* There are many novice users coming to large neutron and photon facilities, which have no experience in this special environment. This is especially true for FEL facilities with users coming from laboratory laser sources. For these users the EAA includes a structured web-based coaching service, which lowers the threshold for them and helps them to write competitive experimental proposals.
    - *Proposal module handling:* This is a good example for the hybrid approach. Proposals can be divided into a *general, scientific part* –describing e.g. scientific background, goal of the experiment – and a *local, facility-specific part* –e.g. specifying the proposers, describing security issues. All this information is stored at the WUO of the respective facility, and that will be unchanged with the Umbrella. The novel feature of the Umbrella is, that a proposer will be able to access the general part of his/her previous proposal, edit it and submit it again together with the local part. No information is stored centrally and the administrative burden for the user is reduced significantly. As by-product of this development the structure of the general part is harmonised between the partners, which again eases the work of the referees in comparing and ranking the submitted proposals.
- *The Umbrella+ system: Coaching* and *Proposal module handling* are only first examples of applications based upon the EAA. A further example is *Remote File Access*, which will allow users to access their experimental data e.g. from the home institute for download of first processing. Another option will be *Remote Experiment Access*, where a member of an experimental team is able to inspect online and remotely experimental spectra. In this way, senior scientists are able to discuss the status of an experiment, even if they are not on site. The Umbrella+ features will be developed by EuroFEL in cooperation with related FP7 projects as PaN-Data, CRISP and NMI3.

The definition of the Web-based Access Point was finalised in spring 2010. It was the basis for the definition of the architecture of the prototype, which after a three-month work was available in August 2010. Again a consultation of the WP2 partners resulted in unanimous agreement. Thus, coding of the prototype could start on September 1, 2010. In order to keep the partners involved, the development of the code was accompanied by several presentations.

The prototype was installed on a special server at PSI and was made available for remote testing. In order to demonstrate the proper functionality, the PSI DUO team provided a test installation of the PSI DUO system and the Umbrella prototype was linked to the DUO test system. From this test setup it was estimated that the modification effort to adapt DUO-type user office systems (majority of the European systems) to the Umbrella system was of the order of days to a week. A similar time estimate was derived by the SMIS (ESRF user office system) experts. The technical description of the Umbrella prototype is available. The technical description of the Umbrella prototype is available. The presentation of the prototype was unanimously accepted by the participating facilities and it was decided to move on in a second step to the test installation at all facilities before proceeding to the final implementation.

WP3 Coordination and Consolidation of Joint Technical Developments

The aim of Work Package 3 was to establish and support a number of activities in areas of joint technical development (JTD) relevant to a potential EuroFEL program and then to assess these activities to see how effective they were and which factors were determining that effectiveness. The activities themselves were technical and did generate technical outputs. However because the WP was largely concerned with JTD process it was formally designated as a Non-Technical Work Package within IRUVX-PP. This distinguished it from WP7 and WP8 which were primarily technical in nature.

The WP3 structure consisted of a small management group and several so called Expert Groups (EGs) of researchers whose members were either already working in a particular technical area or who wished to gain expertise in that area. The EGs were self-formed in response to a call from the management group. Each one chose a spokesperson and drafted a work proposal by consensus. The management group did not direct this process, relying instead on the principle that the program must be decided from the bottom up, by those who were self-motivated to carry it out. EG membership was also not limited to those from within the IRUVX-PP membership. However the condition was imposed that the work must be truly collaborative, with the involvement of staff from several of the IRUVX-PP member institutes, and that support would only be available for material costs (travel and subsistence, meeting organisation, documentation and, where the benefits were truly joint, hardware procurement and sharing). EG member staff costs would not be funded. The aim was that EG activities would carry on under EuroFEL after IRUVX-PP was complete.

The EG proposals were submitted, reviewed and finalised by a peer meeting in Month 6. The decisions were ratified by the IRUVX-PP Steering Committee, and the WP3 management group then worked with the EG spokespersons to produce work plans and allocate budgets. Five EGs were formed at this stage (details below) and a sixth was added at the start of Year 3. At the same time the management group put in place the practical support structures (communications website, T&S rules, claims processes, etc). The EGs began their work towards the end of Year 1. For most of them this was a new way of working and in several cases the group members had not worked together before. Over the next two years it became apparent which types of activities worked well and which didn't, which technical areas were easier to advance and which were harder and which external factors (foreseen and unforeseen) could affect the programs. To maintain progress in these circumstances EG spokespersons had considerable freedom to adapt their work plans within budget constraints. Their activities were reviewed at annual meetings and the overall WP progress was presented at the project's annual meetings and in the annual periodic reports. The experiences gained in WP3, along with those from WP7 and WP8, strongly influenced the JTD proposals in the EuroFEL consortium agreement. At the end of the project it was clear that some of the expert groups would continue to operate although, in the short term at least, this would be on a more informal basis while the future of others was more uncertain.

The WP3 EGs are listed below with examples of their activities and achievements. The range of these is rather wide. They included experimental studies, large-scale scientific meetings, equipment and technique sharing, training and development activities and cross-community standardisation.

EG1 FEL Injector Commissioning – Spokesperson M Ferrario (INFN): As well as organising a number of meetings, including a large scale workshop on 'Photocathodes for RF Guns' at the University of Salento in March 2011, this group also arranged to share a substantial piece of diagnostic equipment – the emittance meter which had been developed on the SPARC accelerator at INFN's Frascati Laboratory. The areas of transport, insurance, staff training and longer-term maintenance of high tech loan equipment all formed part of this activity.

EG2 Transverse Beam Diagnostics – Spokesperson G L Orlandi (PSI): Accurate diagnosis of the very low-emittance electron beams needed for FELs is challenging because of the bright EM radiation which can often accompany them. This relatively small group concentrated on the use of view screens, and in particular OTR and flurorescence screens, to diagnose the beams' transverse properties. Angular OTR distributions were modelled and novel screen materials were considered.

EG3 Longitudinal Beam Diagnostics – Spokesperson M Veronese (ELETTRA): Again the time-resolved measurement of electron bunch properties is critically important for effective configuration and operation of short-wavelength FELs. Members of this group were involved with diagnostic studies during the commissioning phases of several accelerators. In addition they undertook collaborative work on electro-optic sensing and also on terahertz spectroscopy, including the design and production of reference terahertz pyro-detectors.

EG4 Metrology for FEL Optics – Spokesperson F Siewert (HZB): Several accelerator-based light source facilities have metrology laboratories whose task is to ensure that the ultra-precise optics needed to form and transport FEL output beams meet specification. This group's members specified and procured a pair of reference optics which were then circulated to verify the calibration of their equipment and to reveal where discrepancies existed and improvements were required. This very successful activity significantly advanced the degree of standardisation between member laboratories.

EG5 Photon Beam Transport and Diagnostics – Spokesperson M Zangrando (ELETTRA): As well as its experimental program this group was also involved in organising two particularly effective technical meetings. The first, on 'Wavefront Propagation' at Daresbury Laboratory in July 2009 was a focused meeting on the development and use of codes for propagation modelling. This had both a training element, introducing new users to the codes, and also a technical feedback one since the code developers were also present. A much larger 'Workshop on Photon Beamlines and Diagnostics' was held at DESY Hamburg in June 2010. This extended the collaboration beyond just EG5 to include EG4, WP7 and also various attendees from outside Europe.

EG6 FEL Seeding – Spokesperson M Ferrario (INFN): This subject became increasingly topical as IRUVX-PP progressed and this EG was formed in WP3 at the start of Year 3. It allowed a particularly strong European group to share expertise gained in France and Japan with partners across the IRUVX-PP membership. Despite its relatively short life it organised a number of visits both to report results at conferences and also to work on experimental facilities.

WP4 Development of Human Resources

Human resources in the field of accelerators and Free Electrons Lasers are a critical resource for the development and operation of new facilities. The time for recruiting and especially education of new professionals in the field is long and the required qualifications are high not only at the research level, but also for construction and support. The studies in this work package have concentrated on the technical and scientific staff, where the specialist qualifications are to a large extent unique for the field.

A number of key areas have been addressed and the studies conducted in a certain order. The study started with an overview of the Human Resources among the partners. This was regarded as key knowledge for the continued topics. In the process of inventory also job descriptions and categories had to be elaborated to allow a more uniform approach to the data. The concrete statistics show that there is a clear difference in distribution of categories between the partners. This difference is to a large extent driven by the different phases of development among the partners (design phase - construction phase - operation phase), but it also indicates an interesting opportunity to efficiently use the HR between the facilities. Further statistics is now available on numbers within categories as well as levels of education.

A true benefit for a future consortium would be an efficient possibility to exchange staff between the partners. This already exists on a scientific level where mainly post docs frequently move between the partners. The different phases of the facilities would though benefit also from the exchange of personnel on the technical and engineering level, both to fulfill tasks and because of educational aspects. A review of the different regulations and benefits, including salary levels, in the countries of the partners has been carried out. The aim of providing a hand-book for the exchange of staff proved to be highly dependent of the form of a future consortium. While an ERIC would include the necessary legal framework, a collaboration would need a framework of its own and a loose network could possibly address the issues only partner-to-partner. The basic differences and possibilities with the various consortium forms have been studied and sample documents for secondments of staff elaborated.

Connected to the exchange of staff is the possibility of joint recruitment. Such activities are advantageous both in the process of recruiting itself, but also in a later stage they will facilitate the exchange of staff as the personnel have been recruited out of similar requirements. A set of general joint recruitment principles is proposed and should be possible to directly implement as a common ground. The Code of Conduct for Recruitment of Researchers (by the European Commission, May 2005) has been studied and can initially be regarded as a proposal of a set of common values. A problem is that not all partners officially state that they apply or acknowledge the code, but rather rely on local policies.

Both in the view of the facilities and the employees themselves the career development is a key component for the HR development. Thus a generic process and structure for career development and planning has been elaborated. The depicted process involves all steps in career development from preparation, formulating goals to drafting and implementing a career plan. Initially the goal was set to define joint career development plans and tenure tracks between the facilities, but it was proven difficult. Thus the available documentation has to be regarded as a base and a first step in a process towards common career plans.

The last component studied, which also proved to be the most easily reachable, was the issue of training. A survey of the interest and attitude to training showed a very high interest to participate in training. Also a significant interest for training of complementary skills, such as: how to motivate people, teamwork, leadership and giving feedback was shown. Action plans for joint training have been proposed which includes both technical and complementary skills and targets young researchers as well as technicians, engineers and scientists. In addition, schemes for how the training process, including evaluation and feed-back, could be run within the consortium have been elaborated. An application for a Marie Curie training network has been submitted by several of the IRUVX-PP partners utilizing these training ideas.

WP5 Communication and Dissemination

The collaboration of all partners within WP5 was very productive and lively. The most complex project of WP5 was the development of a prototype website for the future consortium. Very significant contributions of WP5 are also the EuroFEL newsletter as well as the creation of a corporate identity and visibility through the logo and the unique look & feel of all communication materials.

Prior to any kind of PR and communication activities, the goal was to create and to cultivate a strong and distinctive corporate identity in order to give the consortium a clear profile, obtain public acceptance and integrate the partners' identity. The competence of the consortium has to be communicated and embedded in the target group's awareness. Some WP5 members were professional designers and created the logo and developed the corporate design and a set of corporate design rules. The core of the design is the logo with its concise wordmark. The logo represents the visual transposition of an FEL. The colours blue and yellow associate with the European Union. In addition to the logo, there are three other important design elements: colour scheme, typography, and graphic elements, which create the whole visual identity of the project. Together, these elements shape the "look & feel" for all communication initiatives.

Within the corporate design, WP5 created a visual system for different communication applications. One example is the design of communication materials for a series of EuroFEL workshops. The aim was to create a visual system for a series of workshops within the existing corporate design – still following the overall corporate design rules, but allowing some "autonomy" for the layouts. Special key visuals were created to give each workshop its own "look & feel".

One objective of WP5 was to develop prototype PR material for a future EuroFEL consortium. The first step was the development of a communication concept to serve as a basis for all future communication projects. This communication concept covers the preparatory phase as well as the "running" phase of a future EuroFEL consortium. Several communication activities were worked out and some realized during IRUVX-PP. The most important „push" communication tool is the EuroFEL Newsletter.

The newsletter aims at a sound mixture of topics combining new project developments with news from the partner facilities. Furthermore, the newsletter should inform the wider FEL community about R&D highlights, FEL related topics, and FEL related events from all over the world. The prominent newsletter columns are: Facility news, R&D highlights, EuroFEL consortium news, Spotlight on international FEL facilities, a column for industry, and a new user corner "ATOMIC TERRA INCOGNITA". Contributing editors were all WP5 contact persons, i.e. in general members of the partners' PR offices, and several EuroFEL consortium members. Editor-in-chief was the project coordinator. The newsletter is available in English. The issues are distributed as 4 or 8 pages PDF files via e-mail, a few copies are mailed as prints. WP5 produced 3 newsletter issues: 12/09, 07/10 and 12/10. A 4th issue was published after the end of IRUVX-PP in June 2011.

An important objective of WP5 was to build a prototype website for a future EuroFEL consortium. The website's main purpose is to be "the" general interface between the consortium and a large target group. It should present the EuroFEL consortium and consortium partners with their national FEL projects on the one hand, and on the other it should be a central platform for the FEL community in Europe. The website should help to promote FELs in Europe and was understood to include the common access point for FEL users as well as an event and conferences information tool.

A state-of-the-art CMS to be used for the website and for an internal collaboration portal was needed. The required CMS must be supported by a partner IT department or an external company. This IT department should be able to host the website and guarantee long-term support. A tendering procedure was set up by WP5. A list of requirements and tender documents were prepared and a first draft sitemap was worked out. The PSI IT department and their new and innovative CMS “Foswiki” were selected to set up and host the prototype website. The structure of the website, master pages and a book of wireframes were developed and the skeleton of the prototype website implemented at PSI. Simultaneously, the editorial work was started by an experienced freelance science writer. The first step is done; the first results can be seen online: http://www-test-eurofel.psi.ch/

WP6 Collaborations with Industry

Collaboration with industry under the IRUVX-PP project was focused on identification of key/critical industrial sectors for the construction of new FEL facilities, establishing the communication tools with industry, holding technical workshops to inform the industry about new developments and required R&D for the realisation of advanced components and systems as well as formulating the strategy for exploitation and management of IPR in knowledge/technology transfer (KTT) activities between the parties and the industry.

The key/critical industry sectors in this case are defined as sectors where there are either no or very few (one or two) suppliers and collaborative R&D is needed for the development and supply of advanced components. The objective was to open a dialog with key industry with the aim of providing information regarding:

- Advanced notification to industry about required specification for realisation of advanced components and systems
- R&D collaboration with industry is required

Two Industry Workshops were held:

1. ‘Instrumentation for Light Sources’, London, 19 Nov. 2009, attended by 80 companies and focusing on the ‘bulk’ instrumentation market for new light sources.

2. ‘IRUVX Meets Industry’, 1st March 2010, Berlin attended by 85 registrants in total with 55 from industry and 30 scientists/engineers from the institutes and 20 industrial exhibitors.

The industry’s main interests were to network with EuroFEL with experts present from the whole Europe and to receive information about pan-European FEL requirements and commercialisation opportunities in terms of technology transfer, market opportunities and procurement plans.

Common technical/procurement needs have been presented as part of the 'IRUVX Meets Industry' workshop initially in the areas of: Photon and e-beam diagnostics, X-Ray optics, Laser systems, Synchronisation and Control systems. Other areas such as advanced undulator concepts, detector development, cryogenic modules and superconducting RF technology will be addressed in future workshops.

Further in this deliverable the supplier selection via the supplier's completion of a Pre-Qualification Questionnaire (PQQ) is discussed. The Pre-Qualification Questionnaire is normally issued by the Authority in connection with a competitive procurement conducted in accordance with the Restricted Procedure under the Public Contract Regulations.

This PQQ sets out the information which is required by the Authority in order to assess the suitability of Potential Providers in terms of their technical knowledge and experience, capability/capacity, organisational and financial standing to meet the requirement. During the PQQ stage, the intention is to arrive at a short list of qualified potential providers for formal Invitation to Tender against the requirement as advertised for example in the OJEU Notice.

To aid the communication with industry, a web page/portal was planned to allow each partner to submit tenders and opportunities into a central site where industry would have a one-stop-shop for access to all European FEL facilities. In addition this site would also promote R&D collaboration and technology transfer opportunities.

In the report on 'Liaison with Industry', the examples of collaboration with industry from the point of view of knowledge/technology transfer activities from both an institute perspective and from an industry perspective are explored and discussed.

The technology transfer between the partners and the industry has been identified as very important as it could lead to significant time and cost savings in construction work of new FEL facilities in getting key components and avoiding costly duplication in the development work. This activity would represent real benefits for the national labs from collaboration under EuroFEL.

For successful technology transfer/licensing process, good working partnership and simplicity of deal was considered important together with:

- An access to a pipeline of IPRs regarding the same product, rather than a single product design and
- Sensible valuation of IPRs, using internal R&D costs as a benchmark.

The use of dedicated facilities (FEL or synchrotron beam time) to qualify new products is prohibitively expensive for some industrial sectors except for the 'facility spin-out' companies and hence further collaboration with licensors is extremely valuable, because they have a vested interest in the success of the product and can often access beam time at a much reduced cost.

The exploitation mechanisms and management of IPRs in knowledge/technology transfer activities is covered in an 'Intellectual Property Rights Handbook', which provides a set of principles aimed at helping EuroFEL members to adopt a common IP and KTT policy.

In particular the IPR handbook covers four main principles for EuroFEL infrastructure concerning the management of intellectual property in knowledge transfer activities:

I. Collaboration agreement between the EuroFEL members, the purpose of which is to specify the relationship between the Parties concerning the management of IP in KTT activities.
II. The principles for an internal IP policy constitute the basic set of principles which EuroFEL should implement in order to effectively manage its own intellectual property.
III. The principles for a knowledge/technology transfer (KTT) policy dealing specifically with the active transfer and exploitation of such intellectual property.
IV. The principles for collaborative and contract research conducted or funded jointly by a public research organisation and the private sector.

Further, the examples are given in the annexes on Non-disclosure Agreement, Joint Invention Agreement, Licensing Agreement and Model Contract/Consortium Agreement.

WP7 Photon Beamlines and Experiments

The existing and upcoming Free-Electron Laser facilities in Europe cover a wide range of photon beam parameters and instrumentation, and, therefore, offer unique research opportunities to a broad user community. The objective of this work package was to prepare common technical infrastructure for user experiments and exploit the new facilities from the start with the highest efficiency. This included joint technical work on advanced photon diagnostics for commissioning and operation as well as optimised concepts for photon beam delivery. Photon beam distribution and focusing as well as pulse-resolved non-invasive monitoring of the FEL radiation require a number of new developments that are not needed at 3^{rd} generation storage rings.
During the course of the project, active exchange among all WP7 participants took place advancing knowledge sharing between the partners. Furthermore, a large number of joint activities like experimental campaigns, systematic surveys, and organization of annual meetings, face-to-face meetings as well as two international workshops have been carried out.
The experience gained at FLASH during the first years of its user operation was used to serve as an instructive guideline with respect to future beamline design as well as many general aspects of a user facility. This report has been released to the IRUVX-PP partners as a ‘Handbook for FEL users’.
The results of all surveys and experimental studies of WP7, whose collaborative efforts were focused on X-ray photon beam optics and diagnostics, were summarized and published in a text book “*Compendium on beam transport and beam diagnostic methods for Free Electron Lasers”* (*A. Lindblad, S. Svensson, K. Tiedtke, ISBN 978-3-935702-45-4, 2011)* and can be downloaded at http://www.iruvx.eu/media/publications/ The book combines an introduction to free electron laser science and technologies with the latest developments in photon beamlines and diagnostics techniques in a way, which is also accessible for scientists new to the field and university students. Moreover, the book will also serve as a basis for upcoming lectures on free-electron lasers at universities and summer schools, helping future students and colleagues to get acquainted with the exciting field of free electron laser science.

Photon diagnostics

Photon diagnostics are essential for commissioning and operation of FEL sources as well as for user experiments. The diagnostics must be pulse-resolved, and ideally should be non-destructive to provide radiation parameters for the pulse that is used for the experiment at the same time. While basic photon diagnostics for FEL commissioning and operation are in routine operation at FLASH, this sub-work package focused on techniques for measuring the lateral and temporal structure of the FEL radiation.

Temporal properties
The temporal properties of the photon beam are a key measure of the performance of a free-electron laser. The *pulse length* is required for the integral pulse power; the *pulse profile* determines the "quality" of the pulse in terms of lengths as well as height and deviation from the ideal pedestal shape. The pulse jitter is the random fluctuation in the arrival time of a pulse.
During the course of this project, different temporal diagnostic techniques like auto- and cross-correlation, a streak camera, and reflectivity modulation have been surveyed and all findings have been summarized in an IRUVX-PP experts' report. Based on this report the abilities and limitations of the different concepts, in particular the autocorrelation and a cross-correlation technique based on reflectivity modulation have been intensively studied. Several articles on this topic have been published in the last years (see *'A. Lindblad, S. Svensson, K. Tiedtke, A compendium on beam transport and beam diagnostic methods for Free Electron Lasers-IRUVX Experts report, ISBN 978-3-935702-45-4, 2011'*, and references therein).

Lateral properties
The lateral properties of the photon beam are important parameters for the beam transport, the focusing, and the experiments. The transverse intensity distribution is required to determine the source size, position, and the so-called quality factor (M^2) of the photon beam. The centroid of the transverse profile gives information about beam angle and position. The spot-size of the focused beam determines the flux density at the interaction volume of the experiment and is -from the users' perspective- one of the most critical factors. In the framework of this project two different methods to determine the size and quality of the beam spot have been established for soft X-ray free electron lasers, namely '*ablation crater analysis*' and '*wave front sensing'* (*see 'A. Lindblad, S. Svensson, K. Tiedtke, A compendium on beam transport and beam diagnostic methods for Free Electron Lasers-IRUVX Experts report, ISBN 978-3-935702-45-4, 2011'*, and references therein). The latter allows a complete characterization of the radiation field by providing the magnitude and the relative phase of the field. Using these results as an input into wave front propagation codes the radiation field at other locations in the beamline, such as the focus position, can be deduced. The *'ablation crater analysis'* allow determination of the focal spot size by analysis of the laser ablation crater imprinted into a well characterized sample, predominantly PMMA (polymethyl methacrylate) using different microscopic techniques.

Optics for beam transport and focusing

Photon beam distribution and focusing of the FEL radiation is very demanding due to the specific properties of FEL sources, wavelength range, highest intensities, ultra-short pulses. In order to preserve important photon beam parameters like time structure, flux and coherence properties, the optics have to fulfil extreme requirements in terms of figure errors, roughness, stability, and radiation hardness. Studies of radiation damage processes of optics and advanced concepts for micro-focusing are key issues in this context.

Radiation damage of optics
The high peak power of the FEL radiation may degrade the optical properties of coatings and substrates thus making the provision of optical elements with a long-term stability a demanding task for all FEL facilities. A scientific effort, in collaboration with international partners, has been initiated at FLASH in order to measure damage thresholds of relevant

optical coatings and materials and understand the underlying physics. This ongoing initiative includes the provision of samples, experimental campaigns at different FEL facilities and international work meetings. Measurements have been performed at FLASH, LCLS (USA), and SCSS (Japan) giving consistent results on non-thermal thresholds and sub-threshold multi-shot damage. Several papers have been published on the work: *Sobierajski R et al., Optics Express 19(1) (2011), Khorsand et al., Optics Express 18(2) (2010), Hau-Riege et al., Appl. Physics Letters **95** (11), 111104 (2009), Chalupský et al., Appl Phys Lett 95 031111 (2009) Chalupský et al., Optics Express 17(1) (2009) Juha et al., J. Appl. Phys 105, 093117 (2009)* and references therein.

In-situ metrology

The main part of this sub-task was the development of metrology tools, in particular techniques for in-situ characterization of the optical performance in order to develop strategies for damage prevention by choosing optimal materials, structures and geometries.

During the course of the project it turned out that wavefront sensing based on the Hartman principle is the most suitable approach. Based on first test measurements at FLASH an improved wave front sensor prototype (*'Flöter B. et al., New Journal of Physics, **12**, 083015, 2010'*) was built and successfully tested at FLASH, LCLS, and FERMI during the last year. Furthermore, the feasibility of using wave front sensors for pulse-resolved in-situ metrology has recently also been successfully demonstrated at the ESRF (*Gaudin J. et al, New Journal of Physics,13, 093003, 2011).*

Microfocusing optics

A large number of future experiments at FEL facilities rely on focusing the photon beam to µm or sub-µm dimensions. One promising solution to meet the demands concerning very small residual slope error of the beam transport optics would be the manipulation of the photon beam by actively manipulating the surface of reflective optics. As a result, a scientific effort has been initiated at ELETTRA to develop adaptive, plane elliptical mirrors which are able to preserve the wavefront and to compensate errors due to imperfections of previous mirrors. Wavefront preservation requires precise optics with less than 5nm peak to valley variation with respect to ideal shape. This is only feasible for plane and spherical mirrors but not for elliptical mirror shapes by state-of-the-art metrology and fabrication procedures. The main idea behind the adaptive optics concept is, thus, to start with a 'perfect' flat mirror surface and bend it to the desired elliptical shape. Since the success of this concept relies critically on the availability of appropriate metrology tools a broad survey of potential tools and a 'round-robin' on existing metrology tools at the partner institutes were initiated. Therefore a pair of high quality spherical mirrors was purchased in IRUVX-PP and measured by all partners giving them a baseline against which to improve their instruments.

Finally, an adaptive optics prototype has been extensively tested and characterised during the last two years of the project (see *Cocco D. et al, Nuclear instruments and methods A, **616** (2-3), 2010*)

Multiple use of the FEL beam

In contrast to storage rings, where a number of insertion devices and bending magnets provide radiation beams for many experimental stations simultaneously, FEL facilities (will) produce only a few beams and must therefore be used very efficiently. A rather inexpensive way of increasing the user capacity is by fast (~1Hz) switching the photon beam between different experimental stations or by splitting the beam using special optical devices. The merits and applicability of two concepts have been evaluated with regard to different classes of scientific applications, and prototypes have been built and tested based on existing technologies.

A fast switching mirror device with a maximum switching frequency of 2.5Hz has being integrated into the FLASH user facility as a permanent device (see Sternberger *R. et al, Nuclear instruments and methods A,* ***635*** *(1), 2011*).
Two different microstructure-based approaches have been studied to realize a FEL beam splitter. Since it turned out that a v-groove-like structure is the most suitable approach the task leader concentrated on further investigation of the corresponding lithographic fabrication processes. By optimising the etching process the surface roughness and thus the wavefront preservation were significantly improved. The latter have been demonstrated in a proof-of-principle beam splitting experiment using an optical laser

WP8 FEL Source

A joint effort in the development of critical technologies is crucial for the timely and cost-effective construction of new FEL sources. Moreover, a baseline design compatible with all facilities will allow their stable and reliable operation while meeting scientific and technical challenges novel to the particle accelerator world. WP8 concerned three main areas of development: An optical synchronization system with 10 fs precision, a longitudinal diagnostics and feedback system for the electron beam, and FEL seeding with high harmonic generation (HHG) lasers. All the relevant scientific/technical objectives have been achieved at the end of the project. Several phone conferences and meetings between partners have been organized during the last three years to exchange information, knowledge and experience, to coordinate the collaboration work and the components industrialization. Young researchers have been travelling among the IRUVX-PP laboratories to participate in the different timing system characterization and commissioning. Due to the novelty to the accelerator world of the WP8 developments, a great effort was devoted to the dissemination of the critical achievements through the presentation at conferences and workshops with the participation of experts and industries from all over the world. Finally, an internal WP8 wiki page was set up for fast and efficient exchange of information among partners. Nevertheless, the greatest WP8 result is the consolidation of a collaboration distributed geographically and not uniform in terms of laws/projects advance/resources. This has created a very solid foundation for future joint technical developments with the perspective of involving new qualified partners and the industry with a leading role in the field.

Ten Femtosecond Timing and Synchronization

The optical synchronization system at FLASH provides the reference for the pump-probe and seeding laser as well as the laser for electro-optical sampling station and timing of the injector laser. During the last three years, the synchronization system has progressed from a bread-board/test-bench implementation to a more permanent engineered infrastructure. A high number of modules and sub-systems to set up and run the synchronization system, including two master laser oscillators, a 16 port free-space distribution unit, seven links (fibers and link boxes) and four bunch arrival time monitors, have been installed, commissioned and are now in operation. The arrival time rms jitter at the undulators has been reduced from 74 fs to 5 fs with longitudinal beam-based feedbacks. Collaboration and sharing of knowledge with the IRUVX-PP partners has been crucial to implement an automated, reliable and error-tolerant system and at the same time, having identified common needs, to develop solutions in synergy with the industry available and compatible for all partners. Devices of great interest to all WP8 partners have undergone the industrialization process and the relevant outcomes of the collaboration with industry are summarized in four industrialization reports. Aging, reliability and behaviour of the critical components of the synchronization system have been investigated in collaboration with HZB. Starting from the analysis of the devices prone to fail early and/or repeatedly, the design of the linear stages not stable enough was modified according to the needs of the optical setup and, consequently, their performances improved significantly. Moreover, a company specialized in customizing fibre Bragg gratings responsible to “lock” the wavelength of the laser diode module was contacted to find a solution to the jumps in the output power. Finally, it was proven that the use of phase stabilized optical fibres (PSOF) and the choice of fibre connectors, as detailed in the industrialization reports, have a relevant impact on the system reliability. The outcomes of this sub-task are available for all IRUVX-PP partners to get their optical timing distribution system straight into a stable operation.

An optical clock distribution system has been setup, installed and commissioned on the ALICE ERL. The installed link is distinct from similar links elsewhere in operating without any bi-directional Erbium-doped fibre amplifier as optical repeater to optimise the passive noise resistance in the system. To study the optical clock distribution system, measurements of the phase noise have been performed on its various components highlighting some high frequency noise in the mode-locked oscillator. A beam arrival monitor has been installed in the ALICE injection line, fed with pulses from the optical link. Timing sensitivity of 26 ps/dB was achieved on the beam arrival monitor with 40 pC bunch charges.

The goal of the tests on direct seeding of Ti:Sapphire amplifiers by the timing pulses was to explore the applicability of such an approach to FERMI@ELETTRA, giving indications to other facilities with analogue timing systems. The prototype contains the three main parts needed to implement the scheme, namely an Erbium doped fibre amplifier for increasing the energy of the pulses from the stabilized fibre link from picojoule to a nanojoule level; a pulse compressor for compensating the chirp of the amplified pulses, and a high efficiency broadband frequency doubling system for obtaining pulses at 780 nm. The tests performed with a rather narrow timing pulse spectrum, showed that the completed prototype is applicable to the photoinjector laser delivering both sufficient power and bandwidth. It was also concluded that a better approach to the use of direct seeding for the seed and user laser would rely on fibre lasers, locked to the fibre link optically. In such a way, the high efficiency frequency-doubling part of the prototype, developed for the direct seeding, can be combined with the results obtained by the work on optical synchronization reported above, for generating the broad and smooth spectrum required to seed ultrafast amplifiers with a very small timing jitter.

Beam dynamics simulations for SwissFEL indicate that the gun laser stability is among the most critical issues for stable SASE operation in the hard X-ray regime. Specifically, in the low charge (10 pC) operation mode of the facility, which is designed to produce ultra-short (< 10 fs) photon pulses for the users, the high electron bunch compression ratio requires an arrival time jitter of the Ti:Sa gun laser at the cathode in the order of 30 fs (rms). The timely availability of the Ti:Sa SwissFEL gun laser in the 250 MeV Test Injector facility provided at an early stage of the project the opportunity to implement and test the link of the gun laser to an optical reference system via optical cross correlation.

Great effort was devoted to the organization of the Workshop ‘IRUVX-PP meets Industry’ in collaboration with the colleagues of WP6. Originally meant as a milestone of the industrialization of critical developments for timing and synchronisation, it has become an occasion to introduce IRUVX-PP and the EuroFEL Consortium to the industries with a crucial role in the field and to discuss and define the FEL technology and procurement needs, the existing and new R&D and collaboration required and the industry involvement and opportunities. Moreover, it has been a chance to define with WP6 colleagues intellectual property rights, how to handle pre-existing know-how within the IRUVX community and the framework for components industrialization.

Longitudinal Feedback

Two broadband single-shot THz spectrometers for compression control in the frequency domain have been installed and commissioned at FLASH. One of them is fully operational and calibrated, available for operators and is regularly used to monitor the bunch compression online for various purposes; the second one is used for ongoing R&D. They are both based on the use of staged blazed gratings and parallel read-out using custom made pyroelectric line detectors. Each grating acts as a dispersive element for short wavelengths and as a mirror for wavelengths longer about 1.8 times the grating constant. In this way, a spectral range of about one order of magnitude is covered simultaneously (single shot) with a set of 5 cascaded gratings. The line detectors are read out in parallel by 120 ADC channels with 9 MHz sampling rate. The spectrometer contains in total two such 5-grating sets that can be exchanged by remote control. In this way, we are able to monitor the compression by observing coherent radiation in the range of 4 um to 450 um.
A prototype and test bed for high time resolution electro-optic diagnostics (EO-TD) has been installed on the ALICE ERL at STFC Daresbury Laboratory. The prototype sought to provide a control-room diagnostic that used the high resolution "temporal decoding" technique. It has successively demonstrated a capability at bunch charges down to 40 pC, a 5-fold reduction in charge (and 25 fold reduction in signal) from previous experiments; these measurements provide confidence in use of EO-TD systems for low-bunch-charge FELs. At the time the WP8 tasks were identified, electro optical bunch length measurements were mainly performed with Ti:Sa lasers. The wavelength of 800 nm though was not perfectly suited and also the maintenance necessary to operate a Ti:Sa laser system made the EO more an experiment than a reliable diagnostic system. The plan in the IRUVX-PP proposal was to design a packaged prototype of an Yb-fibre laser that fits the need of an accelerator facility to be used for routine bunch length measurements. Its wavelength of 1040 nm, bandwidth ~40 nm and a pulse energy of a few nJ that can be reached in an oscillator-amplifier setup made it a promising candidate. Starting from a breadboard laboratory setup of an Yb-fibre laser, a prototype design was developed, but a series of subtle technical problems were experienced and other design flaws further delayed the finalization of the prototype. Finally, in 2009 an Yb-fibre laser from ‘Menlo Systems’ that exactly met the required specifications became available on the market. This laser system, with a cost similar to that envisioned for the prototype, was delivered to DESY in April 2010. Dedicated measurements have shown that it fulfils the required specifications and that it can be used for electro optical measurements. Moreover, DESY took over the development of the prototype of a line detector for high repetition rate measurements. It was decided to base the first working prototype on existing technologies in collaboration with the Lodz Technical University. Two PhD students were hired to develop the basic concept into a full specification document, defining the read-out architecture and a conceptual hardware design. Additionally, contacts with CERN regarding the BEETLE front-end chip designed for the LHCb experiment to parallel read out custom made line detectors have been established. All participating institutions signed a Memo-of-Compliance and a number of ASICs sufficient to build the prototypes was sent to DESY. Negotiations with potential suppliers of the line detector elements have been started and lead to reasonable offers for custom made devices. Due to initial delay of the project, the first detector is foreseen for end 2011.
A prototype of the 11 GHz X-band cavity for the electron phase-space linearization to enhance bunch compression and reducing bunch longitudinal energy spread has been built and successfully characterized at room temperature at SPARC. Two different solutions have been investigated: the nine cells SW structure working on π-mode and the seventeen cells SW structure working on $\pi/2$-mode. Studies to design the cooling system for the final devices were also performed together with innovative technological methods to improve the RF

performance at higher power. Finally, the architecture of a generic feedback framework able to integrate different bunch-by-bunch feedback loops has been designed and implemented. The main issues regarding the longitudinal correction algorithm have been addressed and closed loop simulations using a model of the FERMI@Elettra linac have been carried out.

HHG Laser

Currently many FEL facilities are planning or considering HHG seeding to produce coherent short wavelength FEL radiation. The first year was devoted to the collection of the basic information on HHG activities. To this aim a workshop on the topic ‘Workshop on High-Harmonic Seeding for Present and Future Short Wavelength Free-Electron Lasers’ was organized in Rome in December 2008. The second year was devoted to the definition of the critical HHG issues to address on the base of the data collected. In parallel with the analysis of the workshop outcome the HHG laser performance was tested at the high power laser facility at the Lund Laser Centre (LLC) at Lund University. In particular, as no experimental data were available in the literature, the laser energy and pointing stability were investigated. The activity of the last project year was completely devoted to the verification of HHG source performance for FEL seeding radiation. In particular, HHG pulse energies reported in the literature and how they compare to the seeding requirements at the EuroFEL facilities were investigated. The temporal structure of HHG radiation and how it affects the seeding process was also examined. These studies were completed by experimental measurements of an HHG source stability. Pointing, divergence and HHG pulse energy fluctuations have been measured. A numerical code to calculate the output of an HHG source was also developed. The numerical results agree within a factor of two with the measured pulse energies.

The potential impact and the main dissemination activities and exploitation of results

Introduction to potential impact

It is widely recognized that knowledge in general and scientific knowledge in particular is the basis of competitive, modern economies and that the existence of and access to leading research infrastructures plays a key part in maintaining Europe's competitiveness in research and innovation. Research in curiosity-driven science is also an important driver for technological innovation and economic success. In this context, Research Infrastructures play a clear socio-economic role by generating discoveries and opportunities for new industrial applications. FEL science is an extremely demanding environment in terms of the development of high-tech equipment and generates novel technical approaches that might create significant benefits for many research disciplines such as medical technology, life sciences or instrumentation and ultimately the society.

Due to the international character of EuroFEL, its large scale and the commitment of the EuroFEL partners to strongly cooperate within the EuroFEL project, substantial impacts can be anticipated which are of general societal nature and lead to benefits for the EuroFEL partners.

The key success factors for these positive impacts are the stated objectives of the EuroFEL project:

- To develop a common user platform providing support for access of European users, including EU wide unique user identification; in the first prototype phase, the platform is intended for the FEL user community. In the second phase, the tool will be extended to the full photon / neutron facility user community.
- to integrate their national FEL laboratories into one distributed European FEL facility for Pan-European use in order to fully exploit the complementary features and expertise of the partner facilities;
- to implement structures and working methodologies of their facilities in order to allow efficient construction and operation of EuroFEL facilities as well as to prepare critical technology thus ensuring that all the partner facilities will be exploited with highest efficiency;
- to optimize the cost-benefit ratio through the coordination of activities and efficient use of the resources of members;
- to identify and tackle common scientific and technical challenges;
- to support the joint training of scientific and technical personnel and to establish common training concepts;
- to ensure efficient internal and external communication;
- to advance the transfer of its scientific and technological results through an active collaboration and the transfer of intellectual property to industry.

The above stated mission will create different types of impact as direct and indirect contributions to the development of the regions and societies where partner facilities are located and to the performance of the single partner facilities as well as on the performance of the Consortium as a whole. The effects can therefore be grouped in:

- Societal Impact:

- are direct and indirect impacts on economy and capacity building

- Impact on EuroFEL partners:

- are impacts on EuroFEL as a whole and the benefits created for the EuroFEL partners.

Societal impact

There is a pure economic impact, which is the direct impact of the expenditure, the indirect impact of stimulated additional activities of suppliers and the induced impact by spending of employees and suppliers. Societal impacts are also generated by capacity building in form of contributions of EuroFEL to the human capital in terms of education and training.
European companies will profit from this collaboration which is also a unique chance for them to stay at the forefront of technological developments and remain competitive in the global market.

EuroFEL will stimulate and better control the knowledge generation process and its transfer to industry. The more effective interaction with the industry will lead to new products and consequently to the opening of new markets. Furthermore the concentrated R&D and procurement activities of the EuroFEL partners will increase the attractiveness of the accelerator market for industry. Own investments of the companies will be justified by the size of the accelerator market. The new competencies gained will benefit the companies in this new market as well as in their traditional markets. Contributions to companies commercializing the innovations (spin-off companies) will be made.

In the long term, major societal impact can also be expected by the advances in science originating from the experimental results of the high performance facilities. The understanding of biological processes at the molecular level will lead to new methods for curing diseases and better pharmaceutical products. New products, new materials and new drugs can be expected in the long run from research with Free Electron Lasers and Short Pulse Facilities.

Although the benefits of these actions are immediately obvious, it is difficult to quantify them. Mechanisms have not been identified yet, and methods have not been fully developed to evaluate the socio-economic impact of scientific accelerator projects.

Impact on EuroFEL partners

The implementation of EuroFEL will promote the research field of Free Electron Lasers (FEL) and Short Pulse Facilities (SPF). It will strengthen the leading role of Europe in this scientific area and enhance the attraction of researchers to this field.

In addition there are direct and indirect impacts that the EuroFEL project has on strengthening research capacities in the collaborating labs and in Europe in relation to the objectives of the European Research Area net and EU 2020 vision. Major political, scientific and economic impact for the EuroFEL partners is expected by the envisaged joint actions originating from the commitment of the EuroFEL partners to strongly cooperate within the EuroFEL project.

Impact overview for the partner facilities

In comparison to the societal impact, the impact on the development of research infrastructures, generated by coordination effects and strategy actions is self-evident. The impact of EuroFEL on the partner facilities will be immediate economic effects and an enhancement of excellence which in a long term will also have an economic repercussion.

Major impacts and direct economic benefits for the EuroFEL partners are generated by:

- structural effects
- joint activities
- support and services provided by the EuroFEL team

Structural effects

By improving the visibility of the science a corporate identity will be created for EuroFEL having significant political influence. It will be a strong discussion partner for science policy which will open new opportunities in the interaction with the EU and in this way also potentially improve the national funding situation. It is a chance for Europe to lead this scientific field and become an attractive place for researchers. As an EU-wide organisation it will lead to higher quality service to the research community. Fundamental science and accordingly the exiting field of short pulse generation and their scientific exploitation will attract students to enter this field. A centralized participation in EU programmes can be envisaged.

Joint activities

Joint technical developments will be pursued, leading to a quality enhancement and an acceleration of the production process. Higher resource effectiveness will be reached through sharing concepts and ideas and introduction of common standards. Technologies and their key characteristics will be identified and the future FEL requirements analyzed. A central organization of training will complement and extend partner activities. A centralized outreach programme will satisfy and enhance the public interest, creating in this way a higher acceptance for FEL activities. Dissemination activities will improve the internal and external information exchange. Contributions to capacity building by intensive exchange of know-how and expertise are expected. A coordinated and therefore more effective interaction with the industry will be established. Joint procurement and contracting activities of the partners increase the volumes and thus reduce the risks and the fixed costs for the industrial partners leading to more competitive pricing being offered to the partner facilities.

Support and services

Central support and services will avoid duplication of expertise and infrastructure to the benefit of all partners.

Impact for the partner facilities resulting from the joint core activities of EuroFEL

Coordination of User Affairs

The enhanced political visibility of the science will create a FEL user corporate identity. Representing FEL/SPS user interests towards those determining science policy and strategy will become easier and the interaction with neighboring research fields will be improved.

In addition, benefits for the partner facilities will result from:

- improved EU-wide access to new potential users
- central access portal (Umbrella); a central portal for FEL users
- pool of referees
- high potential for novel possibilities based on the new system
- improved user friendliness and minimized administrative overhead
- avoiding multiple applications
- synergies due to evaluation standards
- expert support for novice users (coaching)
- potential funding of transnational user access

Joint technical developments

The sharing of concepts will lead to standardization and consequently higher effectiveness. It will enhance the quality and shorten the realization time for new developments. Key technologies will be evaluated and new technologies promoted. Also here, the stronger identity will improve the fund raising capabilities.

In addition, benefits for the partners will result from:

- identification of key technologies
- provision of a portal for collaboration support
- provision of web based tools for the coordination of the collaboration
- support for setting up the basic organization
- support for following up the process
- monitoring of overlapping areas of all development projects
- support for applications to the EU
- active fund raising for collaborative activities
- provision of web based tools for the execution of joint projects
- recognised support for partner fund raising will be given

Joint training and education

A central organization of training will avoid duplication of activities and will reduce the workload for the partners. EuroFEL will be an attractive, centralized contact for students and its strong identity will enhance fund raising capabilities for joint training activities.

In addition, benefits for the partners will result from:

- exchange of personnel working on FEL design
- organization of training courses and workshops
- training of FEL/SLS operators (exchange of know-how and experience, sharing best practices, standardization of concepts, equipment, operation tools)
- raising interest for students to enter the field
- advising workshop organizers on emerging technologies, new developments, key issues of the field
- generation of additional funding for the activities
- organization of staff training by exchange of personnel: will lead to a standardization of software tools and also improvements in measurement equipment
- organization of joint training for software developers

Strengthened relations with industry

EuroFEL will also enable a much more efficient collaboration with industry by providing a central point of contact and a long-term strategy. It will be an attractive and powerful partner for industry, strong partner for the development of new key-technologies, will combine the interest of all partners and speak with a single voice to industry. This will be essential for the development and commercialization of cutting edge technologies that are required for the construction of the new facilities.
Technologies and their key characteristics will be identified and the future FEL requirements analyzed. New technologies will be opened to new application domains. Developments of standardized systems for FEL/SPS facilities will be initiated with industry. Common procurement within joint developments or expert teams, or even beyond that, will bring financial advantages.

In addition, benefits for the partners will result from:

- negotiation of competitive contracts with industry
- coordination of developments having wider application with industry
- construction of a data base for qualified and approved suppliers

Dissemination and outreach activities

Improved information exchange will ensure efficient dissemination of know-how. Outreach activities to satisfy and enhance public interest will lead to higher acceptance for FEL activities and consequently influence the funding situation. A centralized interaction with neighboring fields will improve the development of overlapping areas. Complementarities will be enhanced by intensive exchange of information.

Benefits for the EuroFEL Consortium

Benefits for the partners are generated by strategic actions, coordination, support and services. Specifically, the EuroFEL Consortium will improve cost efficiency for the members and the user community, and open new opportunities in the interaction with the EU. It will act as:

- Science driver: by enhancing quality and making new developments available to all partners;
- Economic driver: by solving technology challenges faced during construction and operation that is exploitable in other areas;
- Societal driver: by pursuing an effective approach to education and training and attracting students. The developments with FELs for the benefit of humanity (eg: medicine) will be enhanced;
- Political driver: by increasing visibility and enhancing international activities.

The advantages for EuroFEL Partners will be:

- Economic benefits: resulting from joint activities and joint developments that will lead to standardization and shorter realization times; furthermore by acquiring additional funds for joint programmes;
- Enhancement of excellence: joint training and joint developments will lead to better solutions;
- Widening of expertise: by improved dissemination that brings scientists closer and promotes the exchange of ideas;

- Improved funding situation: by joint outreach activities that will satisfy and enhance public interest and increase the acceptance of FEL/SPS projects;
- Support and Services: for joint collaborations, interaction with industry, user support

Address of project public website and relevant contact details

www.eurofel.eu