7 Role and development of the smaller scale European facilities

7.1 Introduction

This section describes the coordination platform for the development of smaller scale facilities (SSF) already operating in the area of intense and ultraintense laser interactions **with active programmes in Inertial Confinement Fusion and Fast Ignitor related studies.** This platform will enable SSF to provide access for dedicated experiments that do not necessarily require beam time at large scale facilities (e.g. CLF, LULI). Within this initiative, SSFs will also serve as attraction points for young researchers to be hired within other EU programmes (MC, COST, etc). This approach will contribute to establish the "people" issue as a critical one and will contribute to the growth of the community in view of the large number of scientists with expertise in Inertial Fusion Energy required for the HiPER project. Smaller Scale facilities identified for participation to this task will provide **support to the HiPER scientific programme** on the basis of their specific expertise and existing undertaking. To this purpose, smaller scale facilities **will be encouraged and supported** to further expand their research capabilities in their primary area of expertise.

It is well established in the scientific community that HiPER is fundamentally a European science R&D facility that will allow, for the first time, a coordinated effort towards Inertial Fusion Energy (IFE). It is also clear that the complexity and the scale of the undertaking are unique and calls for an unprecedented coordination of existing laser facilities, laboratories and groups actively engaged in IFE or related fields. In view of this approach and following the recommendations of the European Strategy Forum on research Infrastructures (ESFRI), the HiPER community has, since its first general meetings, shared the need of a significant growth of the scientific community to both :

a) consolidate a medium-term programmatic activity on Inertial Fusion Energy and

b) establish a coordination activity among existing Laboratories, *and Laser Facilities* targeted to address weak/risky issues of the inertial approach to fusion energy.

In this section we identify the role and need for a high priority participation of SSFs to the HiPER project. Specific actions have been identified to address items a) and b) above.

7.2 Nature of the facility coordination needed for HiPER

As discussed in previous sections, HiPER's approach to IFE is based upon the so-called Fast Ignitor approach. The demonstration of fast ignition, along with the repetition rate issue, are the key milestones that will change the character of IFE from applied research to a viable future alternative route to an efficient energy source. In view of the programmatic character of HiPER, participating scientists will need to carry out a whole range of systematic studies aimed at advancing the understanding of critical physics issues if FI. This type of *systematic* research, when compared to topical/frontier research where emphasis is given to new interaction regimes and novel physical mechanisms, is often regarded as somewhat "less attractive" for individuals and research groups continuously facing competititive access to gain funding and use of facilities where impact and novelty play a key role in selection criteria. In this scenario, SSF participating to HiPER will provide dedicated access to lasers and target areas complementary to large scale facility. Attracting financial support for the instrumental and human resources needed to provide access is the objective of sub-task 6a1 "Integration and Framework Coordination" within of WP6 "Technical risk management".

Remarkably, it was a common view among HiPER meeting participants that, once established as a long term EU initiative and integrated in national research programmes, HiPER will attract significant local funding and will also enable HiPER-related activity in new and existing EU programmes (LASERLAB, MC training Sites, Relevant COST actions etc.) dedicated to *systematic* studies in a similar fashion as other large international collaborations (e.g. ITER). Also covered within HiPER WP6 is the participation to IFE programmes in US and Japan, as well as in other countries where rapidly growing IFE activity exists, which is regarded a necessary step to develop needed expertise presently not available in EU.

7.3 Resources

A preliminary survey was carried out during the initial stages of the HiPER project to encourage active involvement in the project of the IFE scientific community and related topics. In a later stage, each group running a SSF that had expressed interest in the HiPER infrastructure was asked to fill a standard form to identify their possible participation in terms of existing expertise, institutional medium term work programme, possible research field of involvement and contribution and type of support required to accommodate HiPER tasks. Thanks to this initiative, it was possible to identify a range of topics for which experimental and/or theory resources may be made available to address risky project issues identified in the other topics and subtopics. A summary of this list is provided below, with a short identifier including Institution, Contact person and Main Topic. The complete identification document for each group is provided in a separate attached document.

Institute for Optics and Quantum Electronics*, Jena Germany Eckhart Foerster; Laser development, X-ray Source for time resolved X-ray diffraction*

Laboratory for Attosecond and High-Field Physics, Max-Planck-Institut für Quantenoptik, *Garching, Germany, Contact person Dr. Stefan Karsch - Ultra-Short laser development (OPCPA&Ti-Saphhire),Attosecond science, LPI, Particle acceleration and radiation sources*

Gesellschaft für Schwerionenforschung*, Darmstadt, Germany, Contact person Markus Roth - Es.: Laser development, LPI, X-ray Source, Fusion Related, Ion stopping*

Physique at Haute Intensité, CEA-Saclay (FRANCE), *Contact person Dr. Philippe Martin - Laser diagnostics development, High Intensities High Order Harmonic sources, Fast Particle generation and diagnostics, Plasma diagnostic on sub-picosecond time scales.*

Intense Laser Irradiation Laboratory, CNR, *Area della Ricerca del CNR – Pisa, Italy, Contact person A.Giulietti; - LPI, optical scattering, X-ray time-res. Spectroscopy, K-alpha imaging and spectroscopy - Charged particle acceleration in plasmas; particle beam diagnostics.*

Laboratory for Intense Lasers*, Center for Plasma Physics, Instituto Superior Técnico, Portugal, Contact person Luís Silva, Gonçalo Figueira (Head) - Laser-plasma interaction and high power laser development (CPA Ti:sapphire-Nd:glass, OPCPA, diode-pumped ytterbium media)*

Laboratorio Laser di Potenza, Milano *Dipartimento di Fisica "G.Occhialini", Università di Milano Bicocca, Milan, Italy, Contact person Prof. Dimitri Batani - Laser development, X-ray Source, Fast Ignition related studied, Shock Wave and Hydrodynamics related studies.*

Institute of Plasma Physics and Laser Microfusion (IPPLM), Warsaw, Poland, *Contact persons: J. Badziak and J. Wolowski - Study of physics of laser-matter interaction at medium and high intensities, Study of phenomena related to ICF proton fast ignition - numerical modelling and small-scale experiments.*

CELIA, University Bordeaux *1, Jean-Claude Gauthier - Laser development, harmonics, X-ray Source, Fusion Related, Attosecond pulses, Laser ablation and micromachining*

Max-Born-Institute, Berlin, *Peter V. Nickles - LPI (ion and electron acceleration), , Proton Radiography, X-RayLaser etc., Ti:Sa Laser Development, X-ray Source; Ti:Sa Laser Development; X-ray Source.*

Centre for Plasma Physics*, Marco Borghesi, Queen's University of Belfast (QUB), Belfast, UK, Laser-plasma interaction; (particle acceleration, x-ray sources, x-ray scattering); Laser development.*

TOPS lab, University of Strathclyde *(TOPS), Paul Mc Kenna, Glasgow, Scotland; Laser-plasma accelerators (electrons and ions); wakefield acceleration and application to free electron lasers; Raman processes; terahertz generation Laser-based nuclear physics diagnostic development*

Laboratory of Optoelectronics, Lasers & Plasma Technology*, Department of Electronics/ Technological Educational Institute of Crete (T.E.I. of Crete), Contact person: Assoc. Prof. Michael Tatarakis, , Laser-plasma interactions, Plasma diagnostics, Point intense X-ray sources, Pulsed power plasma generators (X-pinch, Z-pinch), X-ray backlighting, CW laser development, Coherent X-ray sources, Attosecond pulses research*, Secondary sources from laser matter interactions, Theoretical back up scientific team, Electronic Design & Automation*

PALS, Institute of Physics, Prague*, Bedrich Rus - Development and applications of X-ray lasers, XUV and X-ray diagnostics, keV X-ray spectroscopy, ion spectroscopy*

7.4 Distributed science and diagnostic capabilities: a common approach between SSF labs

A rich background of expertise in experimental and theoretical investigation in laser-plasma physics in the IFE relevant regime exists in the above cited labs which is the result of dedicated activity enabled by a broad set of laser laboratories and university departments that are partially interconnected via a range of research programmes EU-wide. This knowledge enables scientists to continuously advance knowledge using diagnostic techniques that are crucial in the understanding of some basic issues in IFE.

Diagnostic issues are extensively discussed in other sections of this report. Here we recall two examples of diagnostic techniques, namely K-alpha imaging and optical probing, with the purpose of discussing the potential benefit that a coordinated approach may have on the community.

It is well known that K-alpha imaging is a key technique in the study of propagation of fast electrons in matter, a fundamental issue in the Fast Ignitor approach to IFE. In fact, the most effective way to unfold the dynamics of electron propagation is through detection of k-alpha radiation emitted as a consequence of electron impact in the target substrate. This is presently approached by using layered targets and by detecting k-alpha emission from each layer. Imaging of such emission allows the history of propagation of electrons to be recovered. This technique benefits from the use of fine X-ray optical systems, based upon diffracting crystals, to achieve spectrally resolved imaging. Examples of SSF where this expertise is well established are QUB, IOQ, and CNR. More recently, the availability of very low noise CCD detectors allows direct imaging with spectral discrimination of photons at the 50 eV level. Dramatic development of this technique has taken place, for example, at LOA, IOQ, CNR. Further, these studies are integrated with the implementation of novel techniques for the simultaneous characterization of spectral and angular properties of fast electrons, a key step in the understanding of electron propagation dynamics, as demonstrated in collaborative research under the LASERLAB framework between CEA-SACLAY, CNR and LULI. Further growth of expertise in advanced X-ray imaging techniques in Europe may arise from collaborations between above cited existing European frameworks (LASERLAB) and leading detector manufacturing companies (e.g. ANDOR). *(see for example M. Galimberti et al., Rev. Sci. Instrum. 76, 053303 (2005); L. A. Gizzi et al., Phys. Plasmas 10, 4601 (2003);F. Y. Khattak et al., Phys. Rev. E 74, 027401 (2006); L. Labate et al., Appl. Phys A, in press (2006); M. Manclossi et al., Phys. Rev. Lett. 96, 125002 (2006); Ch. Reich et al., Phys. Rev. E 68, 056408 (2003); D. Riley et al., Phys. Rev. E 71, 016406 (2005); M. S. Wei et al. Phys. Rev. E 70, 056412 (2004))*

HiPER will provide the ideal framework in which an integrated diagnostic system dedicated to fast electron propagation can be successfully developed through the combined effort of European groups working in this field. An integrated diagnostic system of this kind is expected to provide unambiguous information on the dynamics of propagation of fast electrons in plasmas that will dramatically improve the understanding of FI physics in dedicated experiments at Large Scale Facilities. A non-exaustive list of SSF that already participating include CNR, IOQ, QUB, U.BICOCCA and RAL, where, remarkably, dedicated access for FI related experiments is already being granted within the HiPER science programme in addition to standard access frameworks.

Optical probing is another example of a robust and unique diagnostic technique for a) characterization of underdense, coronal plasmas and b) study of propagation of intense pulses in plasmas. It also plays a crucial role in detecting beam degradation processes (filamentation, self-focusing, break-up etc ..) in ICF related experiments. Recently, the use of an ultra-short optical pulse as a probe pulse can provide information on propagation and interaction of intense pulses in plasmas with unprecedented temporal and spatial resolution, provided issues like probe transit time and other transient phenomena are unfolded. Moreover, the implementation of probing techniques based upon the use of high order harmonics provides now a significant opportunity of probing higher densities with very high temporal resolution. The understanding of laser-target interaction in the FI-like regime will require a reliable understanding of laser-plasma coupling conditions, starting from propagation in the underdense plasma blow-off originated by pulse pedestal/prepulse. This will be crucial to control energy and quality of the fast electron beam produced during the interaction. All these diagnostic techniques are being developed in SSF including TEI, QUB, CNR and CEA-Saclay. Coordination that will come from HiPER will promote joint work for the design of robust integrated diagnostics for advances optical probing that will be established at the non-implosion target areas planned for fusion and non-fusion science at HiPER. *(F. N. Beg et al., Phys. Plasmas 4, 447 (1997); M.Borghesi et al., Phys. Rev. E 54 , 6769 (1996); S. Dobosz et al., Phys. Rev. Lett. 95, 025001 (2005); D. Giulietti et al., Phys. Plasmas 9, 3655 (2002); L.A. Gizzi et al., Phys. Rev. E (2006); L.A.Gizzi et al. Phys. Rev. E, 49, 5628 (1994); P.Squillacioti et al., Phys. Plasmas 11 226 (2004))*

7.5 Specific actions and tasks

A number of specific actions have been identified to address development of SSF and their integration in the HiPER infrastructure. These actions will involve directly and indirectly a significant number of participating institution and reflect the actual workpakage structure. In fact, workpackages from 3 through 6 will enable execution of those tasks the will address SSF integration. A list of identified tasks and their "host" WPis outlined below.

> *Task a) Integration and Framework coordination*; Expertise "procurement" at a laboratory level; HP lasers, HE astrophysics; magnetic fusion, neutron facilities, HEP/accelerators; (links with **all** WPs from 3 through 6).
>
> *Task b) Smaller Scale Facility Capability development: SSF Networking; Identify existing HiPER-relevant capabilities <u>not supported otherwise</u>;* Diagnostic standardization; Target

Area and targetry development; (link with WP6) - Systematic studies for code benchmarking; (link with WP4)

Task c) Design of experiments at *Large Scale facilities for FI relevant studies: link with large scale facilities (RAL, LULI, PETAL. PHELIX);* Access to non-EU facilities. *Connect to science case to back-up key experiments;* Large Scale Facility Upgrade: PETAL*;* Ensure synchronization between experimental configuration and model requirements. This task generates conditions for ensuring flow of information between different tasks to update information needed for detailed design (*link with* WP6 and 4).

Task d) Interlacing with existing programmes and networking activities – LASERLAB, Marie-Curie training sites, relevant COST actions; - Establish links with access programmes for non-competitive (programmatic) experimental programme; - Distribute information of existing funding opportunities for mobility (short term visits); - Stimulate programmatic activity via targeted workshops and meetings. (links with **all WPs**);