EUROPEAN SCIENCE FOUNDATION

Research Networking Programme

Super-Intense Laser-Matter Interactions (SILMI)

Standing Committee for Physical and Engineering Sciences (PESC)

The availability of super-intense laser pulses and the planned development of new large-scale and medium-size facilities dedicated to the generation of laser radiation with unprecedented capabilities calls for a vigorous effort to study laser-matter interactions in the ultra-high intensity regime. Europe is at the forefront of the scientific and technological advances in this fast-growing and highly competitive domain at the frontier of physics, thanks to its strong commitment in the implementation of new sources of super-intense laser radiation. In addition, Europe plays a leading role in the development of sources of high-order harmonics, which deliver pulses of ultra-violet radiation with durations in the attosecond range.

The Super-Intense Laser-Matter Interactions (SILMI) Research Networking Programme supports a combined effort of leading European research groups to investigate fundamental processes and applications in super-intense laser-matter interactions, ranging from ultra-fast phenomena on the attosecond scale to ultra-strong interactions of matter with petawatt pulses.

The SILMI Programme orients research efforts, coordinates their implementation and promotes the transfer of knowledge between the participating groups. It also allows young European scientists to broaden their training and increase their professional skills by interacting with leading scientists in an international environment.

In addition to dedicated SILMI workshops, conferences and schools, SILMI provides financial support for exchange visits of individual scientists from all participating European countries and for the organisation of workshops and conferences.

The SILMI Programme therefore represents an invaluable opportunity to allow European scientists to discuss new trends in the field of super-intense laser-matter interactions, encompassing theory, experiments and applications.

The running period of the ESF SILMI Research Networking Programme is of five years, from May 2009 to May 2014.

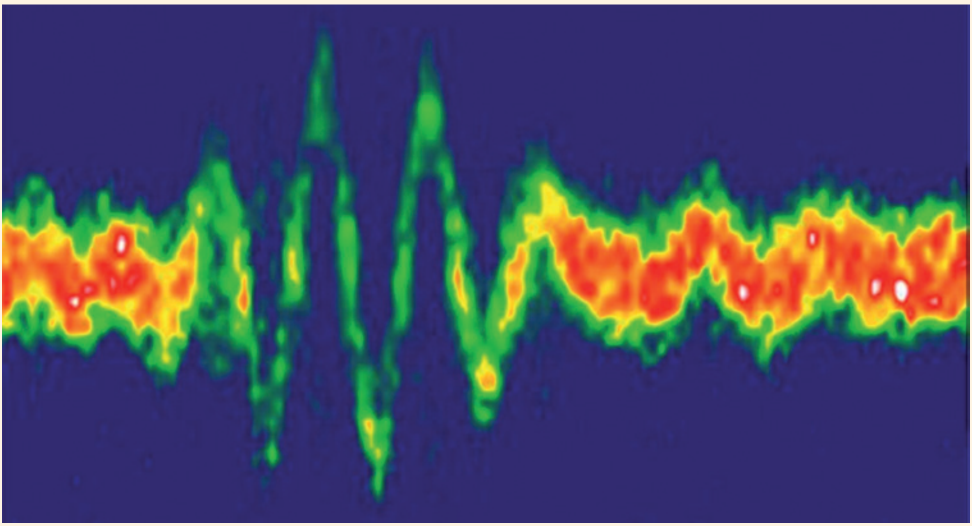
Aims and Objectives

The goal of this Programme is to facilitate exchanges and foster collaborations between the European groups active in the area of super-intense laser-matter interactions, with the aim that the following major objectives be completed by the participants:

1. Super-intense laser-matter interactions at the microscopic level

- To develop a new generation of sources of intense attosecond pulses in order to perform pump-probe experiments at the sub-femtosecond level (see Figure 1).
- To realise the imaging, in real time, of atomic and molecular wave functions in the course of atomic or molecular reactions. The basic idea is to exploit the properties of the electron wave packets that re-collide with the parent atom or molecule after being strongly driven by an infra-red laser field in the process of harmonic generation.
- To control the re-collision process itself for the electron wave packets.
- To understand the mechanisms leading to the enhancements of the plateaus in ATI photoelectron spectra.
- To analyse the dynamics of laser-assisted collisions.
- To control the fragmentation dynamics of laser-driven molecular processes.
- To investigate multiphoton transitions involving inner-shell states and develop new multiphoton spectroscopies in the high frequency domain.
- To create "hollow atoms", through inner-shell multiple ionisation.
- To develop two-colour spectroscopies by combining the femtosecond pulses from both a high-frequency source (XFEL or harmonics) and an IR laser.
- To follow in real time the relaxation of the electronic cloud in inner-shell ionised atoms or molecules.
- To develop a comprehensive theory of the non-linear dynamics of multi-electron systems, taking into account electron

Figure 1. An optical light wave time resolved by an attosecond probe pulse — Courtesy of F. Krausz, MPQ Garching.



correlation effects. This task represents one of the major challenges for theory in the field, given the enormous complexity of *ab-initio* numerical calculations for this class of systems.

- To develop new approaches that properly describe the re-collision of laser-driven electron wave packets with the ionic core in few-cycles laser pulses. This will help to find novel ways to study and control electronic processes in atoms and molecules on attosecond time scales.
- To provide a consistent time-dependent description of the relaxation of the electronic cloud, through Auger-like processes, following inner-shell ionisation.
- To develop new codes for computing angular distributions of the electrons in ATI spectra. This is important in the context of the characterisation of the pulses delivered by the new sources. The existing codes are not precise enough for determining the correct phase-shifts of the continuum wave functions.

2. Super-intense laser-matter interactions at the macroscopic level

- To perform experiments at intensities of 10^{18}–10^{21} W cm^{-2}, fully exploiting existing laser facilities.
- To develop X-ray sources from high intensity laser-matter interactions.
- To understand laser interactions with solids for applications.
- To perform calculations of collisional-radiative processes in plasma and clusters.
- To develop KrF lasers for experiments at 10^{18}–10^{21} W cm^{-2}.
- To develop few-cycle, high-contrast, TW-PW laser pulses using OPCPA.
- To develop plasma-driven particle beams, exploring the bubble regime with few-cycle pulses and developing laser guiding in plasma channels, to achieve GeV energies (see Figure 2).

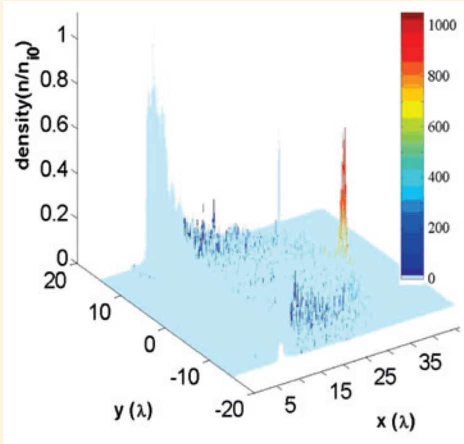


Figure 2. Simulation of a GeV proton beam generated from a solid hydrogen layer when irradiated by a laser pulse of 7×10^{21} W/cm^2 intensity. Colour bar: proton energy in MeV – Yan *et al.*, *Phys. Rev. Lett.* **103**, 135001, 2009.

- To generate high harmonics from solid surfaces by using few-cycle pulses.
- To disturb the vacuum: describing light propagation at intensities near the Schwinger limit and similarities with propagation in ionising media.
- To develop strategies for probing Unruh radiation.
- To study high current transport in compressed matter experiments and perform the corresponding numerical simulations (see Figure 3).
- To analyse laser ablation with short laser pulses and the generation of warm dense matter.
- To investigate the collisional transport in fast ignition simulations and develop the required numerical codes.
- To generate monoenergetic ion beams.

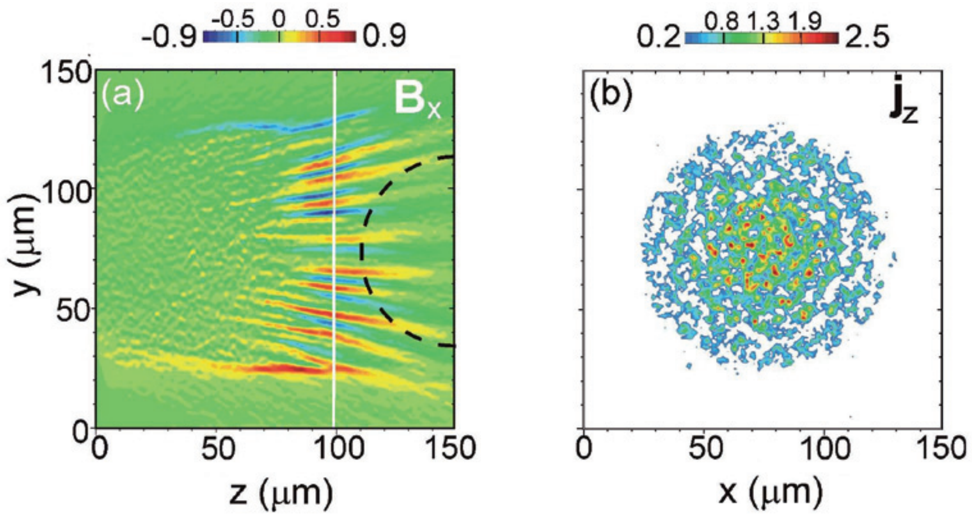
Figure 3. Filamentation of a laser-driven electron beam in the coronal plasma for fast ignition of an inertial confinement fusion target. (a) Magnetic field in kT, longitudinal cut; (b) current density in 10^{14} A/cm^2, transverse cut – Honrubia *et al.*, *Nucl. Fusion* **46**, 25, 2006.

European Context

The study of the interaction of matter with super-intense, ultra-short and high frequency laser pulses is an important new and rapidly expanding branch of physics, where European scientists have made leading contributions in recent years. The potential applications of this research in physics, as well as in chemistry, biology and material science are enormous.

The present programme, involving the leading European experimental and theoretical groups in this field, further develops the existing collaborations between these groups, creates new links and provides expertise for the new European projects (ELI, HiPER and FLASH) under development. It contributes to maintaining the leadership of Europe in this field.

The close collaboration between the groups in this programme builds upon long-standing research links, fully developed since 1999 within the ESF-PESC "FEMTO" programme (1999-2004) and the COST P14 Action "ULTRA" (2004-2008). The SILMI programme builds on the synergy already achieved by the community thanks to many international conferences and workshops organised during recent years. SILMI plans to further support and sponsor these meetings, which bring together leading research groups. Also, SILMI stimulates and supports small or medium-sized pan-European events. With its natural emphasis on interdisciplinarity, the SILMI network establishes links and synchronises its activities with the corresponding programmes of the ESF and of the European Union. The network also works in close collaboration with national research programmes in which members of the Steering Committee are actively involved.



Activities of the Programme

The activities within the programme are organised in four categories as follows:

1. Short research visits to develop collaborations between the teams participating to the programme. These visits allow both young and senior researchers to work within other research groups in the network in order to exchange ideas and foster joint publications.
2. Topical workshops focused on particular themes, where new results are presented and discussed, and joint projects are stimulated.
3. Conferences involving all the scientists in the programme. These conferences allow scientists in the network to keep up with all the research and ensure that cross-fertilisation occurs between the various research areas.
4. Summer schools gathering about 100 participants for a period of two weeks are organised at the Ettore Majorana Centre for Scientific Culture at Erice (Italy). These summer schools allow young researchers to improve their training by learning the most recent advances in the area from the leaders in the field.

Application information

Applications for short research visits grants can be submitted at any time and will be processed within typically 2-4 weeks.

Instructions and application forms can be found on the SILMI website www.esf.org by proceeding as follows: ► Activities ► Research Networking Programmes ► Physical and Engineering Sciences ► Super-Intense Laser-Matter Interactions.

Proposals requesting support for conferences and workshops should be submitted in due time (preferably one year before the event) to allow discussion at a steering committee meeting. Before submitting a full proposal, we recommend informal contact with a member of the SILMI Steering Committee.

Funding

ESF Research Networking Programmes are principally funded by the Foundation's Member Organisations on an *à la carte* basis. SILMI is supported by:

- **Fonds zur Förderung der wissenschaftlichen Forschung in Österreich (FWF)**
  Austrian Science Fund, Austria
- **Fonds de la Recherche Scientifique (FNRS)**
  Fund for Scientific Research, Belgium
- **Akademie věd České republiky (ASCR)**
  Academy of Sciences of the Czech Republic, Czech Republic
- **Grantová agentura České republiky (GAČR)**
  Czech Science Foundation, Czech Republic
- **Det Frie Forskningsråd – Natur og Univers (FNU)**
  The Danish Council for Independent Research – Natural Sciences, Denmark
- **Eesti Teadusfond (ETF)**
  Estonian Science Foundation, Estonia
- **Suomen Akatemia / Finlands Akademi**
  Academy of Finland, Finland
- **Deutsche Forschungsgemeinschaft (DFG)**
  German Research Foundation, Germany
- **Consorzio Nazionale Interuniversitario per le Scienze Fisiche della Materia (CNISM)**
  National Interuniversity Consortium for the Physical Sciences of Matter, Italy
- **Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)**
  Netherlands Organisation for Scientific Research, The Netherlands
- **Norges Forskningsråd**
  Research Council of Norway, Norway
- **Polska Akademia Nauk (PAN)**
  Polish Academy of Sciences, Poland
- **Fundação para a Ciência e a Tecnologia (FCT)**
  Foundation for Science and Technology, Portugal

- **Consiliul National al Cercetarii Stiintifice (CNCS)**
  National Council for Scientific Research, Romania
- **Comisión Interministerial de Ciencia y Tecnología (CICYT)**
  Interministerial Committee on Science and Technology, Spain
- **Vetenskapsrådet (VR)**
  Swedish Research Council, Sweden
- **Schweizerischer Nationalfonds (SNF)**
  Swiss National Science Foundation, Switzerland

SILMI Steering Committee

- **Professor Charles J. Joachain** (Chair)
  Physique Théorique, Faculté des Sciences, Université Libre de Bruxelles, Brussels • Belgium
  Email: cjoacha@ulb.ac.be
- **Professor Dimitri Batani** (Vice-Chair)
  Dipartimento di Fisica “G. Occhialini”, Universita di Milano Bicocca, Milano • Italy
  Email: batani@mib.infn.it
- **Professor Klaus Boller**
  Department of Nanotechnology, Faculty of Science and Technology, University of Twente, Enschede • The Netherlands
  Email: K.J.Boller@tnw.utwente.nl
- **Professor Joachim Burgdörfer**
  Institut für Theoretische Physik, Technische Universität Wien, Vienna • Austria
  Email: burg@concord.itp.tuwien.ac.at
- **Professor Viorica Florescu**
  Faculty of Physics, University of Bucharest, Bucharest • Romania
  Email: vdflor39@yahoo.com
- **Professor Jan Petter Hansen**
  Department of Physics and Technology, University of Bergen, Bergen • Norway
  Email: janpetter.hansen@ift.uib.no
- **Professor Javier Honrubia**
  Departamento Fisica Aplicada, Escuela Tecnica Superior de Ingenieros Aeronauticos, Universidad Politecnica de Madrid, Madrid • Spain
  Email: javier.honrubia@upm.es
- **Professor Ursula Keller**
  ETH Zurich, Physics, Zurich • Switzerland
  Email: keller@phys.ethz.ch
- **Dr Marco Kirm**
  Institute of Physics, University of Tartu, Tartu • Estonia
  Email: Marco.Kirm@ut.ee
- **Professor Jiri Limpouch**
  Faculty of Nuclear Sciences & Physical Engineering, Czech Technical University in Prague, Prague • Czech Republic
  Email: jiri.limpouch@fjfi.cvut.cz

- **Dr Lars Bojer Madsen**
  Department of Physics and Astronomy, Aarhus University, Aarhus • Denmark
  Email: bojer@phys.au.dk
- **Professor José Tito Mendonca**
  Instituto Superior Tecnico, IPFN / Instituto de Plasmas e Fusão Nuclear, Lisbon • Portugal
  Email: titomend@ist.utl.pt
- **Professor Algis Piskarskas**
  Vilnius University, Vilnius • Lithuania
  Email: algis.piskarskas@ff.vu.lt
- **Professor Rainer Salomaa**
  Department of Applied Physics, Aalto University School of Science, Aalto • Finland
  Email: rainer.salomaa@aalto.fi
- **Professor Armin Scrinzi**
  Faculty of Physics, Ludwig Maximilians University, Munich Bavaria • Germany
  Email: armin.scrinzi@lmu.de
- **Professor Claes-Göran Wahlström**
  Department of Physics, Lund University, Lund • Sweden
  Email: claes-goran.wahlstrom@fysik.lth.se
- **Professor Jerzy Wolowski**
  Division of Laser-Produced Plasma, Institute of Plasma Physics and Laser Microfusion, Warsaw • Poland
  Email: jerzy.wolowski@ipplm.pl
- **Professor Arie Zigler**
  Racah Institute of Physics, Hebrew University, Jerusalem • Israel
  Email: zigler@vms.huji.ac.il

ESF Liaison
Dr Thibaut Lery
Science
Ms Carole Mabrouk
Administration

Physical, Engineering and Space Sciences Unit
European Science Foundation
1 quai Lezay-Marnésia
BP 90015 • 67080 Strasbourg cedex
France
Tel: +33 (0)3 88 76 71 69
Fax: +33 (0)3 88 37 05 32
Email: cmabrouk@esf.org

For the latest information on this Research Networking Programme consult the SILMI website:
www.esf.org/silmi

Cover picture:
Generation of an attosecond pulse on a plasma surface. A laser field (broken line) accelerates electrons (dots) to near relativistic velocities and a short burst of XUV radiation (solid line) is emitted.
Courtesy of S. Rykovanov, LMU, Munich

The European Science Foundation (ESF) was established in 1974 to provide a common platform for its Member Organisations to advance European research collaboration and explore new directions for research. It is an independent organisation, owned by 72 Member Organisations, which are research funding organisations, research performing organisations and academies from 30 countries. ESF promotes collaboration in research itself, in funding of research and in science policy activities at the European level.

European Science Foundation
www.esf.org

April 2012 – Print run: 1 000