SCS Workshop
ICTP December, 2010

International Workshop soft X-ray science and instrumentation at the European XFEL

Gerhard Grübel

ICTP, December 16-17, 2010

HELMHOLTZ | ASSOCIATION

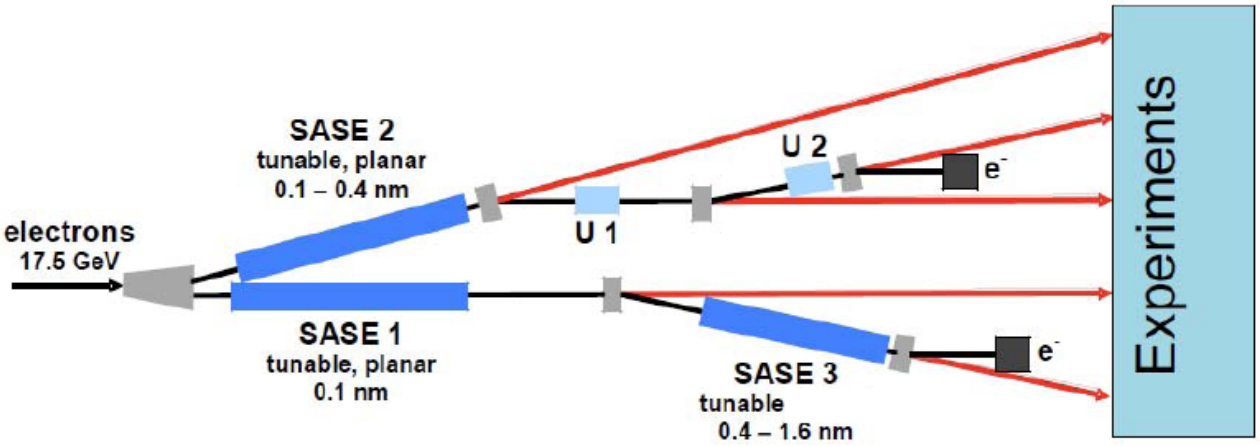
DESY

Soft X-ray science: SASE III

Report of the European Project Team

European XFEL

European XFEL Undulator Layout



Initial configuration: SASE1, SASE2, SASE3 (planar) plus six instruments

SASE III Instruments

European XFEL

Report of the European Project Team

Selection of first instruments

Hard X-rays

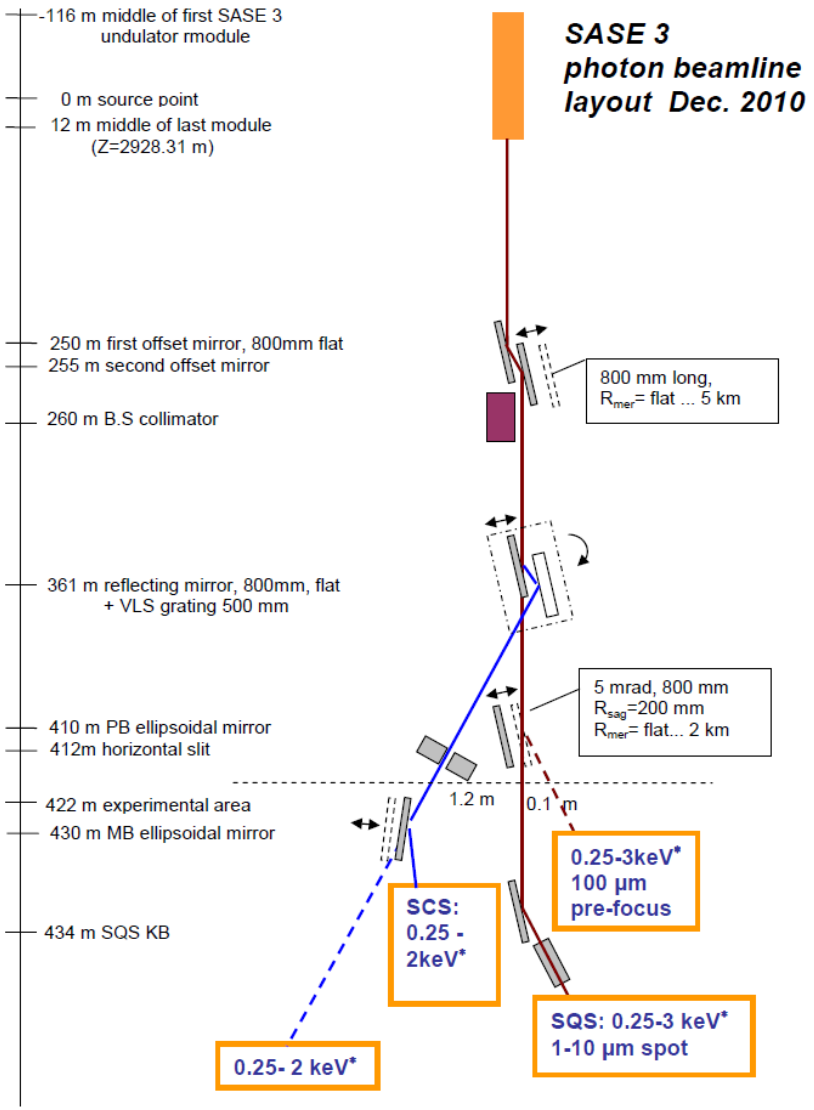
Soft X-rays

Instrument	Brief description of the instrument
SPB	Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules – **Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.**
MID	Materials Imaging & Dynamics –**Structure determination of nano-devices and dynamics at the nanoscale.**
FDE	Femtosecond Diffraction Experiments – **Time-resolved investigations of the dynamics of solids, liquids, gases**
HED	High Energy Density Matter – **Investigation of matter under extreme conditions using hard x-rays, e.g. probing dense plasmas.**
SQS	Small Quantum Systems – **Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena.**
SCS	Spectroscopy and Coherent Scattering –**Structure and dynamics of nano-systems and of non-reproducible biological objects using soft X-rays.**

Massimo Altarelli – European XFEL Project Team Leader

PSI SCS Workshop June 2009

Layout SASE III



December 2010

Agenda

Scientific Motivation: Spectroscopy and Coherent Scattering (SCS)

SCS 3: Imaging, Dynamics & PCS (Magnetic Systems)

(*WG 3: Spin, charge and orbital dynamics in complex materials)*

Ultrafast demagnetization (Beaurepaire ,96)

All optical switching (Kimel/Rasing '07)

Magnetization dynamics in nanostructured materials

Phase separation in correlated materials

Progress since June 2009

Impact on Key Requirements

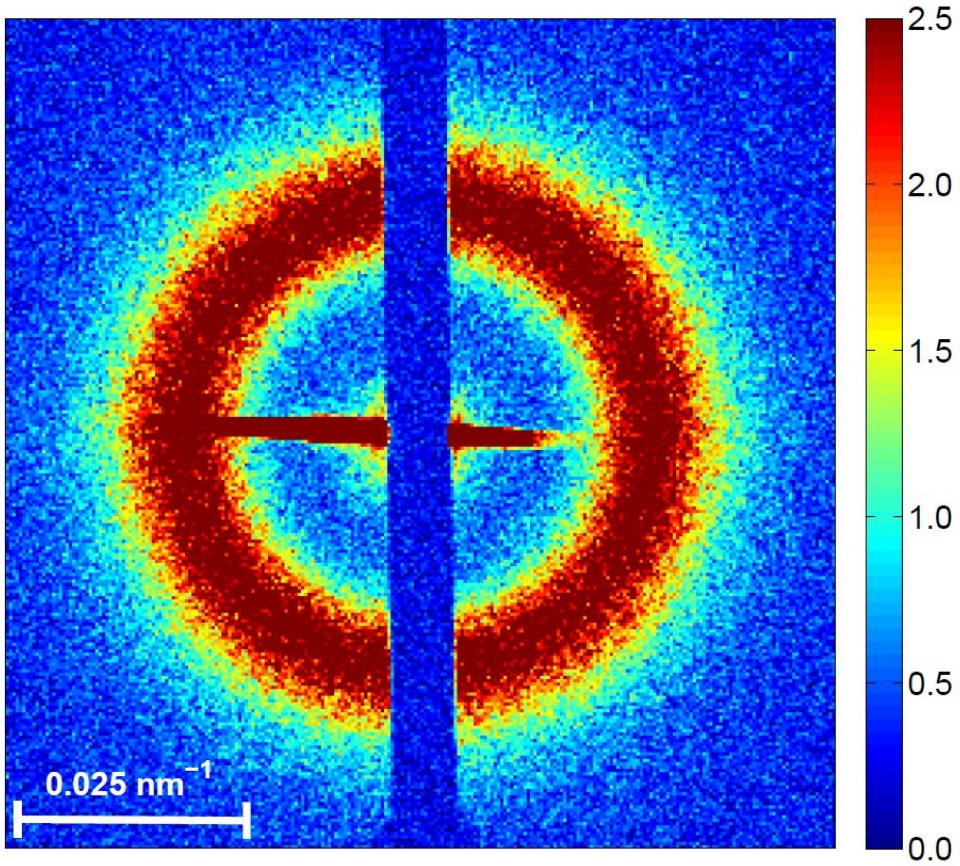
Single shot magnetic SAXS of CoPt multilayer at Co $M_{II/III}$ (FLASH)

λ=20.8 nm (59 eV): Co $M_{2,3}$

30 femtosecond pulse length
(4 μJ/pulse:4x10^{11} ph/pulse)
$\Delta E/E \approx 0.5–1$ %
250 μm beamsize

Single-shot (30 fs) magnetic SAXS pattern.

CoPt multilayer sample is not destroyed!



[Co(0.8nm)/Pt(1.4nm)]$_{16}$ on 50nm Si_3N_4 substrate

2048x2048 13.5μm pixel CCD (40 mm from sample)

C. Gutt et al., Phys. Rev. B 81, 100401(R), (2010)

Since 6/2009:

- Resonant magnetic scattering is feasible at FEL sources
- A “time resolution” of 20-30 fs is available
- Samples are NOT destroyed

  (there are regimes in which single shot patterns can be taken and there appears to be no influence on the magnetic domain structure)
- Optical pump – FEL probe experiments are feasible
- Demagnetization processes can be studied Q resolved !
  - FEL light is coherent
  - Coherence based techniques are applicable: Imaging, XPCS

- Suite of other experiments at FLASH:

  Charge-orbital ordering and Verwey Transition in Magnetite (Fe_3O_4)

  …

- First experiment at LCLS-SXR (L-edges) in 2010

LCLS SXR station

SLAC today

First Soft X-rays Explore Ultrafast Magnetic Behaviors

The first user experiments on the Soft X-ray instrument at the Linac Coherent Light Source wrapped up yesterday. Research led by Andreas Scherz, a physicist at the Stanford Institute for Materials and Energy Science, and Jan Lüning from the University Pierre and Marie Curie in France looked to explain on the nanoscale how magnetic fields switch between "up" and "down" states—a key process used to store data in computers.

Researchers have been investigating this phenomenon since 1996 with a variety of experimental techniques. X-rays have been used to probe magnetic films with a resolution of tens of nanometers, while optical methods have been used to observe ultrafast demagnetization on the macroscale. But examining such magnetic behaviors on the nanoscale remained difficult.

An international collaboration of researchers and students successfully completed the first user experiments on the SXR instrument at LCLS.

- **L-edges available**
- **Resonant magnetic scattering at the Co L3 edge**
- **Fast demagnetization in CoPt ML confirmed**
- **Single shot imaging (@L3) shown**
- **Pulse length dependent resonant effects**

SCS III

Experimental techniques at SCS:

XPCS (k-space):

- **200 ns to 600 µs: movie mode**
- **below: delay line mode**

Imaging (real space): CDI, FTH and others

- **2D mostly**

SCS III

Energy: 450 – 2000 eV

Resolution: ΔE/E = 1e-4 to pink
energy and monochromaticity need to be characterized

Polarization: **circular is a must !**

>90% circular < 1.5 keV: few % stability and/or measured
linear (in any orientation)

Focussing: beamsizes 5-10 microns for imaging ; 20-300 microns for XPCS
access to virgin beam
space for additional optics

Absorber: Gas absorber, solid state absorber in unfocussed beam

Timing: **short pulse needed**
sub 10 fs
pulse length characterization; time(zero) characterization

Coherence: as high as possible
shot-by-shot characterized

SCS III

Split&delay line: time separation 100 fs to nanoseconds. Capturing ultrafast demagnetization and thermalization processes via XPCS – or pump-probe type of experiments

Optical laser: 800 nm, 35-100 fs, fluence at least 100 mJ/cm^2, focus down to 50 microns

Jitter: 20 fs, ensure spatial and temporal overlap, collinear geometry pump-probe

Detector: **XPCS compatible 2-D detector remains unsolved issue**
fast MHz detector for slow domain dynamics (movie mode)
2D pixel detector (20 microns) for delay line mode
(high frame rate, single photon sensitivity, moderate counter depth,..)
2D (200 µm pixel o.k. for imaging, but more than 500 images desired)
moveable detector (x,y some cm, z some 10 cm)
allow for detector distance of up to 10m in SAXS mode
sample translation stage (x,y,z, theta) precision 100 nm

diagnostics: **Shot-to-shot**
intensity and wavefront (coherence)
alignment laser, alignment microscope
beamstop translation stage

SCS III

Sample Environment:

reach Curie temperatures above 1000 K
He-Cryostat
few TESLA vector field
(pulsed magnetic field: electric field)
THz pump (to be evaluated)
UHV sample transfer
goniometer with micron sample positioning and stability
polarization analysis of scattered radiation
provision for roll-in /oll-out endststations

Software:

all-in-one software to read out the detectors and make fast 'on-the-fly', standard coherence analysis of: speckle contrast, speckle sizes, speckle correlations, FTH and CDI-runs
"user" usable data storage/handling and control
"user"usable online analysis

The end