Mid Term Report (Sachbericht)

Fördermaßnahme: Virtuelle Institute	
Förder-Nr.:	VH-VI-302
Titel des Vorhabens:	Femtosecond x-ray science: FLASH imaging of nanoparticles and biosamples
Sprecher der Kollaboration:	Prof. Dr. Thomas Möller
Projektadministration:	Dr. Gerhard Grübel
Federführendes Helmholtz-Zentrum:	Deutsches Elektronen-Synchrotron DESY
Beteiligte Universitäten und andere Partner:	TU Berlin, Uppsala University, Universität Hamburg
Berichtszeitraum:	1.3.2008 bis 31.12.2008

Mit Term Report

a) Progress on the working plan of the proposal

The prime motivation of the project is to explore and develop experimental techniques which allow structure determination and imaging of non-crystalline objects with single femtosecond x-ray pulses.

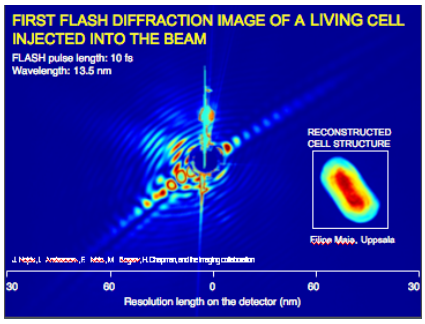
Two work-packages (1+5) deal with FEL pulse diagnostics and the coherence characterization of FEL pulses. In 2008 we attempted a first bunch-by-bunch characterization of the temporal coherence properties of the FLASH Free Electron Laser (FEL) in Hamburg. The study was based on a statistical analysis of static x-ray speckle pattern(s) recorded with single bunches of FEL light. The measurements were performed at the fundamental wavelength of λ = 20.8 nm. The FEL pulses had 20 fs duration with an energy of 2-10 µJ per pulse, focused to a diameter d = 100 µm spot at the sample position. The pulses have almost complete transversal coherence and bandwidth limited longitudinal coherence (bandwidth $\Delta E/E$ = 0.7%). The photons transmitted through the samples were recorded by a soft x-ray CCD camera with a pixel size of 13.5 µm and 2048 x 2048 pixels on the chip. As a sample we used CoPt multilayer samples on a 50 nm thick Si_3N_4 membrane as model system.

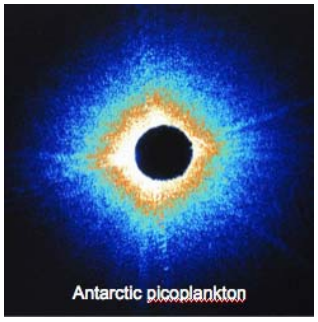
We recorded non-destructively 20 magnetic speckle patterns of the same sample, allowing us to compare the speckle images. A speckle contrast analysis versus q revealed an energy bandpass of $\Delta E/E$ = 1.2% or $\Delta E/E$ = 0.4% for a d=50um beam. The theoretical energy resolution for FLASH is $\Delta E/E$ = 0.7%. The results thus indicate a pulse-by-pulse fluctuation of the energy bandpass $\Delta E/E$.

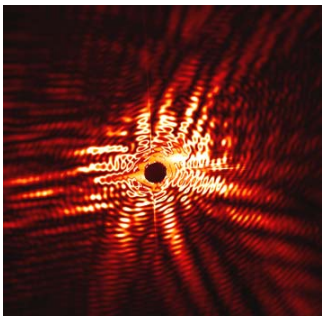
The team from the TU Berlin has started to work on the workpackages 2 and 4. For workpackage 2 a new optics concept for pump-probe experiments was developped allowing these type of experiments at different harmonics of the FLASH machine. In addition novel concept were developped within workpackage 4 for time-resolved experiments. Several components (mirrors, detectors, etc., ..) were tested in fall 2008 at FLASH.

The workpackage 3 deals with high-resolution imaging of picoplankton. The team has successfully injected picoplankton and other cells into the FEL beam under conditions where they were alive. The quality of the diffraction patterns permits reconstruction, and the reconstructed images show no signs of damage (work in progress, manuscripts in perparation). We intend to drive these experiments to near atomic resolutions when short wavelength FEL

pulses become available. Picoplankton samples used in the present studies came from fresh water lakes and from the Arctic and Antarctic Polar Oceans where we have a research







programme on photosynthetic carbon fixation by picoplankton.

First results from workpages 3: High-resolution imaging of picoplankton.

The goal of workpackage 6 is to explore the possibilities to manipulate (by optical means) nanoscale materials under vacuum conditions with the ultimate goal to position samples in the FEL beam. This novel approach needs to identify suited prototype nano- system that in fact will allow optical manipulation with a suited laser source. The original approach of using carbon nanotubes had to be abandonned since i) there is a lack of reliable spectroscopic data in the literature and ii) there is no local experise in preparation and characterization of these systems. It was rather decided in collaboration with Prof. Hajdu from the Uppsala group to launch a project involving the transport of bacteria systems with optical means. The Uppsala group masters the preparation of the bacteria samples under vacuum conditions. A NdYAG fiber laser system was identfied as the most suited lightsource to manipulate the samples and this system will be purchased in 2009. A compatible vacuum chamber is under design, will be manufactured, tested and commissioned in 2009.

b) Archieved milestones

- Experimental bunch-by-bunch characterization of the longitudinal coherence length. The analysis of the data is ongoing.
- A two color multilayer mirror for time resoved experiments was successfully tested.
- First injection of picoplankton and other cells into the FEL beam under conditions where they were alive.
- Conceptual design of a laser-and vacuum sytem for workpackage 6.

c) Adherence to the time and financial plan

- The finance and time plan was kept.
- Funds for workpackage 6 will be spent in 2009, since a very intense planning phase was necessary.
- The funds for workpackage 3 (comprising a 130 kEuro laser dissection and particle trapping unit and a 68 kEuro fluorescence microscope) have been re-allocated towards a mobile container laboratory and its equipment since the originally foreseen items had become available in the meantime at FLASH financed from other resources. This re-allocation will serve not only workpackage 3 but the whole VI.

d) Publications, Talks

The following talks and publications originated from the work at FLASH:

Magnetic Imaging of Co/Pt Multilayers and Co/Pt Nanostructures by X-Ray Holography,
XRMS-2008, Hamburg, 2/2008, Simone Streit-Nierobisch (invited)

Magnetic Imaging of Nanostructured Co/Pt Multilayers by X-Ray Holography,
404. Heraeus-Seminar, Bad Honnef, 3/2008, Simone Streit-Nierobisch (invited)

Ultrafast Resonant X-Ray Scattering - Interaction of Free-Electron Laser Pulses with Magnetic Multilayers,
XRMS-2009, Paris, 1/2009, Simone Streit-Nierobisch (Poster)

Resonant magnetic scattering with femtosecond soft X-ray pulses from a free electron laser at 1.59 nm
C. Gutt, l.-M. Stadler, S. Streit-Nierobisch, A.P. Mancuso, A. Schropp, B. Pfau, C.M. Günther, R. Könnecke, J. Gulden, B. Reime, J. Feldhaus, E. Weckert,I.A. Vartaniants, O. Hellwig, F. Staier, R. Barth, M. Grunze, A. Rosenhahn, D. Stickler,H. Stillrich, R. Frömter, H.P. Oepen, M. Martins, T, Nisius, T. Wilhein, B. Faatz,N. Guerassimova, K. Honkavaara, V. Kocharyan, R. Treusch, E. Saldin, S. Schreiber, E.A. Schneidmiller, M.V. Yurkov, S. Eisebitt and G. Grübel,
NJP, submitted

Nanoplasma formation and neutralization soft X-ray irradiated clusters
M. Hoener, C. Bostedt, H. Thomas. E. Eremina, T. Fennel, K.H. Meiwes-Broer, M. Kuhlmann, E. Plönjes, K. Tiedtke, R. Treusch, J. Feldhaus, A.R.B. de Castro, T. Möller,
J. Phys. B 41, 181001 (2008)

Numerical simulation of small angle scattering (SAXS) for large atomic clusters
A.R.B. de Castro, C. Bostedt, E. Eremina, M. Hoener, H. Thomas, T. Möller
J. Ele. Spectr. Rel. Phen. 166–167, 21–27 (2008)

Multi-Step Ionisation of Argon Clusters in intense femtosecond XUV pulses
C. Bostedt, H. Thomas. M. Hoener, E. Eremina, T. Fennel, K.H. Meiwes-Broer, M. Kuhlmann, E. Plönjes, K. Tiedtke, R. Treusch, J. Feldhaus, A.R.B. de Castro, T. Möller
Phys. Rev. Letters 100, 133401 (2008)

Femtosecond non-equilibrium dynamics of clusters irradiated with short intense VUV pulses
B. Ziaja, H. Wabnitz, E. Weckert, T. Möller
New J. Phys. 10, 43003 (2008)

Atomic clusters of various sizes irradiated with short intense VUV pulses
B. Ziaja, H. Wabnitz, E. Weckert, T. Möller
Euro. Phys. Letters 82, 24002 (2008)

Experiments at FLASH
C. Bostedt, H. N. Chapman, J. R. Crespo López-Urrutia, S. W. Epp, J. Feldhaus, A. Föhlisch, M. Meyer, T. Möller, R. Moshammer, M. Richter, K. Sokolowski-Tinten, A. A. Sorokin, K. Tiedtke, J. Ullrich and W. Wurth;
Nucl. Instr. Meth. A, 601, 18 (2009)

Femtosecond time-delay X-ray holography
Henry N. Chapman, Stefan P. Hau-Riege, Michael J. Bogan, Sasa Bajt, Anton Barty, Sebastien Boutet, Stefano Marchesini, Matthias Frank, Bruce W. Woods, W. Henry Benner, Richard A. London, Urs Rohner, Abraham Szöke, Eberhard Spiller, Thomas Möller,

Christoph Bostedt, David A. Shapiro, Marion Kuhlmann, Rolf Treusch, Elke Plönjes, Florian Burmeister, Magnus Bergh, Carl Caleman, Gösta Huldt, M. Marvin Seibert, Janos Hajdu
Nature 448, 676 (2007)

Massively parallel X-ray holography
Stefano Marchesini, Sebastien Boutet, Anne E. Sakdinawat, Michael J. Bogan, Sasa Bajt, Anton Barty, Henry N. Chapman, Matthias Frank, Stefan P. Hau-Riege, Abraham Szöke, Congwu Cui, David A. Shapiro, Malcolm R. Howells, John C. H. Spence, Joshua W. Shaevitz, Joanna Y. Lee, Janos Hajdu, Marvin M. Seibert
Nature Photonics, 2, 560 (2008)

Single Particle X-ray Diffractive Imaging
Michael J. Bogan, W. Henry Benner, Sébastien Boutet, Urs Rohner, Matthias Frank, Anton Barty, M. Marvin Seibert, Filipe Maia,Stefano Marchesini, Saša Bajt, Bruce Woods, Vincent Riot, Stefan P. Hau-Riege, Martin Svenda, Erik Marklund, Eberhard Spiller, Janos Hajdu, and Henry N. Chapman
NanoLetters, 8, 310, (2008).