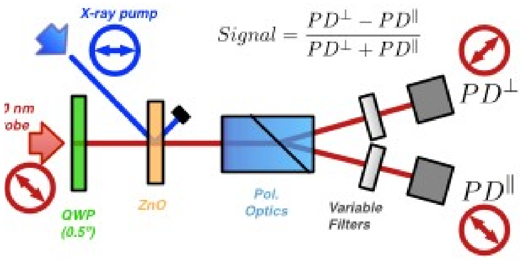

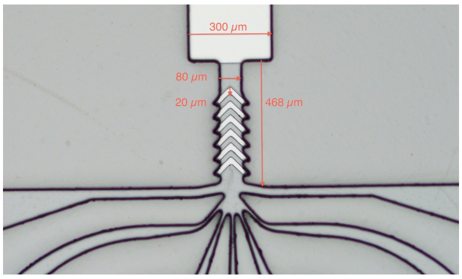

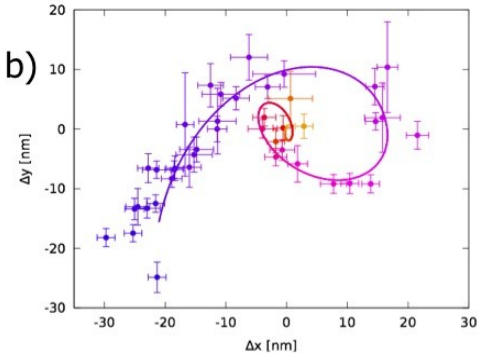

SLS Symposium on

Dynamics

Tuesday, December 2, 2014

10:00 to 11:45, WBGB/019

10:00 Novel X-ray Streaking Technique for Single-shot Investigations of Ultrafast Magnetisation Dynamics at FELs
Michele Buzzi, M. Makita, A. Kleibert, B. Vodungbo, N. Jaouen, J. Perron, L. Howald, P. Zeitoun, J. Raabe, K. Tiedtke , H. Redlin, C. David, F. Nolting and J. Lüning

10:30 X-ray induced ultrafast transient anisotropy in ZnO
Andrés Ferrer, J. Johnson, T. Huber, S.M. Oddsson, C. Milne, P. Beaud and S.L. Johnson

11:00 Coffee

11:15 Magnetic Skyrmions: Statics and Dynamics
Christoforos Moutafis, F. Büttner, B. Krüger, C.A.F. Vaz, C. Moreau-Luchaire, N. Reyren, J. Sampaio, P. Warnicke, P. Wohlhüter, N. Van Horne, M. Weigand, J.H. Franken, R. Lavrijsen, H.J.M. Swagten, M. Kläui, S. Eisebitt, V. Cros, A. Fert and J. Raabe

~~**11:45 *Time-resolved SAXS experiments at the cSAXS beamline***~~
~~*Ivan Rajkovic and A. Menzel*~~

Novel X-ray Streaking Technique for Single-shot Investigations of Ultrafast Magnetisation Dynamics at FELs

Michele Buzzi[a], Mikako Makita[a], Armin Kleibert[a], Boris Vodungbo[b,c], Nicolas Jaouen[d], Jonatan Perron[b], Ludovic Howald[a], Philippe Zeitoun[c], Jörg Raabe[a], Kai Tiedtke[e], Harald Redlin[e], Christian David[a], Frithjof Nolting[a] and Jan Lüning[b,c,d]

[a] Paul Scherrer Institut, Villigen, Switzerland

[b] Sorbonne Universités, UPMC Univ Paris 06, UMR 7614, LCPMR, 75005 Paris, France CNRS, UMR 7614, LCPMR, 75005 Paris, France

[c] Laboratoire d'Optique Appliquée, ENSTA ParisTech - CNRS UMR 7639 - École Polytechnique, Chemin de la Hunière, 91761 Palaiseau, France

[d] Synchrotron SOLEIL, L'Orme des Merisiers, Saint-Aubin, BP 48, 91192 Gif-sur-Yvette Cedex, France

[e] Deutsches Elektronen-Synchrotron DESY, Notkestrasse 85, 22603 Hamburg, Germany

Understanding what processes are at the origin of laser-induced ultrafast magnetisation dynamics is an intensively discussed topic of both scientific and technological interest. In this work, we present a novel experimental approach that allows following with a single, intense X-ray pulse of an XFEL, the temporal evolution of laser-induced magnetisation dynamics. To do so, we employ an off-axis grating to introduce a pulse-front tilt and to focus the probe pulse on the area of the sample excited by the near-infrared pump pulse. Transverse Magneto Optical Kerr Effect at the $M_{2,3}$ edges of 3d-metals is used to probe the time evolution of the magnetisation. As a result, the time axis is encoded on a spatial coordinate on the CCD detector that collects the beam reflected off the sample. For the parameters used in our experiments, the accessible time window is about 1.5 ps.

In this presentation we will discuss the concept of this novel technique which enables resolving, with unprecedented sensitivity, time constants and eventual delays of the early dynamics as well as probing the eventual presence of non-deterministic processes. After presenting the results from our first experiments at FLASH, we will conclude with an overview of other scientific domains where we would expect this novel experimental technique to have an impact in the future.

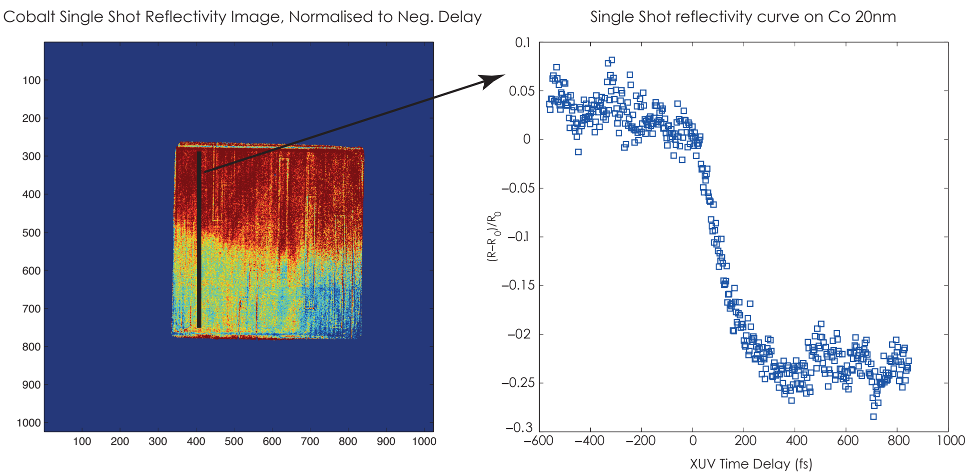

Figure 1: (left) Reflectivity map recorded on a cobalt thin layer using a single FLASH pulse. The FEL was operating at 60eV. (right) Line scan extracted from the reflectivity map showing the evolution of the reflectivity of the sample over the first 1.5ps around the IR excitation pulse.

X-ray induced ultrafast transient anisotropy in ZnO

<u>Andrés Ferrer</u>,[a,b] **Jeremy Johnson**[b], **Tim Huber**[a], **Simon M. Oddsson**[b], **C. Milne**[b], **Paul Beaud**[b] **and Steven L. Johnson**[a]

[a] *Institute for Quantum Electronics, Physics Department, ETH Zurich, CH-8093 Zurich, Switzerland*
[b] *Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland*

E-mail: andres.ferrer@psi.ch -or- aferrer@phys.ethz.ch

With the advent of new x-ray sources such as XFELs, x-ray science is entering a new regime where nonlinear interaction of x-rays with matter becomes potentially important [1]. Although this is a completely new field, some work has been already done in simple gases [2,3]. We have chosen ZnO as a test system to study the nonlinear interactions of hard x-rays with solids. We have performed a hard x-ray pump / optical probe experiment aiming to excite a coherent phonon mode via Impulsive Stimulated Raman Scattering. The detection setup was set as a standard Optical-Heterodyne-Detected Optical-Kerr-Effect experiment (OHD-OKE, see inset of Figure 1). The retrieved data (Figure 1) shows a new ultrafast anisotropic response at high x-ray pump intensities whose origin is not yet totally clear. The initial (near time-zero) and late (near 2-3 ps) anisotropy signals will be discussed and compared to all-optical data.

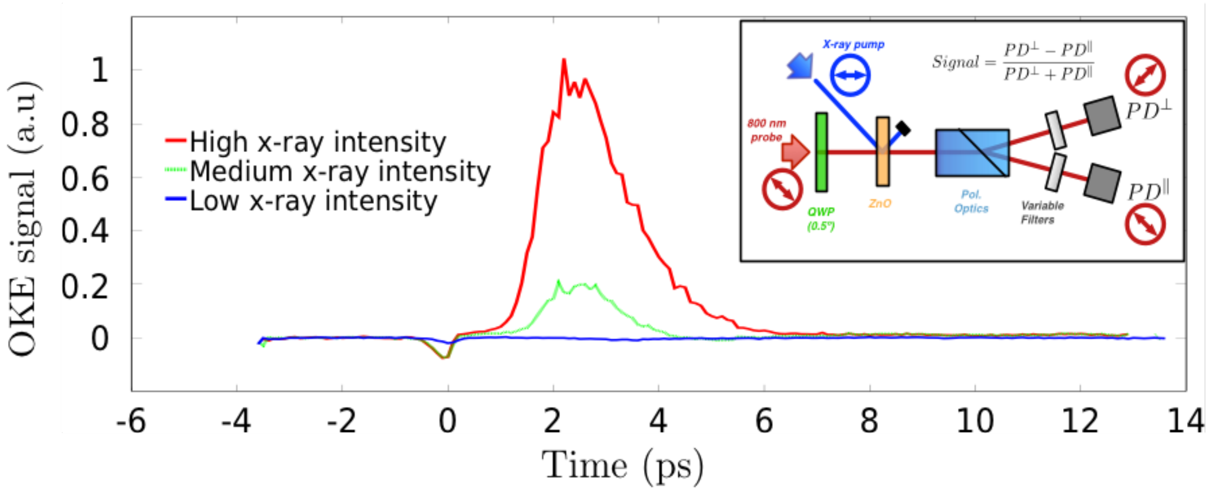

Figure 1. Symmetry breaking in ZnO 2 ps after hard x-ray excitation as shown by the OKE signal retrieved at 800 nm for increasing hard x-ray pump intensities. The inset shows a schematic of the experimental setup.

References:

[1] B. Adams, Nature Physics 7, 675 (2011).

[2] T. E. Glover, M. P. Hertlein, S. H. Southworth, T. K. Allison, J. van Tilborg, E. P. Kanter, B. Krässig, H. R. Varma, B. Rude, R. Santra, A. Belkacem, and L. Young, Nature Physics 6, 69 (2009).

[3] Y.-P. Sun, J.-C. Liu, C.-K. Wang, and F. Gel'mukhanov, Phys Rev A 81, 013812 (2010).

Magnetic Skyrmions: Statics and Dynamics

Christoforos Moutafis[1], F. Büttner[2,3], B. Krüger[2], C.A.F. Vaz[1], C. Moreau-Luchaire[4], N. Reyren[4], J. Sampaio[4], P. Warnicke[1], P. Wohlhüter[1], N. Van Horne[4], M. Weigand[5], J.H. Franken[7], R. Lavrijsen[7], H.J.M. Swagten[7], M. Kläui[2], S. Eisebitt[3,6], V. Cros[4], A. Fert[4], J. Raabe[1]

1. Paul Scherrer Institut, Villigen, Switzerland. 2. Johannes Gutenberg Universität Mainz, Germany.3. Institut für Optik and Atomare Physik, Technische Universität Berlin, Germany. 4. Unité Mixte de Physique CNRS/ Thales and Université Paris-Sud, France. 5. Max Planck Institute for Intelligent Systems, Stuttgart, Germany. 6. Helmholtz Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany. 7. Center for NanoMaterials, Eindhoven University of Technology, Netherlands.

christoforos.moutafis@psi.ch

Magnetic skyrmions are topologically protected particle-like spin structures, with a topology characterised by their Skyrmion number. They can arise due to the interplay of various interactions, including exchange, dipolar and anisotropy energy in the case of magnetic bubbles and an additional Dzyaloshinskii-Moriya interaction (DMi) in the case of chiral Skyrmions. Numerical predictions suggest that they exhibit rich dynamical behaviour governed by their topology, such as the basic gyrotropic and breathing eigenmodes [1,2]. While recent advances have brought the static manipulation of skyrmions under control, their dynamical behaviour is largely unexplored experimentally. We provide here the first observation of the basic eigenmode dynamics of skyrmion bubbles. In particular, we present picosecond nanoscale imaging data i) of the gyrotropic mode of a single skyrmion bubble in the gigahertz regime (Fig. 1) and ii) the breathing-like behaviour of a pair of skyrmionic configurations, confined in nanostructures comprised of symmetric CoB/Pt multilayers. The observed dynamical behaviour is used to confirm the skyrmion topology and show the existence of an unexpectedly large inertia that is key for describing skyrmion dynamics. These results demonstrate new ways for experimentally observing skyrmion dynamics and provide a framework for describing their behaviour. Furthermore, the results reveal a link between the dynamical behaviour of skyrmions and their distinct topology, with possible ramifications for Skyrmions research including recently proposed technological applications [3]. As a next step, our aim was to stabilise chiral skyrmions in nanostructures at room temperature. We used asymmetric layers (Co layers sandwiched in-between 5d-metal layers) to tune both of the effects that are necessary for the presence of chiral skyrmions: i) the DMi amplitude [4] and ii) the perpendicular magnetic anisotropy [1]. By systematically investigating the size of magnetic domains in magnetic field cycles, and comparing to micromagnetic simulations, we show that we can engineer multilayers with a finite DMi amplitude. Our goal is to demonstrate chiral skyrmions confined in such nanostructures and integrate them in novel spintronics devices [3].

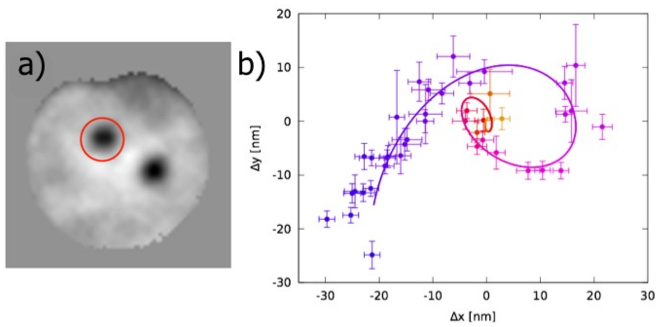

Fig. 1: A CoB/Pt dot (550 nm diameter) in a multi-bubble state. b) The gyrotropic trajectory of the investigated bubble (outlined by a red circle in a)).

References:

[1] C. Moutafis, S. Komineas, J. A. C. Bland, Phys. Rev. B 79, 224429 (2009).
[2] N. Nagaosa, & Y. Tokura, Nat. Nanotech. 8, 899–911 (2013).
[3] A. Fert, A., Cros, V. & Sampaio, Nat. Nanotech. 8, 152–156 (2013).
[4] S. Pizzini et al, arXiv:1403.4694 (2014).