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Single shot time resolved XMCD experiment at Free Electron Laser

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With the advent of X-ray Free Electron Lasers (XFELs) femtosecond time resolved experiments employing advanced X-ray probe techniques have become routinely possible in a wide variety of scientific domains. A significant number of these experiments concerns the relaxation dynamics following an externally supplied excitation, which is typically realized by an electromagnetic pump pulse originating from a femtosecond IR laser pulse. In general, repetitive pump-probe cycles are required for different delay values to assemble the overall time trace of the relaxation dynamics. In consequence, identical experimental conditions have to be re-established for each pump-probe cycle, a necessity which may be compromised due to practical aspects like the preparation of a sample's initial state, the realization of identical pump parameters or the presence of a temporal jitter between pump and probe pulses. A fundamental restriction concerns the reproducibility of the process itself, which limits the application of pump-probe techniques to the investigation of the reproducible component of ultrafast dynamics.

To overcome this limitation we have conceived a novel experimental approach, which allows continuous probing of a relaxation process with a single X-ray pulse. For this we employ a Fresnel zone plate to stretch an incoming X-ray pulse while introducing at the same time an angular encoding of the arrival time of the X-rays. In recent experiments realized at FLASH we have demonstrated the feasibility of this technique by following with a single X-ray pulse the laser induced demagnetization dynamics [Buzzi17] thanks to transverse magneto-optic Kerr effect.

In order to extend this technique to the pump-probe spectroscopy field, we have performed this single shot x-ray streaking experiment in a transmission geometry at FERMI through a magnetic thin film. Our results show that we are sensitive in one single shot to XMCD signal variation smaller than 1 %. This opens the path for single shot time resolved spectroscopy study. Furthermore, the systematic study of the dynamics of CoDy alloy with different composition and pump intensities shows that the demagnetization time does not depend on the pump fluence but only on the sample composition. This indicates that the ultrafast demagnetization depends only on the sample magnetic properties and not on the temperature rise induced by the pump, at least in the linear demagnetization regime.

Primary authors: JAL, Emmanuelle (Sorbonne Université - LCPMR - 4 place Jussieu 75005 Paris, France); Prof. LÜNING, Jan (Sorbonne Université - LCPMR - 4 place Jussieu 75005 Paris, France); Dr CAPOTONDI, Flavio (Elettra Sincrotrone Trieste S.C.p.A., Strada Statale 14, KM 163.5, 34012 Basovizza, TS, Italy); Dr PEDERSOLI, Emanuele (Elettra Sincrotrone Trieste S.C.p.A., Strada Statale 14, KM 163.5, 34012 Basovizza, TS, Italy); MAKITA, Mikako (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland); RÖSNER, Benedikt (Paul Scherrer Institut); JAOUEN, Nicolas (Synchrotron SOLEIL, Saint-Aubin, 91192 Gif-sur-Yvette Cedex, France); LIU, Xuan (Sorbonne Université - LCPMR - 4 place Jussieu 75005 Paris, France); HOWALD, Ludovic (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland); KLEIBERT, Amin (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland); RAABE, Jörg (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland); SAVCHENKO, Tatiana (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland); VODUNGBO, Boris (Sorbonne Université - LCPMR - 4 place Jussieu 75005 Paris, France); DAVID, Christian (PSI Villingen); Prof. NOLTING, Frithjof (Paul Scherrer Institut, 5232 Villigen PSI, Switzerland)

Presenter: JAL, Emmanuelle (Sorbonne Université - LCPMR - 4 place Jussieu 75005 Paris, France)

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