Probing structural and magnetic ultrafast dynamic profiles by time resolved X-ray Resonant Magnetic Reflectivity

Valentin Chardonnet,[a,*] Marcel Hennes,[a] Romain Jarrier,[a] Renaud Delaunay,[a] Nicolas Jaouen,[b] Marion Kuhlmann,[c] Nagitha Ekanayake,[c] Cyril Leveillé,[b] Clemens von Korff Schmising,[d] Daniel Schick,[d] Kelvin Yao,[d] Xuan Liu,[b] Gheorghe S. Chiuzbăian,[a] Jan Lüning,[e] Boris Vodungbo,[a] and Emmanuelle Jal[a]

(a) Sorbonne Université, CNRS, Laboratoire de Chimie Physique–Matière et Rayonnement, 75005 Paris,France
(b) Synchrotron SOLEIL, L'Orme des Merisiers, Saint-Aubin, B.P. 48, 91192 Gif-sur-Yvette, France
(c) Deutsches Elektronen-Synchrotron, 22607 Hamburg, Germany
(d) Max Born Institut für Nichtlineare Optik und Kurzzeitspektroskopie, 12489 Berlin, Germany
(e) Helmholtz-Zentrum Berlin für Materialien und Energie, 14109 Berlin, Germany

* email : valentin.chardonnet@sorbonne-universite.fr

Despite more than two decades of research on ultrafast magnetism dynamics, we are still struggling to get a complete picture of the microscopic mechanism driving ultrafast demagnetization. Among all the models existing, we can focus on two: Elliott-Yafet spin-flip scattering mechanism [1] or the superdiffusive spin transport model [2]. Elliott-Yafet spin-flip scattering will reduce the magnetization locally. Its magnetization depth profile will depend directly on the excitation depth profile [3]. While the superdiffusive spin transport model is a non-local process able to transport spin current in non-magnetic metal [2]. Thus the demagnetization depth profile predicted by these two models is different [3]. To distinguish one of both models or a combination of both, the transient magnetization depth profile has to be known and measured.

The X-Ray Resonant Magnetic Reflectivity (XRMR) is one of the few techniques to study the magnetization depth profile. It is a non-destructive probing technique with a sub-nanometer precision, which combines the layer profile as well as the magnetic depth profile of a specific element [4]. Combined with the femtoslicing source at BESSY2, this technique showed that the time-resolved XRMR (tr-XRMR) experiment can be used to measure simultaneously transient magnetization and structural dynamics. However, this study shows that to access a depth-resolved magnetization profile, higher photon flux and/or energy resolution are needed [5].

The only way to get a sub-picosecond photon pulse with more flux is to use a Free Electron Laser (FEL). Here we present the first tr-XRMR experiment which has been performed at an XFEL, namely FLASH 2 in Hamburg. In order to perform this tr-XRMR experiment we have developed our own reflectometer and we have used the third-order radiation of FLASH 2 to reach the Fe L-edge. In the first part, I will present the technical specificities and the performances of our tr-XRMR experiment. In the second part, I will explain how our results allow us to measure simultaneously the transient depth profile of the magnetization and structure. I will show that there are two dynamics on different time scales. In the first time, we observe a non-homogeneous loss of magnetization and suggest an evolution of the transient magnetic profile. Then in a second time, the demagnetization is followed by a significant dilation of 2 Å of the layer thickness followed by oscillations.

References

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