Ultrafast dynamics studied by time-resolved x-ray diffraction

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Control of magnetic states by optical excitations in magnetically ordered materials has attracted considerable attention since the demonstration of ultrafast demagnetization in Ni within 1 ps, explored by time-resolved magneto optical Kerr effect studies 1). For this study, we chose time-resolved x-ray measurements to study ultrafast spin dynamics in transition-metal oxides.

X-rays from synchrotron radiation (SR) have time structures related to the SR pulse width of several 10 ps. X-ray free electron laser (XFEL) creates intense ultra-short (fs) x-ray pulses, enabling much more detailed study of the dynamics of the materials. We performed a time-resolved x-ray diffraction and scattering study in a pump-probe setup by using XFEL in LCLS (USA) and by using SR in BESSY (Germany). The pump light is Ti:sapphire laser (800 nm), and the probe is XFEL or SR.

Figure 1 (a) shows the time evolution of the intensity of the superlattice re ection (2 1/2 0) in charge and orbital ordered $Pr_{0.5}Ca_{0.5}MnO_3$ thin films 2). One can see clear oscillations, which correspond to the frequency of coherent phonons. Figure 1 (b) shows the time-resolved x-ray magnetic circular dichroism (XMCD) intensity in ferromagnetic $BaFeO_3$ thin films, showing rather slow demagnetization of ~ 100 ps 3), but this time scale was much faster in higher-fluence regions, suggesting photoinduced insulator-metal transitions.

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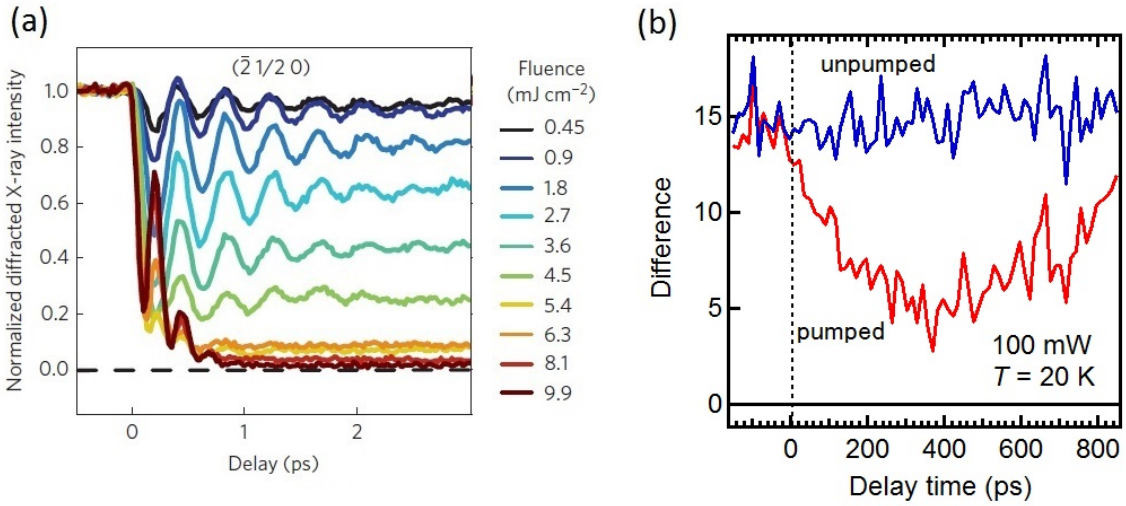

Figure 1: (a) Time evolution of the normalized diffracted x-ray intensity for the (2 1/2 0) reflection in $Pr_{0.5}Ca_{0.5}MnO_3$ thin films taken at 6.53 keV (off resonance). This superlattice peak is sensitive to the structural atomic motion. (b) Time evolution of the XMCD intensity in $BaFeO_3$ thin films taken at 710 eV (Fe $2p_{3/2}$ edge).

Reference

1) E. Beaurepaire *et al.*, Phys. Rev. Lett. **76**, 4250 (1996).
2) P. Beaud, H. Wadati *et al.*, Nat. Mater. **13**, 923 (2014).
3) T. Tsuyama, H. Wadati *et al.*, arXiv:1511.03365v1.