X-ray techniques: synchrotron, FEL, HHG

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In this lecture I will introduce how femtosecond pulsed X-ray sources have been employed to study ultrafast magnetization dynamics. Relevant experimental results and the respectively employed techniques will be introduced and novel experimental schemes, currently implemented or envisioned, will be discussed.

Lecture topics:

1. Introduction
    a. X-ray related interactions with the sample
    b. X-ray optics
    c. …
2. Synchrotron based techniques
    a. Types of X-ray sources
    b. XMCD
        i. Element specificity
        ii. Sum rules
        iii. MTXM
        iv. X-PEEM
    c. X-ray diffraction
    d. Linear magnetic dichroism
    e. …
3. Free electron lasers
    a. Recent development
    b. ...
4. High-harmonic-generation X-ray sources
    a. Principle
    b. State of the art
    c. …

Recommended reading:

[1] E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996).
[2] C. Stamm et al., Nature Materials 6, 740 (2007).
[3] B. Vodungbo et al., Nature Communications 3, 999 (2012).

Since the discovery of the ultrafast demagnetization phenomenon in 1996 [1], the field of femtomagnetism has developed to an active research area. Initial experiments relied mostly on all-optical pump-probe techniques, which raised concerns about optical artifacts affecting the measurement. Since these limitations can be overcome by X-ray based techniques, the advent of sources providing femtosecond short X-ray pulses was awaited for by the interested community. In addition to accessing the complete electronic structure, X-ray techniques offer additional advantages: their shorter wavelength matches naturally the nanometer length scales expected to be of relevance in ultrafast magnetization dynamics; X-ray techniques provide via the accessible core electron absorption resonances element sensitivity and offer a wide variety of magnetic dichroism effects. This allows probing of the magnetization dynamics of individual components of complex, heterogeneous materials on the nanometer length scale.

These expectations were indeed fulfilled already by the first experiments realized at the femtosecond pulsed tunable X-ray sources emerging since the mid 2000's, i.e., the BESSY femtoslicing facility (e.g., [2]) and HHG sources (e.g., [3]). With the recent advent of X-ray free electron lasers (XFELs) emitting in the XUV and soft X-ray photon energy range, unprecedented experimental capabilities became available.

In this lecture I will introduce how femtosecond pulsed X-ray sources have been employed to study ultrafast magnetization dynamics. Relevant experimental results and the respectively employed techniques will be introduced and novel experimental schemes, currently implemented or envisioned, will be discussed.