Probing Ultrafast Optical Demagnetization with an HHG Source

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Studying Ultrafast Optical Demagnetization

Motivation
Ultrafast Optical Demagnetization Discovery

Article by Beaurepaire et al. in Physical Review Letters, 1996.

Ultrafast Spin Dynamics in Ferromagnetic Nickel

E. Beaurepaire, J.-C. Merle, A. Daunois, and J.-Y. Bigot
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(Received 17 October 1995)

The relaxation processes of electrons and spins systems following the absorption of femtosecond optical pulses in ferromagnetic nickel have been studied using optical and magneto-optical pump-probe techniques. The magnetization of the film drops rapidly during the first picosecond, but different electron and spin dynamics are observed for delays in the range 0–5 ps. The experimental results are adequately described by a model including three interacting reservoirs (electron, spin, and lattice). [S0031-9007(96)00167-6]
Ultrafast Optical Demagnetization

Three temperature model


Laser pulse

Electronic system

Spin system

Lattice

Surrounding material

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Magnetization Amplitude Probing Technique

**MOKE** (Magneto-Optic Kerr Effect)

- Technique used by *Beaurepaire et al.*
- Reflectivity measurement
- Near infrared pump and probe

![Diagram of MOKE](image)
Magnetization Amplitude Probing Technique

RXMS (Resonant X-ray Magnetic Scattering)

\[ f^n = (e^*_s \cdot e_i)f_c^n + i(e^*_s \times e_i) \cdot M^n f_{m1}^n + (e^*_s \cdot M^n)(e_i \cdot M^n) f_{m2}^n \]

\[ I \propto TM^2 \]

60 eV (20.7 nm)
Magnetization Amplitude Probing Technique
RXMS (Resonant X-ray Magnetic Scattering)

- XUV probe – spatial resolution
- No need for an external magnetic field
- Holds information on the magnetic structure of the sample
- Low efficiency (10^{-6})
- Requires a specific magnetic structure
- Magnetization must be out-of-plane

How to produce short XUV pulses?
Experimental Details

High Harmonics Generation


Tunnel ionisation  Propagation  Recombination
Experimental Details
High Harmonics Generation

Laser: 800 nm, 50 fs
Gas: neon

Intensity [a.u.] vs. Photon energy
Experimental Details

Setup

- Beamsplitter
- Multilayer focusing mirror
- Focusing mirror
- Delay line
- Filter
- Gas cell (HHG)
- Beamstop
- Sample
- CCD
Experimental Details

Sample

\[
\text{Si}_3\text{N}_4(30\text{nm}) / \text{Pt}(2\text{nm}) / [\text{Co}(0.6\text{nm}) \text{Pt}(0.8\text{nm})]_{20} / \text{Al}(3\text{nm})
\]
Results
Results
Wavelength scaling

![Graph showing normalized intensity over time delay for different wavelengths (400nm, 800nm, 1800nm).](image)
Conclusion and Prospects

• Ultrafast optical demagnetization measurements by RXSM in ALLS laboratory

• New parameters
  • Wavelength
  • Pulse duration

• Next step
  • Spatial resolution
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Coming up

Presentation at the Frontiers in Optics 2017 conference (In revision)