

## Electron microscopy and spectroscopy

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Electron microscopy and spectroscopy techniques have been for long developed to provide researchers with ultimate spatial resolution characterization as the characteristic dimensions of studied objects are continuously shrinking. When applied to magnetic materials, electron-based approaches do not only offer the ultimate spatial probe for magnetic fields via Lorentz force and Aharonov-Bohm phase, but also the possibility to study their crystallographic structure, chemical composition and dynamic magnetization effects in time domain (Ultrafast TEM) or frequency domain (electron energy loss spectroscopy - EELS). We will give an introduction into pertinent techniques and discuss their basic principles.

### Lecture topics:

1. Electron microscopies for magnetic materials
  - a. TEM based magnetic imaging techniques
    - i. Lorentz TEM
    - ii. Electron holography
    - iii. Differential Phase Contrast
  - b. SEM based magnetic imaging techniques
  - c. Comparison of the methods – when to use what?
2. Electron spectroscopies and time-resolved approaches for magnetic materials
  - a. EELS and Energy-Loss-Chiral Dichroism (EMCD)
  - b. Ultrafast TEM

### Recommended reading:

- [1] M. D. Graef, Magnetic imaging and its applications to materials, Academic press (2001).
- [2] P. Schattschneider, Linear and Chiral Dichroism in the Electron Microscope, Taylor and Francis (2012).