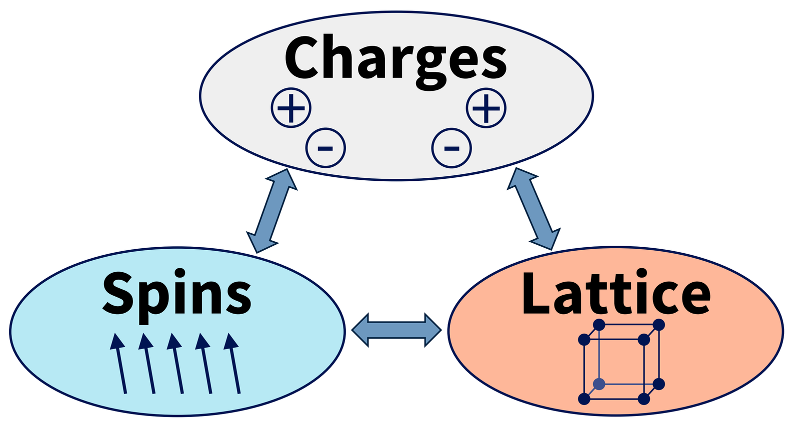
Universität Zürich[UZH]

Christian Tzschaschel

Ultrafast optical spectroscopy of strongly correlated quantum materials

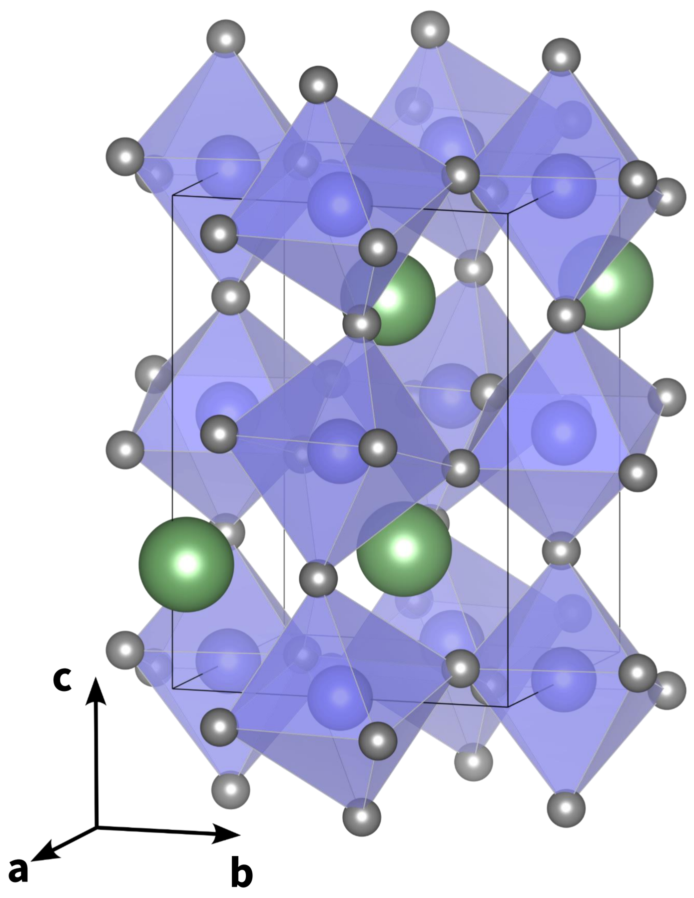
Strongly correlated quantum materials

- Characterized by an intricate interplay between *charge*, *lattice* and *spin* degrees of freedom
- Physical properties are defined by the strong correlations between these materials
  → provides a handle to tune functionalities
- Control of quantum materials may enable, e.g.,
  - Unconventional superconductivity
  - Efficient electrical control of magnetism
  - Giant optical responses
  - etc…

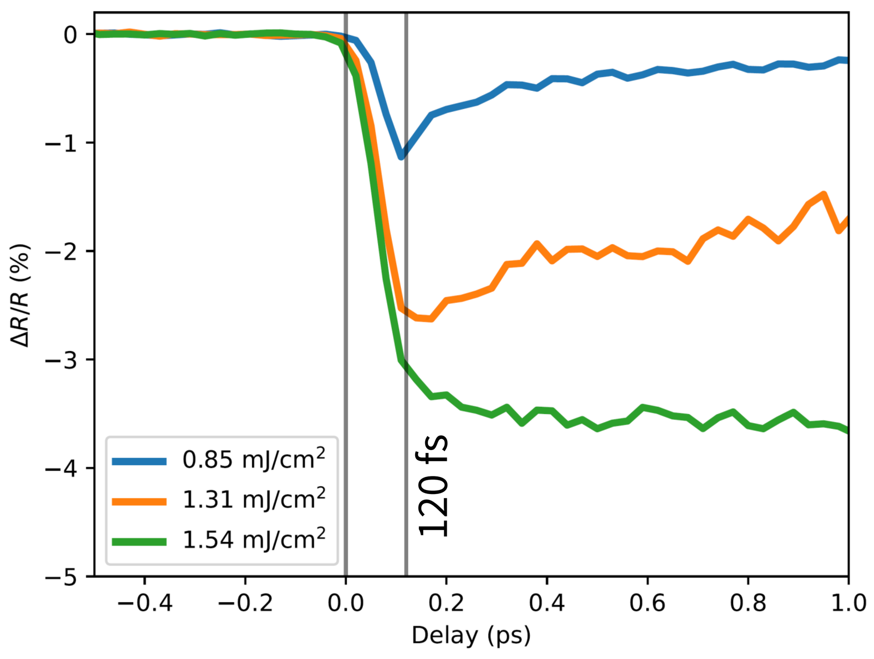


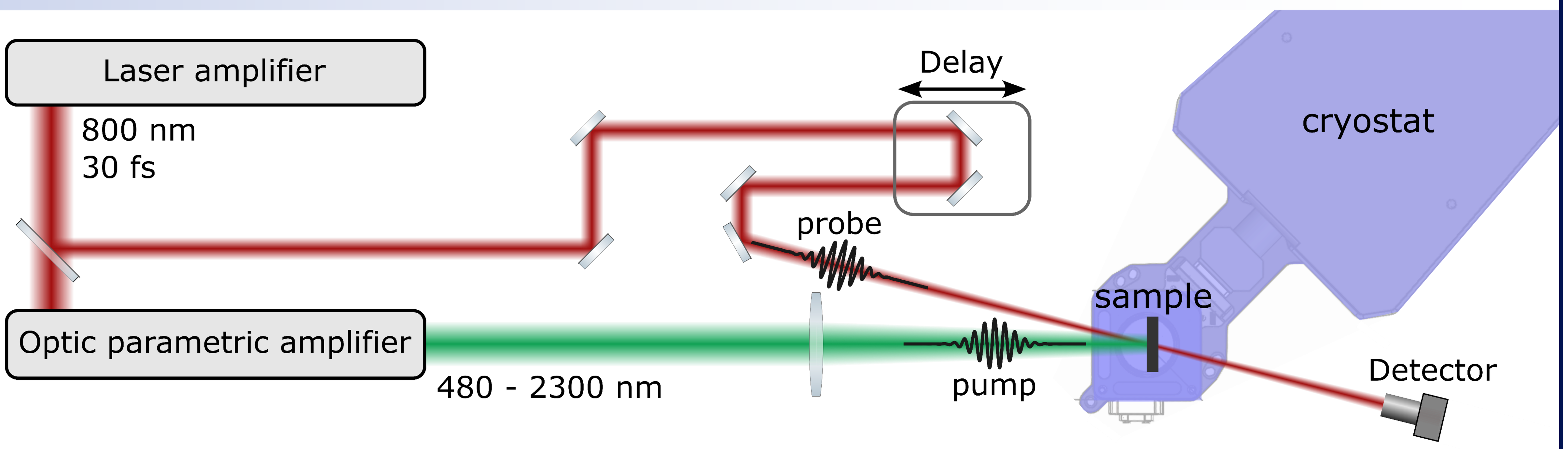
Problem: strong correlations are difficult to disentangle in equilibrium. Which microscopic property drives which material response?

Approach: go out of equilibrium



Ultrafast laser spectroscopy





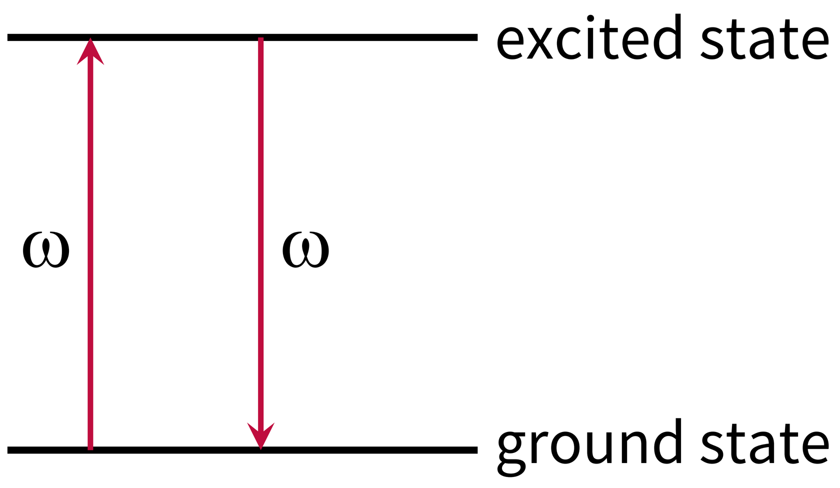
Pump-probe approach for time-resolved spectroscopy

- Optical *pump* pulse drives material out of equilibrium (pump fluence >100 GW/cm²)
- Delayed *probe* pulse interrogates the sample and detects dynamic changes with sub-100-fs temporal resolution
- Extremely successful approach to study ultrafast dynamics

Optical probes of quantum materials

Linear optics

e.g. reflectivity, Faraday rotation, magneto-optical Kerr effect

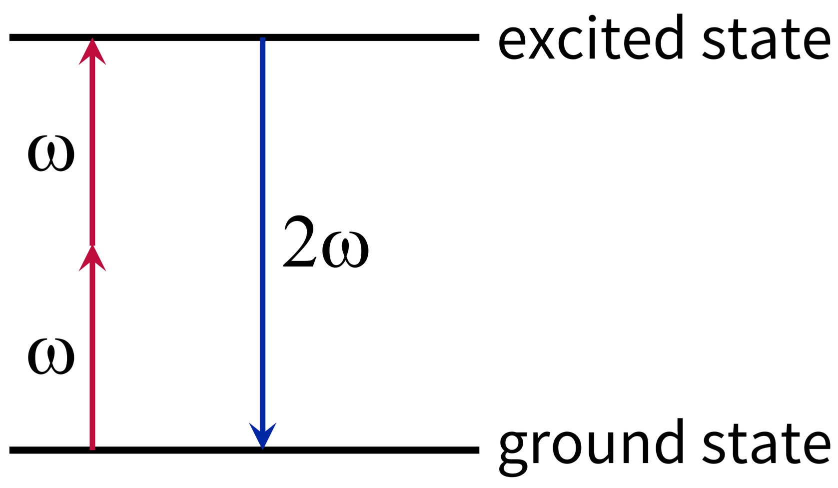


Provides insight into

- Conductivity
- Magnetization
- Chirality

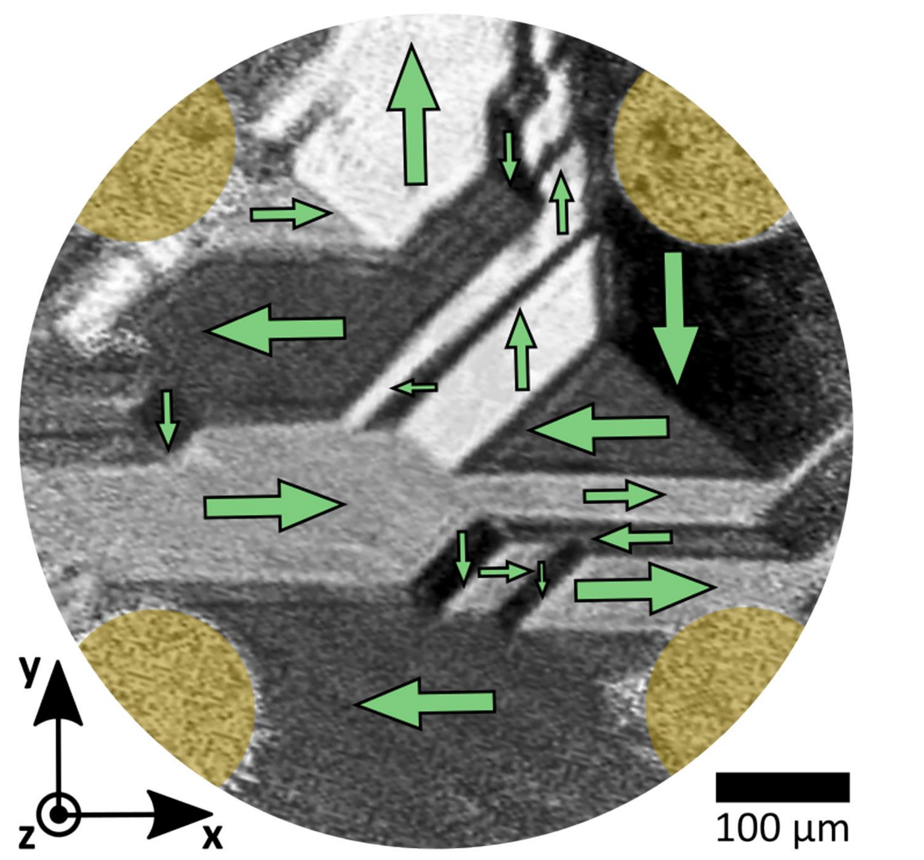
Nonlinear optics

e.g. second-harmonic generation (SHG), photogalvanic effect



Provides insight into

- Electric Polarization
- Magnetization
- Antiferromagnetism
- Other ferroic orders



SHG imaging of magnetic domains in magnetic Weyl semimetal CeAlSi. Four domain states are distinguished.

CT et al., *Nat. Commun.* **15,** 3017 (2024).

Sounds interesting? Reach out about possible thesis projects!

contact: christian.tzschaschel@physik.uzh.ch

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