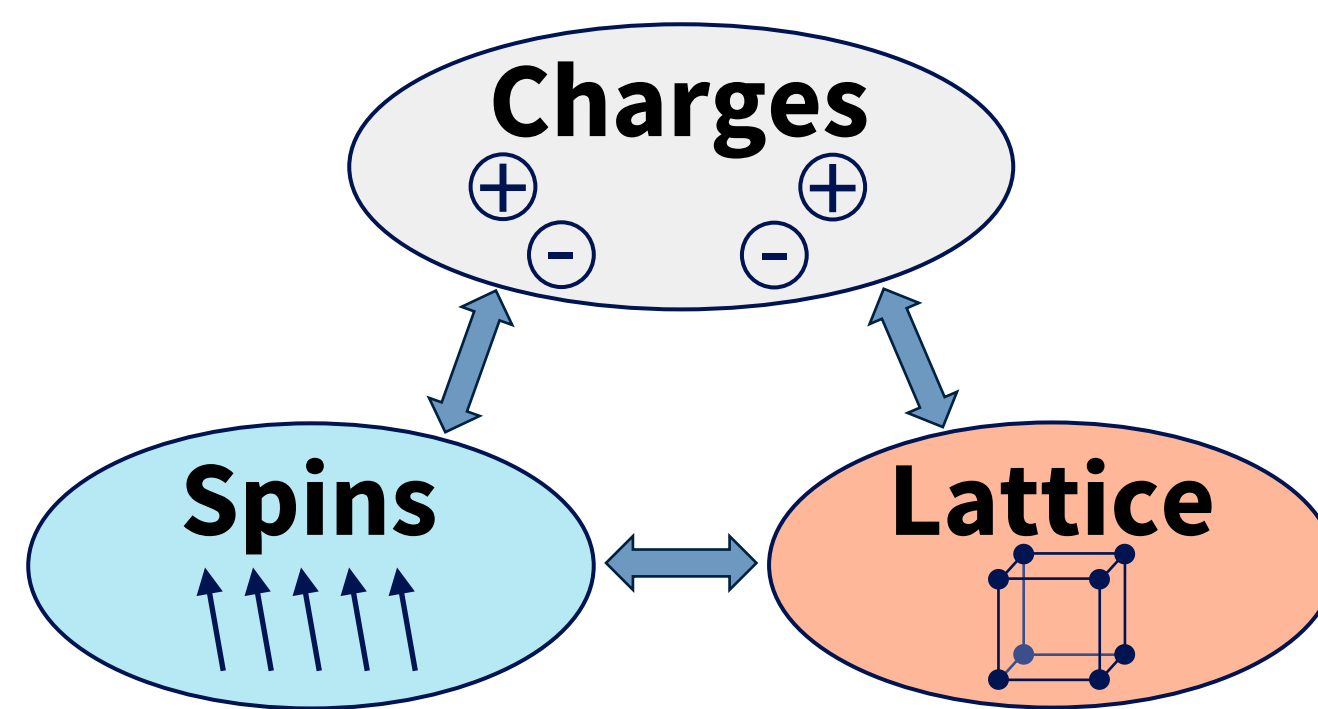


# Ultrafast optical spectroscopy of strongly correlated quantum materials

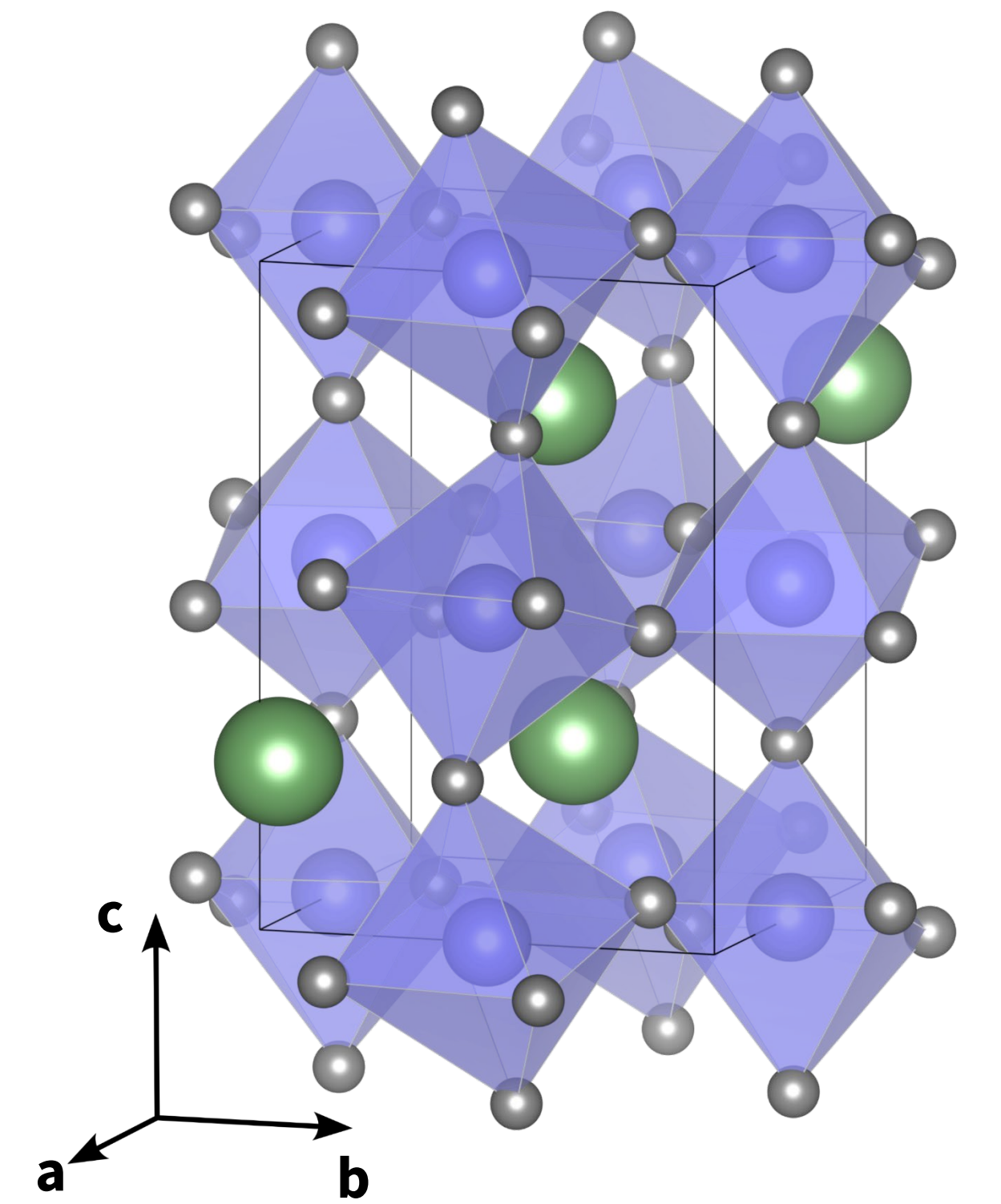
## Strongly correlated quantum materials

- 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...

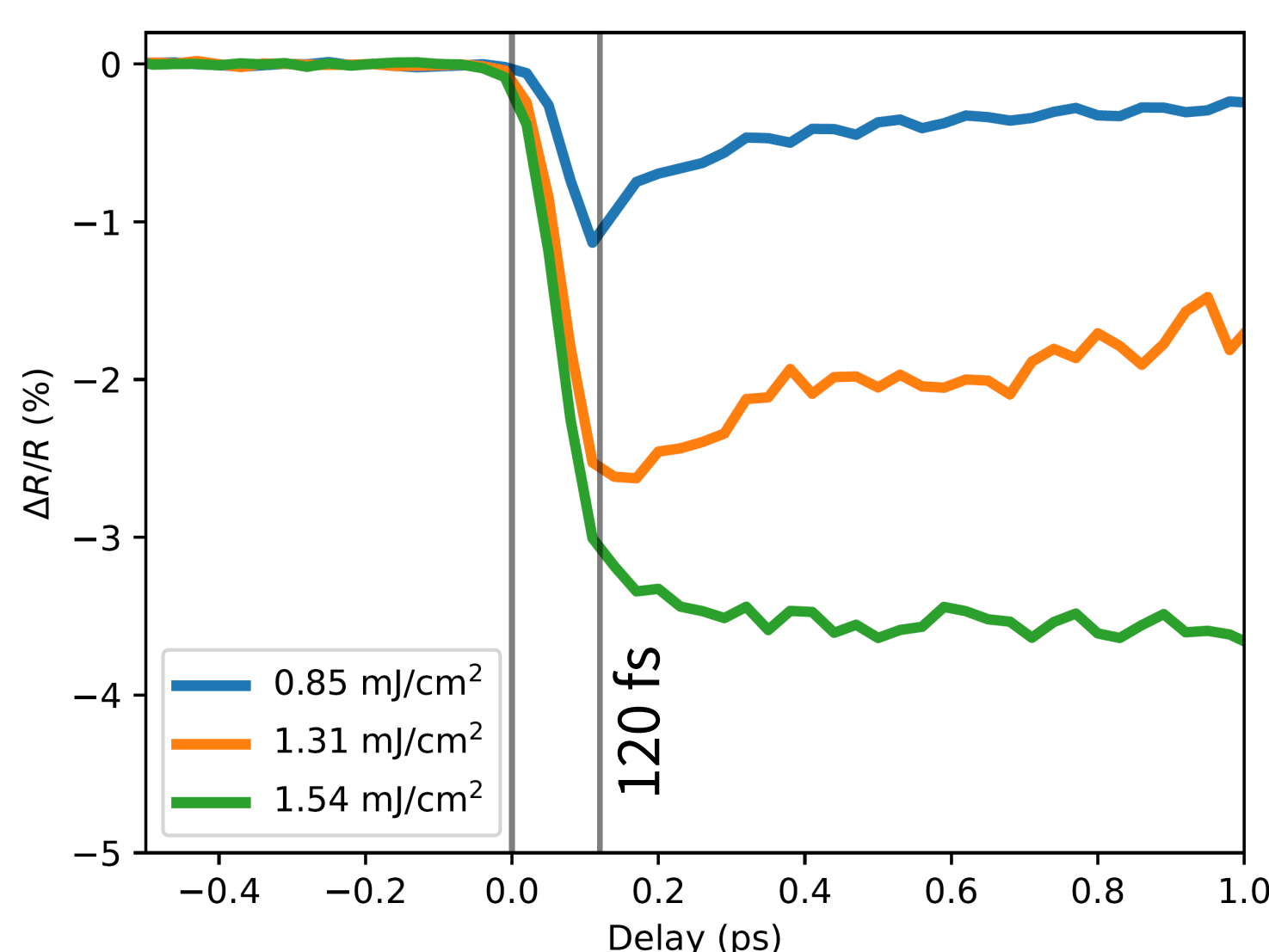
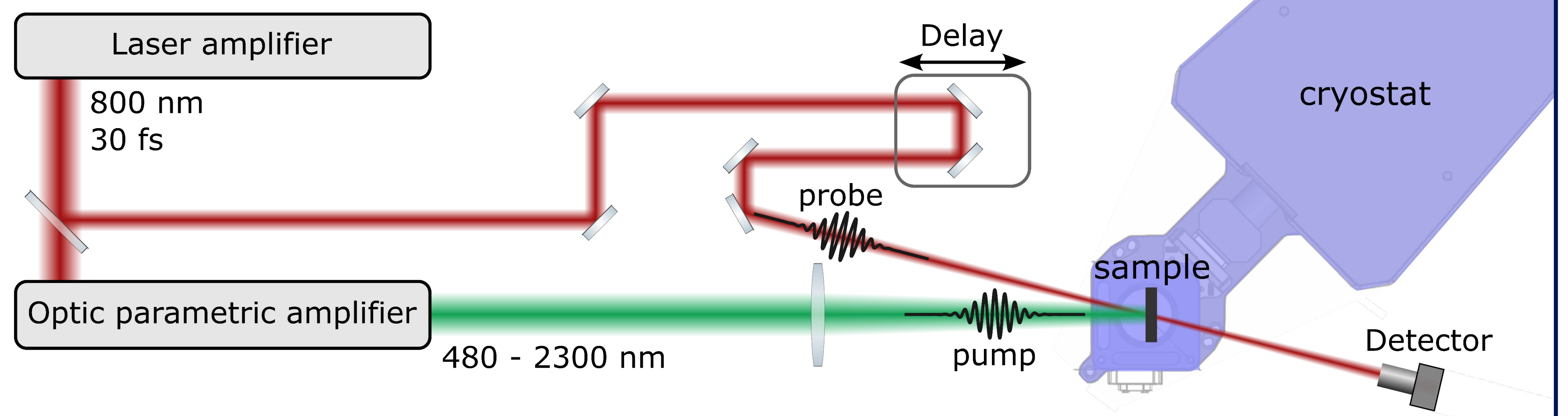


**Problem:** strong correlations are difficult to disentangle in equilibrium. Which microscopic property drives which material response?

**Approach:** go out of equilibrium



## Ultrafast laser spectroscopy



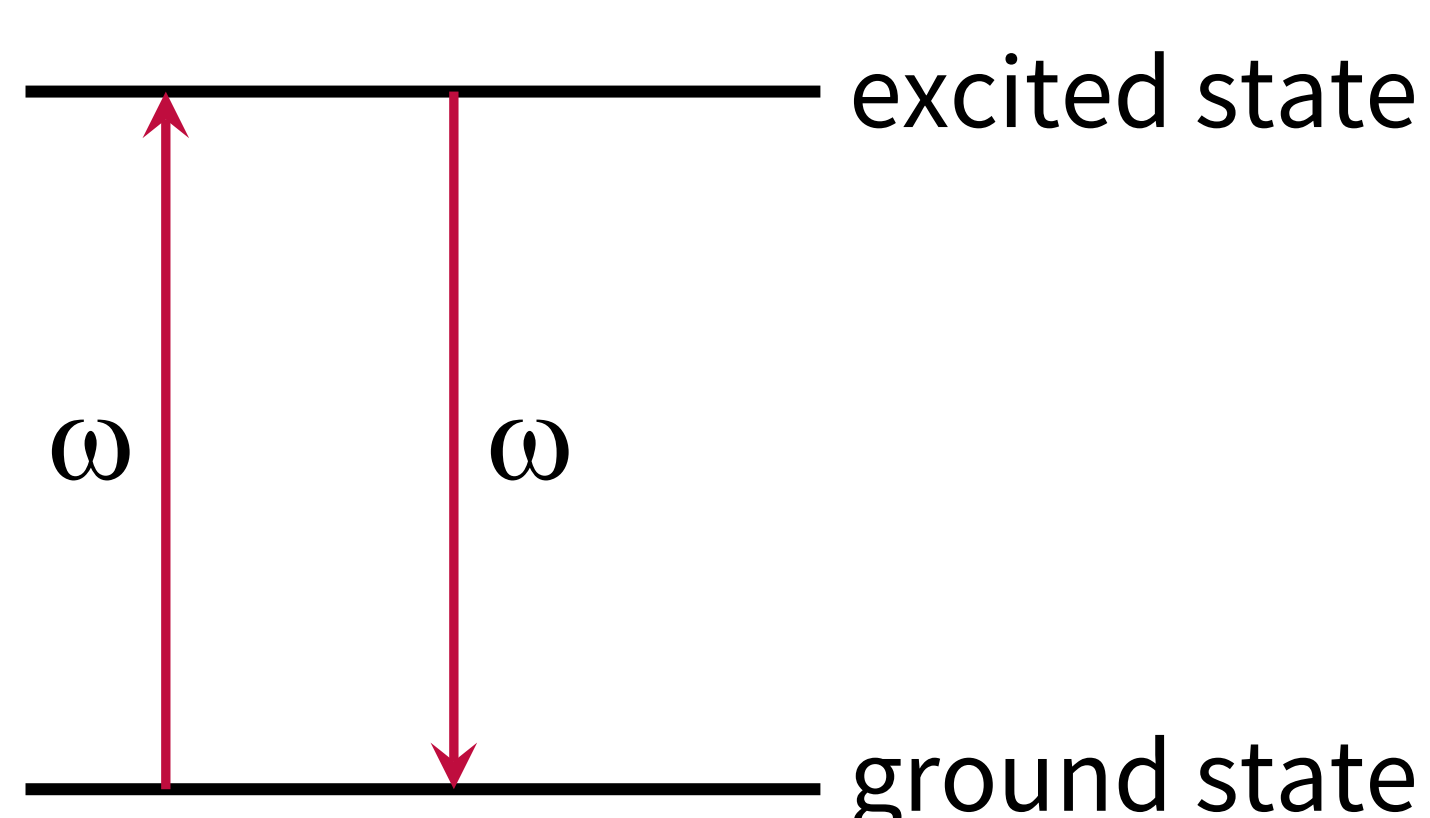
### Pump-probe approach for time-resolved spectroscopy

- Optical *pump* pulse drives material out of equilibrium (pump fluence >100 GW/cm<sup>2</sup>)
- 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

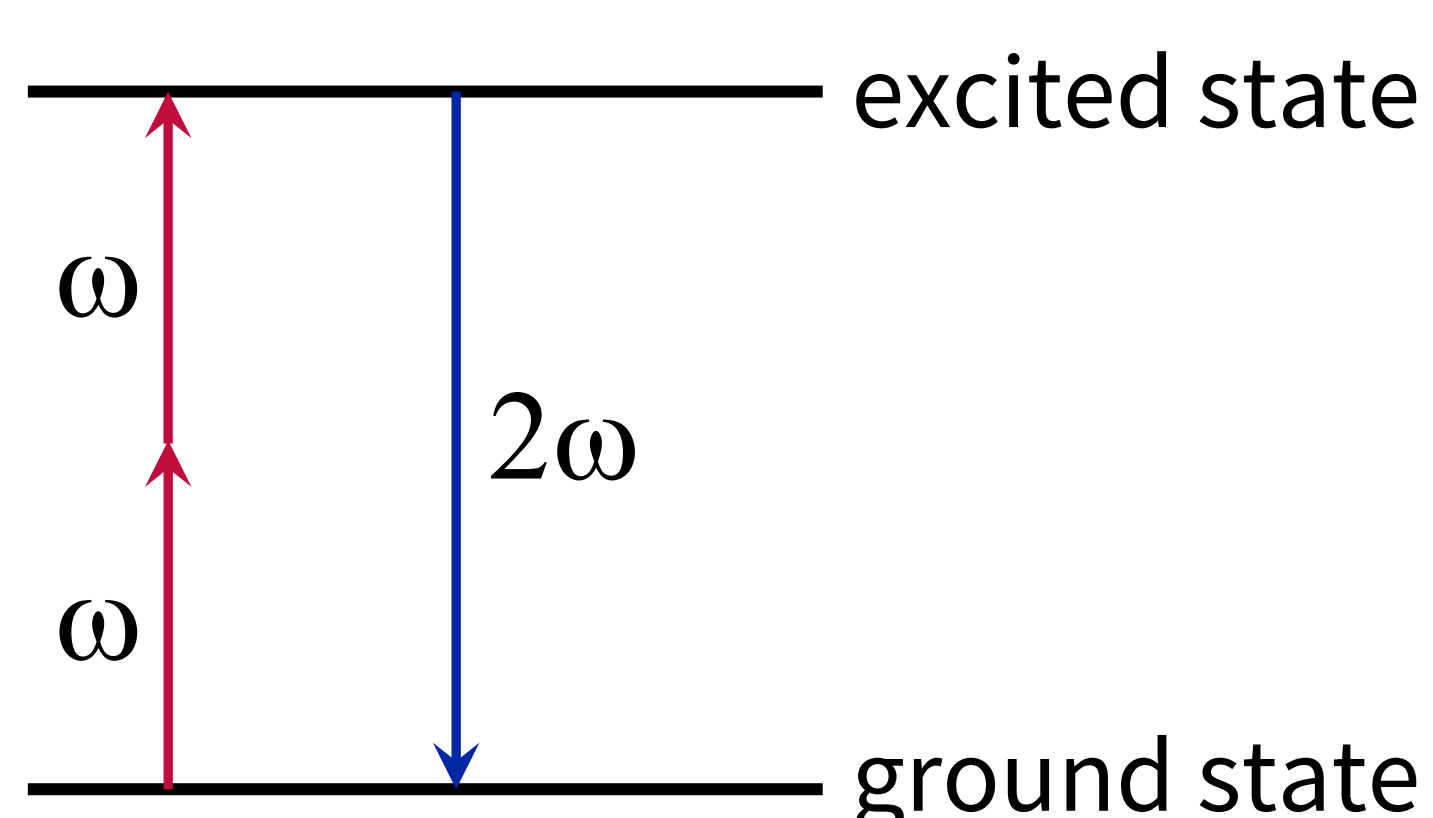


#### Provides insight into

- Conductivity
- Magnetization
- Chirality

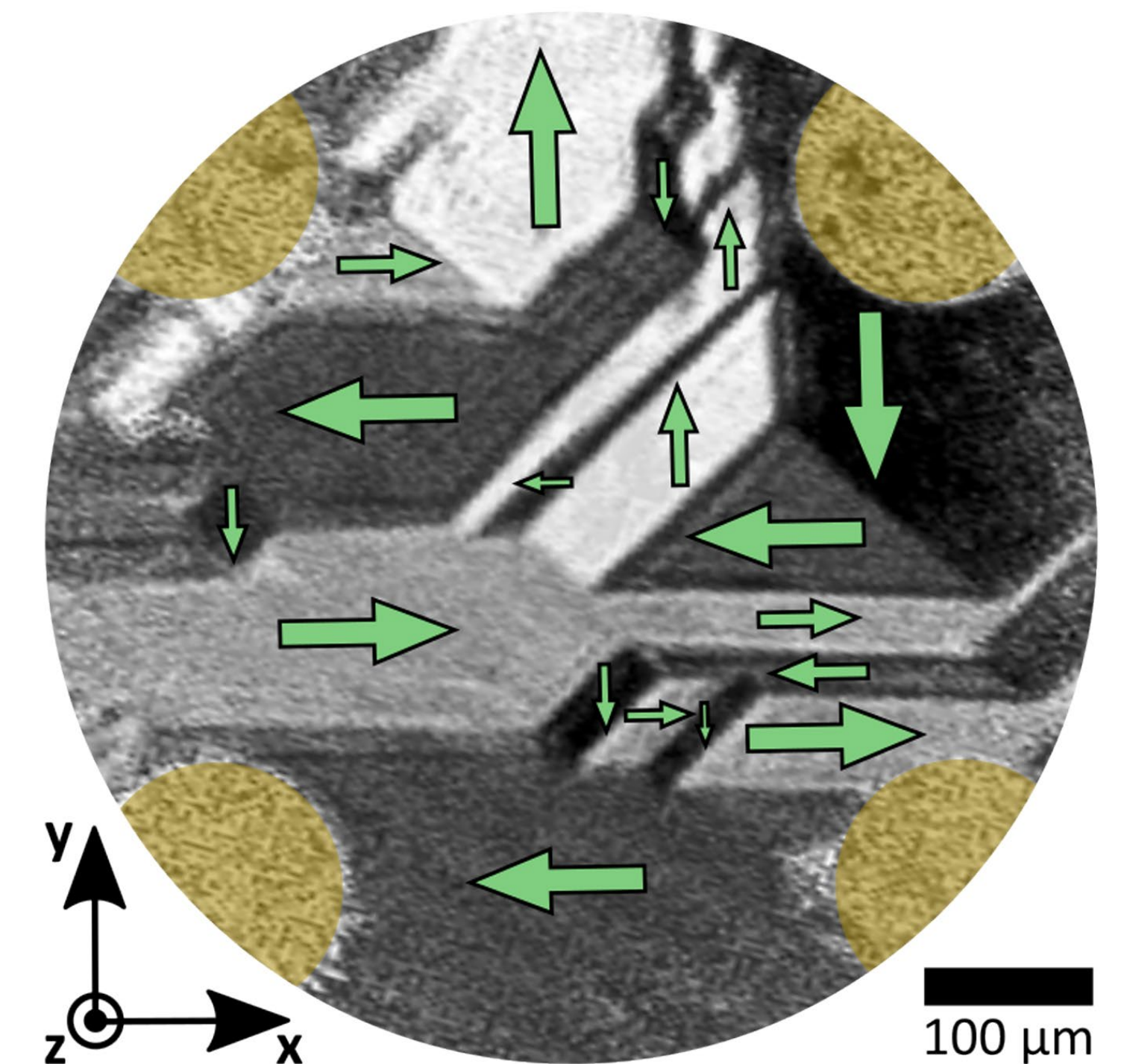
### Nonlinear optics

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!**

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