A UK XFEL for Quantum Materials

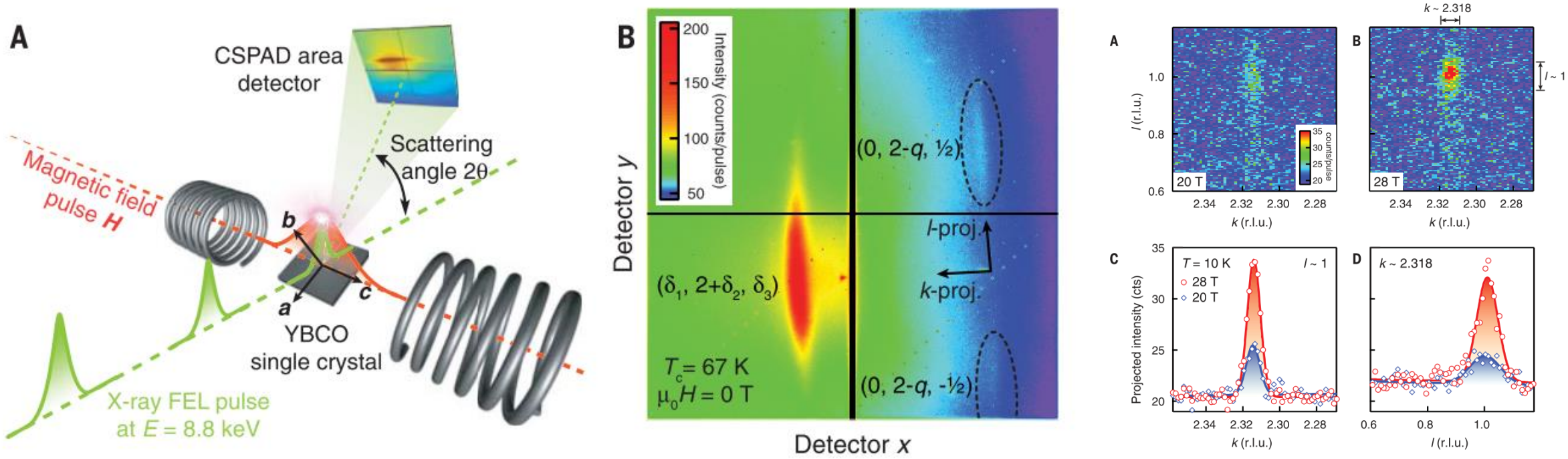
Nov 27th ***Quantum Materials & Nanotechnology (Southampton)***

Simon Wall, Anna Regoutz, Markus Newton, Mark Dean and Ian Robinson

- We outlined the key advances that FELs have made in the study of quantum materials to date and future perspectives.
- “Killer app” yet to be fully developed and now is the time to act!

New Approaches to Conventional Spectroscopies

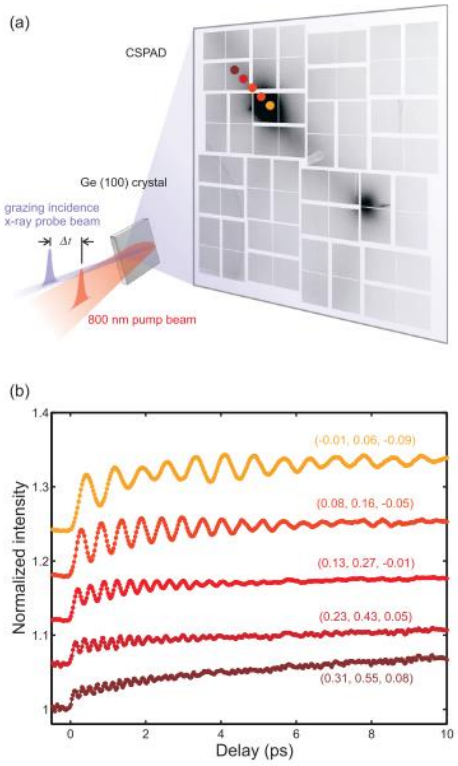
Ultra-bright pulsed light source combined with pulsed magnetic field: Access to new regimes

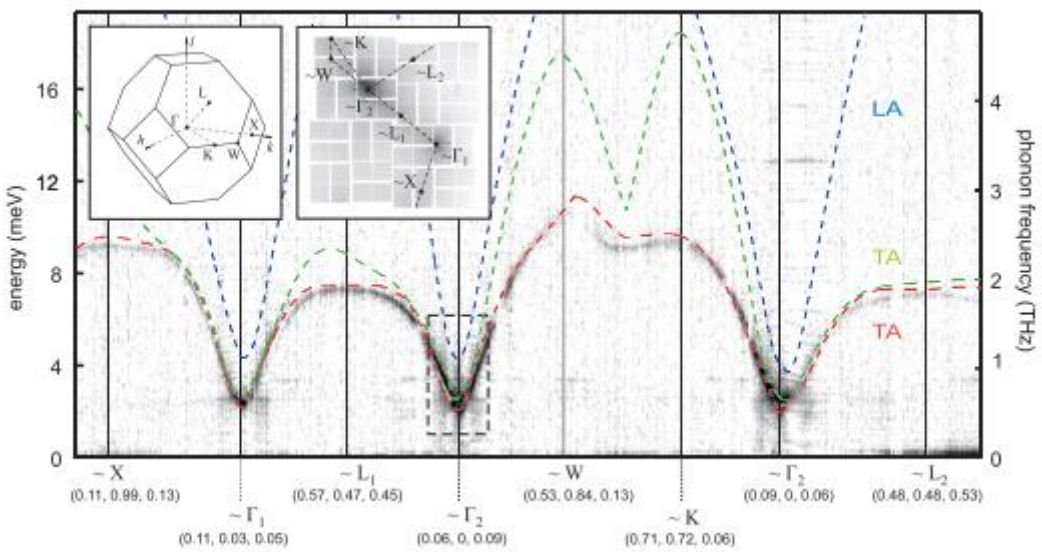


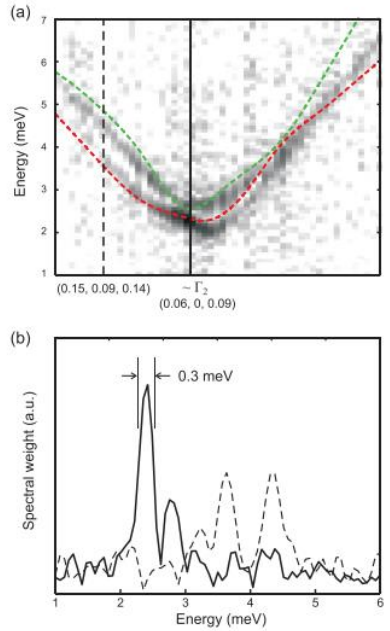
Gerber et al. Science (2015)

New Approaches to Conventional Spectroscopies

Short pulse X-rays enable time domain approach to phonon spectroscopy – sub meV energy resolution

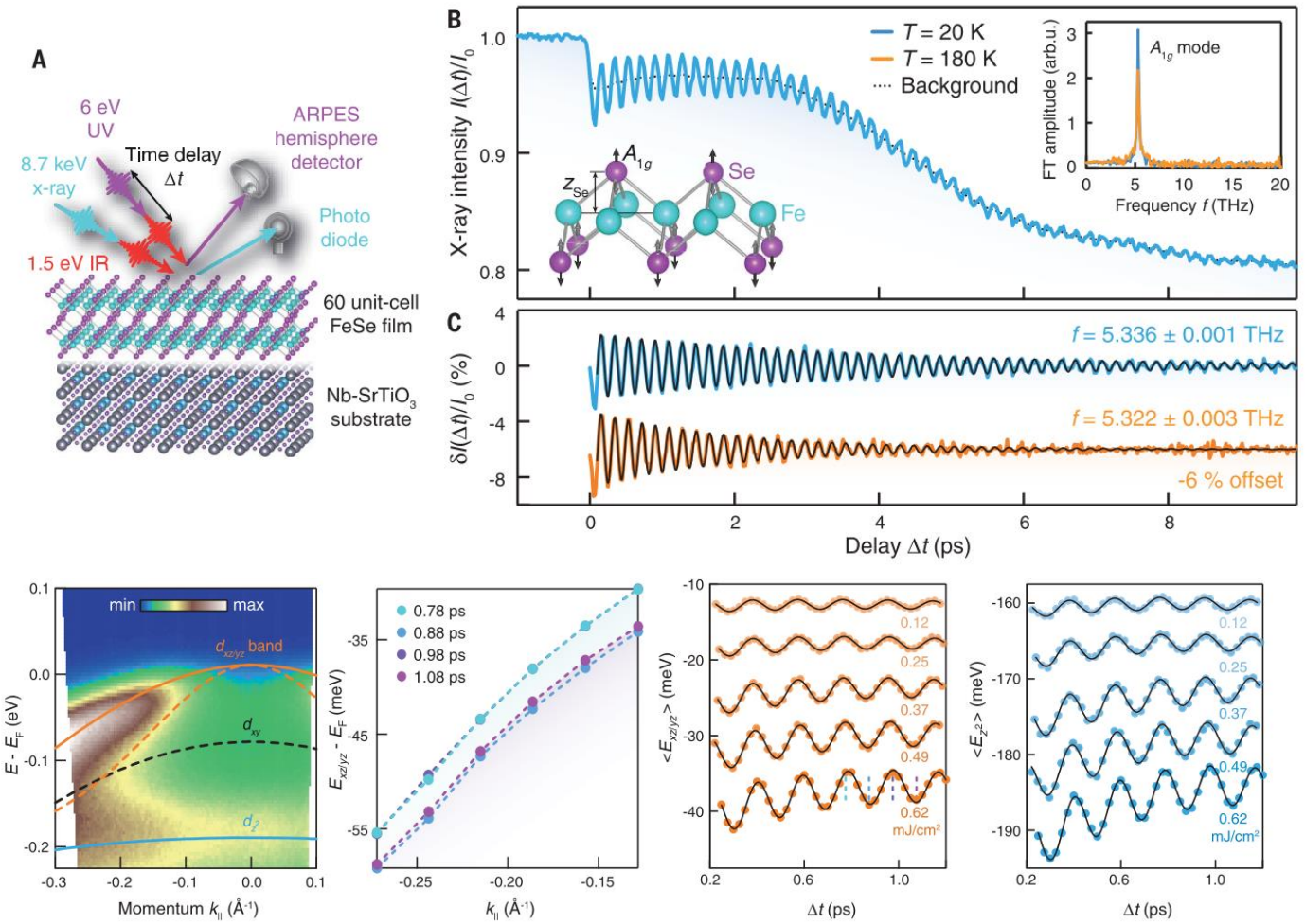






Zhu et al. Phys Rev B (2015)

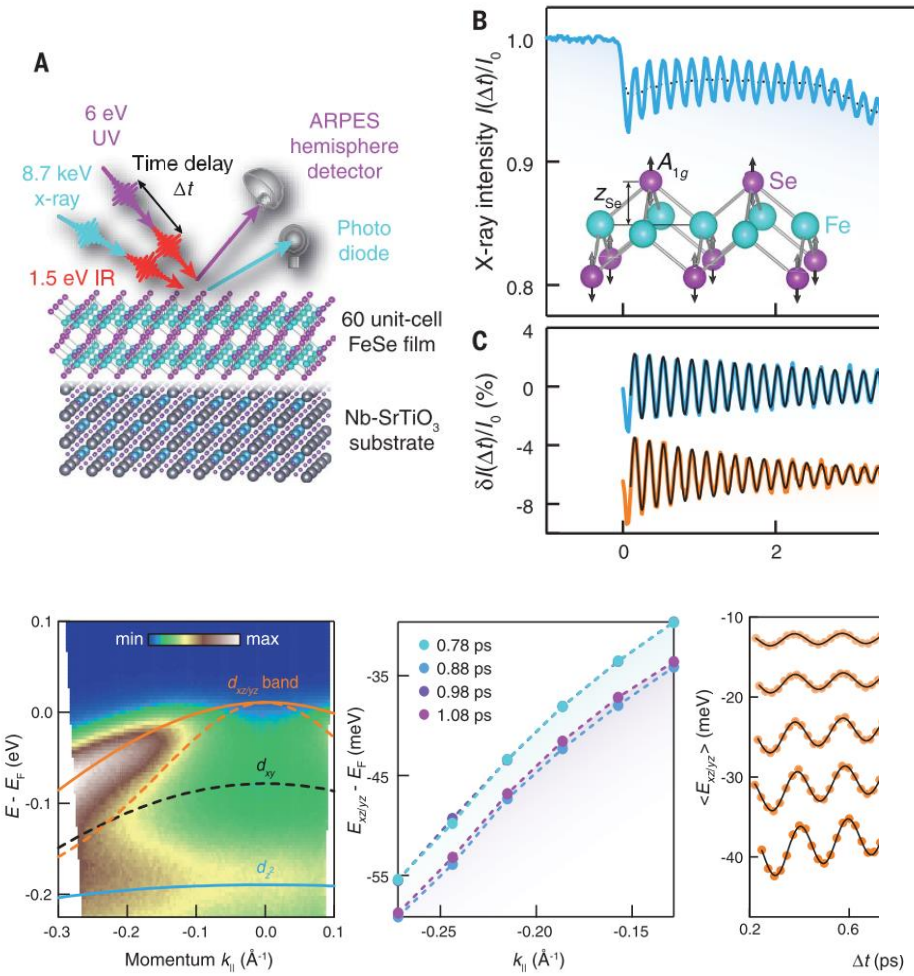
New Approaches to Conventional Spectroscopies



Combining time-resolved diffraction with time-resolved photoemission to provide model free determination of the electron-phonon coupling constant

Gerber et al. Science (2017)

New Approaches to Conventional Spectroscopies



Gerber et al. Science (2017)

Combining time-resolved diffraction with time-resolved photoemission to provide

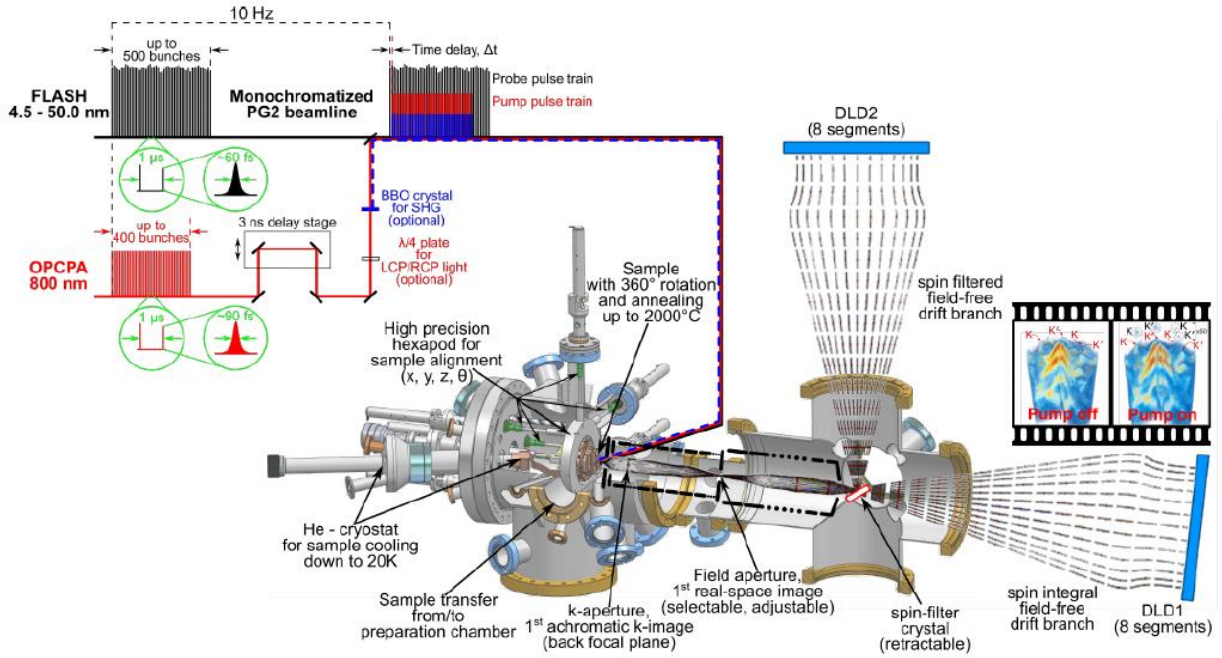
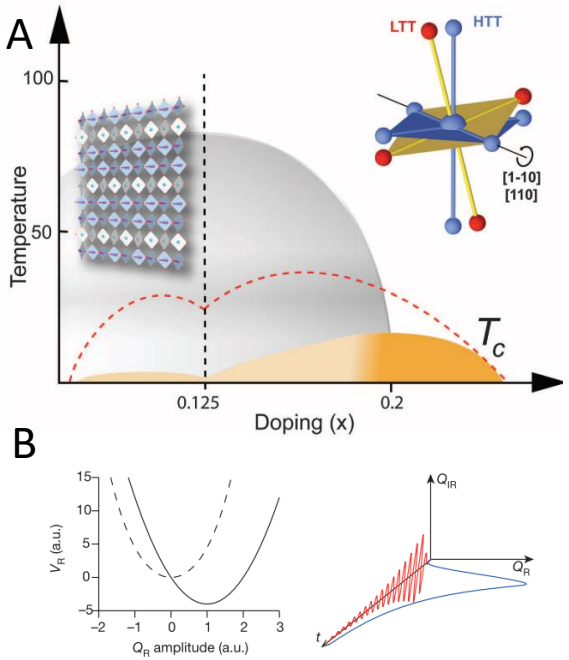


Figure 5.9: Simplified overview of the FLASH pulse structure, the PG2 beamline with synchronized pump laser (top left) and the experimental setup (middle) used to perform time-resolved momentum microscopy and acquire volumetric band-mapping movies (right inset) by means of a multidimensional recording scheme. [73]

New Visions into Non-Equilibrium Dynamics

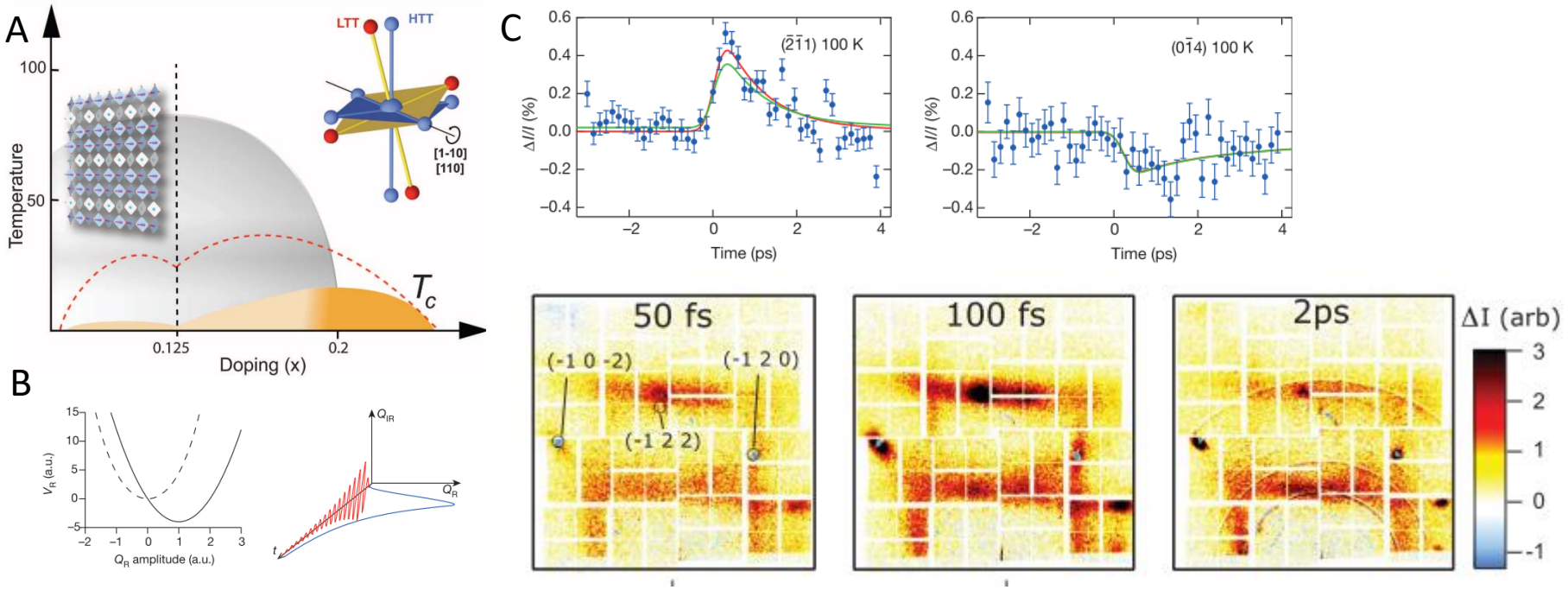
Viewing the transient structure of crystals – Insights into non-equilibrium superconductivity



Fausti et al. *Science* (2011)
Mankowsky et al. *Nature* (2014)

New Visions into Non-Equilibrium Dynamics

Beyond diffraction – phonon dynamics throughout the Brillouin Zone

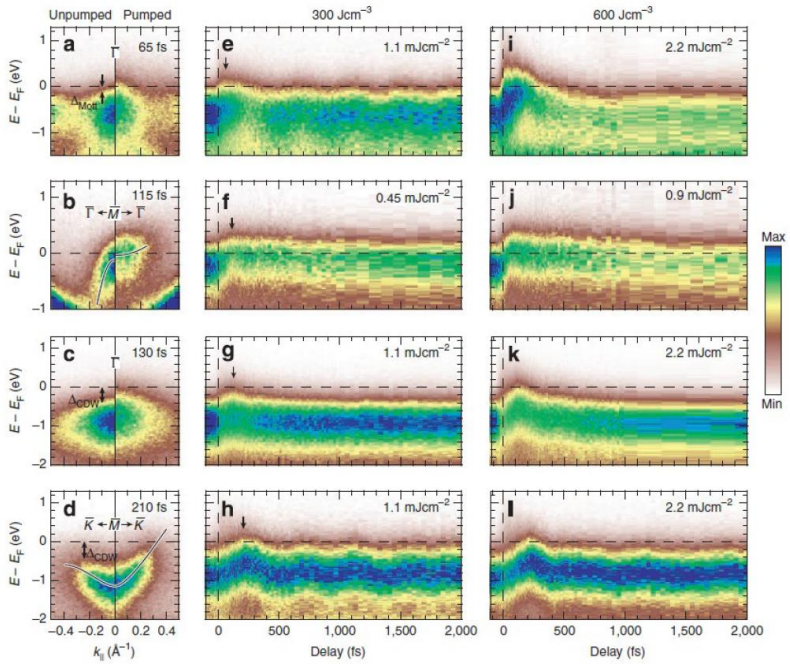


Fausti et al. *Science* (2011)
Mankowsky et al. *Nature* (2014)

Wall et al. *Science* (2018)

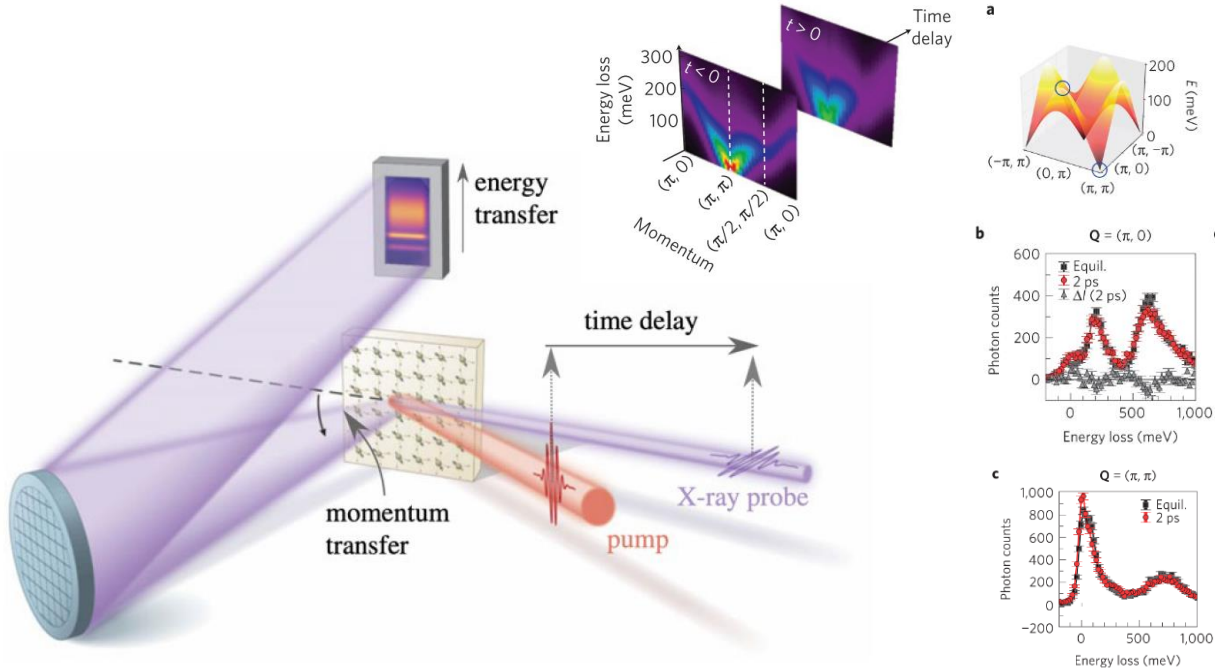
New Visions into Non-Equilibrium Dynamics

Mapping electron dynamics in bands
– full BZ access, resonances, core levels



Hellman et al. Nat Communications (2012)

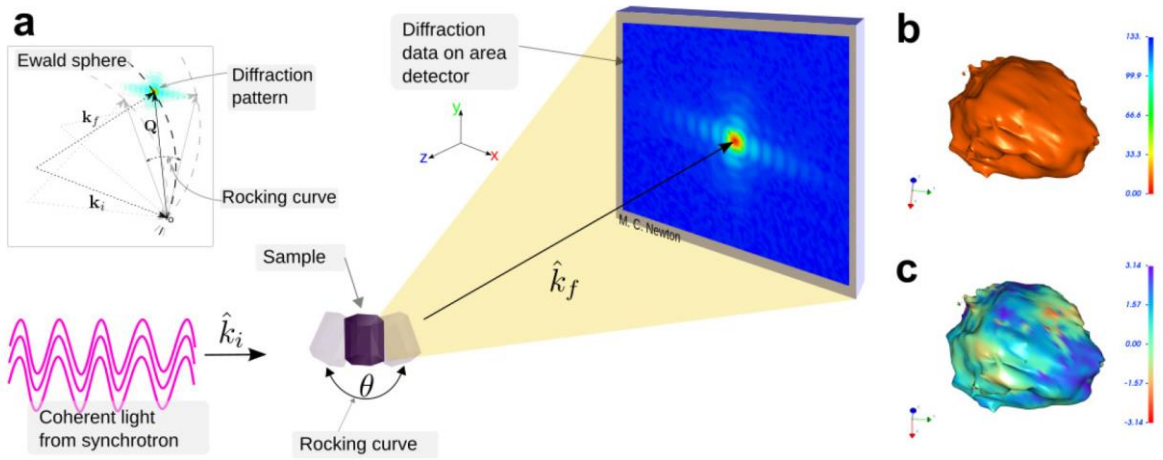
Mapping magnon bands in transient structures



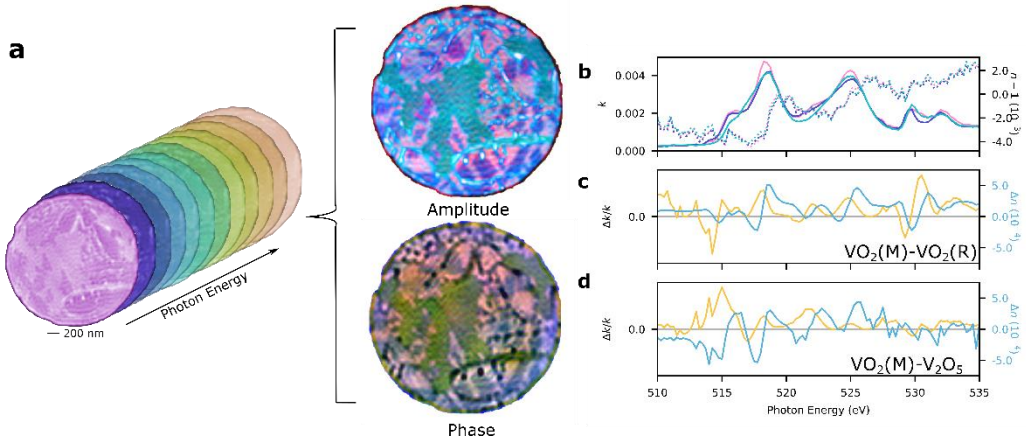
Dean et al. Nature Materials (2016)

Imaging Quantum Materials in Space and Time

Coherent imaging of nanoparticles with X-rays
Bragg CDI (hard X-ray)

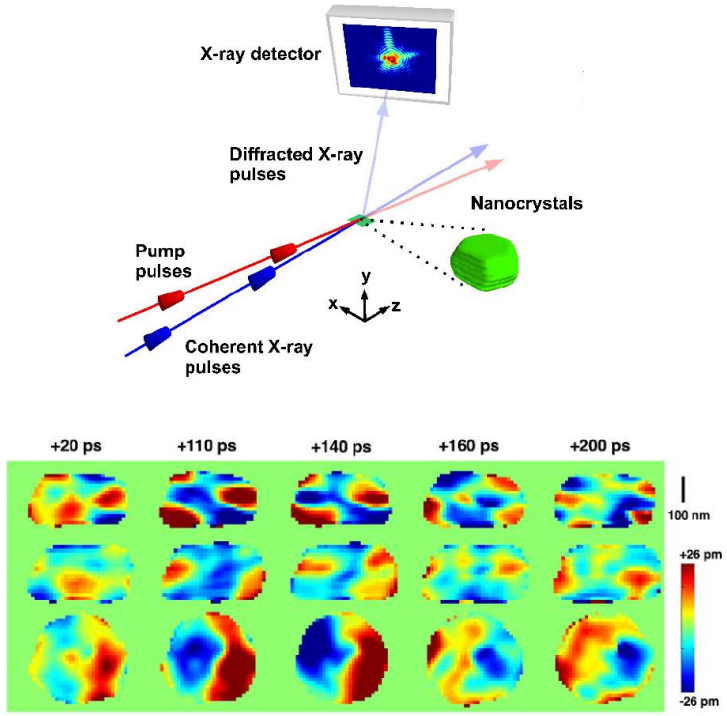


Coherent imaging of phase separation (VO_2(M1) VO_2(R), V_2O_5) with soft X-ray CDI



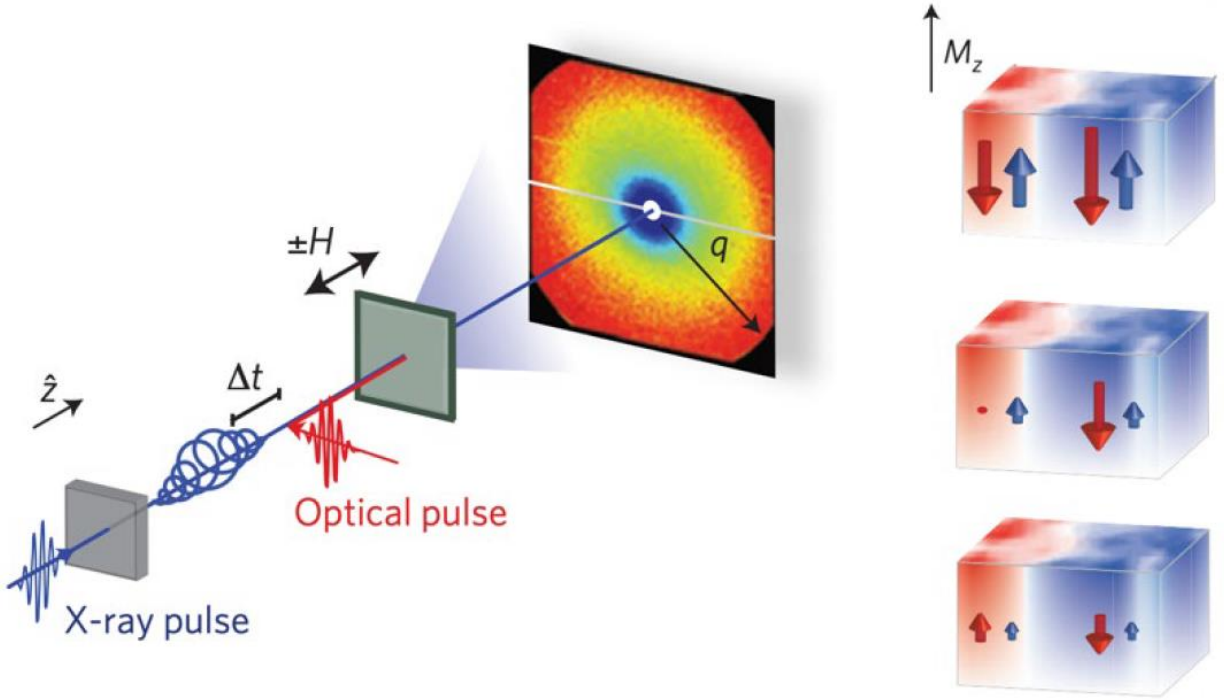
Imaging Quantum Materials in Space and Time

Coherent imaging of nanoparticles with X-rays
Bragg CDI (hard X-ray): Acoustic wave propagation



Clark et al. Science (2013)

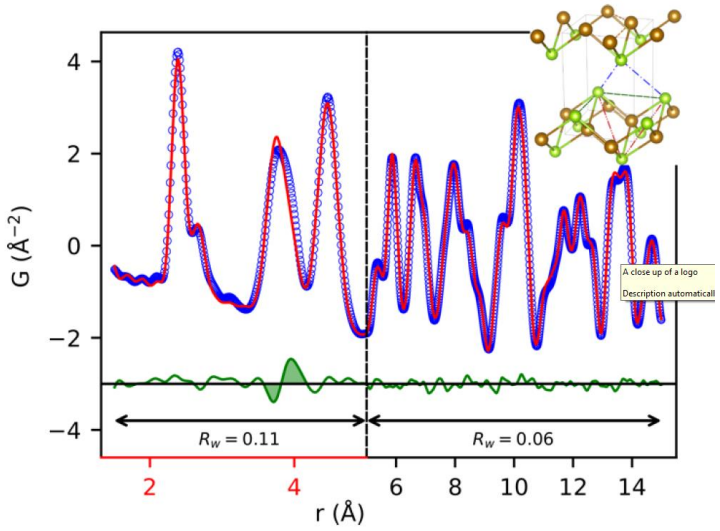
Ultrafast diffusion of spins



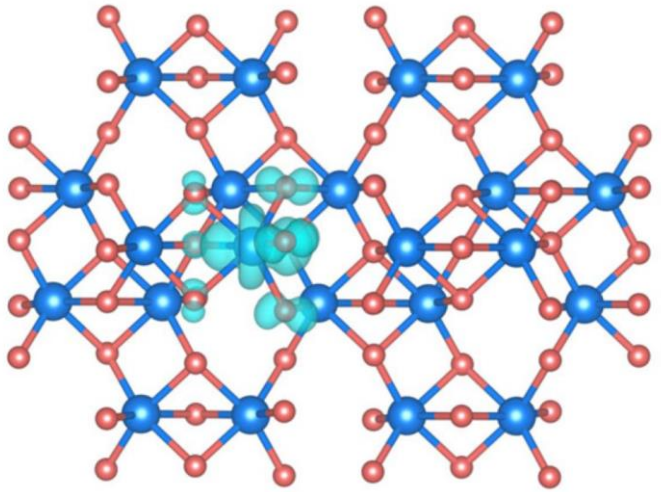
Graves et al. Nature Materials (2013)

Atomic scale dynamics?

New possibilities with tr-PDF: Capturing fluctuations, imaging polarons…



Orbital fluctuations in FeSe?
Koch Phys. Rev. B (2019)



Proposed small polaron in hematite, α-Fe_2O_3.

Pastor Nat. Commun (2019)