Summary - CDI/XPCS

Speakers on June 29

Oleg Shpyrko – Intro: Coherent scattering and Imaging
Anders Madsen (replacing G. B. Stephenson) – Intro: Coherent scattering and dynamics
Mark Sutton – Proposal for Fourier Transform X-ray Spectroscopy
Andrej Singer – Coherent x-ray imaging of ultrafast processes at XFELO
Zheng Li – Proposal: Radiation-damage-free two-photon diffraction, ghost diffraction
Alfred Baron – time domain is not always preferred over energy domain

Gerhard Grübel, Oleg Shpyrko, Andrej Singer, Anders Madsen joined the discussion today

What is the distinct advantage of the XFEL Oscillator as compared to regular high gain FEL (e.g. LCLS-II)

XFELO is mostly about higher quality beams!

Advantage of average flux
($10^{14\text{-}15}$ coherent ph/s)

- Better possibilities for CDI (in-situ/operando, magnetic scattering, difficult stuff,…)
- Higher spatial and temporal resolution possible, e.g. **ultrafast time-resolved imaging of nanoscale disorder in strongly correlated electron systems**

- Possibility to **access μs regime in XPCS** (movie mode), will also benefit from stability and bandwidth control
- science case: supercooled liquid to glass transition, access to higher-order correlation functions $G(t_1,t_2)$, χ_4, $g^{(4)}$, intermittent dynamics, phonon anharmonicity,..
- science case: critical phenomena, phase transitions, quantum criticality,..

- The pulsed (MHz) nature of the XFELO limits the fastest timescales accessible, *i.e.* "movie mode" XPCS remains in a regime also targeted by MBA SR sources. However, XFELO has a clear flux advantage.

Advantage of stability and small bandwidth ($\Delta\lambda/\lambda \sim 10^{-6}$)

- Better speckle contrast at high Q for thick samples due to better temporal coherence. Monochromator not needed for movie mode XPCS/CDI

- Higher stability of complicated optical schemes, e.g. Split-Delay Line (SDL)

- Possible to **access $g^{(1)}$ (field autocorrelation function) by FTXS**.
- Important for systems where the Siegert relation does not hold
- FTXS similar to FTIR spectroscopy where the pulse is split and the overlap scanned.
- High stability requirements to FTXS SDL, possibly heterodyning or simultaneous interferometry can help
- Science case: entering the “inaccessible phonon region” between IXS/INS and Brillouin light scattering, possibilities for coherent control, etc…

- $\langle E(t_1,q_1)E^*(t_2,q_2)\rangle$, higher order field correlation function? Input from theory.

Drawbacks of low photon number per pulse ($10^{8\text{-}9}$ ph/pulse)

- Really less ps/pulse than high gain FELs (by 3-4 orders of magnitude)
- Sparse speckle patterns will be even more diluted with obvious drawbacks for single shot experiments. Possibly, for certain experiments, this can be mitigated by the MHz rep rate.

Other:

- Large NA focusing optics is bandwidth limited. XFELO may be better to achieve record small foci. Could be important for single molecule imaging and all non-linear phenomena
- MHz area detectors need to be developed. Smart detectors (2 photon events)
- Need to develop high stability optics (X-ray SDL for FTXS)
- Stereoimaging? Split, delay & inclined beams? Standing waves?