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Applications of HHG SXR

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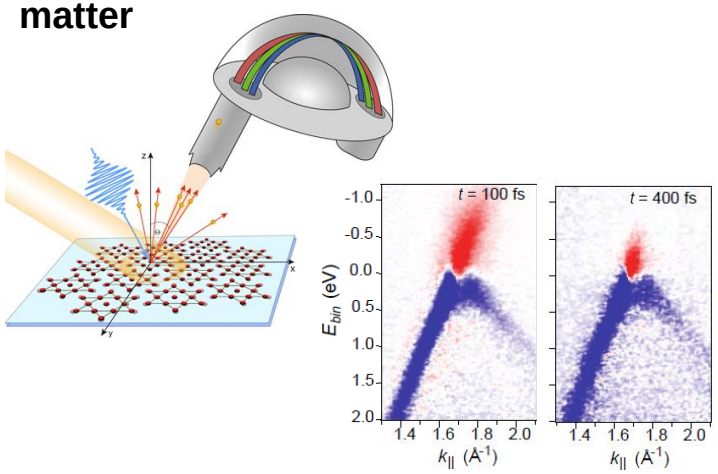
Artemis, Central Laser Facility
Nov 13th 2019

Artemis: XUV science

Spatially and temporally coherent, ultrashort pulses from 30 – 120 eV

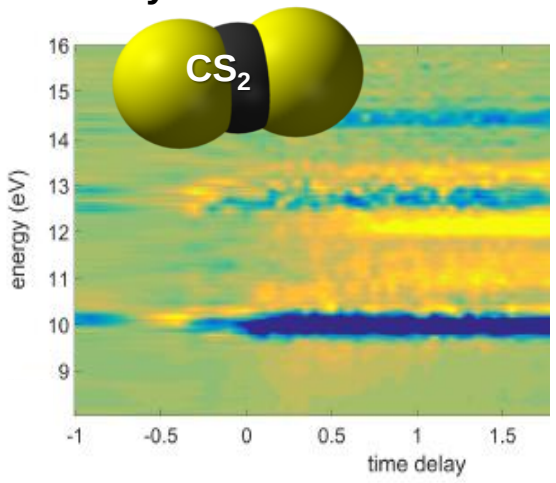
Femtosecond time-resolution: ultrafast probes of electron dynamics

Ultrafast processes in condensed matter



Time- and angle-resolved photo-emission in graphene and 2D materials

Molecular dynamics

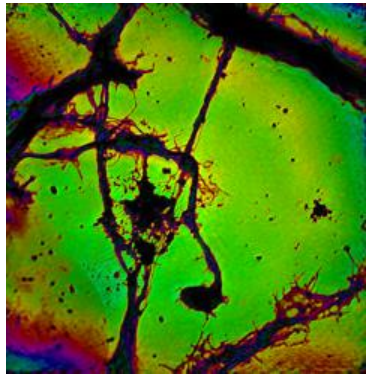


XUV photo-electron spectroscopy in gas-phase molecules

*Smith PRL **120** 183003 (2018)*

Spatial coherence: lensless XUV microscopy

HHG ptychography



Widefield imaging of biological samples without staining.

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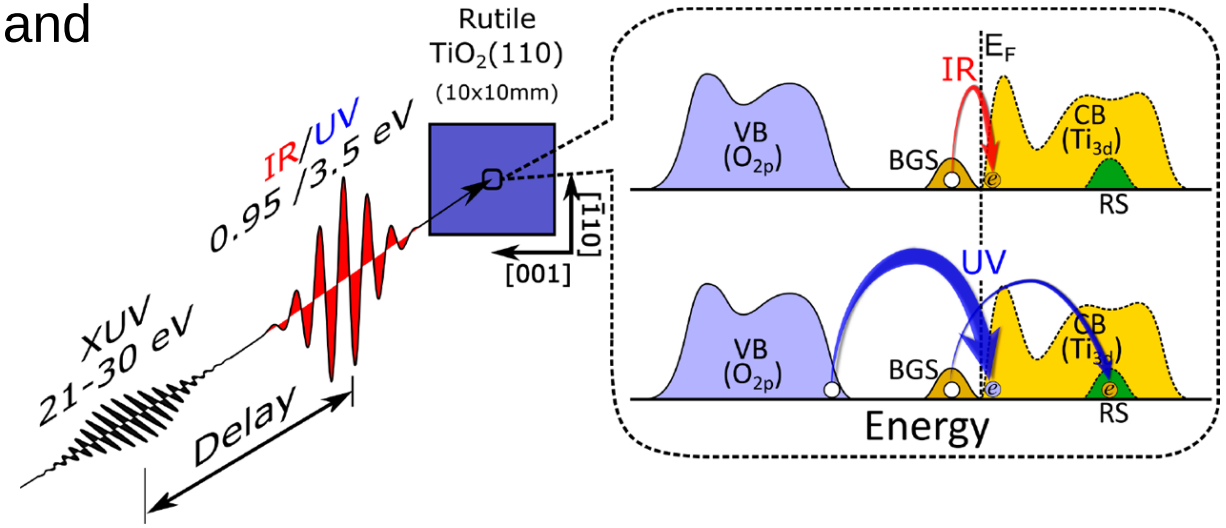
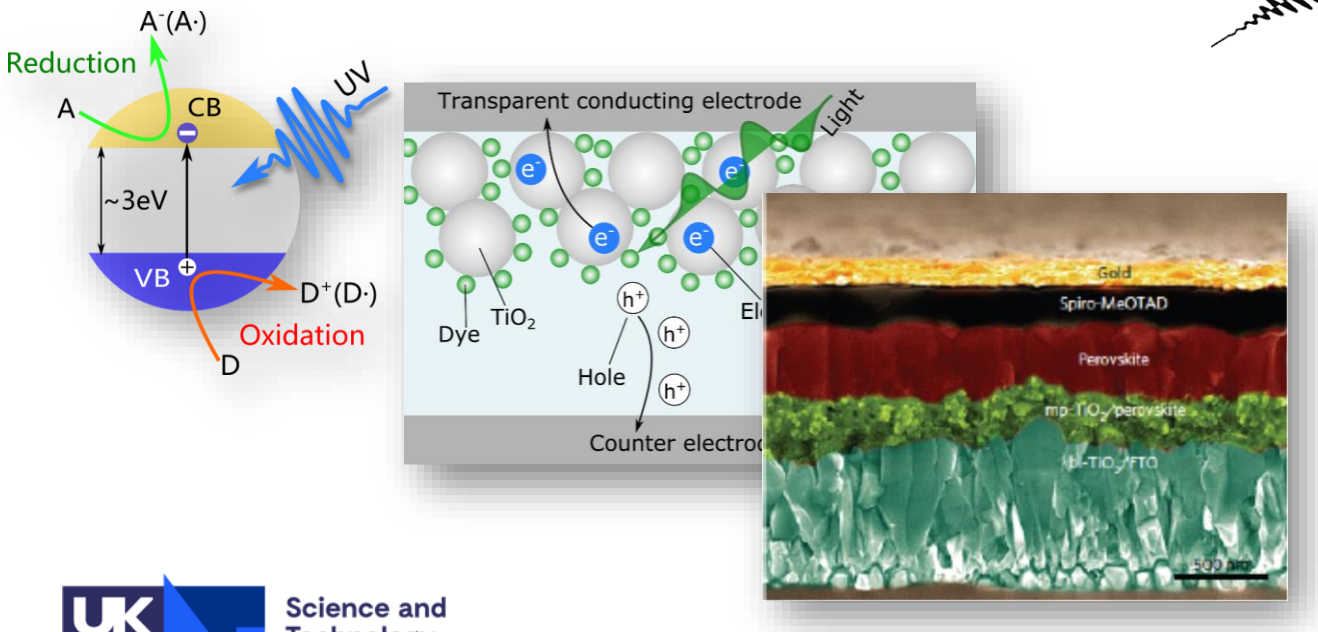
Electron dynamics in transition metal oxides

- Applications in photovoltaics, photochemistry and catalysis.
- Large band gap of a few electron volts.
  - ✓ **TiO_2** band gap: ~3 eV
  - ✓ Photo catalysis and light harvesting





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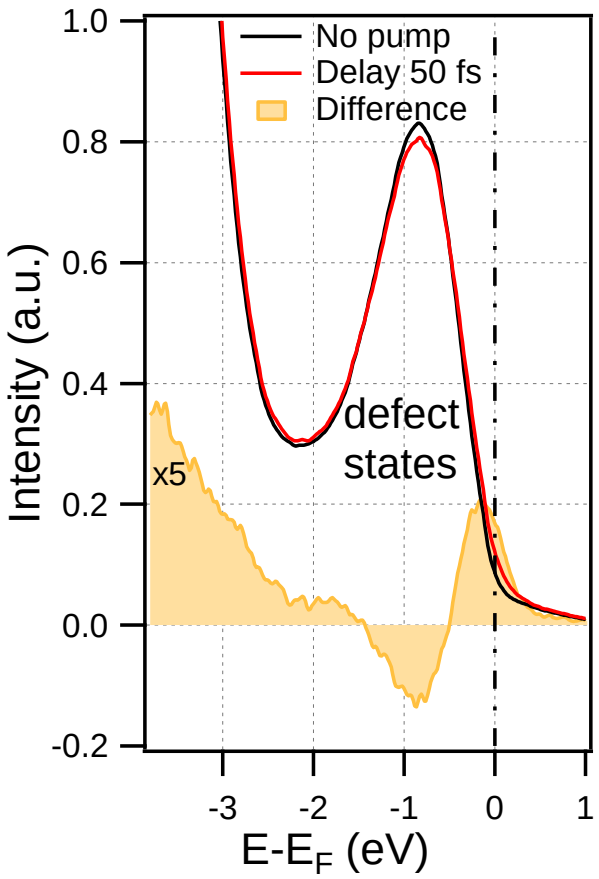
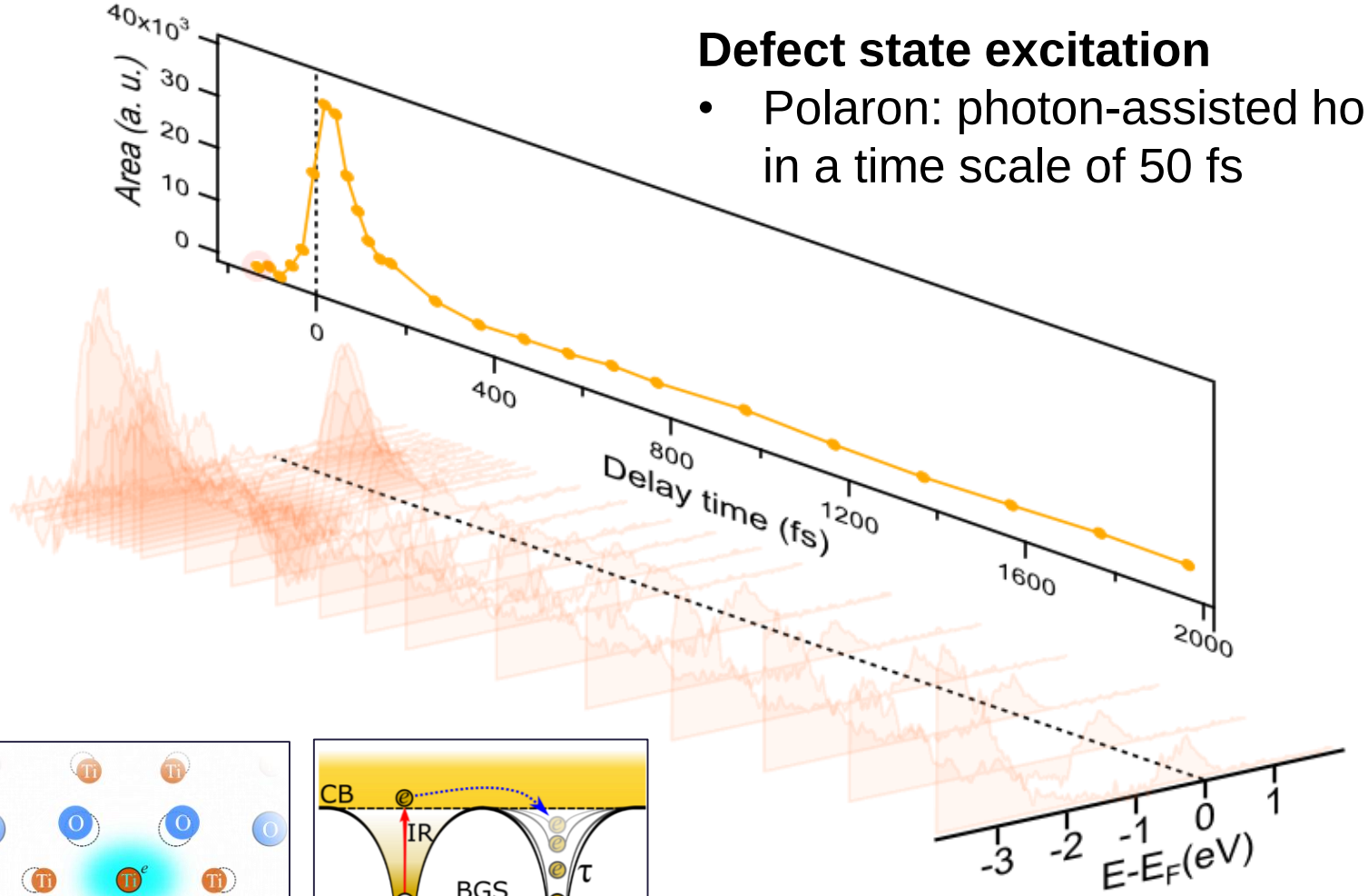
Time-resolved photoelectron spectroscopy with XUV.

- Dynamics of conduction band (CB) and valence band (VB)
- Selective excitations
  - ✓ VB→CB transition
  - ✓ Defect state excitation

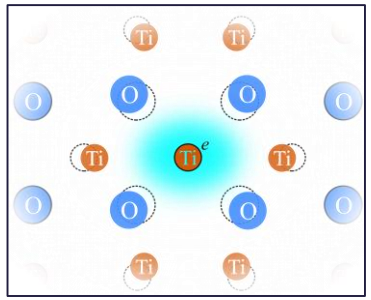
Electron dynamics in transition metal oxides





Defect state excitation

- Polaron: photon-assisted hopping in a time scale of 50 fs



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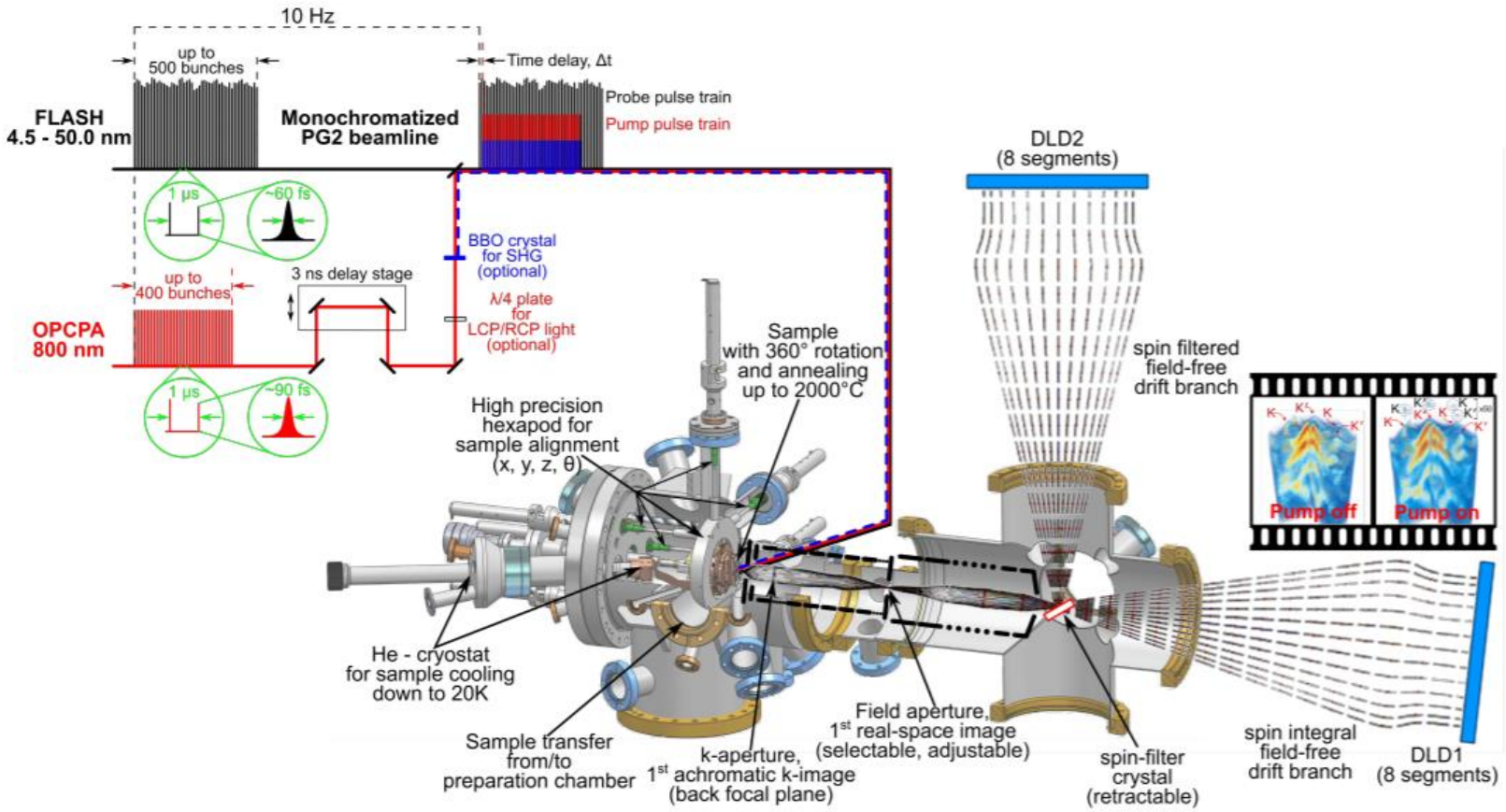
Y Zhang, D Payne, C.L. Pang, C Cacho, R.T. Chapman, E Springate, H.H. Fielding, G. Thornton, J. Phys. Chem. Lett. 2019, 10, 5265

Photoelectron spectroscopy at FELs



- Higher photon energies cover wider range of momentum space
- Broad energy tunability allows
  - Access to 3D momentum information
  - Means to study surface v bulk phenomena
  - Probing core-level states (XPS) to complement valence-band measurements
- Adding momentum-resolution to XPS yields x-ray photo-diffraction (XPD) measurements
  - Possibility to study ultrafast and element-specific changes in electronic structure

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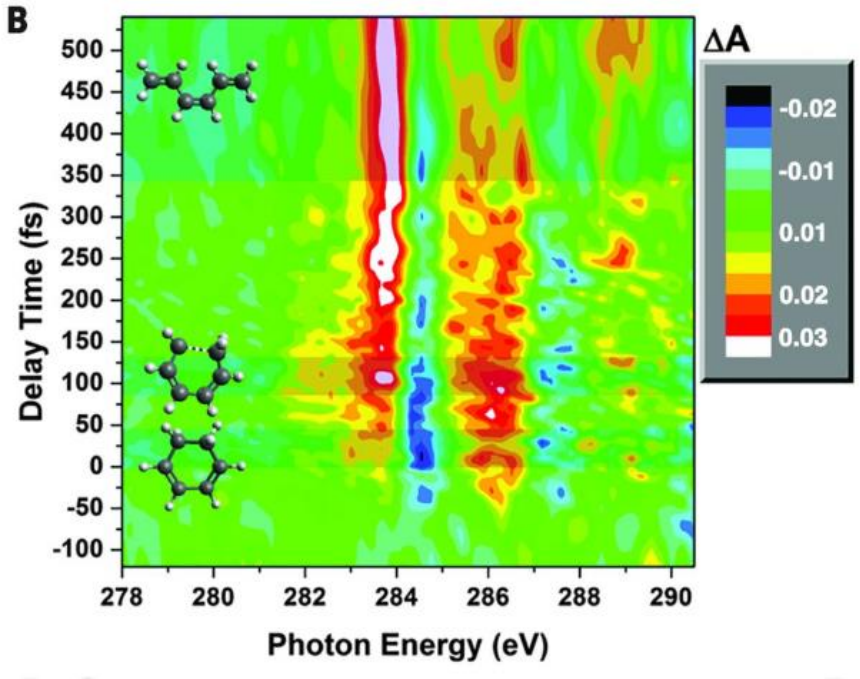
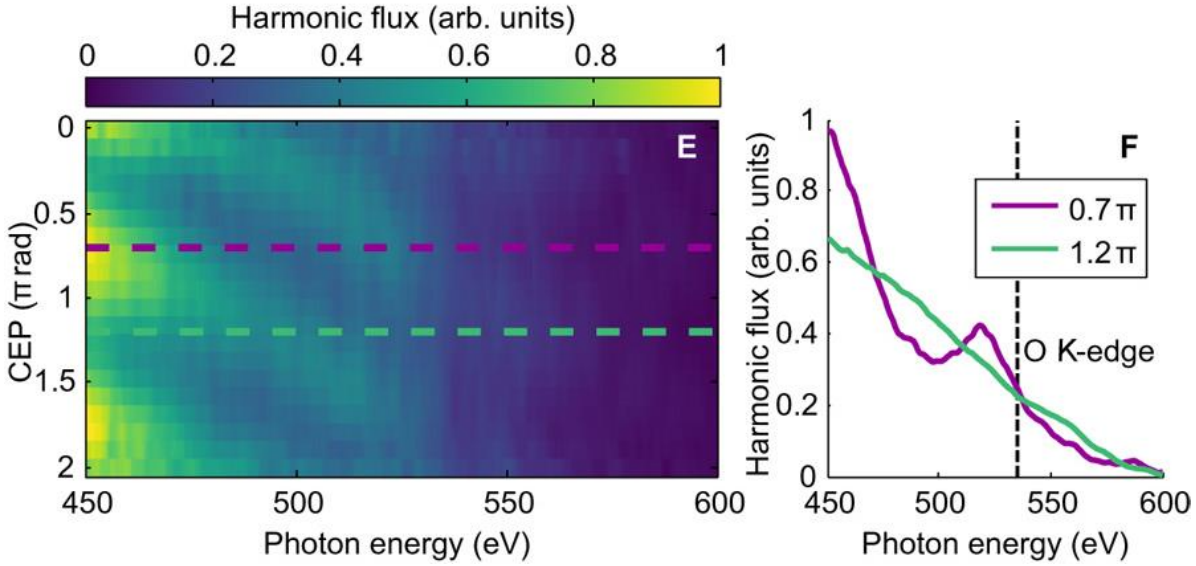
D Kutynakov, ….. K Rossnagel, J Demsar, R Ernstorfer, Ph Hofmann, R Ernstorfer, G Schonhense, Y Acremann, W Wurth et al, arXiv 1906.12155

Other key application of HHG: transient absorption spectroscopy



- Ring-opening of cyclohexadiene
- HHG to carbon K-edge from 1300 nm laser

*A Attar… S Leone, Science **356** 6333 (2017)*



- HHG to oxygen K-edge from 1700 nm few-cycle laser

AS Johnson… JWG Tisch, JP Marangos, Sci Adv eaar3761 (2018)

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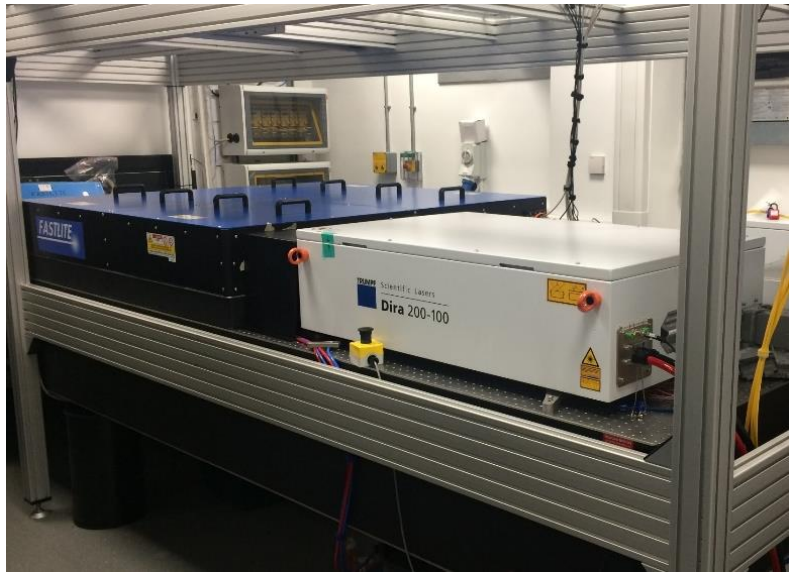
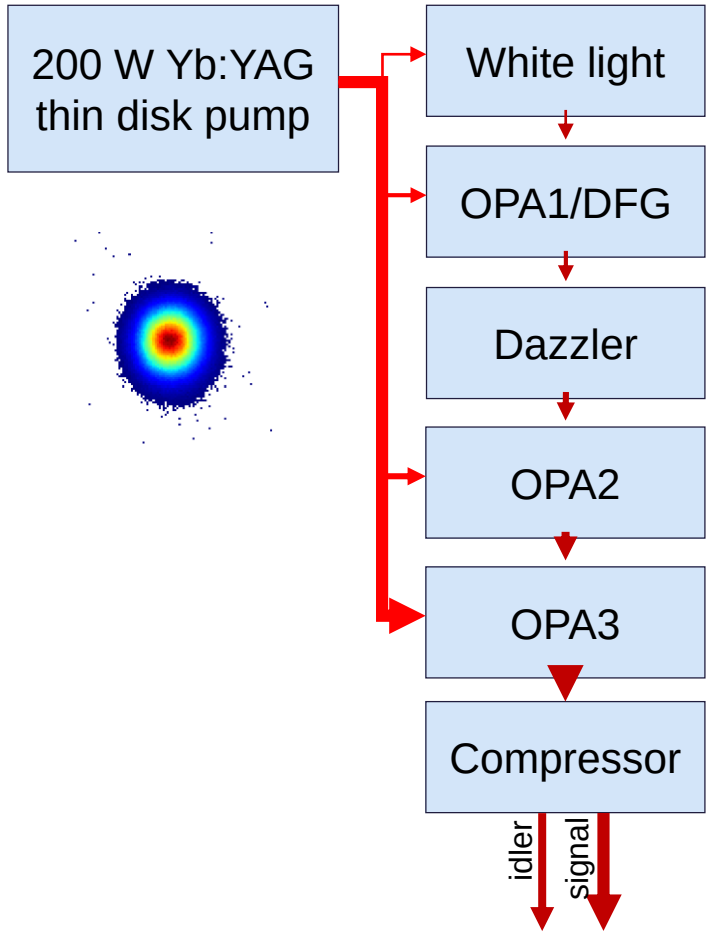
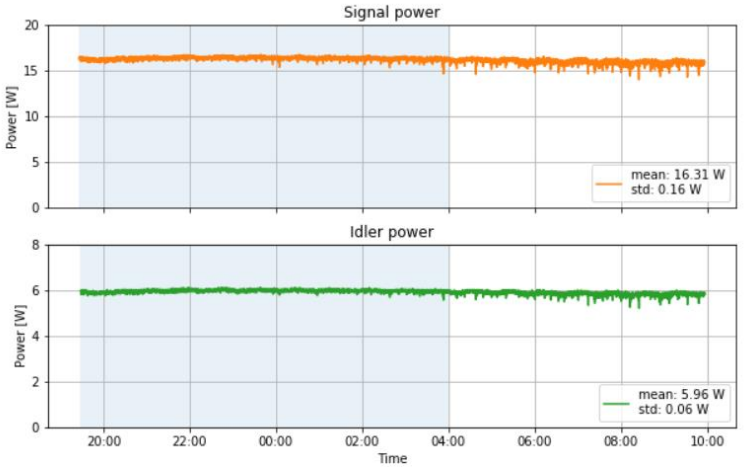
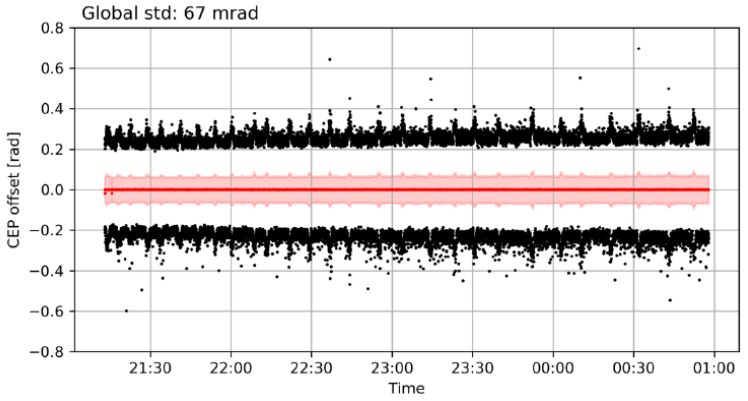
New 100 kHz IR OPCPA laser at Artemis



- 160 uJ, 50 fs pulses at 1700 nm
- 50 uJ, 60 fs pulses at 3000 nm
- Power stability 1% over 8 hours
- CEP-stable







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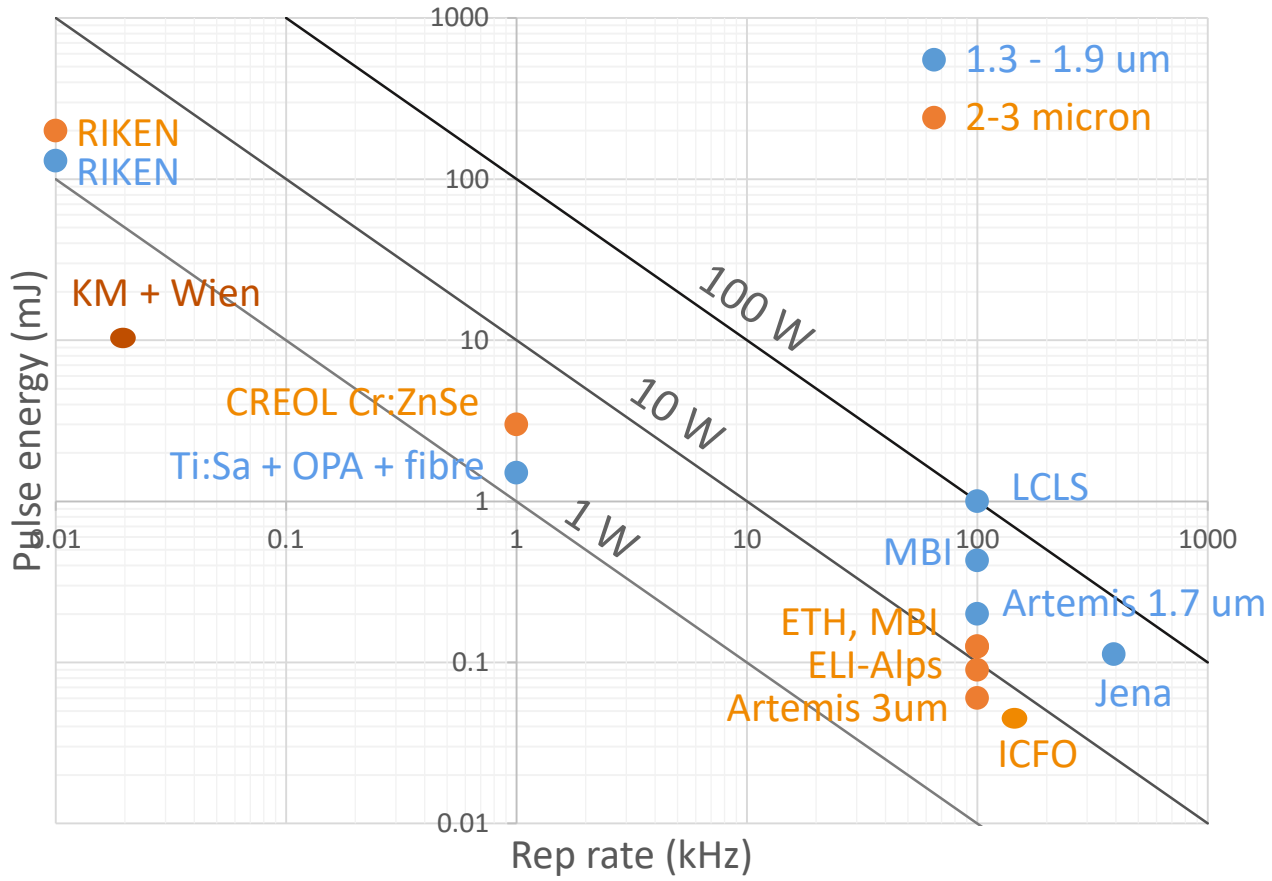
Rapid progress in ultrafast long-λ laser technology



- Where will be in 10 years when UK XFEL arrives?
- Will optical pump-probe measurements up to keV be best done with HHG-based sources?
- Certainly huge opportunities for lasers to sync to XFEL as pumps and probes

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Thank you

www.clf.stfc.ac.uk/Pages/Artemis.aspx