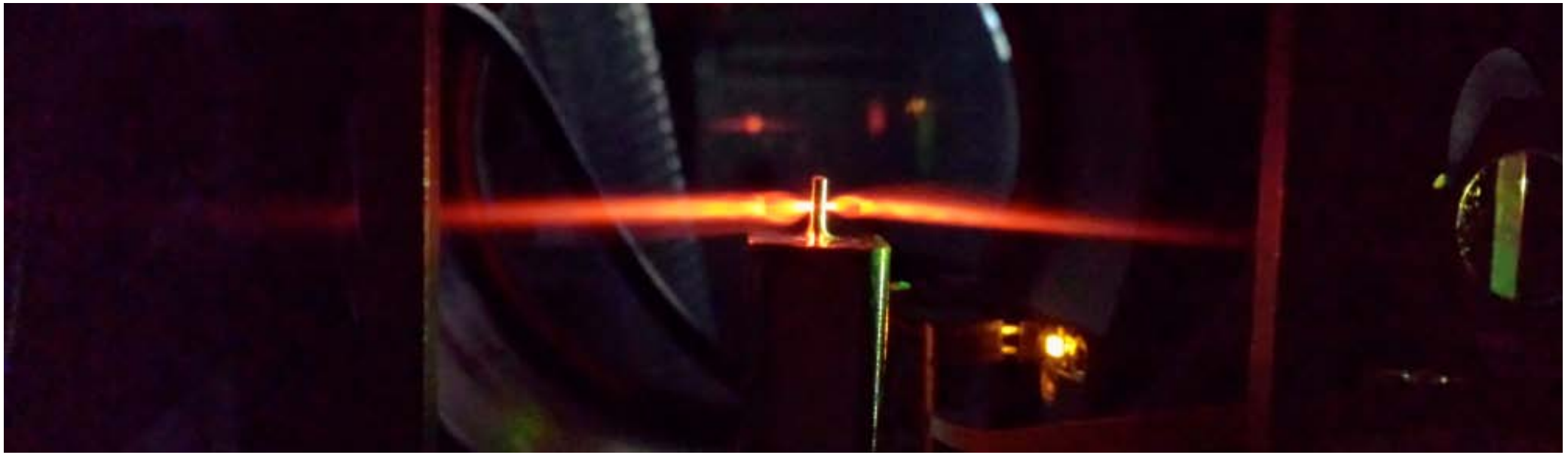
Real time 4D imaging of energy flow towards intelligent designer materials.



J. Biegert

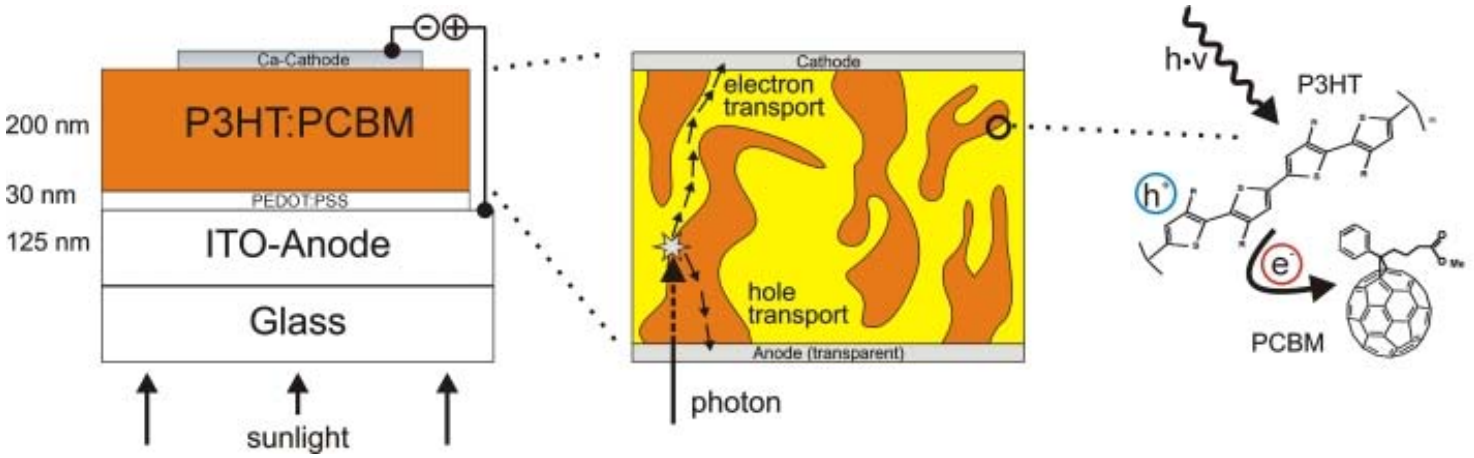
ICFO Institut de Ciències Fotòniques

ICFO - The Institute of Photonic Sciences
The Barcelona Institute of Science and Technology
08860 Castelldefels (Barcelona), Spain
atto.icfo.eu

ICREA

The problem - one example

Energy Harvesting - Organic Solar Cells



Courtesy: KIT, Inst. Verfahrenstechnik

Efficiencies < 10%

Report of the Basic Energy Sciences Advisory Committee, United States Department of Energy

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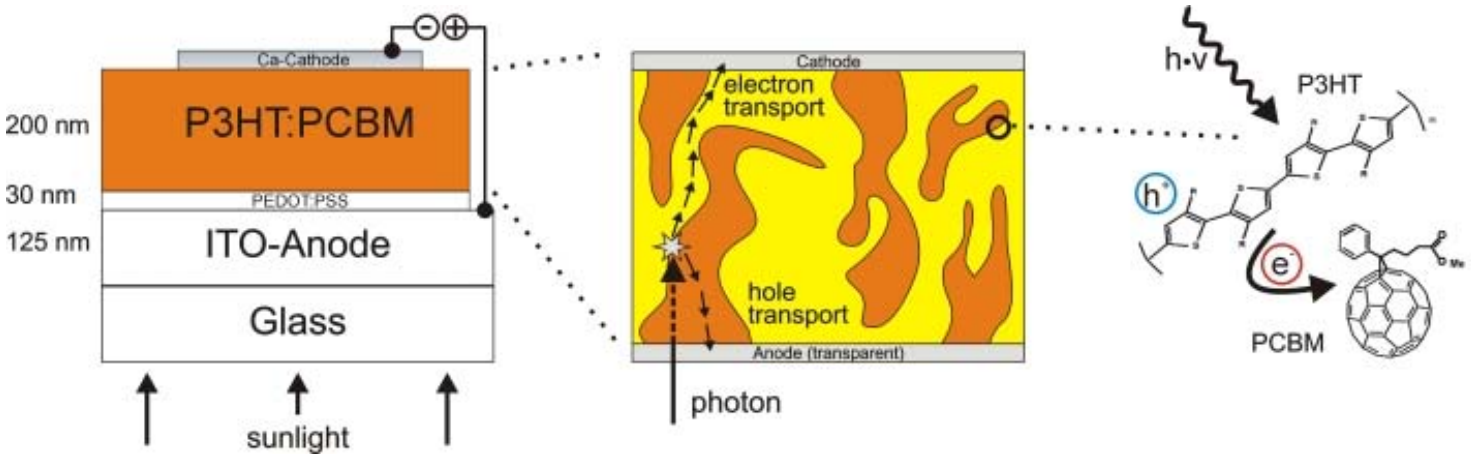


Courtesy: KIT, Inst. Verfahrenstechnik

Efficiencies < 10%

The key: Insufficient time resolution to study exciton formation and dynamics

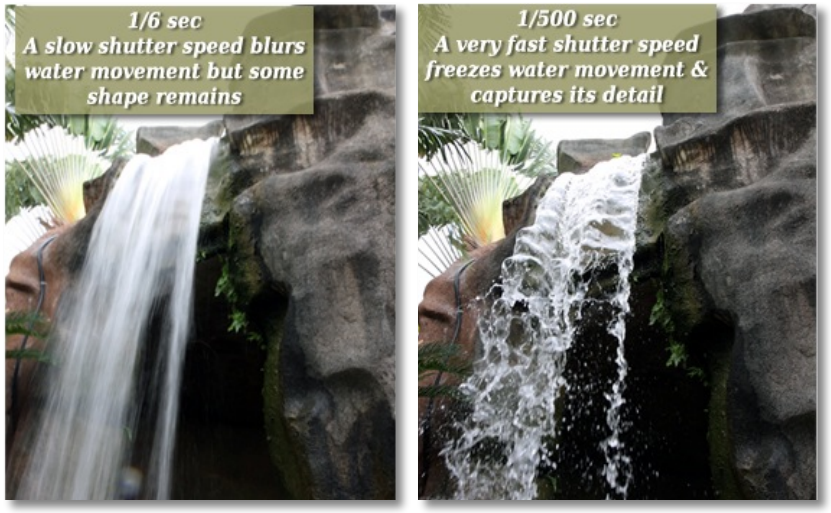
From material alchemy to synthesis

Need tools to understand dynamics with element specificity!

Report of the Basic Energy Sciences Advisory Committee, United States Department of Energy

The requirement

Tools are needed to scrutinize electronic/molecular dynamics on their native length and timescale.



Follow dynamics to understand function!

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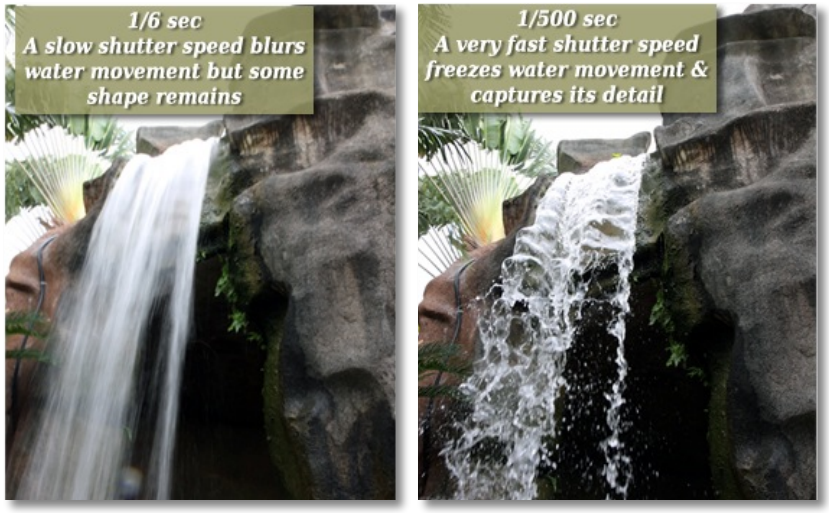

Follow dynamics to understand function!

Atto- to femtosecond pulses

with element / state specificity

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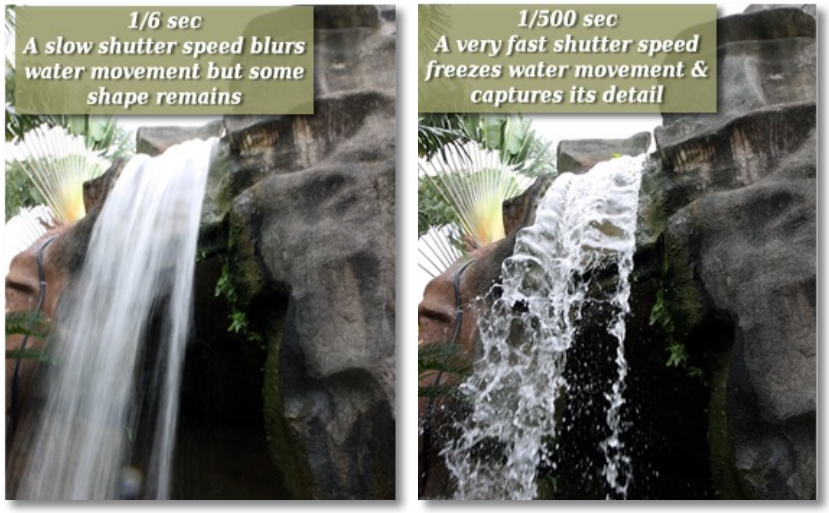


Follow dynamics to understand function!

Atto- to femtosecond pulses

with element / state specificity

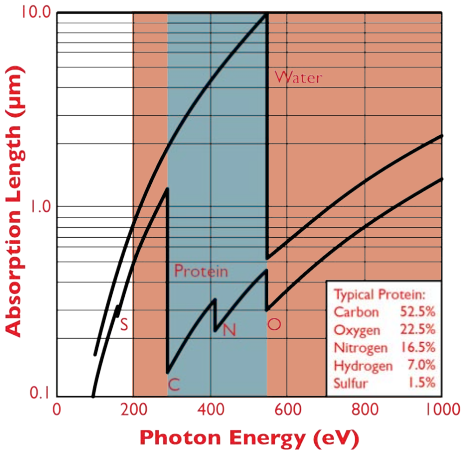
Ultrafast soft/hard X-Ray Absorption and Diffraction

Friedrich, Knipping, Laue (1912), Bragg (1913), Moseley (1913)

- X-Ray Synchrotron / FEL: 100 fs -10 fs, 1.9Å
- keV High Harmonic Generation: as - fs

M-B€ **synchronization / random pulses**
radiation doses
low yield wavelengths long
broadband imaging unsolved

The method

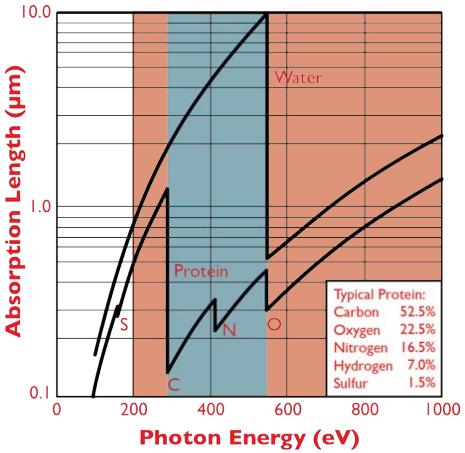


- **gives geometric and electronic structure!**

  oxidation/spin state, ligation, symmetry

- **works with gas, liquid, solid phase**

The method



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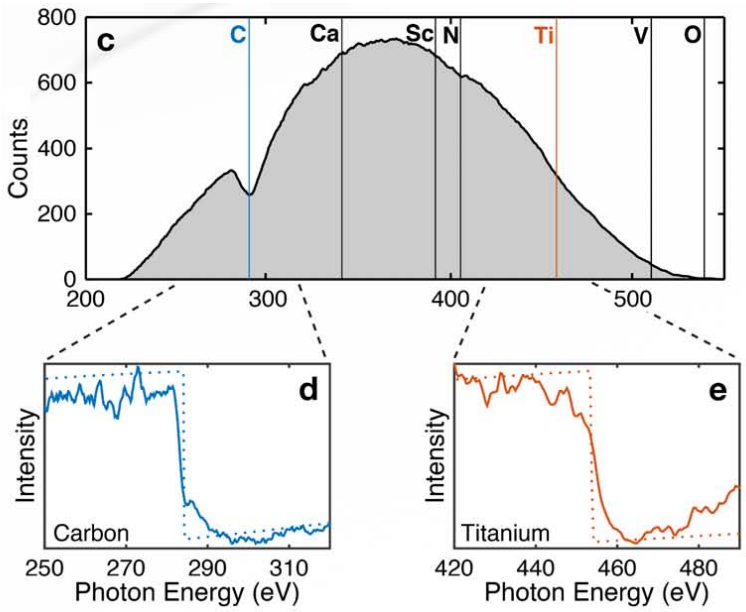
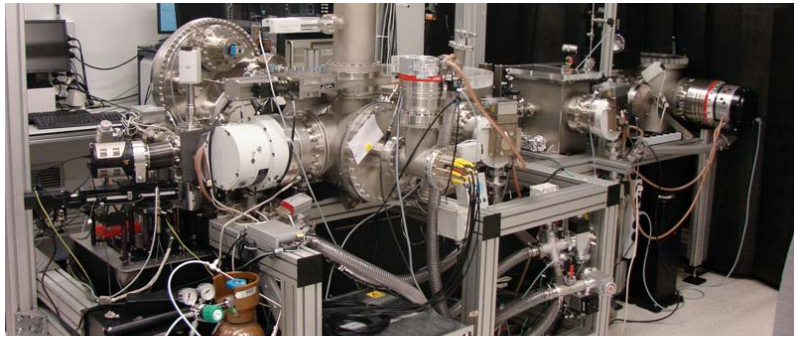
First table top attosecond SXR source at ICFO:





F. Silva et al. Nature Commun. 6, 6611 (2015)

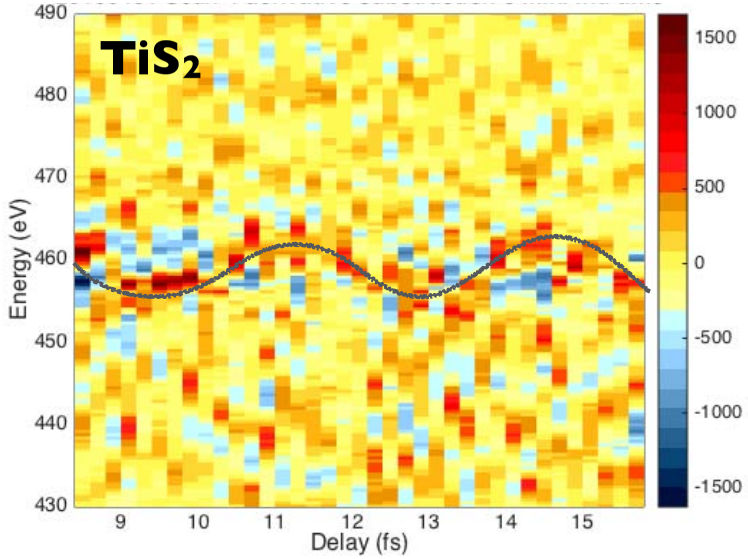
S. Teichmann et al. Nature Commun. 7, 11493 (2016)

also being developed at

Stanford, RIKEN, Berkeley, JILA, MIT, MPQ, MBI, DESY, BESSY, …

What is the problem?

First attosecond real-time XAFS measurement in condensed matter!



(2D TMDC for spin and valleytronics)

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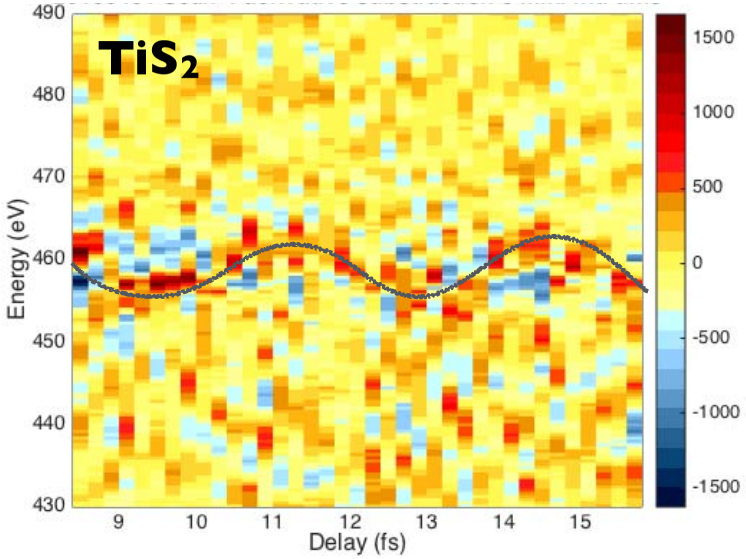


(2D TMDC for spin and valleytronics)

- **8h measurement**

  impossible to do otherwise

- **Detection resolution and efficiency**

  dE/E ~ 1/100 only < 400 eV 10%

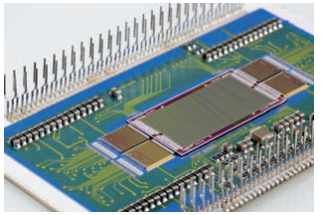
Rapid 4D (2D + energy + time) detection is the bottleneck

Proposal

Energy resolving 2D detection + pump and probe = 4D

- Energy resolving per pixel *SDD limit 127 eV*

PNDetector



12.7 mm x 12.7 mmm 1 kHz, 145 eV @ Mn Kα

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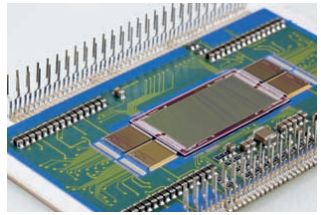

12.7 mm x 12.7 mmm 1 kHz, 145 eV @ Mn Kα

- Photon counting also below ~ 1 keV

heliotis

- Lock-in detector with on chip demodulation

90 billion samples/s to 5k frames/s for 300 x 300 pixels

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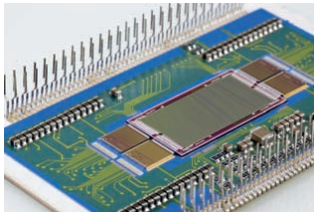

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lock-in detection + energy dispersive + single photon

Element specific real-time imaging for every lab and company

Exciton imaging, biochemical hyper spectral imaging, X-ray imaging, volume and surface tomography, security