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

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Introduction

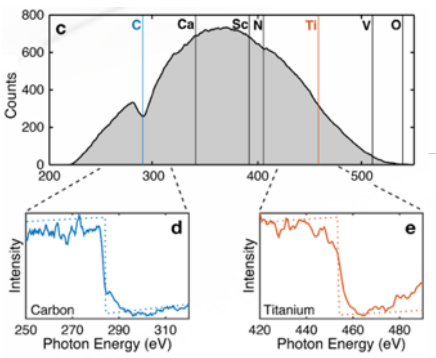
Intelligent designer materials with exactly tailored properties and function are centrepiece to future technological developments with impact across many areas of society including medicine and biochemistry, energy and information processing, just to name a few.

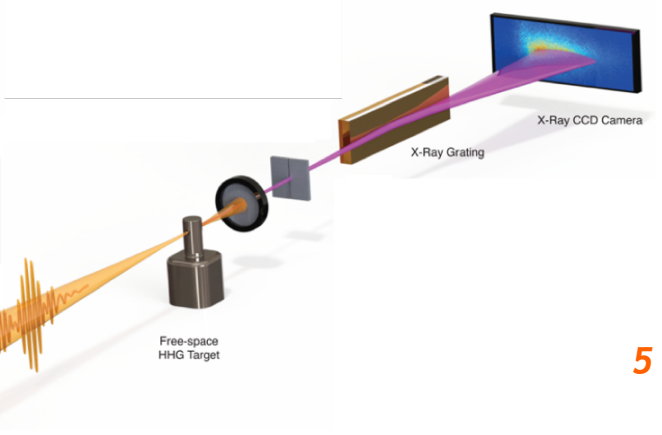
The basic requirement to understand and control functionality is therefore our ability for probing and understanding the dynamics of interactions between photons, electrons and chemical bonds starting from the fastest "triggering" events, on the attosecond time scale, and at the shortest relevant length-scales, on the Ångstrom length scale. I.e. we need the combined atto-femtosecond and pico-nanometer resolution.

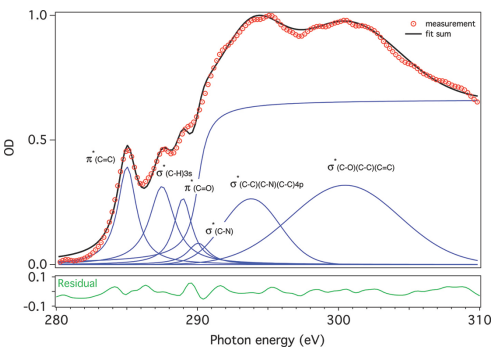
see also: Report of the Basic Energy Sciences Advisory Committee, United States Department of Energy.

The Idea/Concept

❖ **Method: Time (atto-femtosecond) space (pico-nanometer) resolved x-ray absorption and diffraction**







5 min tabletop instead of 2 h synchrotron

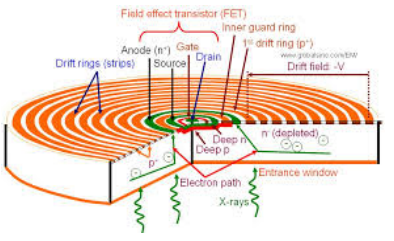
F. Silva .. J. Biegert, Nature Commun. 6, 6611 (2015) *S. Teichmann .. J. Biegert, Nature Commun. 7, 11493 (2016)*

Table top attosecond x-rays exist now, but detection is a standing problem!

☂ ***Current impediment: signal-to-noise + energy resolution + acquisition speed***

❖ **Proposal: 4D phase sensitive camera for the soft x-ray regime:**

- Energy resolving single pixel at 1eV. Current SSD energy resolution is 127 eV
- Single photon counting capability in SXR energy range
- Lock in CCD with on chip demodulation (time of flight camera)



(Heliotis VIS CCD: Demodulate 90 Billion samples/s to 5k frames/s for 300 x 300 pixels)

☀ ***Breakthrough: lock-in detection + energy dispersive + single photon detection in SXR***

Potential Impact

A camera with 4D single photon sensitivity would enable real time imaging of energy flow and molecular transformation with molecular fingerprinting accuracy within electronic sensors and magnetic storage materials, biological tissue or biochemical assemblies. Such capability would profoundly impact fundamental science and, at the same time, radically advance and transform many areas of industry and technology.

E.g. exciton imaging, biochemical hyper spectral imaging, X-ray imaging, volume and surface tomography, security