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Bright Attosecond Soft and Hard X-ray Supercontinua

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In this talk, I will present an experimentally feasible and straightforward route for generating bright, fully coherent, x-ray light by combining attosecond science with extreme nonlinear optics. By driving high-order harmonic generation using longer-wavelength mid-infrared lasers, I show that, in theory, bright coherent beams can extend into the soft and hard x-ray regions of the spectrum for the first time, essentially solving the phase matching problem in extreme nonlinear optics. Experimentally, we demonstrated bright high harmonic beams in the water window region of the spectrum and around the L-edges of magnetic materials - at the magnetic heart of the matter - for the first time. Most importantly, scaling of the macroscopic x-ray yield is surprisingly favorable as the laser wavelength is increased and the generated harmonic wavelength decreases. The macroscopic physics of phase matching requires higher gas pressures, which compensates for the poor microscopic single-atom high harmonic yield due to quantum diffusion of the rescattering electron wavepacket during the longer time spent in the continuum between ionization and recombination. Extrapolating this approach further, bright ultrafast harmonics can extend even into the hard x-ray region of the spectrum, promising to realize the coherent tabletop version of the Roentgen X-ray tube. This will enable atomic-site-specific electron dynamics in molecules, materials or at surfaces to be captured in their characteristic time scales, as well as opening up applications bio-imaging of thick samples without the need for labeling or sectioning. Finally, the ultrabroad supercontinua can support coherent pulses as short as few attoseconds, and possibly even zeptosecond pulses in the near future.

[1] T. Popmintchev et al., "Phase matched upconversion of coherent ultrafast laser light into the soft and hard x-ray regions of the spectrum", PNAS 106, 10516 (2009).
[2] T. Popmintchev et al., "The Attosecond Nonlinear Optics of Bright Coherent X-Ray Generation", Nature Photonics 4, 822 (2010). Featured on cover.