**Quantum Design of Coherent X-rays for Imaging at the Space-Time Resolution Extreme**

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Nonlinear optics revolutionized the ability to create directed, laser-like light particularly in the regions where lasers based on conventional approaches are not practical. New breakthroughs in attosecond extreme nonlinear optics promise a similar revolution in the X-ray regime.

In this talk, I will discuss the limits of the fundamental quantum physics and the extreme nonlinear optics of the process of high order harmonic generation in the context of creating coherent X-ray waveforms which can be tailored at the moment of generation. Such a versatile designer light is ideal for effective 5 dimensional studies of various bio- and nano-systems with attosecond temporal and nanometer spatial resolution, as well as with element specificity. I will also discuss the path forward for generating bright coherent X-ray beams from a laboratory-scale apparatus at photon energies of 1-10 keV and greater with unprecedented attosecond-to-zeptosecond pulse durations, and with arbitrary spectral, temporal shapes, and polarization state. A fully spatially and temporally coherent version of the Roentgen X-ray tube with exquisite quantum control of the properties of the soft and hard X-ray light may be possible.

1. T. Popmintchev, et al., Science **336**, 1287 (2012).
2. D. Popmintchev, et al., Science **350**, 1225 (2015).
3. T. Fan, et al., PNAS **112**, 14206 (2015).