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# ФАКУЛТЕТЕН СЕМИНАР

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## *Frontiers in Extreme Nonlinear Optics: Attosecond-to-Zeptosecond Laser-Like X-rays on a Tabletop*

The past three years marked the 50th anniversaries of three significant innovations in optics: the invention of the laser, the discovery of the nonlinear upconversion of laser light (second harmonic generation) in a spectral region where laser emission has not been possible, and the outlining of phase matching in nonlinear optics – a recipe that makes the new laser-like light bright and usable. The same revolution that made it possible to create well-directed beams in the visible region of the spectrum is only now happening for X-rays. Large-scale X-ray Free Electron Lasers (XFELs) are promising to capture images of ultrafast dynamics in a single shot. An extreme version of nonlinear optics, called high harmonic generation, can also generate bright, coherent, beams of X-rays, with very short wavelengths <7.7 angstroms, in a tabletop-scale setup for the first time. This process practically realizes a fully coherent version of the Roentgen X-ray tube in the soft X-ray region. The process essentially uses novel ultrafast mid-infrared lasers to drive a nonlinear optical process of ultrahigh order (>5000th harmonic), and most importantly, to simultaneously phase match this extreme upconversion to make the emission bright. The high harmonic X-ray light is indistinguishable from a true laser light emission. Furthermore, it is more than a laser light – it is a coherent X-ray “white light” with the largest amount of coherent frequencies that any light source, large or small scale, can generate to date. Such broad spectral bandwidths can support ultrashort pulses as short as few attoseconds and are scalable towards zeptosecond pulse durations. These unique, ultrafast, laser-like X-ray beams promise revolutionary new capabilities for understanding and controlling how the nanoworld works on its fundamental time and length scales. This understanding is relevant to the next generation data and energy storage devices, nano-electronics, bio-imaging, and future medical diagnostics.

*Popmintchev et al., Prov. US Patent (2008); CLEO Postdeadline (2008); Opt. Lett. 33, 2128 (2008); PNAS 106, 10516 (2009); PRL 105, 173901 (2010); Nature Photonics 4, 822 (2010); CLEO Postdeadline (2011); Science 336, 1287 (2012).*