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Extreme Nonlinear Optics: Applied Attosecond Science[1]

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High-order harmonic generation (HHG) provides a useful source of coherent, ultrafast light in the extreme ultraviolet (EUV) region of the spectrum, with applications in ultrafast atomic and molecular dynamics, coherent control of electron dynamics, lithography, high-resolution imaging, site-specific spectroscopy and bio-microscopy. In HHG, an intense laser pulse is focused into a medium. The highly nonlinear interaction between the laser light and the atoms creates higher-order harmonics that emerge from the medium as a coherent, low-divergence, beam. In general, to generate the brightest harmonics from a medium, the conversion process must be phase matched, even in the presence of significant levels of ionization that introduce a large plasma-induced dispersion and prevent the laser and the harmonic light from propagating at the same phase velocity. A short pulse is also needed, since this reduces the ionization level at a particular laser intensity and harmonic photon energy. And finally, an atom with large effective susceptibility is needed to generate the brightest harmonics. In this talk, we show that by combining phase matching, quasi phase matching (QPM), and pulse compression in a single gas-filled waveguide, we can shift the phase-matching region in large atoms to significantly higher energies. We also show that use of a temporally-sharp laser pulse generates an x-ray continuum at low pressure, which may correspond to an isolated, 50 attosecond, pulse. Finally, the role of carrier-envelope phase stabilization of the driving laser pulses on the output harmonics from the medium will also be discussed. Applications of high harmonics in ultrafast surface and photoacoustic spectroscopies will also be presented. N. Wagner et al., "High-Order Harmonic Generation up to 250 eV from Highly Ionized Argon," Phys. Rev. Lett. 93, 173902 (2004). A. Paul et al., "Quasi-phase-matched generation of coherent extreme-ultraviolet light," Nature 421, 51 (2003). E.A.Gibson et al., "Coherent soft x-ray generation in the water window with quasi- phase matching", Science 302, 95 (2003). I.P. Christov et al., "Attosecond Pulse Generation in the Single Cycle Regime," Phys. Rev. Lett. 78, 1251 (1997).

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