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Opto-Optical Phase Control of Coherent Extreme Ultraviolet Light Pulses[1]

JOHAN MAURITSSON, Lund University

We present an experimental and theoretical study of opto-optical phase modulation of extreme ultraviolet (XUV) free induction decay (xFID)[1]. Coherent XUV light, from high-order harmonic generation [2], is used to promote an ensemble of atoms to a superposition of the ground state and a series of excited states. The technique is demonstrated for a number of different target atoms and includes both bound states and higher lying auto ionizing states. When an ensemble of atoms is exposed to a short, coherent light pulse it will respond collectively and the excited atoms will act as oscillating dipoles. These dipoles may continue to oscillate coherently for a long time after the excitation pulse has passed, resulting in forward scattered light known as free induction decay (FID) [3,4]. This forward scattered light has the same spatial properties as the excitation pulse, but the phase is shifted by π. The overlap between the two fields will therefore yield the normal absorption spectrum observed in optical spectroscopy. Applying an infrared probe pulse after the excitation pulse we can control the phase of the emitted light. If the delay controlled IR pulse is co-linear, but non-coaxial, with the XUV pulse a Stark induced phase gradient can be induced resulting in a precise control of the direction and timing of the xFID emission. With a single IR control pulse we can form an opto-optical switch, or with multiple pulses an opto-optical modulator. Applications for the opto-optical phase modulator include reducing the temporal jitter in optical-FEL pump-probe experiments, background free 2D spectroscopy in the XUV, and ultrafast which-way interferometry. [1] S. Bengtsson et al. submitted [2] M. Ferray et al. J. Phys. B **21**, L31 (1988) [3] R. G. Brewer and R. L. Shoemaker, Phys. Rev. A **6**, 2001 (1972) [4] F. A. Hopf, R. F. Shea, and M. O. Scully, Phys. Rev. A **7**, 2105 (1973)

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