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Ultrashort non-linear interactions of x-rays with atoms[1]

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Upcoming x-ray free electron laser sources (XFELs) will open the pathway to study non-linear optical effects in the x-ray regime for the first time. In this contribution we will present model calculations of resonant and non-resonant interaction of XFELs with atoms, tailored to predict and plan first experiments on atomic neon at the Linac Coherent Light Source at Stanford. The most fundamental textbook example of a resonant, non-linear interaction of photons with atoms is Rabi flopping – the coherent, oscillatory population transfer in a quasi two-level system by absorption and stimulated emission of photons. In the x-ray regime, resonant excitation of an inner-shell electron results in a core-excited state, which decays on the time-scale of a few fs. Ultrahigh intensities are therefore needed, to efficiently drive the back and forth transitions, which will become available with upcoming XFEL sources. The relatively long durations of these sources, in the range of 100 fs, will, however, hamper to study this fundamental effect in the time-domain. Shorter x-ray pulses of fs or sub-fs duration are therefore needed to study quantum optical processes involving core electrons. A possible route to sub-fs pulses with intensities comparable to XFEL sources is to use XFELs to pump an inner-shell atomic x-ray laser. Thereby a variety of different lasing pulse structures can be realized: isolated, transform limited x-ray bursts of sub-fs duration, pulses of 10 fs duration with increased temporal coherence as compared to XFELs and trains of fs pulses of different wavelength. The latter would open the pathway for ultrashort two color pump-probe sources in the x-ray regime. Self-consistent gain and amplification calculations and possible applications of this new kind of multi-color x-ray source will be discussed.

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