Amplified spontaneous x-ray emission in atomic and molecular gases

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X-ray free-electron lasers (XFELs) provide ultra-short x-ray pulses of unprecedented peak brightness, opening a pathway to transfer quantum electronics and quantum optical processes to the x-ray domain. We present results of the first experimental demonstration of an x-ray laser based on amplification of x-ray radiation on an atomic inner-shell transition in Neon [1]. The population inversion is achieved by rapid K-shell photo-ionization [2,3] or resonant excitation [4] with an XFEL pulse. Gain saturation of the K-α transition in Neon could be demonstrated in a recent experiment at the Linac Coherent Light Source. In addition to experimental results, we present numerical solutions of the generalized Maxwell-Bloch equations. The emitted x-ray pulses have ultra short time durations, ranging from sub femtoseconds to a few femtoseconds and are nearly transform limited, despite pumping with a stochastic XFEL source of only limited temporal coherence. We will discuss the extension of the x-ray lasing scheme to amplified spontaneous emission and self-stimulated x-ray Raman scattering in diatomic molecules, thereby creating a tunable x-ray laser based on inner-shell transitions in molecules.

[1] N. Rohringer, D. Ryan, R. A. London, M. Purvis, F. Albert, J. Dunn, J. D. Bozek, C. Bostedt, A. Graf, R. Hill, S. P. Hau-Riege and J. J. Rocca, Nature 481, 488 (2012).
[2] N. Rohringer and R. A. London, Phys. Rev. A 80, 013809 (2009).
[3] M. A. *Duguay* and G. P. Rentzepis, Appl. Phys. Lett. 10, 350 (1967).
[4] Y.-P. Sun, J.-C. Liu, C.-K. Wang and F. Gel' mukhanov, Phys. Rev. A 81, 013812 (2010).