Narrow-band hard-x-ray lasing with highly charged ions

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The development of high-quality x-ray sources with well-defined intensity and frequency is of great importance in several areas of science. We present a scheme for the generation of fully coherent x-ray radiation via population inversion in highly charged ions [1]. The ions are generated in a laser-produced plasma and population inversion is achieved by inner-shell photoionization using x-ray pulses from a free-electron laser (FEL). In such systems, the autoionization channel hindering the lasing process is nonexistent due to the lack of outer-shell electrons. By choosing a lasing transition which decays slowly, on the one hand, it enables lasing for photon energies above 10 keV, on the other hand, it results in a further reduction of the x-ray laser bandwidth by several orders of magnitude, as compared to existing methods using neutral atoms or ions in low charge states as lasing medium [2,3].

For a time-dependent description of the process we solve the Maxwell–Bloch equations numerically with different realizations of simulated FEL pulses originating from self-amplified spontaneous emission. Atomic structural properties are obtained with the multiconfiguration Dirac-Fock method. Initial populations of the states of the involved highly charged ions under given plasma conditions are computed with the FLYCHK code [4]. Our theoretical simulations show that with the scheme we put forward one may obtain high-intensity, femtosecond x-ray pulses of relative bandwidths on the order of $\Delta\omega/\omega = 10^{-5}$–$10^{-7}$, and with photon energies up to the hard x-ray regime. Such x-ray lasers may be applicable, e.g., in the study of x-ray quantum optics and metrology, investigating nonlinear interactions between x-rays and matter, or in high-precision spectroscopy studies in laboratory astrophysics.

References

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