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DENSITY-MATRIX DESCRIPTIONS FOR LASER-MATTER INTERACTIONS*

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An investigation has been in progress on the influence of autoionizing resonances on atomic processes in high-temperature plasmas, particularly those encountered in magnetic- and laser-fusion research and in astrophysics. In the kinetic-theory description, account is taken of the indirect contributions of autoionizing resonances to the effective rates for excitation, de-excitation, ionization, and recombination. A microscopic kinetic-theory foundation is adopted as the fundamental starting point for a systematic reduction to the macroscopic radiation-hydrodynamics (or radiation-magneto-hydrodynamics) description. From the spectral perspective, particular emphasis has been directed at radiative emission processes from autoionizing resonances. These processes can give rise to resolvable dielectronic-recombination satellite features, which have been analyzed to determine plasma temperatures, densities, electric and magnetic field distributions, and charge-state distributions.

We also investigate radiative absorption processes, which play important roles in the denser plasmas encountered in laser-matter interactions. Particular emphasis is directed at radiative excitation processes involving autoionizing resonances, which can provide significant contributions to the non-equilibrium ionization structures and to the radiative absorption and emission spectra in the presence of intense electromagnetic fields. A reduced-density-matrix formulation has been under development for a microscopic description of the electromagnetic interactions of many-electron atomic systems in the presence of collisional and radiative decoherence and relaxation processes. A central objective is to develop a fundamental quantum-statistical formulation, in which bound-state and autoionization-resonance phenomena can be treated on an equal footing, together with processes involving the plasma electrons. An ultimate goal is to provide a comprehensive framework for a systematic and self-consistent treatment of non-equilibrium (possibly coherent) atomic-state and plasma-particle kinetics together with high-resolution (possibly overlapping) spectral-line shapes. This should enable a unified treatment for a broad class of atomic processes in laboratory and astrophysical plasmas covering extensive density and field regimes.

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