

LASER COOLING THEORY FOR GROUP II ATOMS: THREE LEVELS AND MORE

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Over the past few years, a variety of laser-cooling techniques have been applied to Group II atoms. These techniques utilize the properties of Group II atoms to cool them below the canonical two-level Doppler limit. We will discuss the recent theoretical contributions to understanding such cooling mechanisms. We explore the use of multidimensional polarization-gradient cooling methods to these atoms. For most of the Group II atoms, the close spacing (on the order of the excited-state linewidth) of the hyperfine manifolds introduces complexities not encountered in atoms with more separated hyperfine structure. Non-cooling transitions can then occur, as well as non-negligible inter-manifold coherences which can act to decrease the effectiveness of the cooling. We present detailed three-dimensional numerical calculations of such cooling processes that provide insight and predictive power into the mechanisms driving the dynamics. For Group II atoms without magnetic substructure, which do not support polarization-gradient cooling, a novel cooling scheme utilizing three internal atomic levels can be useful. Numerical calculations provide quantitative cooling predictions which we then can use to extract a qualitative understanding of three-level cooling mechanisms that involves coherent quantum interference and relates to electromagnetically induced transparency. Finally, we will discuss the possible use of cavities to enhance the velocity-capture range of multilevel polarization-gradient cooling schemes and which may lead to much more effective cooling in practice.