Efficient optical pumping and cooling in Dy
and other complex systems

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The talk will briefly touch upon three sub-topics and will emphasize the connections among them.

1. Methods of optical pumping [1] will be discussed that are applicable to open, high-angular-momentum transitions in atoms and molecules, for which conventional optical pumping would lead to significant population loss. Instead of applying circularly polarized cw light, as in conventional optical pumping, techniques for coherent population transfer (e.g., adiabatic fast passage) are used to arrange the atoms so as to increase the entropy removed from the system with each spontaneous decay from the upper state. This minimizes the number of spontaneous-emission events required to produce a stretched state, thus reducing the population loss due to decay to other states.

2. The experimental apparatus for the radio-frequency spectroscopy in Dy, that lead to constraints on a wide range of physics beyond the standard model, is being upgraded at Mainz for new measurements of parity violation in Dy [2]. Parity violation experiments in Dy are realized on the $F_B = 10.5 \rightarrow F_A = 10.5$ transition of a non-zero-nuclear-spin isotope $^{163}\text{Dy}$ ($I=5/2$). An experimental limitation is the signal dilution due to the population distribution among the many different hyperfine states and magnetic sublevels. A significant improvement in our measurement’s statistical sensitivities is, therefore, possible by the application of an efficient optical pumping scheme for the odd-neutron number isotopes, in our case $^{163}\text{Dy}$, which will allow us to transfer population to the $F_B = 10.5$ state from some or all of the ground hyperfine states. Such an improvement will allow us to reach the intended statistical sensitivity to weak matrix elements of $\frac{H_{\mu}}{2\pi} \leq 10 \text{ mHz}$ within few hours of data acquisition.

3. Recently, a novel cooling technique was proposed and demonstrated [3], which is capable of overcoming the maximum photon scattering rate of the radiation pressure force set by the spontaneous decay rate from the upper state of the cooling transition. Furthermore, since this technique utilizes adiabatic population transfers between the ground state and the excited state it should be also applicable to systems where no closed transitions are available. We investigate the applicability of this technique in atomic dysprosium on the J=8 to J=9 transition at 626 nm (136 kHz linewidth) in two scenarios: atoms released from a magneto-optical trap and Zeeman slowed atoms in an atomic beam and compare the cooling and velocity changes achieved to conventional radiation-pressure cooling.