Measuring Multipole Moments of the CPT Density Matrix Under Optical Field Polarization-Modulation Conditions

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Chip-scale atomic clocks (CSACs) based on Coherent Population Trapping (CPT) are at the forefront of next-generation timekeeping for diverse applications, including global navigation satellite systems (GNSS), satellite communications, cell-phone networks, and hand-held GNSS receivers. Notwithstanding the potential ubiquity of this atomic device, a performance-limiting aspect of CSACs is the vapor-phase signal-to-noise ratio (SNR) of their ground-state (m_F = 0 to m_F = 0) atomic hyperfine resonance. Specifically, in commercially available devices angular-momentum optical pumping "pushes" atomic population towards high $|m_F|$ Zeeman sublevels at the expense of population in the 0–0 clock transition. Though mitigation strategies for this SNR limiting process have been proposed and demonstrated, there has to date been little direct measurement of the population distribution among Zeeman sub-states for atoms undergoing CPT, and how that population distribution is altered by SNR-improving mitigation strategies. Here, we describe our initial studies examining this question.

Our focus is on CPT in warm ^{87}Rb vapors using a VCSEL to generate the CPT signal. More specifically, in our initial studies we are examining the phase/polarization dual-modulation mitigation strategy for SNR improvement. Briefly, the laser polarization is modulated at a fast rate, so that on average no angular momentum is transferred to the vapor. Concomitantly, to account for π phase changes in the Rabi frequency as the polarization is modulated, the phase of the field is modulated. In our experiment, we employ a probe laser that is colinear with the CPT laser to probe the monopole, dipole, and quadrupole moments of the ground-state population distribution in the two (coupled) ground state hyperfine manifolds.

In this presentation, we will: 1) provide more detailed rationale for studying multipole moments in atomic device systems, 2) outline our experimental approach to studying the three lowest state multipoles of the ground-state population distribution, and 3) provide our preliminary results assessing these multipole moments in "standard" CPT clocks systems and CPT systems employing the dual-modulation mitigation strategy for SNR improvement.