Abstract

The three-photon laser excitation scheme (*5S1/2 → 5P3/2 → 6S1/2 → 37P*) in single rubidium atoms confined in an optical dipole trap is of particular interest for studying interactions in *nP*-states.

In this three-photon excitation scheme, semiconductor lasers serve as both the pump laser and second-stage excitation laser. For coherent atomic transitions, these lasers must exhibit long-term frequency stability and narrow emission linewidths. However, laser sources are subject to various noise components - including current noise (flicker noise), acoustic noise, and power supply noise - which lead to linewidth broadening, while thermal effects cause long-term frequency drifts.

This work demonstrates frequency stabilization of semiconductor lasers for experiments involving excitation of single cold rubidium atoms to Rydberg states. We implemented Pound-Drever-Hall (PDH) frequency stabilization of the semiconductor laser, achieving a laser linewidth of 25 kHz as estimated from the PDH error signal.

Following successful frequency stabilization and linewidth narrowing of the second-stage excitation laser, we report the first observation of Rabi oscillations in a single rubidium atom under three-photon excitation to the 37P state.