INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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Laser Cooling and Trapping of Yb and Rb Atoms Towards Quantum Computing

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SHORT ABSTRACT

Neutral atom systems form an important platform for quantum computing and quantum simulation due to the scalability and controllability enabled by optical trapping and manipulation techniques. Laser cooling and trapping provide essential tools for preparing and controlling such systems. In this thesis, we present an experimental and theoretical study of laser cooling and trapping of neutral Yb and Rb atoms.

We demonstrate a magneto-optical traps (MOT) for Yb operating on the 399 nm and 556 nm transitions, with particular emphasis on the direct loading of a green MOT using the narrow intercombination transition at 556 nm. We achieve direct loading of the green MOT by superimposing the green laser beam within the hollow core of the blue MOT beam. Using this core-shell configuration, we load up to 3.4×10^8 atoms within 1 s. We also investigate an alternative center-shifted dual-MOT configuration, in which we shift the overlap region of the blue MOT toward the Zeeman slower. Although this configuration avoids loss of blue laser power, it yields a lower atom number of approximately 2×10^7.

In parallel, we carry out experimental studies with Rb atoms that are central to neutral-atom quantum computing architectures. We demonstrate single-atom trapping in an optical dipole trap, a building block for neutral-atom quantum computing. We investigate electromagnetically induced transparency (EIT) involving Rydberg state in a thermal Rb vapor cell. We study EIT in a V + inverted Ξ system ($5S_{1/2} \rightarrow 5P_{3/2}$ and $5S_{1/2} \rightarrow 6P_{1/2} \rightarrow r = 69D_{3/2}$) using probe and control lasers at 780 nm, 421 nm, and 1003 nm. This configuration exhibits a high signal-to-noise ratio at room temperature with a linewidth of about 9 MHz. For completeness and comparison, we also study EIT in an inverted Ξ system using the $5S_{1/2} \rightarrow 6P_{1/2} \rightarrow 69D_{3/2}$ transitions.