Towards Quantum Simulations with Ultracold Thulium Atoms at an Optical Lattice Formed by 1064 nm Laser Light

A V Akimov[1]

[1] *Quantum simulators and Integrated Photonics group, Russian Quantum Center, Innovation Center Skolkovo, Bolshoy boulevard, 30/1, 121205, Moscow, Russia. Contact Phone: +79163473597*
Contact Email: aa@rqc.ru

Bose-Einstein condensation (BEC) is a powerful tool for a wide range of research activities, a large fraction of which is related to quantum simulations. Various problems may benefit from different atomic species. Thulium atoms possess dipole moment of 4 Bohr magneton in the ground state, allowing long-term interactions. It also has number of non-chaotic low-field Feshbach resonances, allowing fine control of the near-filed interactions. It also has relatively simple level structure compared to the other magnetic lanthanoids and thus is a quite promising subject for applications in quantum simulations. Nevertheless, cooling down novel species interesting for quantum simulations to BEC temperatures requires a substantial amount of optimization and is usually considered to be a difficult experimental task. Specifically, previous attempts of cooling thulium atom to Bose-Einstein condensation temperature at 532 nm dipole trap were not successful. Here we report on implementation of the Bayesian machine learning technique to optimize the evaporative cooling of thulium atoms and achieved BEC in an optical dipole trap. The developed approach could be used to cool down other novel atomic species to quantum degeneracy without additional studies of their properties. We also analyzed the atomic loss mechanism for the 532 nm optical trap, used in the Bose-condensation experiment, and compares it with the alternative and more traditional micron-range optical dipole trap. Then, we measured the scalar and tensor polarizability of thulium at 1064 nm and was found to be 167 ± 25 a.u. ($275 \pm 41 \times 10^{-41}\mathrm{F} \cdot \mathrm{m}^2$) and -4 ± 1 a.u. ($7 \pm 2 \times 10^{-41}\mathrm{F} \cdot \mathrm{m}^2$). While the condensate of the thulium atom has a lot of applications in quantum simulations and other areas of physics, it can also serve as a unique diagnostic tool for many atomic experiments. In the present study, the Bose-Einstein condensate of the thulium atom was successfully utilized to diagnose an optical lattice and detect unwanted reflections in the experiments with the 1064 nm optical lattice, which will further be used in a quantum gas microscope experiment.