# Narrow-Line Cooling and Initial State Preparation of Thulium Atoms Using the Transition at 506 nm

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Thulium atoms have a various advantages for their use as a platform for transportable optical clocks and quantum simulators. The low sensitivity of the clock transition frequency to blackbody radiation and convenient wavelengths for laser cooling and optical lattice simplify the experimental setup [1]. At the same time, thulium has a relatively high magnetic moment in the ground state ($\mu = 4\mu_B$) and a wide range of Fano-Feschbach resonances, which makes it a promising candidate for BEC research [2].

Both optical clock and Bose-Einstein condensation experiments have an evaporative-like technique as one of the stages of experiment. These techniques are sensitive to the initial temperature and the number of atoms at the beginning of evaporative cooling. Most thulium MOT experiments contain two stages of laser cooling with final temperatures around 20 µK, which is relatively high and leads to significant losses in the evaporative cooling stage. Previously, as a solution to this problem we proposed using the additional cooling transition at a wavelength of 506.2 nm.

In the case of the atomic clock experiments, another advantage of thulium atoms is the possibility to eliminate the second order Zeeman shift using the synthetic frequency technique [3]. This approach requires to prepare atoms in the central magnetic sublevels of two hyperfine components of the ground state. These states can be populated using the optical pumping technique [4]. However, this technique does not allow these states to be populated equally, which can degrade the performance of the setup. This problem also can be solved using another hyperfine components of transition at 506.2 nm.

In this work, we demonstrate a third stage cooling of thulium atoms using the transition at 506.2nm, which increased the phase density of the atomic cloud to $3 \times 10^{-3}$, which is about two orders of magnitude higher than in the two-stage cooling regime [5]. We also demonstrate the structure of the double cloud in the optical lattice, which can be used in precision measurements and quantum simulations. We then demonstrate the population transfer between hyperfine sublevels of the ground state, using the transition $F = 4 \rightarrow F = 4$ at 506.2 nm. An accurate study of 506nm transitions has shown that it can be used to improve system performance in both atomic clock and quantum simulation experiments with thulium atoms.

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## References

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