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Detection of 1.14 μm Magnetic Dipole Transition in Ultracold Thulium

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Today the precision measurement of time and frequency is of a great importance not only for fundamental science but also for technologies that used for telecommunication networks and navigation systems. The SI second is currently realized by the microwave transition in Cs atoms with fractional uncertainty of 10^{-15}. Thanks to the frequency comb technique which established the direct link between optical and microwave frequencies, the optical clocks have attracted the interest as a future atomic clock of a superior precision. To date the optical clocks based on single ions have achieved the lowest systematic uncertainty of any frequency standard [1]. In the same time the many-atom lattice clocks have shown advantages in measurement precision even over trapped-ion clocks. The many-atom Sr clock that achieves an accuracy of 6.4×10^{-18} has been demonstrated in JILA, which is not only better than a single-ion-based clock, but also reduces the required measurement time by two orders of magnitude [2].

The fine structure of the thulium ground state $4f^{13}6s^2$ is optically coupled to a narrow (the spectral linewidth of 1.2 Hz) magnetic dipole transition at 1.14 μm. This transition is a good candidate for the optical clock realization because of two reasons. First, 4f electron is shielded by outer closed 5s and 6s shells that makes it much less sensitive to external disturbances. Second, as both levels are two components of the fine structure of ground level, they have very similar polarisabilities that should significantly cancel AC-Stark shift in optical lattice and the BBR shift.

Since 2009 our group is focused on developing of the optical lattice clock based on ultracold Tm atoms. For optical cooling the strong transition $4f^{13}({}_2F^0)6s^2 - 4f^{12}({}_3H^5)5d_{3/2}6s^2$ at 410.6 nm with natural linewidth $\gamma = 10$ MHz has been chosen and first magneto optical trap of thulium atoms was realised [3]. To improve MOT lifetime and reach lower temperatures needed for optical lattice loading (~ 1μK) second stage optical cooling was implemented [4] on transition $4f^{13}({}_2F^0)6s^2 - 4f^{12}({}_3H^6)5d_{5/2}6s^2$ at 530.7 nm with 360 kHz linewidth.

Nowadays we reload about 50% of atoms from MOT to 1D optical lattice. The clock laser on 1.14μm is stabilized to ULE-cavity and its frequency is scanned with an acousto-optic modulator. When clock laser radiation gets into the resonance with the transition, we detect decrease of atoms in

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the trap (see fig. 1) We were also able to observe Zeeman splitting of this transition applying constant magnetic field.

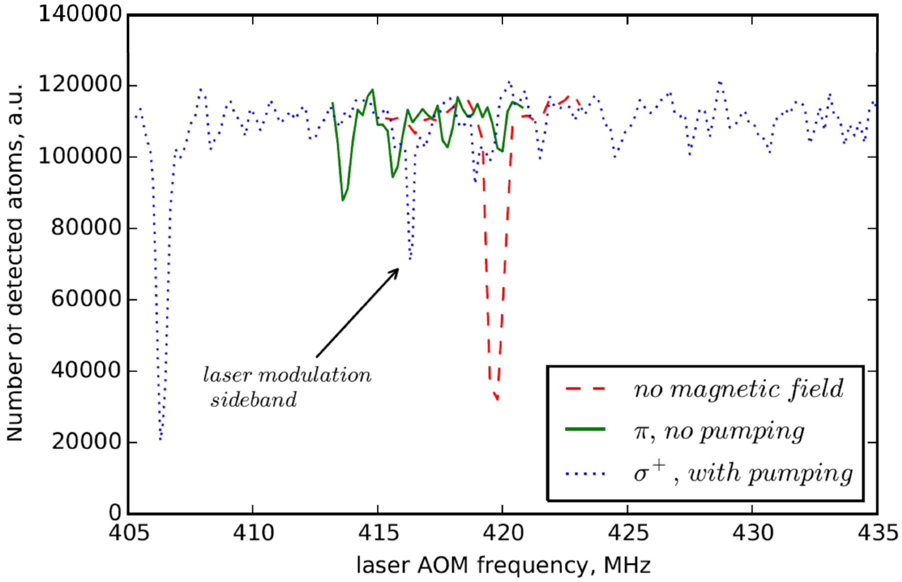

Figure 1. Number of atoms in the ground state in the optical lattice vs. frequency detuning of the clock 1.14μm laser from the resonance.

The resonant frequency of the laser was measured using Angstrom WS-5 wavemeter and equals to 262.955 GHz with uncertainty 3GHz (due to the wavemeter calibration precision).

References

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