Compact optical frequency standard based on ^{87}Rb D1 line

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Abstract

We investigate the modulation transfer spectroscopy of ^{87}Rb D1 line under noncycling transitions. The line shape of the MTS signal was determined, and the system's long-term stability was measured. Results showed that the system consistently performed at a short-term and long-term stability of E-14 level estimated from the residual error signal, indicating high performance of the compact optical frequency standard.

Introduction

Modulation transfer spectroscopy (MTS) is a heterodyne spectroscopy technique with high signal-to-noise ratio, which can be used to build compact optical frequency standard[1]. Laser stabilized to ^{87}Rb D1 line has widely use in cold atom experiments, and its stability can be improved by use of MTS[2]. Up to now, stability of MTS stabilized laser to ^{87}Rb D1 line has not been reported.

We investigate a compact optical frequency standard based on ^{87}Rb D1 line by utilizing of the MTS for the first time. The frequency standard is highly integrated with a total volume of 8 L, of which the optics is 2.75 L and the electronics is 5.16 L. The system has an outstanding instability of E-14 level for both short and long-term.

Experimental results

The signals of MTS and saturated absorption spectroscopy (SAS) obtained by experiments are displayed in the top and bottom of Fig.1, respectively. The three peaks from left to right are $F_g=2 \rightarrow F_e=1$, crossover peak and $F_g=2 \rightarrow F_e=2$. In MTS, we set the modulation frequency to 4.2 MHz. Among these peaks, the slope and amplitude of the MTS signal of $F_g=2 \rightarrow F_e=1$ are the largest, and the corresponding signal-to-noise ratio is the highest. We use this signal as error signal and lock the laser frequency to this hyperfine energy level transitions.

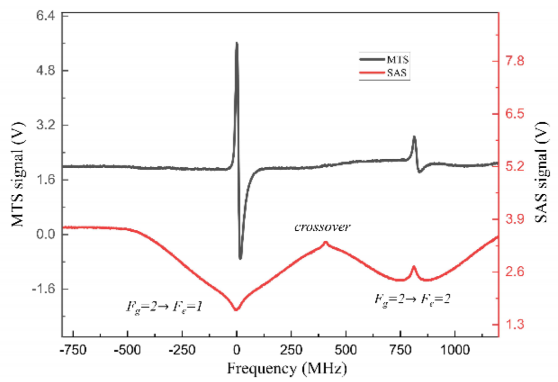

Fig.1: Spectra signals of MTS (top) and SAS (bottom)

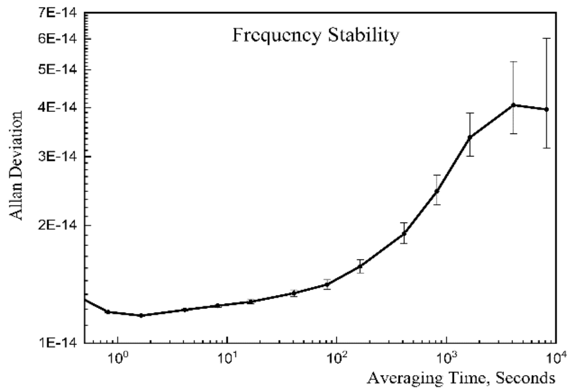

Fig.2: The Allan deviation of the system

The system stability curve obtained by the self-evaluation method is shown in Fig.2. The frequency stability of 1 s integration time is better than E-14, and the long-term stability of the laser reaches 4E-14, indicating good performance of closed-loop locking of the system. Further assessment of the out-loop stability will be carried out in the future.

Conclusion

In summary, we have studied MTS for the D1 line of ^{87}Rb and build the compact optical frequency standard. The self-evaluated frequency stability of 1 s integration time is better than 1.2E-14, and the long-term stability of the laser reaches 4E-14, indicating good performance of closed-loop locking of the system. The highly stable 795 nm laser can play an important role in the field of atomic physics such as cold atom physics. The obtained results provide an alternative method for the high frequency stability of 795 nm laser.

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