Frequency Shift Properties of $^1S_0$-$^1P_1$ Transition of a Calcium Beam Optical Clock

Yu Chen, Yabei Su, Lei Han, Jun Ge, Xiaobo Xue and Shengkang Zhang

Science and Technology on Metrology and Calibration Laboratory, Beijing Institute of Radio Metrology and Measurement, Beijing, China

Email: zhangsk@126.com

Atomic beam frequency standards, such as cesium beam clocks[1], have been used worldwide in scientific research, industrial manufacture, and daily life. Optical frequency standards based on atomic beams have the potential to operate as time-keeping clocks. Thus researches on calcium[2], strontium[3], and ytterbium[4] atomic beams have attained more and more attentions. While most groups focus on the performance of the clocks, researches on the atomic beam itself are rarely reported. Here we investigate the frequency shift properties of the neutral calcium atoms' $^1S_0$-$^1P_1$ transition at 423 nm. Preliminary experimental results are useful for the optimization of calcium beam physical apparatus and the improvement of the calcium beam frequency standard[5].

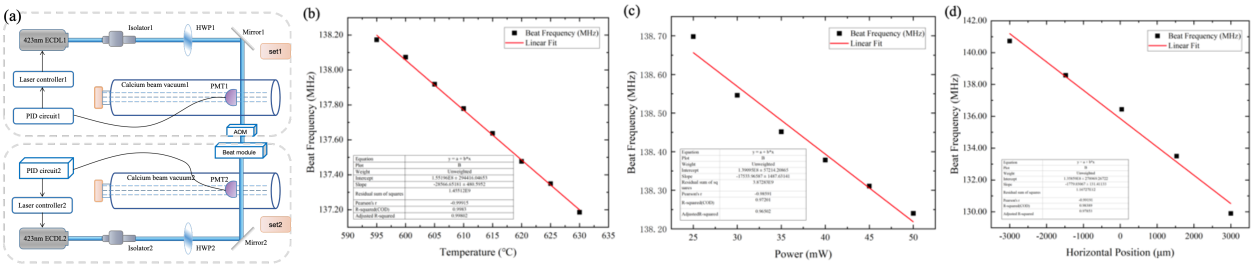

Fig. 1: (a) The schematic of frequency beating. The frequency shift caused by (b) oven temperature, (c) laser power, and (d) laser beam pointing.

The frequency shift is measured by beating the two 423 nm lasers, which are locked to two atomic beam vacuums individually. An acousto-optic modulator is used to generate a frequency shift of 144 MHz for set1. Keeping the temperature of one vacuum at 600 °C, and changing the other one from 595 °C to 630 °C, the frequency shift caused by oven temperature is measured to be 28.6 kHz/K. We change the laser power of one 423 nm laser from 25 mW to 50 mW, while the other laser remains at 17 mW. The frequency shift caused by laser power is 17.5 kHz/mW. A beam quality analyzer is applied to measure the beam position, and the frequency shift caused by laser beam pointing is 1.78 kHz/μm. At present, it has been found that the long-term instability of the calcium beam system is mainly limited to the ambient temperature fluctuations. Further, we will study the frequency shift properties of the neutral calcium atoms' $^1S_0$-$^3P_1$ transition at 657 nm, which helps to optimize the optical frequency standard.

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