The progress of the NIM6 fountain clock in NIM

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Abstract

A new fountain clock NIM6 is under construction. Besides some improvements on the vacuum system, a new Ramsey cavity and a microwave synthesizer are made to reduce the Type B uncertainty. Another feature of NIM6 is collecting atoms from a MOT loading optical molasses to get more atoms with a more uniform density distribution. With a new ultra-stable microwave frequency synthesizer based on cryogenic sapphire oscillator (CSO) or ultra-stable laser, NIM6 is aiming to reach the quantum projection noise, thus leading to a reduced Type A uncertainty.

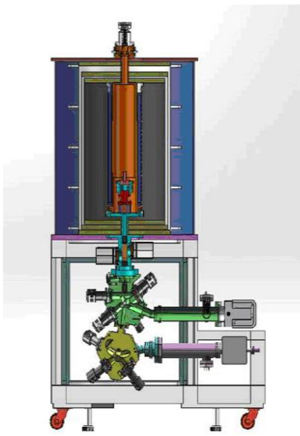
1. Introduction

Many National Metrology Institutes (NMIs) built cesium fountain clocks, and reported to the BIPM with fractional frequency uncertainties in the range from a few parts in 1015 to a few parts in 1016 [1-7], making fountain clocks the major contributor to the accuracy of the International Atomic Time (TAI). A new cesium fountain clock NIM6 is under construction in the National institute of metrology of China. Compared to NIM5 fountain clock which has already been reported to the BIPM [1], some improvements on the vacuum system, Ramsey cavity and microwave synthesizer are made to reduce the Type B uncertainty. The cold atoms from a 3D MOT are loaded to optical molasses. The atom density will be more uniform compared with a 2D MOT loading optical molasses, and the diameter of the atom cloud can be adjusted by the intensity and detuning of lights during the post cooling to keep the collisional-induced frequency shift low. With a microwave frequency synthesizer based on a cryogenic sapphire oscillator (CSO) or an ultra-stable laser [8], NIM6 is aiming to reach the quantum projection noise, thus lead to a reduced Type A uncertainty compared to NIM5.

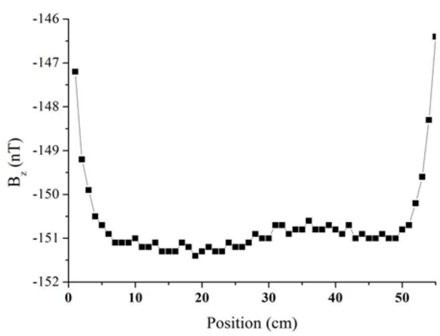
2. The design of NIM6

A cutaway figure of the NIM6 physical package is shown in the figure 1(a). The entire physics package is enclosed in a layer of soft iron and the flight tube is surrounded with another three layers of μ metal shielding with a shield factor of about 105. The measured magnetic field distribution inside the flight tube is shown in figure 1(b). Atoms are collected in the lower MOT chamber and then launched to the upper optical molasses chamber with a small angle (10°) to reduce the background Cs atoms flying into the detection chamber directly. The lower MOT chamber is pumped by a 20 l/s ion pump and the upper OM chamber is pumped by a 50 l/s ion pump together with a getter pump. Another getter pump is on the top of the flight tube to keep the ultra-low pressure in the atom interrogation region.

The new fountain is operated in a lab with temperature fluctuations to be less than 0.3 K, and no active temperature control system will be added outside the flight tube. Instead, an isothermal liner will be surrounded the flight tube [9]. It reduces the temperature fluctuations and gradients. With several precision PT standard thermometers which have a temperature uncertainty of less than 10 mK. Hopefully, the total temperature uncertainty will be less than 50 mK, which will keep blackbody-radiation-induced frequency uncertainty less than one part in 1016.



(a)



(b)

Figure 1. (a) Schematic of the NIM6 cesium fountain clock; (b) The measured B field distribution in the flight tube.

A 4-feeds Ramsey cavity with a loaded Q factor of about 16000 was made, and a long copper tube is sit on the cavity to reduce the microwave leakage effect. The major uncertainty of NIM5 comes from an RF interferometric switch which is applied in the microwave synthesizer chain to reduce the microwave leakage. With the new cavity design, an RF interferometric switch may not be necessary, but will be still in the system to check the leakage effect.

3. MOT loading optical molasses

In NIM6, Cs atoms will be collected in the lower MOT chamber and launched to the center of the upper OM chamber. The separation between these two centers is 280 mm, the flying time is about 50 ms with a launching velocity of 5.5 m/s. The final temperature of the cloud after launching can be adjusted by the intensity and detuning of the post cooling beams to make sure the cloud expanded enough when reaching the OM center in order to keep collisional shift low. The atom velocity and temperature will be re-adjusted in the optical molasses region. Then, atoms are launched vertically to the flight tube. The advantage of this design is not only able to collect more atoms compared to a direct optical molasses loading like NIM5, the background Cs gas in the detection chamber is also reduced due to a differential pumping. Furthermore, the atom density distribution is more uniform than loading OM from a 2D-MOT. Another feature here is that the cooling beams for MOT and OM are applied at different times. The lights for the MOT cooling, OM cooling can be provided by only one tapered amplifier with a total output power of about 700 mW. The whole vacuum system has been built and cold atoms have been collected in the upper optical molasses. The parameters are optimizing to increase the atomtic signal.

4. Summary

A new cesium fountain clock NIM6 is under construction in the National Institute of Metrology of China. Besides some improvements on the design of the Ramsey cavity to reduce the distributed cavity phase shift and microwave leakage, cold atoms are loaded from a 3D MOT to optical molasses, leading to a better signal to noise ratio at the detection. A new cryogenic sapphire oscillator (CSO) based frequency synthesizer and ultra-stable microwave generated from ultra-stable laser are also under developing to reduce the microwave phase noise in order to reach the quantum projection noise, thus leading to a lower Type A uncertainty of the new fountain.

5. Acknowledgements

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6. References

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