NIST CESIUM FOUNTAIN FREQUENCY STANDARD : PRELIMINARY RESULTS

D.M. Meekhof, S.R. Jefferts, D. Lee, C. Nelson
Time and Frequency Division
National Institute of Standards and Technology
325 Broadway
Boulder, CO 80303

Abstract

We have designed and constructed a laser-cooled cesium fountain for use as a primary frequency standard. This standard incorporates several unique design features, including a method for mapping the C-field region, a second microwave cavity for use in state preparation and a cavity design with extremely low distributed cavity phase shift. Preliminary results of the evaluation and performance of this device will be discussed, including several novel design features.

Summary

We have designed and built a cesium fountain for eventual use as a primary frequency standard. The cesium fountain frequency standard built by Clairon et al. at Laboratoire Primaire des Temps et Frequences (LPTF) is currently the most precise frequency standard in the world.[1,2] The LPTF device has demonstrated the inherent advantages of the fountain configuration as first discussed by Zacharias many years ago.[3]

The NIST fountain has demonstrated the ability to "toss" atoms with times of flight in excess of 1/2 s and temperatures on the close order of 5 μK. See Figure 1. The techniques used for the preliminary gathering of the cesium sample as well as the subsequent "toss" and post-cooling in the moving frame of the atoms will be discussed.

The NIST fountain contains two unique microwave cavities used for manipulation of the hyperfine level populations of the atomic sample. These cavities have been designed to minimize systematic frequency shifts associated with distributed cavity phase shifts. Each of the two TE 011 cavities

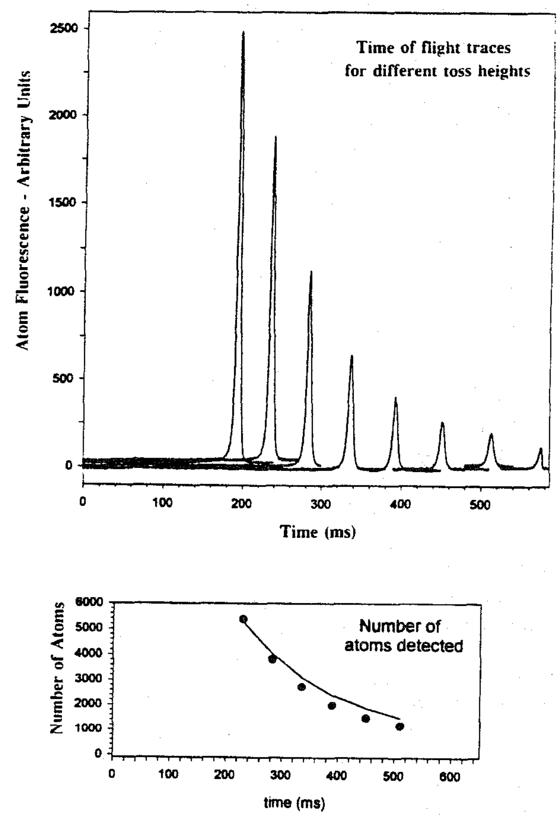

Figure 1 - The upper curve is a measure of relative fluorescence as a function of time for various toss heights. The lower curve shows the number of atoms detected as a function of the time of flight along with a theoretical fit to the data giving a transverse temperature of 6 μK. These data are used to extract the atom temperatures in both the vertical direction and the horizontal plane.

has four microwave feeds at 90 degree intervals around the circumference. These feeds to the main cavity are in turn fed by a pair of resonant mode filters at 9.192 gHz. In normal operation the lower cavity is used as a state selector so that only F=4 m=0 atoms are present in the atomic sample which under goes Ramsey excitation. This technique minimizes systematic frequency shifts caused by cold Cs-Cs collisions. The upper cavity is used for Ramsey style excitation of the atomic sample, with a $\pi/2$ microwave pulse being applied on the way up through the cavity and again on the way back down through the cavity approximately 3/4 of a second later.

Additionally, the fountain discussed here has a novel method of "mapping" the C-field magnetic environment. In this scheme low frequency rotary magnetic fields are used to couple magnetic hyperfine levels. The use of true rotary magnetic fields, as opposed to linear fields and use of the rotating wave approximation, allows the preparation of specific coherent superposition states not previously used in clock metrology. This scheme also completely suppresses the Millman effect allowing accurate mapping of the magnetic field in the region above the microwave cavities (C-Field region).

Finally preliminary results of the evaluation of the fountain as a frequency standard will be presented.

[1] A. Clairon, S. Ghezali, G. Santarelli, Ph. Laurent, S.N. Lea, M. Bahoura, E. Simon, S. Weyers and K. Szymaniec, "Preliminary Accuracy Evaluation of a Cesium Fountain Frequency Standard, *Proc. of the 5th Symposium on Frequency Standards and Metrology* (Woods Hole 1995), pp. 49-59, 1995.

[2] Bureau International des Poids et Mesures, Circulaire **T 119**, 12 December 1997.

[3] Norman F. Ramsey, *Molecular Beams*, Clarendon Press 1956, pp 138.