The Design of an Atomic Fountain Frequency Standard Prototype at NIST

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We are in the process of constructing and testing a prototype for possible future atomic fountain cesium frequency standards at NIST. The layout of the experiment is shown in Figure 1.

The atoms are first accumulated in a magneto-optical trap. The magnetic field is then switched off and the atoms are further cooled in optical molasses. The atoms are launched in a one dimensional vertical moving molasses with the atoms in the F=4 state. The moving molasses is created by detuning the upward beam to the red and the downward beam to the blue of the molasses frequency. The two beams have crossed linear polarizations (lin ⊥ lin configuration). Another cooling phase in the transverse directions may be added after the launch.

The atoms first enter the lower "cleanup" microwave cavity. A one millisecond pulse of RF is applied to the atoms when they are in the center of the cleanup cavity. This π-pulse is tailored to drive only the |4,0> to |3,0> transition. A laser beam is then directed downward onto the atomic sample. This laser beam is tuned to the F=4 to F'=5 optical transition, and removes the F=4 atoms from the sample with resonant light scattering forces, leaving a clean sample consisting only of |3,0> atoms. This will reduce both line pulling and collisional shifts.

The atoms transit the upper microwave cavity twice, once before and once after apogee, completing a Ramsey interaction. This Ramsey interaction is performed on the |3,0> to |4,0> clock transition. The drift regions between microwave cavities and above the clock cavity are copper tubing below cutoff for 9.2 GHz. This ensures no microwave interactions during drift phases.

The number of atoms and their state after the Ramsey interaction is detected by resonant light scattering and fluorescence detection in two separated regions. The population of the F=4 state is detected from the amount of fluorescence when the atoms are excited by a laser tuned to the F=4 to F'=5 optical transition. Normalization is provided by adding a repumping laser tuned to the F=3 to F'=4 optical transition in a second fluorescence detection region.

This design is being pursued with the goal of a signal that is atomic shot noise dominated for short time scales (with 10^6 atoms) and has random and systematic uncertainties of less than one part in 10^{15}.

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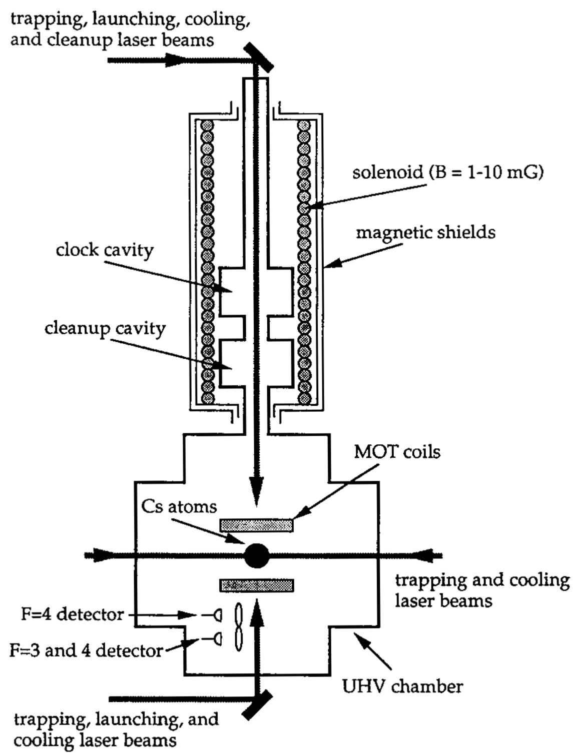

Ekstrom et al. "Design of an Atomic Fountain..." Figure 1

Fig. 1. Layout of the fountain experiment. Cs atoms are accumulated in the lower UHV chamber and then launched upward through the microwave cavities. Atomic state detection is performed below the trap region after the atoms have been interrogated in the microwave cavities.