

## Progress towards the Brazilian Cesium fountain second generation

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**Abstract:** The operation of a Cesium fountain primary frequency standard is strongly influenced by the characteristics of two important subsystems. The first is a stable frequency reference and the second is the frequency-transfer system. A stable standard frequency reference is key factor for experiments that require high accuracy and precision. The frequency stability of this reference has a significant impact on the procedures for evaluating certain systematic biases in frequency standards. This paper presents the second generation of the Brazilian Cesium Fountain (Br-CsF) through the opto-mechanical assembly and vacuum chamber to trap atoms. We used a squared section glass profile to build the region where the atoms are trapped and colled by magneto-optical technique. The opto-mechanical system was reduced to increase stability and robustness. This newest Atomic Fountain is essential to contribute with time and frequency development in metrology systems.

**Keywords:** Atomic Clock, Atomic Fountain, Metrology, Time and frequency standards

### 1. INTRODUCTION

Since 1967 the time unit "second" of the international system of units (SI) has been defined using the ground state hyperfine transition of the Cesium atom <sup>133</sup>Cs. The International Atomic Time (TAI) is a time scale calculated with a weighted average algorithm (Algos) by BIPM. The timescale traceable to TAI is kept by laboratories (about two hundred atomic clocks) which maintain the best primary cesium standards.

Primary frequency standards are commonly used for calibration of secondary time and frequency standards. Atomic clocks also play a vital role in navigation systems, like the Global

Positioning Systems (GPS) and other Global Navigation Satellite Systems (GNSS) (GLONASS, Galileo, Beidou), relying on the accuracy and the stability of atomic clocks. Atomic frequency standards are also used for network synchronization in telecommunication. They are also extremely useful in fundamental research fields, such as: relativity, atomic physics, astronomy and dark matter [1-6].

The goal of this work is to present some progress in the Brazilian Cesium fountain Second Generation under development in our laboratory at the University of São Paulo in São Carlos campus. This follows previous experiment that keep going in course for the first atomic fountain in our laboratories [7].

## 2. OPTICAL SETUP AND VACUUM SYSTEM

The optical system use three lasers: a master laser used to cool and to trap atoms; repumping laser used to the repump transition; and detection laser used to detect atomic transition after the interrogation of the atomic cloud. For the master laser we use a commercial laser made (TOPTICA TA100), which produces 400 mW of collimated laser beam. The detection laser is commercially made by Radiant Dyes and for repumping one of used our homemade laser. Both detection and repump lasers were built with an intracavity very narrow frequency filter in extended cavity. This filter ensures more frequency stability.

The Master laser is tuned to the transition  $6^2S_{1/2}|F=4, m_f=0\rangle \rightarrow 6^2P_{3/2}|F'=5, m_f=0\rangle$ . Its light is divided in six beams, each of them coupled in optical fiber and taken to the beam expanders. This expanders have fixed alignment that provide more robustness.

The repump laser is tuned in the transition  $6^2S_{1/2}|F=3, m_f=0\rangle \rightarrow 6^2P_{3/2}|F'=4, m_f=0\rangle$ . This laser beam is divided in two other beams which feed two optical fibers.

Using a pair of coils that generate a quadrupole magnetic field and six laser beams, we can trap and cold an atomic cloud, using a magneto-optical technique [8]. The trap region is shown in Figure 1.

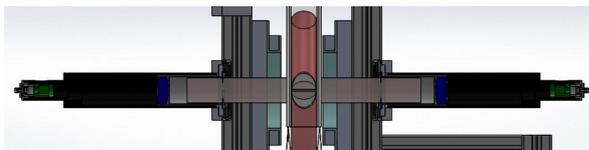


Figure 1: Trapping atoms region, using two coils and six beam expanders. In figure is shown a pair of transverse beams.

We used a square glass profile as a cavity to trap atoms. This provides a great optical access to the preparation chamber and gives more flexibility concerning alignment. The use of glass also prevents the generation of spurious fields by residual magnetization of traditional stainless

steel chambers. The alternative aluminum or titanium chambers are a bit tricky to work or expensive. The vacuum system is composed by an ionic pump of 60 l/s.

The Cesium reservoir uses three getters of cesium. These getters are capable of liberating cesium when a current up to  $I = 3$  A is applied. The assembly of getters is shown in Figure 2.



Figure 2: Three Cesium Getters used as a cesium supply.

## 4. RESULTS

Up to now, we were concerned with the general assembly. Two coils for the magnetic field were made and put on anti-Helmholtz configuration, that produces a quadrupole magnetic field. Using a Hall probe, we characterized the magnetic field. The coils can produce 20 gauss/cm of field divergence, using only 3 A of current. This data is shown in Figure 3. This field is enough for a magneto-optical trap [7].

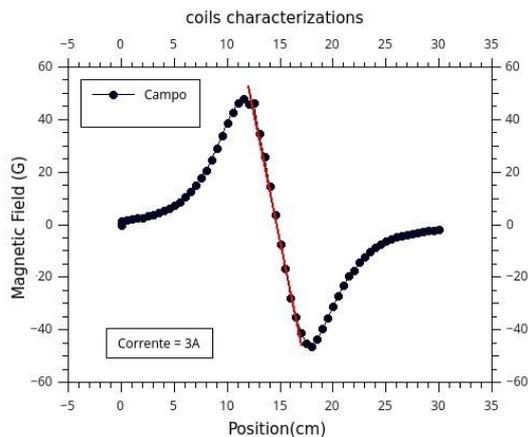


Figure 3: Characterization of the magnetic field produced by two coils in anti-Helmholtz configuration. The measurement was performed using a Hall sensor and coils supplied with 3 A of current.

For the vacuum system, we use an ionic pump controlled by Driver Multivac, made by Varian. Using its electrical current meter, we can estimate the pressure. This measurement was made for many days and shown in Figure 4. The vacuum evolves during this time. By the date of this text, the pressure is  $9,1 \times 10^{-7}$  Pa.

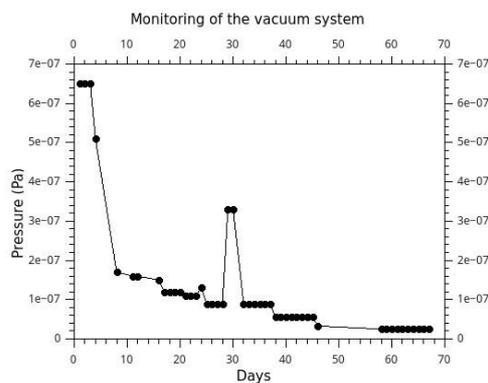


Figure 4: Monitoring of the vacuum system, using Multivac driver controller.

We are finalizing the optical alignment of the MOT beams and the trapping of atoms is expected to happen in a short timescale. This should validate the system as it is and provide more data concerning the reliability of using the getters supply with the glass chamber. This new kind of system should provide a new manner of

producing atomic fountains, opening the opportunity of simpler systems.

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