The New PTB Caesium Fountain Clock CSF2

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***Abstract*— At PTB a second caesium fountain clock, CSF2, is in the process of being set up. It differs from the first PTB caesium fountain standard CSF1 in a number of details, which are consecutively specified. First cold atoms have been prepared in the new apparatus.**

I. Introduction

The caesium fountain frequency standard CSF1 has been operating at PTB since 1999. So far, CSF1 has contributed fifteen times to international atomic time (TAI) as a primary frequency standard. A relative short term instability of 2×10^{-13} $(\tau/1s)^{-1/2}$ and a relative uncertainty slightly below 10^{-15} have been obtained [1, 2]. However, further diagnostics and improvements are hampered by the fact that in our laboratory only hydrogen masers can reasonably be used as frequency references, which often exhibit daily relative frequency variations of several 10^{-15}. This was a major reason for the decision to start construction of a second fountain standard. CSF2 differs from CSF1 in a number of details. It will become operational in the near future.

II. Design Features of CSF2

Fig. 1 shows a sketch of the new PTB fountain CSF2. Differing from CSF1, in CSF2 a (1,1,1) laser beam geometry makes it possible to use six large-diameter (22 mm at the $1/e^2$ intensity points) laser beams for cooling of the atoms in an optical molasses. Fiber output couplers with integrated collimating lenses are directly attached to six ports of the cooling chamber. The direction in which atoms are launched can be controlled by a swivel device which allows us to swivel the bottom part of the fountain including the cooling region and a 25 l/s ion pump below it around a pivot point at the center of the cooling region. The small ion pump improves the residual gas pressure in the cooling region.

A stainless steel TE201 state selection cavity is installed just above the cooling region, followed by the detection region, so that one of the horizontal detection laser beams can be used for pushing the remaining F = 4 atoms after the state selection process following the launch of the atoms. The dimensions of the cavity are chosen such that this cavity is suited as well for a state selection of rubidium atoms (^{87}Rb, 6.8 GHz), if needed for future operation.

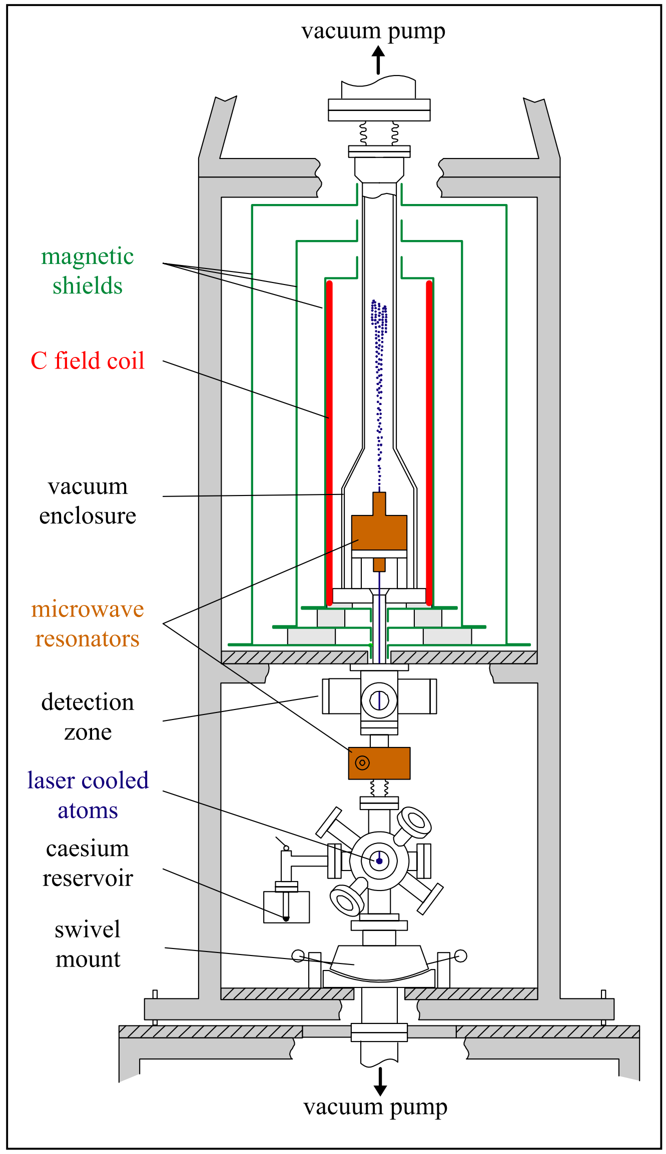

Figure 2. Sketch of the CSF2 vacuum subsystem.

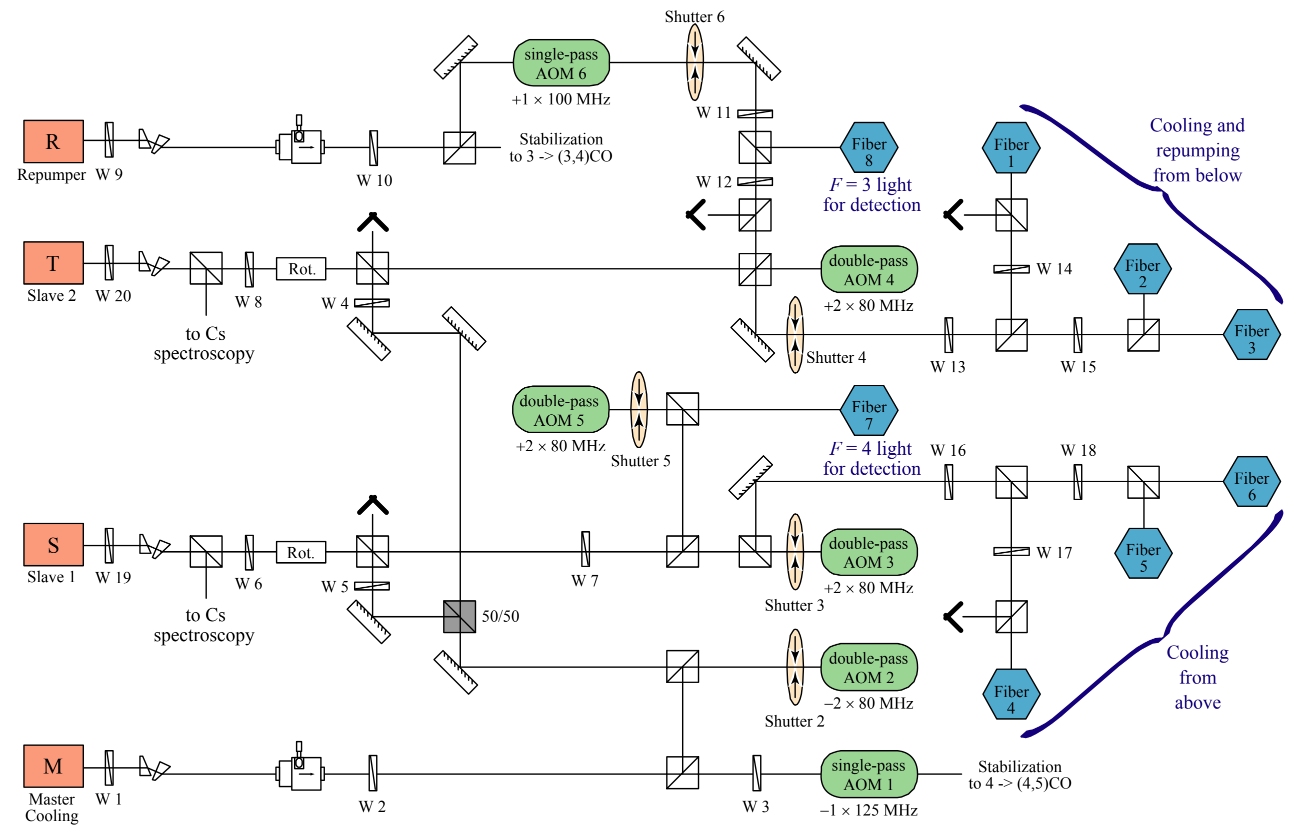

Figure 2. Optical setup of CSF2.

The TE011 Ramsey cavity is a copy of the cavity used in CSF1 [3].

The detection region comprises two photodetectors with the respective optics for imaging of the atomic fluorescence, located at opposite sides of the fountain and aligned for the two detection zones for F = 4 and F = 3 atoms, respectively.

The main vacuum tube is made of copper. This ensures a higher thermal conductivity than for the titanium that is used in CSF1. A three-layer magnetic shield was designed with improved geometry and better contact between the shielding cylinders and their end caps.

The optical system (Fig. 2) has been redesigned and includes two commercial extended-cavity diode laser systems (DL 100, TOPTICA), which are used as master and repumping laser, respectively. The master laser injects two 150 mW slave laser diodes, which provide the laser light for cooling and detecting the atoms using the $F = 4 \rightarrow F' = 5$ transition.

A portion of the master laser beam is frequency modulated (AOM 1) and used for locking to a crossover line of the caesium saturated-absorption spectrum. Hence there is no frequency modulation on the corresponding cooling and detection light beams.

The laser light is coupled into polarization maintaining optical fibers and guided to the cooling and detection regions of the fountain, respectively.

As a last point, it should be mentioned that the electronics for the control of the optical system has undergone a complete redesign. It now uses phase-locked loop techniques instead of several arbitrary-function generators and single-sideband mixers, as it was initially the case for CSF1.

III. Present Status of CSF2 and Future Plans

The vacuum system has been completed recently and a base pressure of less than 10^{-7} Pa is obtained. We succeeded to cool first clouds of cold caesium atoms in an optical molasses recently.

Next steps will be the implementation of the new control electronics, launching of atoms, homogenization of the C field by supplementary coils and generation of Ramsey fringes.

For the frequency synthesis initially a system built for the conventional PTB primary caesium clocks will be used, which is based on a commercial high performance BVA quartz oscillator. Recently the development of an improved frequency synthesis system in collaboration with the NPL

India has been started. The new frequency synthesis system will also be capable of applying phase modulation instead of frequency modulation for the interrogation of atoms.

In the medium term, for a better control of the effects of cold collisions we also plan the implementation of the technique of population transfer by adiabatic passage [4].

IV. Outlook and Conclusion

The second PTB caesium fountain CSF2 will become operational in the near future. Full operational capability as a primary standard is not expected before 2006, however.

With two caesium fountains in our laboratory we expect to make effective progress in the uncertainty and instability evaluation of both fountains, as in the past the lack of a proper reference was a major obstacle. In the longer run it is envisioned that one of the fountains could contribute to TAI on a near-continuous basis while the other fountain may be used for further investigations.

References

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