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Development of vacuum, optical and electronic sub-systems for the 2nd generation Cesium fountain frequency standard at NPLI

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The transition frequency between two hyperfine levels (i.e. |F =4|mf=0 and |F =3|mf=0) of natural Cs-133 atoms is used to define SI second. This definition of SI second is realized in practice using Cs atomic fountain primary frequency standard (PFS). At CSIR-NPL (NPLI), India's first ever Cesium fountain primary frequency standard, NPLI-CsF1 was indigenously developed, evaluated, successfully compared with fountains from Germany, Russia and China, approved as PFS by CCTF (consultative committee on time and frequency) and contributed to international atomic time (TAI) for few months [1-3]. However, due to some inherent design issues, the fractional frequency uncertainty of the fountain could not be improved beyond 2.5×10^{-15}. With the motivation to have better and stable fountain with improvised design features, a second-generation Cs fountain is currently under development at NPLI.

Some new design features have been added to the second fountain which enable to carefully investigate the systematic errors in order to enhance the accuracy of our frequency standard to a few parts in 10^{16}. Optical pumping will be used to increase the S/N ratio in this fountain. The cavity design has been improved to reduce distributed cavity phase shifts and the MOT geometry of (1,1,1) has been chosen to reduce light shifts. In the process to develop the second fountain, various sub-systems are being indigenously developed. On the vacuum part, various sub-assemblies like cooling chamber, detection chamber, flight tube etc. have been individually assembled and vacuum tested. The optical viewports have been indigenously designed and assembles. All the viewports have been tested for vacuum leaks with iterative baking and cooling cycles. In the electronics part, the Cesium source temperature controller, Constant current sources for magnetic field, the C-field solenoid etc. have been assembled and tested. These systems have been upgraded from their counterparts being used in the first fountain. The constant current sources have also been automated for better control. The magnetic field mapping in the flight tube region has already been done using current sources, c-field solenoid and compensation coils. In the optics part, the lasers have been characterized. Work in being done to stabilize the frequency of the lasers. The beam expanders design has been completely upgraded as the angular alignment is much more critical for using (1,1,1) geometry for cooling and launching of atoms. A new alignment technique was also developed to test the alignment accuracy of the beam expanders. Ten beam expanders have been assembled and tested and are ready to be installed on the cooling and detection chamber.

For employing optical pumping, rigorous theoretical calculations have been completed and experimental implementation is being worked out. Microwave cavity was designed with collaboration of NPL-UK and Prof. Kurt Gibble at Penn State University in USA. The cooling chamber with (1,1,1) geometry was designed at NPLI and manufactured by a vacuum company in India. With the development of various sub-systems, it is expected to assemble and operate the second fountain as soon as the optical set-up is fully ready and aligned. In this paper, design and assembly of aforementioned sub-systems for second Cs fountain at NPLI will be discussed in detail.

[1] P Arora, S B Purnapatra, A Acharya, A Agarwal, S Yadav, K Pant and A Sen Gupta, *IEEE Trans. Instrum. Meas.*, **62** (7), 2036 (2013).

[2] A. Acharya, V. Bharath, P. Arora, S. Yadav, A. Aagrwal and A. Sen Gupta, *MAPAN – J. Met. Soc. Ind.* DOI: 10.1007/s12647-016-0190-4 (2016).

[3] https://www.bipm.org/en/bipm-services/timescales/time-ftp/Circular-T.html#nohref, nos. 323, 335.