URSI GASS 2023, Sapporo, Japan, 19 – 26 August 2023

Upgradation and Evaluation of Optics and Control Electronics for the operation of Cs Fountain Frequency Standard

Navraj Poudel[*(1,2)], Aniket Gupta[(1)], Suchi Yadav[(1)], Manoj Das[(1,2)], Amitava Sen Gupta[(3)] and Poonam Arora[(1,2)]
(1) CSIR- National Physical Laboratory, New Delhi, 110012, India; e-mail: arorap@nplindia.org
(2) Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, 201002, India
(3) The North Cap University, HUDA Sector 23-A, Gurgaon, 122017, India

CSIR-NPL indigenously developed India's first Cesium fountain primary frequency standard [1]. During the fountain operation, production of cold atoms, launching them through ultra-high vacuum, microwave interaction and detection is done in a cyclic and sequential way. In order to produce cold atoms, the layout of optics and the sequential operation of various processes using control electronics are crucial. The optical setup consists of two ECDLs: master and re-pump laser. We have replaced the existing master laser from low output power model with analog locking with higher power model with high mechanical and thermal stability along with advanced FPGA locking system with automatic LIR and PID optimization which keeps the frequency locked for more than a month. Laser frequency stabilization of re-pump laser is done using an upgraded version of phase sensitive detection based analog locking circuit. The optical setup of various optical components with five acousto-optic modulators (AOM) are used to create a frequency and intensity controlled set of six cooling beams and two detection beams. The relay-based shutters (which are obsolete now) were replaced with indigenously developed fast mechanical shutters and drivers. These shutters are light weight with low acoustic noise and have fast response.

The entire sequence of fountain operation is synchronized using a common trigger pulse. For the automated control of fountain operation, an instrument to control the RF drives of AOMs and the timing sequence of the fountain operation by generating timed control triggers for different electronic subsystems is used [2]. The laser power and frequency of each of the beams is independently controlled by Radio Frequency (RF) applied to the AOMs with voltage-controlled attenuators. The different RF signals for the respective AOMs are generated and characterized for this purpose. AOMs' RF power and amplitude control, mechanical shutter control, and magnetic field control (for magneto-optical trap (MOT)) in the physics package are all provided by this sequence controller, which is one of the most crucial equipment for smooth operation of the fountain.

A precisely tunable microwave synthesizer is used to feed microwaves to the Ramsey cavity and state selection cavity. An extremely stable 5 MHz oven-controlled crystal oscillator (OCXO) (Oscilloquartz-8607) is employed as external reference for the synthesizer. An interface circuit of the crystal oscillator, 5-channel frequency distribution circuit, mixer stage, servo control (PI controller) circuit, and necessary power supply have all been indigenously developed. A phase lock loop (PLL) circuit has been employed to lock the oscilloquartz output with the active hydrogen maser (AHM) output as a perfect reference. The phase difference between the two signals is minimized by the phase locking circuit's design until it is approximately zero, and it is then servo locked to produce a constant and precise frequency output with almost no phase noise.

Optical set up, automation and control electronics are extremely crucial for the fountain operation. The details of upgradation, characterization and evaluation of the optical set up and control electronics will be discussed in this paper.

References

[1] P. Arora, S. B. Purnapatra, A. Acharya, A. Agarwal, S. Yadav, K. Pant, and A, S. Gupta, "NPLI Cesium Atomic Fountain Frequency Standard: Preliminary Results," *IEEE Transactions on Instrumentation and Measurement*, **62**, 7, July 2013, pp. 2037-2042, doi: 10.1109/TIM.2013.2255974.

[2] S. Yadav, A. Acharaya, P. Arora, and A. S. Gupta, "An electronic sequence controller for the Cs fountain frequency standard developed at CSIR-NPL India," *Measurement*, **75**, August 2015, pp. 192-200, doi.org/10.1016/j.measurement.2015.07.041.