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The NRC-FCs2 primary frequency standard at the National Research Council Canada

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Abstract—**At the National Research Council Canada, we are performing final assembly and initial testing of our new atomic fountain clock, NRC-FCs2. This fountain clock incorporates several improvements in the optical, microwave, and computer systems from our previous generation clock, NRC-FCs1, as well as a new physics package designed at the National Physical Laboratory (UK). With these changes, NRC-FCs2 is expected to reach uncertainties < 5×10^{-16}. We will discuss the recent improvements made in the various subsystems of NRC-FCs2 and present preliminary results in its evaluation.**

Keywords—Primary frequency standard, clock, atom cooling and trapping

I. Introduction

Caesium fountain clock primary frequency standards provide the most accurate realization of the SI second. Through continued advances, fountain clocks have reached fractional uncertainties approaching 10^{-16}. Primary frequency standards hold particular importance in the world of metrology as in addition to serving as the reference for frequency and time, the SI second is fundamental in the definitions and practical realizations of the SI metre and candela, as well as in the volt and the future kilogram and kelvin.

At the National Research Council (NRC), we are currently integrating a new physics package into our system for our new primary frequency standard, NRC-FCs2, and beginning initial testing of its performance. This fountain clock utilizes several refurbished subsystems of our previous generation fountain, NRC-FCs1. In addition, the physics package of NRC-FCs2 was designed and assembled at the National Physical Laboratory (NPL) in the UK. We will discuss our recent improvements and our preliminary results from testing and evaluation.

II. Apparatus

Many systems have been improved from NRC-FCs1. This includes the laser and optical system, where the laser lock bandwidth and stability have been improved by adding fast current feedback to the cooling laser diode. The optical layout has been modified to improve stability and efficiency. In addition, improved servos to the AOM powers have yielded higher stability and control of the laser intensities. The computer system has been modified to give improved flexibility and control of the experimental sequence. We have also improved our microwave local oscillator to the system which will allow us to reach short term stabilities of $\sigma_y(1\ s) \sim 2 \times 10^{-13}$, an improvement of more than a factor of two over the previous performance.

The physics package of NRC-FCs2 was built at NPL (UK) and was based on the proven design of NPL-CsF2 fountain clock. The physics package includes a vacuum system containing atom trapping and detection regions, a magnetically shielded drift region with a water cooling jacket for temperature stabilization, and microwave cavities for Ramsey and state selection interactions. The system design allows for the cancellation of the collisional shift and includes a Ramsey cavity design which minimizes the distributed cavity phase shift, one of the main contributors to the systematic uncertainty in state of the art fountain clocks [1, 2, 3].

III. Initial Testing

The physics package for NRC-FCs2 was shipped to Canada from the UK and arrived in late January, 2017. The vacuum system was still under ultra-high vacuum upon its arrival after a door-to-door shipping time of about 20 days. Caesium ampoules were added to the system, and after two weeks, the entire system (with Cs) was at a pressure of $\sim 10^{-10}$ mbar.

Within a month of its arrival at the NRC, the physics package had been integrated with our other systems such that we observed the laser-cooled atoms in a magneto optical trap, and detected atoms after a launch to 30 cm above the Ramsey cavity. The microwave local oscillator and magnetic shielding will soon be added to the system, at which point Ramsey fringes can be detected.

IV. CONCLUSION

The expected type-B uncertainty for NRC-FCs2 after full evaluation is at the level of a few parts in 10^{16}, at which point it is expected that it will contribute to the steering of UTC/TAI. We are currently working to test the performance of NRC-FCs2 and evaluate the frequency shifts and associated uncertainties of several systematic effects. We will present results from our measurements of shifts associated with the second order Zeeman effect, cold atomic collisions, microwave leakage, and blackbody radiation. We will also present our progress on evaluating the distributed cavity phase and microwave lensing shifts of NRC-FCs2.

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