Aging study on a micro-fabricated Cs buffer-gas cell for atomic clock applications

Salman Abdullah[1], Christoph Affolderbach[1], Florian Gruet[1], Yves Pétremand[2], Gaetano Mileti[1]

[1]Laboratoire Temps-Fréquence (LTF), Institut de Physique, Université de Neuchâtel
Av. de Bellevaux, 51, 2000 Neuchâtel, Switzerland
[2] Centre Suisse d'Electronique et de Microtechnique (CSEM), 2000 Neuchâtel, Switzerland
Email: Gaetano.mileti@unine.ch

There has been a strong drive towards the miniaturization of atomic clocks and other devices using on micro-fabricated alkali vapor cells. However rare attempts have been made at studying the aging of the miniature cells themselves that are used in these clocks, and existing studies partly suffer from relatively big measurement uncertainties.

Here we report an aging study on miniature MEMS Cs-Ne cells, conducted by repeatedly measuring the cell's intrinsic clock frequency over a period of 5 months. The micro-fabricated MEMS Cs-Ne cell studied has an interrogation chamber of 2 mm inner diameter and 1.4 mm length. It contains Ne buffer gas and atomic Cs produced by post-activation from a Cs dispenser contained in the cell[1]. The cell was maintained at a temperature of 80°C throughout the study, and its clock transition frequency was measured by operating it in an experimental CPT atomic clock[2].

For each consecutive frequency measurement, the light-shift-free clock frequency was found by extrapolating the measured clock frequencies to vanishing light intensity, resulting in uncertainties of < 5 Hz only for the light-shift-free frequency. A linear fit to the resulting frequency evolution yields a negative frequency drift around $-2*10^{-9}$ /month, with an uncertainty of few percent, corresponding to a buffer-gas pressure change inside the cell on the order of -40 μbar/month.

The impact of possible changes in various experimental parameters on the observed frequency drift was analyzed, including drifts in cell temperature, magnetic field strength, and atmospheric pressure. All these parameter changes are found to result in frequency drifts much lower than the observed drift of the light-shift-free clock frequency, and even below the level of its uncertainty.

We therefore conclude that the observed frequency drift is dominated by a change of buffer-gas pressure in the cell. The negative sign of the frequency drift suggests that the Ne pressure inside the cell is decreasing with time, possibly due to Ne atoms being absorbed by the Cs dispenser.

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