Microfabricated vapor cells with tunable buffer gas mixtures using laser-actuated break-seal reservoirs

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Microfabricated cells are the core component of a wide variety of chip-scale atomic devices, such as clocks or magnetometers [1]. In those instruments, the cell is generally filled with a pressure of buffer gas. The presence of buffer gas reduces the atom-wall collision rate, enhances the atomic coherence lifetime and therefore improves the stability or sensitivity of the device.

In microwave clocks, buffer gas mixtures are often used. Each buffer gas shifts the hyperfine clock frequency with opposite signs such that an inversion temperature, around which the clock frequency dependence is cancelled at the first order, can be obtained by tuning properly the buffer gas pressure ratio. Stabilizing the cell at the inversion temperature is then beneficial to improve the long-term stability of the clock frequency.

Wafer-level vapor cells are in general filled with buffer gas by backfilling the bonding chamber with buffer gas prior to the final cell sealing. Several approaches have been explored for the cell filling including the thermal decomposition of BaN_6-RbCl precursors [2], the employment of UV-decomposed alkali azides [3] or the use of alkali pill dispensers [4]. In general, the target pressure for all cells of a given wafer is the same while some non-negligible dispersion on the gas pressure measured in each cell of the wafer can be observed. In [5], the tunability of nitrogen pressure in micromachined cells was demonstrated through the activation of getter compounds in an alkali pill dispenser. Nevertheless, this approach might not be efficient with other types of gas while both decomposition and adsorption processes of N_2 might continue, even at small rate, limiting the long-term stability of atomic clocks.

In this work, we report on the development and characterization of Cs vapor microfabricated cells filled with tunable He-Ne buffer gas mixture using laser-actuated break seal reservoirs. The idea is here to release He gas, pre-loaded into reservoirs annexed to the main science cavity, prefilled with neon, using femtosecond laser ablation of a silicon wall membrane. With this approach, we demonstrated the progressive increase of He gas in the main cavity by consecutive openings of He reservoirs around the cell, confirmed by the progressive increase of the clock frequency inversion temperature, adjusted here up to almost 100°C. A cell, tuned at 95°C, was used on a CPT clock setup, achieving a fractional frequency stability of 9×10^{-11} at 1 day. These results demonstrate the possibility to develop wafer-level microfabricated cells with tunable buffer gas mixtures [6]. We plan to develop cells with alternative buffer gas mixtures in the future using this approach. A summary of results will be presented at the conference.

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