HIGH-CONTRAST SATURATED-ABSORPTION RESONANCE OBSERVED IN A MEMS VAPOR CELL UNDER THE TWO-FREQUENCY LIGHT EXCITATION

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Modern quantum technologies require the development of highly-sensitive, compact and even miniaturized, low-power consumption and high-performance devices, including atomic clocks, lasers or sensors. These instruments are to date often based on the use of chip-size diode lasers and microfabricated (MEMS) cells filled with alkali-atom vapors [1].

An interesting challenge concerns the development of miniaturized optical frequency references. Different approaches have been engaged in this direction. A recent example is the use of two-photon spectroscopy of rubidium atoms in a vapor microcell. Such an experiment, using a microfabricated cell and numerous chip-size components, has recently demonstrated a remarkable frequency stability level of $10^{-12}\ \tau^{-1/2}$ up to 1000 s [2]. Miniaturized versions of the iodine-stabilized laser [Acef:2016] could be certainly also envisioned with an analog approach.

In the present work, we consider a simple alternative approach based on the well-known saturated-absorption resonance (SAR) spectroscopy method [3]. More interestingly, it has been reported recently that the contrast of nonlinear SAR signals could be remarkably increased by using a dual-frequency regime of excitation, leading to demonstrate encouraging laser frequency stability results [4]. This approach was analyzed in detail theoretically and experimentally in [5] and was implemented with success to improve the short-term fractional frequency stability of a high-performance coherent population trapping Cs cell clock [6]. In the latter studies, regular cm-size vapor cells were exploited for observation of the high-contrast resonances.

In the present study, we report the investigation of dual-frequency saturated absorption spectroscopy in MEMS Cs vapor cells. The employed miniature Cs cell technology is described in [7]. The cell diameter is 2 mm and its length is 1.4 mm. The used laser source is a narrow-linewidth external cavity diode laser tuned on the Cs D1 line. We demonstrate the detection of high-amplitude Doppler-free dips in Cs microfabricated cells. We study the resonance amplitude, width and amplitude-to-width ratio of the detected resonance versus several experimental parameters including the laser power, the cell temperature or the reflecting mirror position. Results are compared with those obtained for a conventional single-frequency SAR scheme. In addition to this experimental study, we have developed a general theory of the high-contrast SAR effect beyond the qualitative theory developed previously in [5]. The latter qualitative model, presented in [5], allowed to reveal physical origins of the new effect but could not quantitatively predict any real values for the resonance amplitude and width. Obtained results could be interesting for the development of a simple-architecture miniaturized frequency-stabilized laser.

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