Electromagnetically Induced Absorption for a Cesium Vapor-Cell Microwave Frequency Reference

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The coherent population trapping (CPT) phenomenon[1] has been widely used for the development of cell-based microwave frequency references, including the demonstration and even commercialization of chip-scale atomic clocks (MACs)[2]. In CPT physics, atoms are driven into a dark state uncoupled from the excited state by making the atoms interact with a dual-frequency optical field such that the Raman detuning is null. CPT induces a reduction of the light field absorption in the vapor cell, leading to the detection of a resonance peak (increased transmission) in the bottom of the absorption line. The CPT dark resonance is usually excited in commercial MACs with a simple circularly polarized dual-frequency light field. Alternative excitation schemes have also been proposed[3,4].

Electromagnetically induced absorption (EIA)[5] is an alternative technique for the creation of quantum coherent superposition of atomic states, yielding to the detection of a "bright" state resonance. A wide variety of EIA schemes using single-frequency or dual-frequency optical fields has been reported in the literature. However, none of them was applied to the development of an atomic clock.

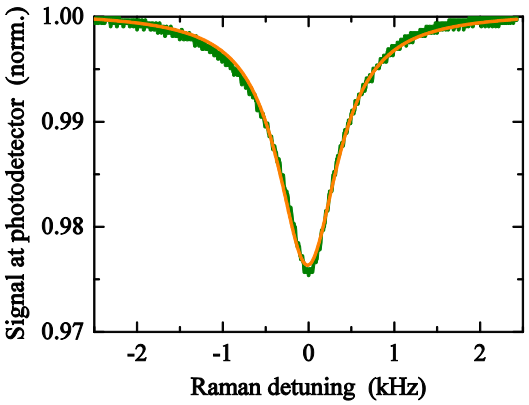

Fig.1: EIA resonance in the proposed scheme. The pump and probe wave powers are 40 μW and 4.5 μW, respectively. T_{cell}= 60°C. The signal is normalized by the background absorption level. Orange curve is a Lorentzian fit. Contrast ≈ 2.5%, FWHM ≈ 850 Hz.

In this work, we report a novel excitation scheme for the detection of sub-natural EIA resonances on the cesium D1 line, adapted for atomic clock operation. Dual-frequency counter-propagating light beams with equal circular polarizations are used. A CPT state created by the pump beam appears as a "bright" state for the probe beam, leading to the observation of EIA at null Raman frequency detuning (Fig.1) and fixed static magnetic field. A proof of concept EIA-clock experiment based on a 5-mm long buffer-gas filled vapor cell has been mounted to validate the approach. A preliminary clock fractional frequency instability of $5.8\times10^{-12}\tau^{-1/2}$ up to 20 s is demonstrated. The authors thank Russian Science Foundation (17-72-20089), Région Bourgogne Franche-Comté, Agence Nationale de la Recherche (Labex FIRST-TF, Grant 10-LABX-0048, Oscilator-IMP Grant 11-EQPX-0033).

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