Post-doc position

Institut FEMTO-ST

Time-Frequency Department
26 rue de l'épitaphe 25030 Besançon, France

Subject: Exploring light-shift immune pulsed interrogation protocols in miniature atomic clocks

Duration: 12 months (possible extension)

Over the last decade, the combination of coherent population trapping (CPT) physics, microfabrication techniques and semi-conductor diode lasers, has allowed the development of miniature atomic clocks [1-4]. These clocks, now commercially-available [5], are attractive candidates for numerous industrial and strategic applications since they combine a total volume of about 15 cm^3, a power consumption of 150 mW and a fractional frequency stability of 2 10^{-11} à 1 s and 10^{-11} at 1 day integration time.

Despite these remarkable performances, a major limitation to the frequency stability of these miniature atomic clocks for integration times higher than 100-1000 s is light-shift effects. Light-shifts mainly traduce the sensitivity of the clock frequency to variations of the laser power, laser frequency or sidebands asymmetry. Different methods have been reported in the literature to reduce these effects [6-15]. However, the efficiency of these methods remains limited and light-shifts remain most of the time a major limitation to the mid- and long-term stability of miniature CPT atomic clocks.

A possible approach to reduce light-shift effects in atomic clocks is to use a pulsed Ramsey-based interrogation method [16]. In a vapor cell CPT clock, this method consists to make the atoms interact with an optical CPT pulse sequence where each pulse is used both for CPT pumping and detection and separated by a free-evolution time.

However, Ramsey spectroscopy exhibits a non-negligible residual sensitivity to frequency shifts induced by the probing field during the interaction pulses [17]. Over the last decade, impressive theoretical efforts have been pursued in several groups [18] in order to propose robust and sophisticated composite interrogation protocols aiming to eliminate probe-field induced light shift effects. Among these protocols, Auto-Balanced Ramsey (ABR) spectroscopy, initially proposed by PTB [19] and generalized in [20], has generated exciting results and a significant stimulation in the time and frequency community.

In FEMTO-ST, we have recently demonstrated the implementation of the Auto-Balanced Ramsey interrogation protocol onto a high-performance CPT-based Cs vapor cell atomic clock (not a MEMS-cell-based clock) [21]. We have proposed an optimized symmetrical ABR (SABR-CPT) interrogation sequence [22], yielding a drastic reduction of the clock frequency sensitivity to laser power variations (80 times smaller than in the Ramsey-CPT case, 800 times smaller than in the continuous regime case), rejecting greatly this contribution to the clock stability at 10^4 s. More recently, original variants of the ABR interrogation protocol have been proposed, allowing a relevant simplification of their experimental implementation [23,24].

During many years, the interest to apply pulsed Ramsey-based interrogation techniques in miniature atomic clocks was not justified. Indeed, the limited CPT coherence lifetime in a MEMS cell should limit the best achievable Ramsey fringe linewidth (i.e. also short-term stability) to a value comparable to what can be achieved in the classical continuous (CW) regime. However, the implementation of pulsed interrogation protocols in a MEMS cell based CPT clock could possibly help to reduce light-shift effects and then possibly help to improve their mid- and ling-term stability performances.

In the frame of the SUPREM project funded by LabeX FIRST-TF (http://first-tf.fr), the post-doc candidate will explore and study the possibility to implement and demonstrate the efficiency of pulsed interrogation protocols in a microcell-based CPT clock. The candidate will have the opportunity to investigate this research path by using a microcell-based CPT clock prototype already available in the laboratory. First tests will be performed with the Ramsey-CPT interrogation technique, in order to demonstrate the detection of narrow-linewidth Ramsey-CPT fringes in MEMS cells [25] and to evaluate the potential of this approach (short-term stability and light-shift studies).
In a second time, the implementation of ABR-CPT interrogation protocols will be envisioned. The ABR-CPT protocol is based on two consecutive Ramsey-CPT sequences with different free-evolution times (T), from which are extracted two error signals. The first error signal, extracted from the long-T cycle, is used in order to compensate for the light-induced frequency shift induced during the atom-light interaction. The second error signal, extracted from the short-T cycle, is used to stabilize the local oscillator frequency. The light shift correction can be implemented using different means: by the application of phase correction to the local oscillator during the dark time [19,22], by probing the central Ramsey fringe with displaced frequency jumps [23] or by using a unique error signal resulting from the normalized combination between both above-mentioned error signals [24]. The candidate will contribute to evaluate performances of a microcell-based atomic clock with some of those different possible methods, with a particular attention onto light-shift sensitivity and resulting clock stability for integration times higher than 100 s.

The candidate will integrate the OHMS Group ((http://teams.femto-st.fr/equipe-ohms/) in FEMTO-ST Institute (www.femto-st.fr), Time-Frequency Department. This group has more than 10 years of experience with the development of CPT-based miniature atomic clocks and is an internationally-recognized laboratory in this domain [4].

The candidate should have a strong background PhD thesis experience in the domain of applied physics disciplines and/or atomic physics experiments. The candidate should have strong competences with instrumentation, coding and experiment piloting (Python language preferred), digital and analog low-noise electronics. The candidate should have competences with optics and laser spectroscopy. The first mission of the candidate will be to code and compute the Ramsey-CPT and ABR-CPT sequences onto the microcell-based CPT clock prototype. Once fixed, the candidate will perform a rigorous metrological characterization of the clock stability performances using different interrogation methods. A background experience with the design and development of FPGA-based electronics could be a real plus-value.

The candidate will evolve in a research group of about 25 persons, composed of research scientists, engineers, technicians and PhD students. The candidate will benefit from electronics, mechanics and informatics services from FEMTO-ST and from a high-level measurement platform dedicated to oscillators short-term stability and phase noise metrology (http://oscillator-imp.com/dokuwiki/doku.php). The candidate will aim to present her/his results in international conferences and to report them in peer-reviewed scientific journals.

Postdoc application:

Required background : PhD thesis in physics/applied physics/engineering sciences
Start date: as soon as September 2019
Salary: about 2.2 k€/month (for 0 years of experience after the phD / increased if past postdoc experiences)
Procedure: Send a CV, motivation letter and if available recommendation letters

Contact:

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