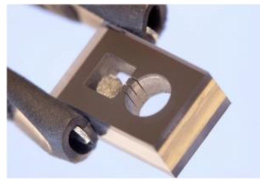
PhD thesis proposal

Ultra-stable microcell-based optical clock



Subject:

FEMTO-ST has worked over the last ~20 years onto the development of miniaturized atomic clocks. These **microwave** clocks, based on the interaction of hot alkali atoms confined in a micro-fabricated cell with an optically-carried microwave signal, demonstrate unrivaled size-power-stability budget with a volume of 15 cm^3, a power consumption of 150 mW, and a fractional frequency stability of about 10^{-11} at 1 day integration time (~1 µs/day) [1]. Nevertheless, these clocks suffer from limitations. The laser frequency noise limits the clock short-term stability and the presence of buffer gas in the cell jeopardizes the clock long-term stability.

FEMTO-ST targets now the development of new-generation chip-scale **optical** atomic clocks. These clocks, that consist to stabilize the frequency of a narrow-linewidth laser onto an optical atomic resonance detected in a pure microfabricated vapor cell, aim at offering a frequency stability > 1000 times better than current commercially-available miniaturized atomic clocks. These clocks might find a plethora of applications in satellite-based navigation systems, secure communications, metrology, geodesy, or defense.

To date, two main approaches have been explored. The first one is the use of the two-photon transition spectroscopy of the Rb atom at 778 nm [2-3]. The second is the use of the dual-frequency sub-Doppler spectroscopy (DFSDS) technique [4-5] with Cs atom. Both of them have already demonstrated short-term stability levels of a few 10^{-13} at 1 s in microfabricated cells.

The present PhD project aims to initiate the exploration of a novel spectroscopy approach at FEMTO-ST. Here, the idea is to directly stabilize the frequency of a near-UV laser onto the $6S_{1/2} – 7P_{1/2}$ transition at 459 nm of the Cs atom. To our knowledge, this approach [6] has never been demonstrated in a microfabricated cell. This transition reveals to be an attractive candidate for achieving a microcell-based optical frequency reference entering the 10^{-14} range stability level at 1 s. In addition, this cell-stabilized laser might serve in the future as a pumping source to stimulate superradiance in a hot vapor cell coupled to an optical cavity. This approach might be the basis of an active optical clock with promising stability performances.

The candidate will implement a table-top proof-of-concept experiment targeting to demonstrate a microcell optical clock using the 459 nm transition of the Cs atom. Spectroscopy of the sub-Doppler resonance will be performed to find experimental parameters that optimize the short-term stability and metrology studies will be performed to improve the clock mid- and long-term stability. The candidate will also contribution to the development of a Cs MEMS cell with strengthened functionalization and optical addressing (e.g. embedded heating, anti-reflection and reflective coatings), coupled with improved internal atmosphere purity.

[1] J. Kitching, Appl. Phys. Rev. 5, 031302 (2018).
[2] V. Maurice et al., Opt. Exp. 28, 17, 24708 (2020).
[3] Z. L. Newman et al., Opt. Lett. 46, 18, 4702 (2021).
[4] M. Abdel Hafiz et al., Opt. Lett. 41, 13, 2982 (2016).
[5] A. Gusching et al., accepted in Opt. Lett. (2023).
[6] J. Miao et al., Phys. Rev. Appl. 18, 024034 (2022).

Candidate Profile

The PhD thesis candidate will work in the OHMS group (http://teams.femto-st.fr/equipe-ohms/) of Time-Frequency department at FEMTO-ST (www.femto-st.fr) , in close collaboration with the MOSAIC group (https://teams.femto-st.fr/MOSAIC/) from MNS2 department.

The candidate should appreciate applied physics disciplines in general, for working in a highly-interdisciplinary subject. The candidate should have a good knowledge, and ideally competences, with optics, low-noise electronics, mechanical design, instrumentation and programming (Python preferred) and be attracted by high-precision metrology. Some knowledge with atomic physics is a clear plus-value but is not mandatory. In addition, some background, through lab works for example, with clean-room techniques and processes will be an important point.

The candidate will evolve in a ~30 people group, composed of researchers, engineers, technicians and will benefit from the support and skills of FEMTO-ST internal services (electronics/mechanics/computing), in an environment with access to a large number of instruments dedicated to time-frequency metrology. The candidate will present his/her work in international conferences and will target the publication of his/her studies in high-impact peer-reviewed international scientific journals.

PhD thesis Funding

The PhD work is *envisioned* to be funded by CNES (https://cnes.fr/fr/) and AID (https://www.defense.gouv.fr/aid/theses-aid-classiques-2023). To be confirmed. The PhD subject has already been validated by CNES. However, the full validation of the thesis funding will be made through the quality of the candidate.
Salary ≈ 1600 € net/month.

PhD start date

Between 1st October and 1st December 2023

Application contact and deadline

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Phone: 03 81 40 28 56
CNES funding application for candidates: https://recrutement.cnes.fr/en/annonce/2039327-23-175-ultra-stable-microcell-based-optical-frequency-reference-25000-besancon
Deadline CNES application: 16 March 2023