Development of a Yb Optical Clock for International Comparisons

This Ph.D. project, based at the Division of Quantum Metrology and Nanotechnologies of INRiM (Italian National Institute of Metrological Research), aims to develop a high-precision Ytterbium (Yb) optical clock, a leading-edge technology in the field of frequency metrology. In this experiment, a clock laser is used to measure the frequency of an atomic energy transition, offering unprecedented accuracy compared to traditional microwave-based clocks, such as the cesium fountain clocks, which are currently used as the international standard for time. The project will also involve the integration of four additional lasers for cooling and trapping the atoms, which are essential steps for measuring its unperturbed clock frequency. Lastly, a mode-locked femtosecond pulsed laser will be employed to convert the optical clock frequency into other spectral ranges, allowing for precise counting.
Optical clocks play a crucial role in the future redefinition of the SI second, and have wide-ranging applications in metrology, fundamental science, and space technology.

INRiM possesses extensive expertise in the development of optical clocks based on Yb atoms, having successfully implemented a prototype that is currently operational (Figure 1). At present, the clock's performance is constrained by technical limitations of the vacuum system used as spectroscopy cell. To address this, we propose the construction of a second experimental setup aimed at surpassing the accuracy of the existing system. The candidate, appropriately guided by senior researchers, will be responsible for designing and constructing a new Yb optical clock, which will be employed for advanced metrological measurements and international clock comparisons. The candidate will address technical challenges in designing the vacuum system apparatus, implementing laser stabilization techniques, developing the optical setup for atomic cooling and trapping, and performing data analysis.
Specifically, the research will focus on one of the following two directions, based on the candidate's choice:

- Design and construction of a Yb optical clock: the goal will be to develop a Yb optical clock with a target accuracy of 10^{-18}. The candidate will be in charge of the operability of the clock focusing on the robustness of the experiment and on its transportability which represents challenges towards the space-based implementation of metrology.
- International measurements and comparisons using frequency combs: the candidate may choose to focus on the measurement and international comparison aspect, specializing in the use of frequency combs to compare optical clocks with other international reference systems.

This experiment will be involved in several international collaborations with leading research institutes in the field of optical clocks. As part of the Ph.D. program, the candidate will have the opportunity to spend a period abroad at one of these research institutes.

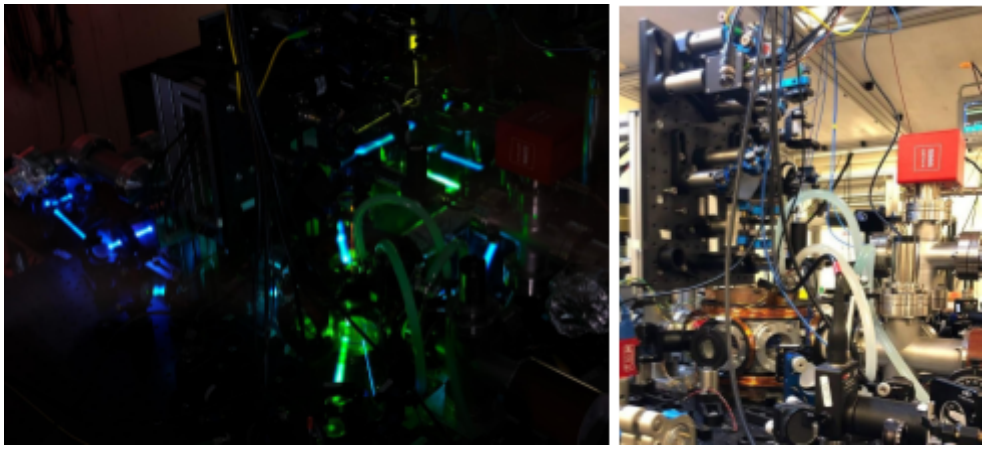

Figure 1: Pictures of the Yb clock developed at INRiM.