

## Chip-scale ultra-precise atomic clock

### Detailed topic description

Space navigation, geodesy, and timekeeping strongly depend on ultra-precise clocks. However, current commercial devices fall short of the precision required for next-gen developments in these fields. In contrast, ultra-accurate clocks using cold atom techniques, advanced laser systems, and low-noise electronics are primarily confined to lab settings at National Metrology Institutes and are not portable. Miniaturizing these systems for practical, portable use is a significant challenge, driving a new area of research that combines microwave and digital electronics with optics and photonics [[Z. Newman, Optica 6, 680 \(2019\)](#)].

This PhD research project, based at the Italian National Institute of Metrology (INRIM), tackles this challenge by aiming to develop a novel clock prototype entirely based on photonic integration. The prototype will utilize an infrared laser stabilized to a narrow transition of an atomic vapour confined in a micro-machined cell, followed by coherent frequency down-conversion from the optical to the THz/GHz microwave domain through a photonic-integrated frequency comb created by a nonlinear optical resonator.

As a PhD candidate, you will be directly involved in designing and implementing low-noise optoelectronic components for the clock's key functions, including laser beam manipulation, atom interrogation, and stabilization of the nonlinear optical process for optical-to-microwave conversion. You will also be responsible for testing and characterizing the clock's performance in terms of accuracy, stability and environmental sensitivity—essential for real-world deployment.

For engineers or physicists with a passion for innovation, this project offers an opportunity to exploit low-noise microwave and digital electronics in advanced atomic physics, explore novel photonic microresonator designs, nonlinear optics, and next-gen chip-integrated functionalities. These cutting-edge developments will be carried out in collaboration with INRIM's Piquet facility, specializing in advanced micro and nanofabrication techniques [<https://piquetlab.it/>].