Theses on atomic clocks at INRIM

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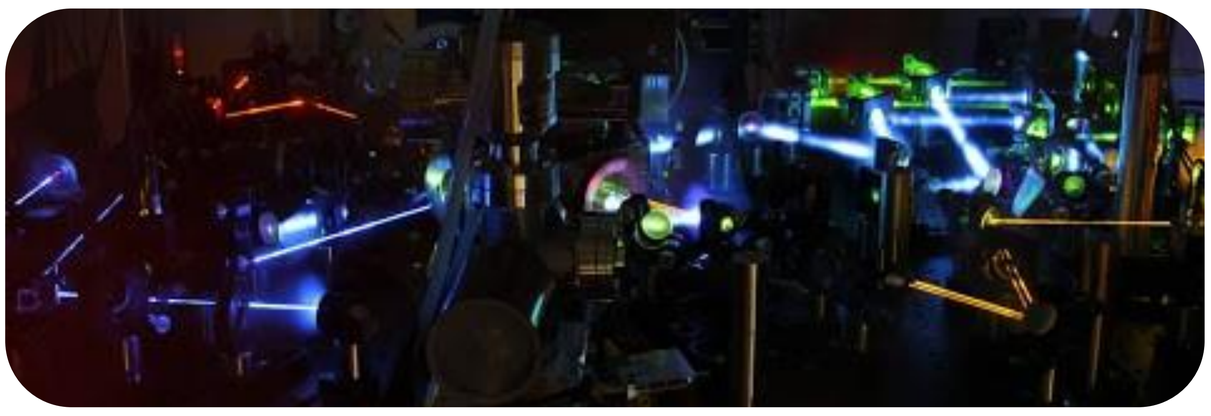
We are the **Atomic Frequency Standard group** at **INRIM**, part of the **Quantum metrology and Nanotechnology division**. The group comprises about **20 people** among permanent staff and students, and it is active in a **strong international context**. Our group maintains the **cesium atomic fountain**, which is the primary realization of the second in the International System of Units (SI).

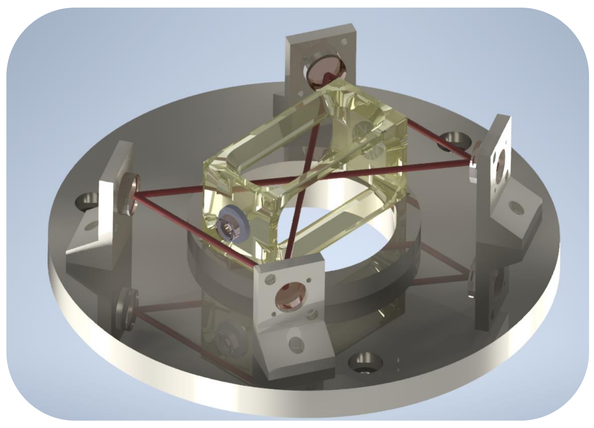
Our research aims at developing new frequency standards beyond the state of the art, as well as related technologies such as **optical clocks**, **ultrastable lasers**, **optical frequency combs**, **optical fibre links**, **compact and on-chip clocks** for transportable and space applications.



Sr optical lattice clock

Thesis proposals:

- Development of a homodyne detection system for the **"quantum non demolition" detection** of collective atomic states
- **Laser frequency stabilization** to an **ultrastable optical cavity** at the thermal noise limit and beyond
- **Fluorescence imaging system** of ultracold atoms with an EMCCD and application to an optcal lattice clock
- **Isotope shift** and **collisional** properties of Sr atoms
- Narrow-line laser **Doppler cooling** of ^{87}Sr atoms for an optical lattice clock



Keywords: Optical lattice clock; quantum non-demolition detection; ultrastable cavity; atomic cooling; isotope shift

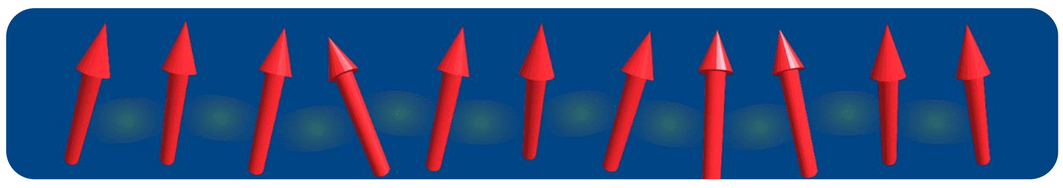
References:
Status and Perspectives of INRIM Sr Cavity-Enhanced Optical Clock
M. Barbiero et al., Joint Conference EFTF/IFCS (2023)

Broadband serrodyne phase modulation for optical frequency standards and spectral purity transfer
M. Barbiero et al., Optics Letters 48, 7, 1958-1961 (2023)

Quantum many-body theory

Thesis proposals:

- **Quantum Monte Carlo** study of trapped interacting **atomic gases**
- Cumulant approximation study of **entanglement** generation in **cavity-enhanced atomic clocks.**
- Theoretical and computational study of **quantum entangled states** in a **cavity-enhanced optical clock**



Keywords: Quantum Monte Carlo; atomic clocks; Bosons and fermions; nonperturbative interaction effects; quantum optics of atoms in optical cavities; Lindblad equation; Schroedinger equation; parallel simulation

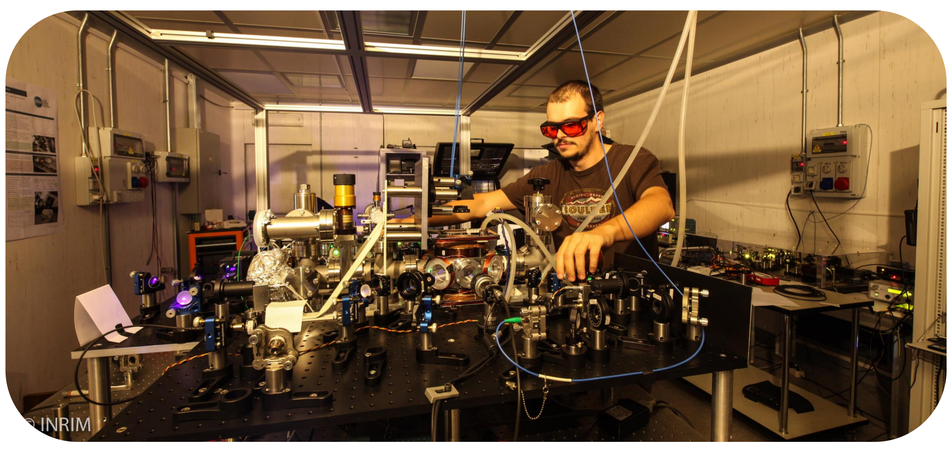
References:
QuantumCumulants.jl: A Julia framework for generalized mean-field equations in open quantum systems
D. Plankensteiner et al., Quantum 6 (2022)

Quantum Monte Carlo Study of the Role of p-Wave Interactions in Ultracold Repulsive Fermi Gases
G. Bertaina et al., Phys. Rev. A 107, 053305 (2023)

Yb optical lattice clock

Thesis proposals:

- Characterization of the **laser source** and development of **optical setup** for the realization of an **optical lattice** at the magic wavelength for **Yb atoms**
- **Ultra-low noise laser** with high Q **Fabry-Pérot resonator**



Keywords: optical lattice clock; lattice laser source; frequency stabilization

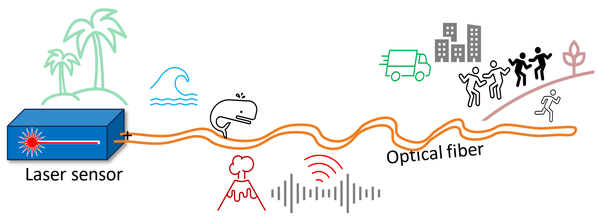
References:
Absolute frequency measurement of a Yb optical clock at the limit of the Cs fountain
I. Goti et al., M. Pizzocaro, Metrologia 60, 035002 (2023)

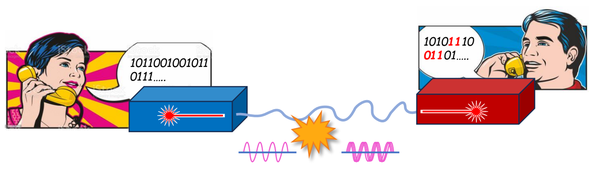
Intercontinental comparison of optical atomic clocks through very long baseline interferometry
M. Pizzocaro et al., Nature Physics **17**, 223–227 (2021)

Fiber link and applications

Thesis proposals:

- Realization of **integrated lasers** and devices for **laser interferometry on optical fiber,** for earthquake & geophysical signal detection (field-tests in Torino, Mediterranean Sea, central Italy)
- **Advanced signal processing** of geophysical signals collected by optical fibers: **automatic pattern recognition**, **modeling** the fiber response, validation with experimental data





- Development of experimental devices for **quantum key distribution** based on narrow-linewidth lasers, interferometric detectors and advanced phase/amplitude modulation

Keywords: Narrow-linewidth lasers, laser interferometry, optical fibers, quantum key distribution, earthquakes detection; data mining

References:
Coherent phase transfer for real-world twin-field quantum key distribution
C. Clivati et al., Nature Commun. **13**, 157 (2022)

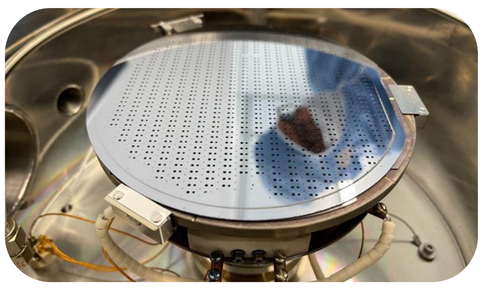
Earthquake observatory with coherent laser interferometry on the telecom fiber network
S. Donadello et al., arXiv:2307.06203 (2023)

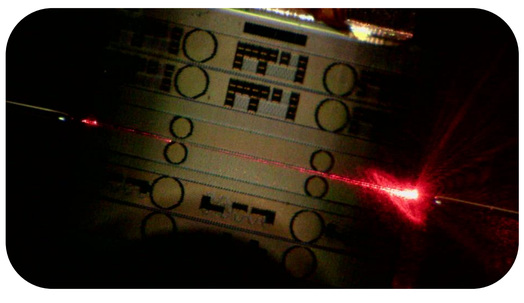
Ultrastable laser interferometry for earthquake detection with terrestrial and submarine cables
G. Marra et al., Science 361,6401 (2018)

Chip-scale optical clock

Thesis proposals:

- Two-photon laser spectroscopy for the realization of a chipscale Rb clock
- Optical frequency combs on a chip for space applications





Keywords: optical atomic clock, hot vapors, microcell, compact clock, two-photon transition

References:
Miniaturized optical frequency reference for next-generation portable optical clocks
V. Maurice et al., Optics Express Vol. 28, pp. 24708-24720 (2020)

A pulsed-laser Rb atomic frequency standard for GNSS applications
S. Micalizio et al., GPS Solutions **25**, 94 (2021)

Contacts and info

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