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AN Yb TRANSPORTABLE CLOCK CONNECTED TO THE REFIMEVE FIBER NETWORK FOR CHRONOMETRIC GEODESY



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Motivation: Apply quantum sensors to Earth Sciences

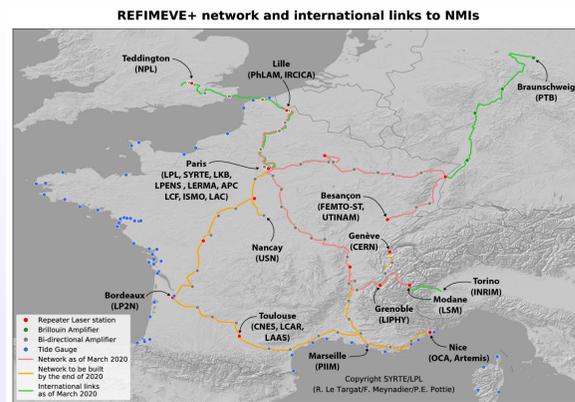
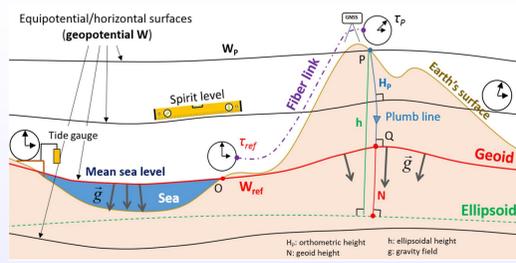
Optical Lattice Clocks allow a control of **18 significant digits** (10^{-18}) of their frequency, with a statistical

resolution of $\sigma(\tau) = \frac{10^{-16}}{\sqrt{\tau}}$, with τ the integration time,

As predicted by Einstein, atomic frequencies ν are sensitive to the local gravitational potential W and therefore to the altitude h (c being the speed of light):

$$\frac{\Delta\nu}{\nu} = \frac{\Delta W}{c^2} \approx \frac{g \cdot \Delta h}{c^2}$$

In turn, an atomic clock travelling in the field can be used to perform a **cartography of the geopotential**, by remote comparisons with ~12 existing optical clocks in Europe, connected by ultrastable fiber links.



The Equipex **REFIMEVE+** disseminates a **1542 nm ultrastable IR carrier** throughout France, with connections to corresponding networks in Germany, UK and Italy.

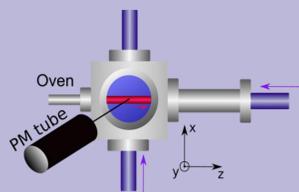
Phase noise due to propagation is compensated via interferometers, and the power is regenerated with remote slave lasers.

At each REFIMEVE+ output, a frequency comb attached to the clock therefore will allow the measurement of:

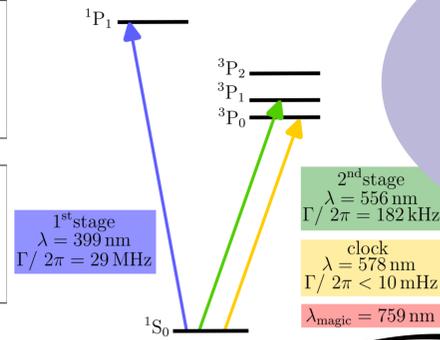
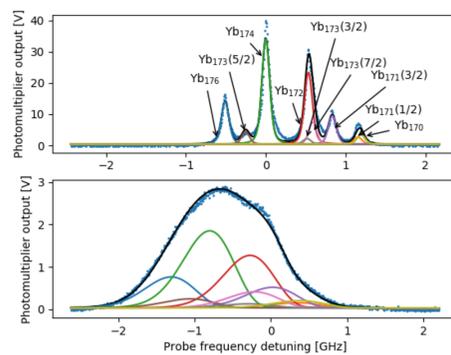
$$\nu_{\text{mobile clock}} \\ \nu_{1542 \text{ nm}}$$

The clock design: anticipate field conditions

• Ytterbium atomic flux

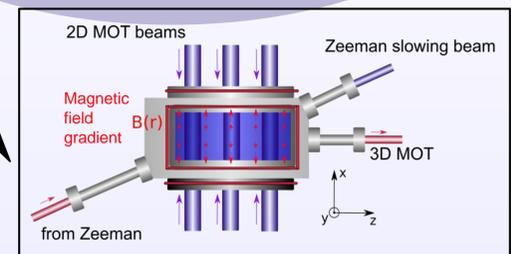


Atomic beam divergence : 5.4-6.8 ° (half angle)
To charge 10^4 atoms in an optical lattice it requires a **high flux** of cold atom **focused and collimated**, the divergence needs to be **corrected**.



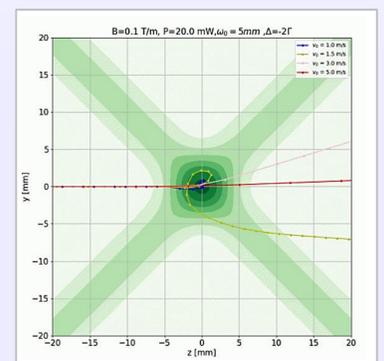
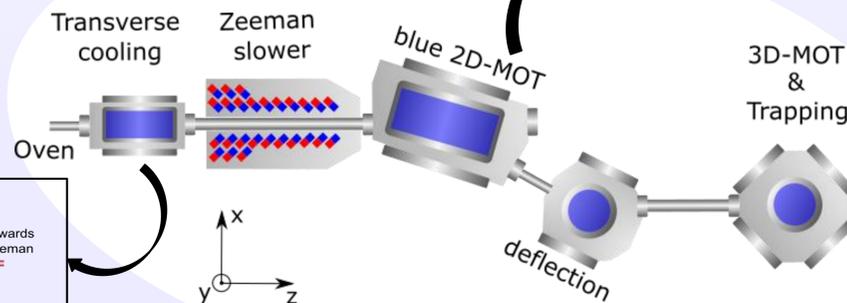
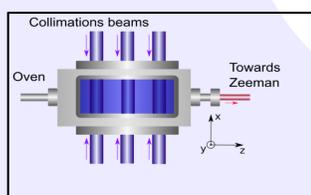
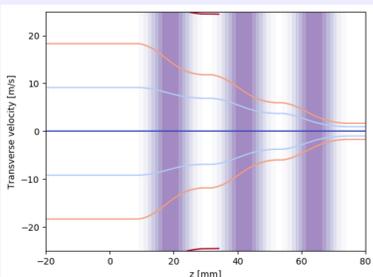
• 2D Magneto optical trap

- Target: collimate the atomic beam at the output of the Zeeman slower for loading in a 3D MOT.
- Since we want to reduce the impact of the oven bodyradiation on the trapped cold atoms, there is an angle of 10° between the Zeeman slower and the 2D MOT.



• Transverse cooling

- The optical molasses is a technical solution that we will use for this task
- It will collimate the beam and help trap more atoms for the clock



• Zeeman slower

- Target: slowdown a large amount of Yb atoms on the longitudinal axis from **400 m/s** down to a velocity of **20m/s**



• 3D MOT and Optical Lattice

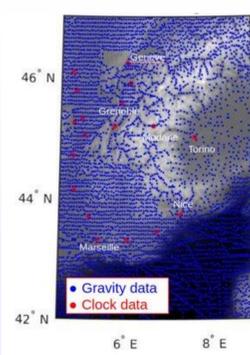
- First, trap and cool a cloud of Yb atoms.
- Then, trap and confine atoms into an optical lattice, a one-dimensional standing wave.
- Objective: load and cool $N_{at} \geq 10^4$ atoms in <150 ms in a few 10 ms

Objectives of the project

Vertical Reference Frames

French reference levelling network NIREF

benefit of clock measurements, synthetic and real data experiments



Geodynamic processes

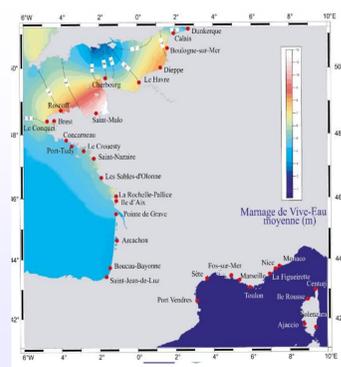
Identify and model geodynamic signals

Possible monitoring :rise of the sea level, early signs of brutal events (earthquakes, tsunamis)

Geoid models in coastal areas

measure the height of the tides

Decouple the motions of the tide gauges and sea level rise



Towards the next definition of the second

Test of Fundamental Physics

European comparisons of clocks (Sr, Hg, Yb, Yb+, Al+ ...)

Funding

