

Ultra-cold atomic source on chip for on-board applications

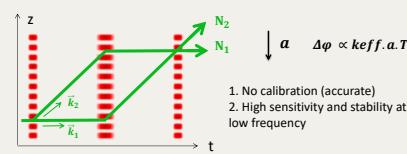
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1 Principle of an atom interferometer:

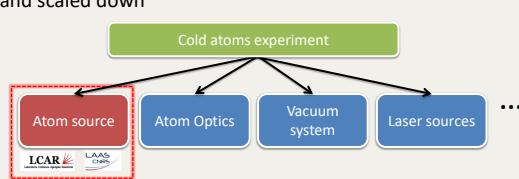
Mach-Zehnder interferometer:

The population in the states depends on the accumulated phase



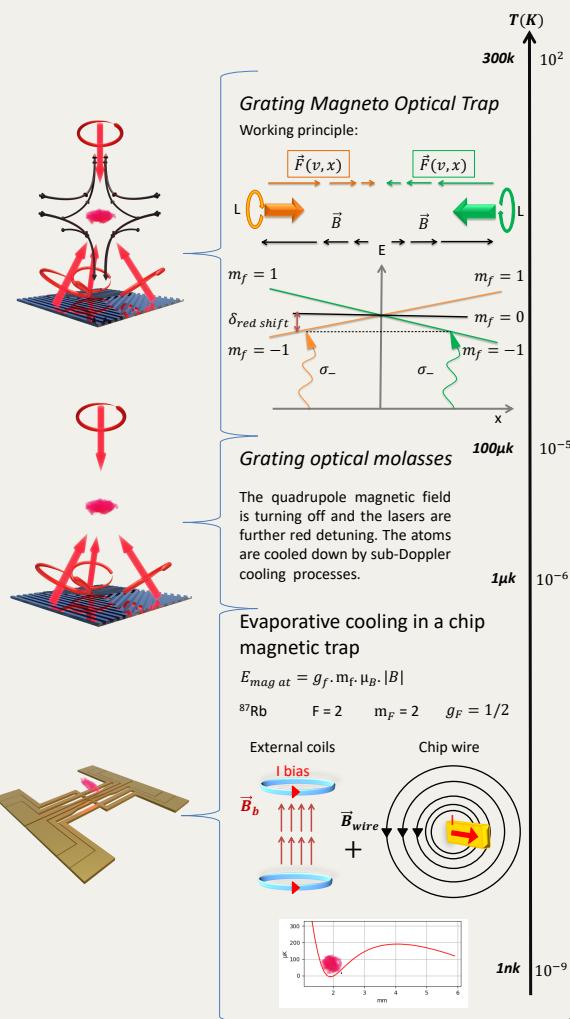
1. Léveque, T., et al. « Gravity Field Mapping Using Laser-Coupled Quantum Accelerometers in Space ». Journal of Geodesy 95, no 1
2. Alonso, et al. « Cold Atoms in Space: Community Workshop Summary and Proposed Road-Map ». arXiv, 19 janvier 2022.

3 Each sub-system of a cold atoms experiment must be robust and scaled down



4 Combine optical and magnetic features on a chip:

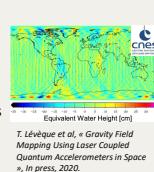
- Optical grating: 3D laser cooling from a single beam.
- Magnetic chip: robust ultra cold atoms production.



2 Motivation of on-board cold atoms

Space applications

Quantum gravimetry for earth observation



Atomic sensors for fundamental science

- Tests of the universality of free fall (mission proposal: STE-QUEST)
- Dark matter detection
- ...

Ground sensors

Gravimeter

Measuring the gravity field



Gradiometer

Measuring the gravity field gradient



Inertial navigation

Calculating the position of a vehicle without GNSS by measuring the acceleration and the rotation.

5 Grating Magneto Optical Trap (GMOT) conditions:

Balanced optical molasses:

$$\sum_{j=0}^5 l_j \cdot k_j = \vec{0}$$

$$\eta_B = \frac{3 \cdot \eta_1 \text{ moy}}{(1 - \eta_0 \text{ moy})} = 1$$

Minimized zero order diffraction:

$$\eta_{0 \text{ moy}} = 0$$

Preserved/Flipped polarizations:

The polarization handedness of the first order opposite to the one of the zero order and incident beams

$$S_{3 \text{ inc}} = S_{3 \text{ 0}} = -S_{3 \text{ 1}}$$

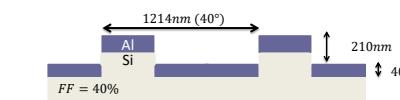
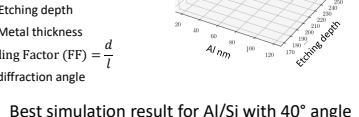
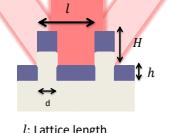
Circular polarization conserved after diffraction

$$|S_{3 \text{ inc},0,1}| = 1$$

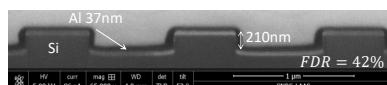
6 Sizing and fabrication of the grating

Simulation (RCWA)

$$\alpha = 40.0^\circ; \eta_1 = \pm 0.05; \eta_0 \leq 0.08; S_3 \geq 0.95$$

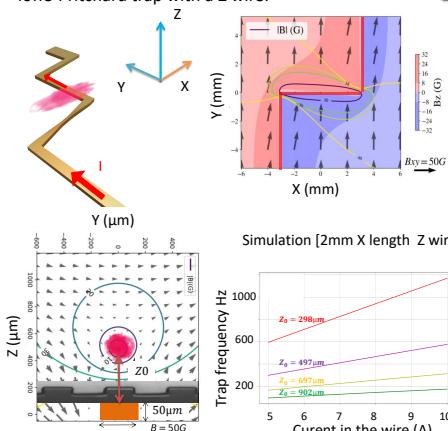


Experimental result for Al/Si with 40° angle



7 Magnetic chip trap:

Ioffe-Pritchard trap with a Z wire:



8 Hybridization process

Mesoscopic wire gluing



Atom chip hybridized



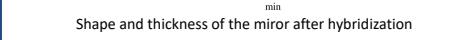
Brazing of the magnetic chip



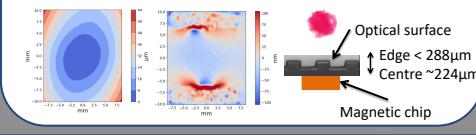
Thinned optical function gluing



Heating of the chip



Shape and thickness of the mirror after hybridization

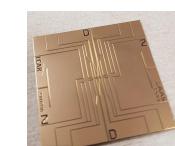


9 Conclusion and prospects

Grating with the target parameters for GMOT fabricated



Magnetic chip is sized and fabricated



Complete Hybridization process tested



Next step : Final magnetic chip and grating hybridization

