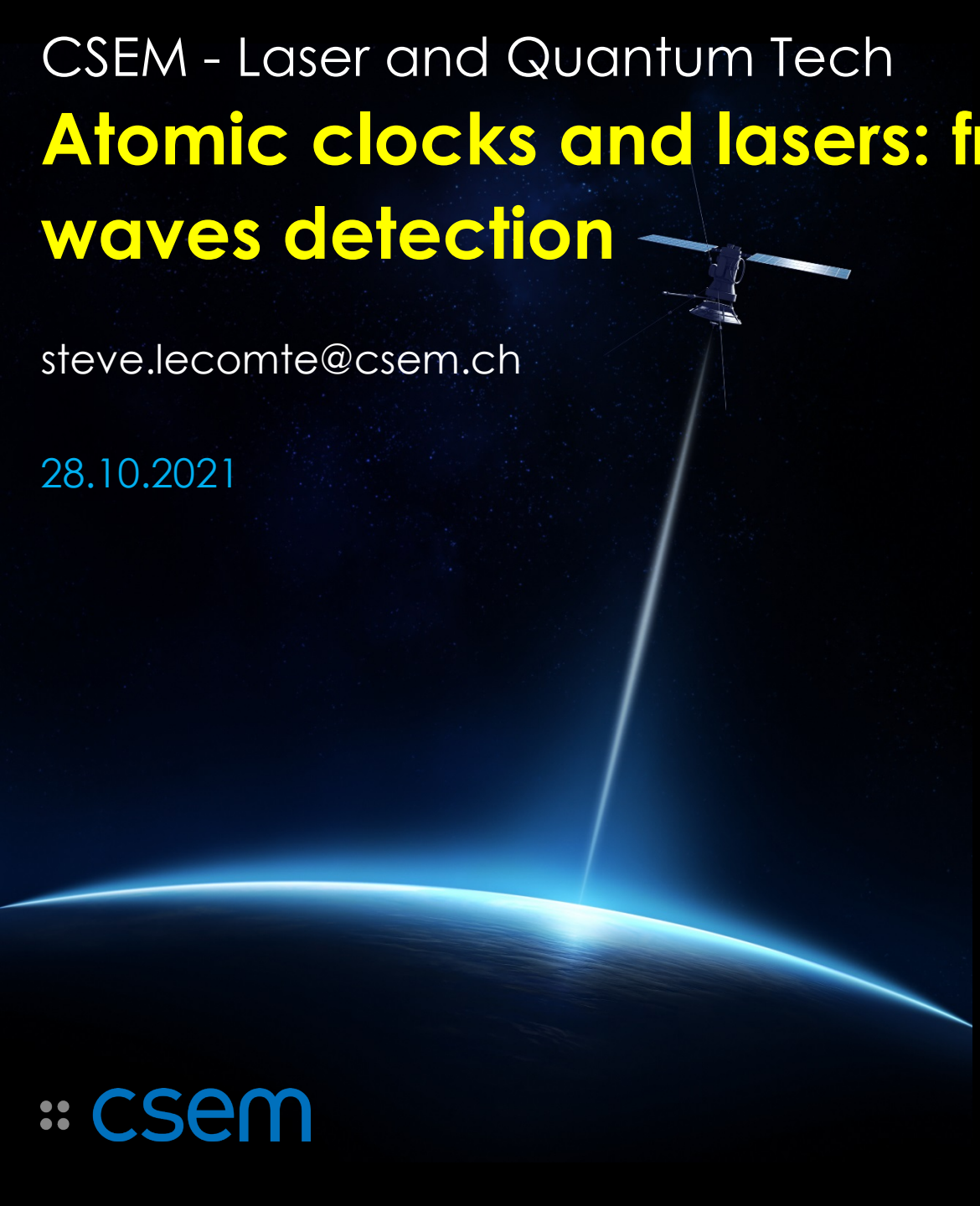
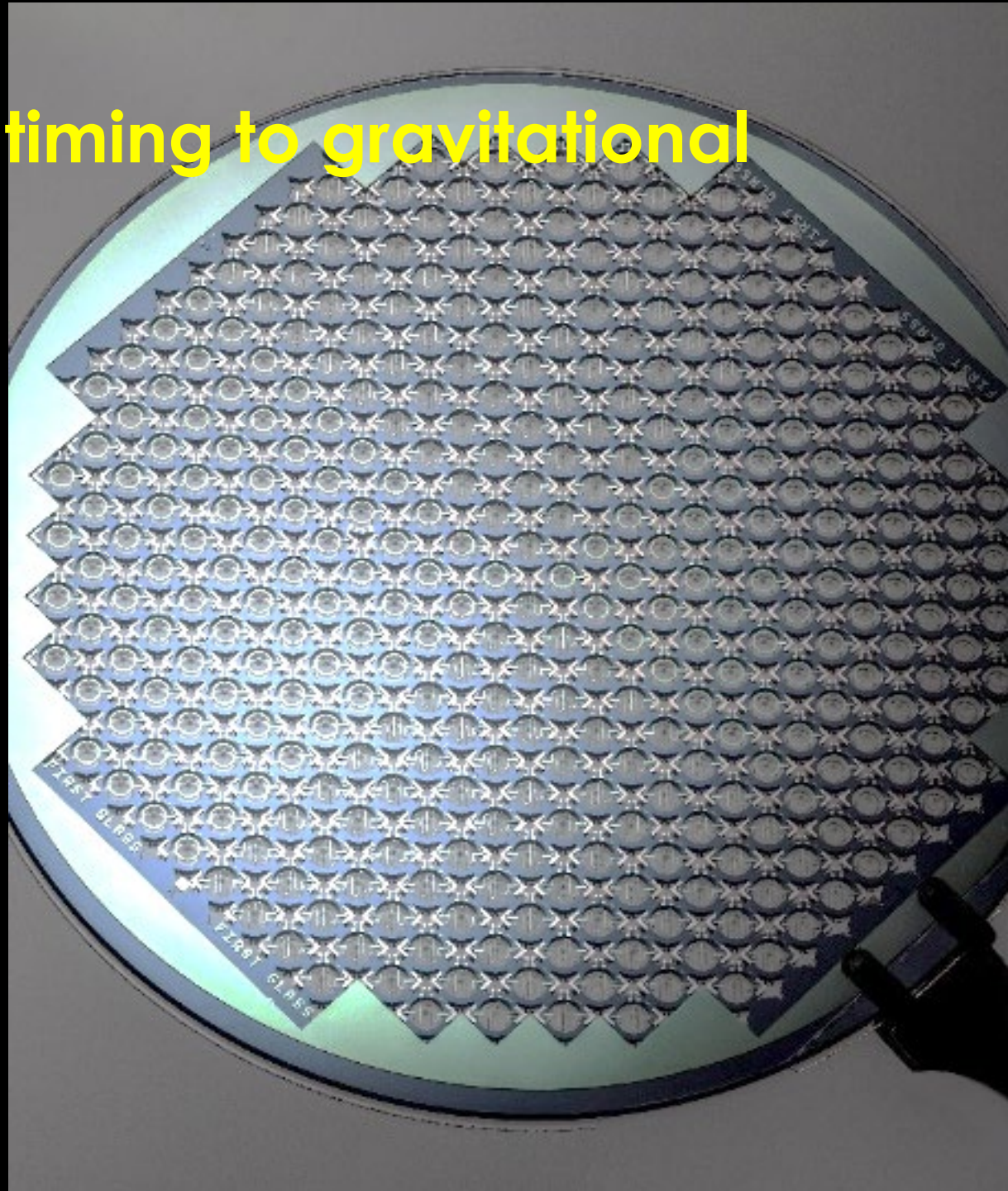
CSEM - Laser and Quantum Tech

Atomic clocks and lasers: from timing to gravitational waves detection

steve.lecomte@csem.ch

28.10.2021





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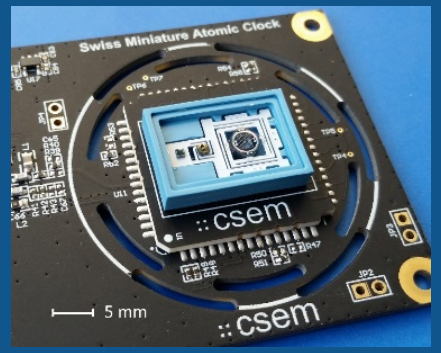
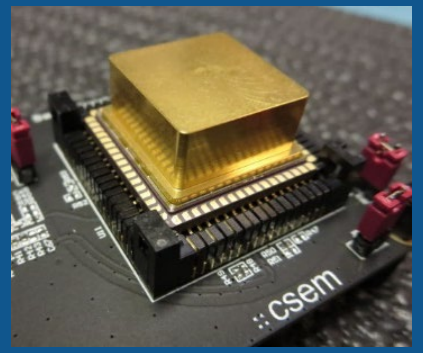
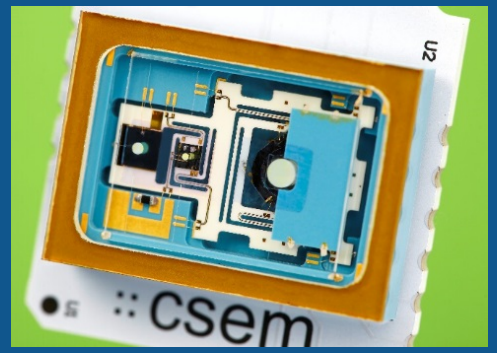
Laser and Quantum Technologies

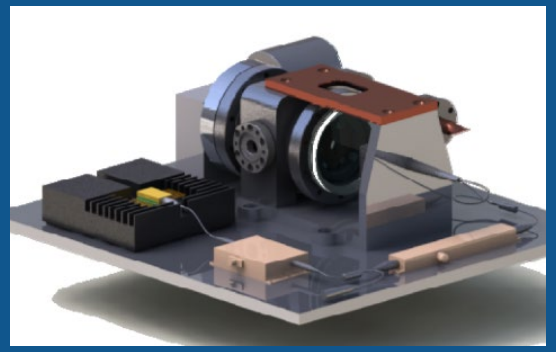
Quantum systems

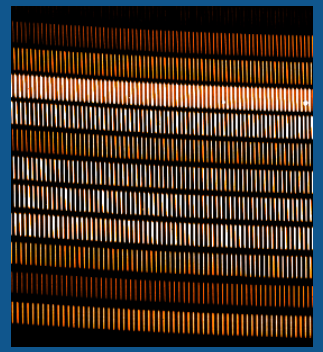
Lasers

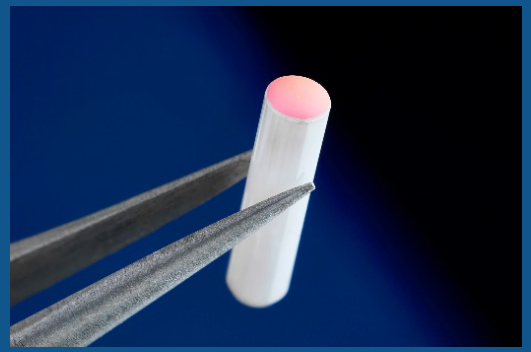












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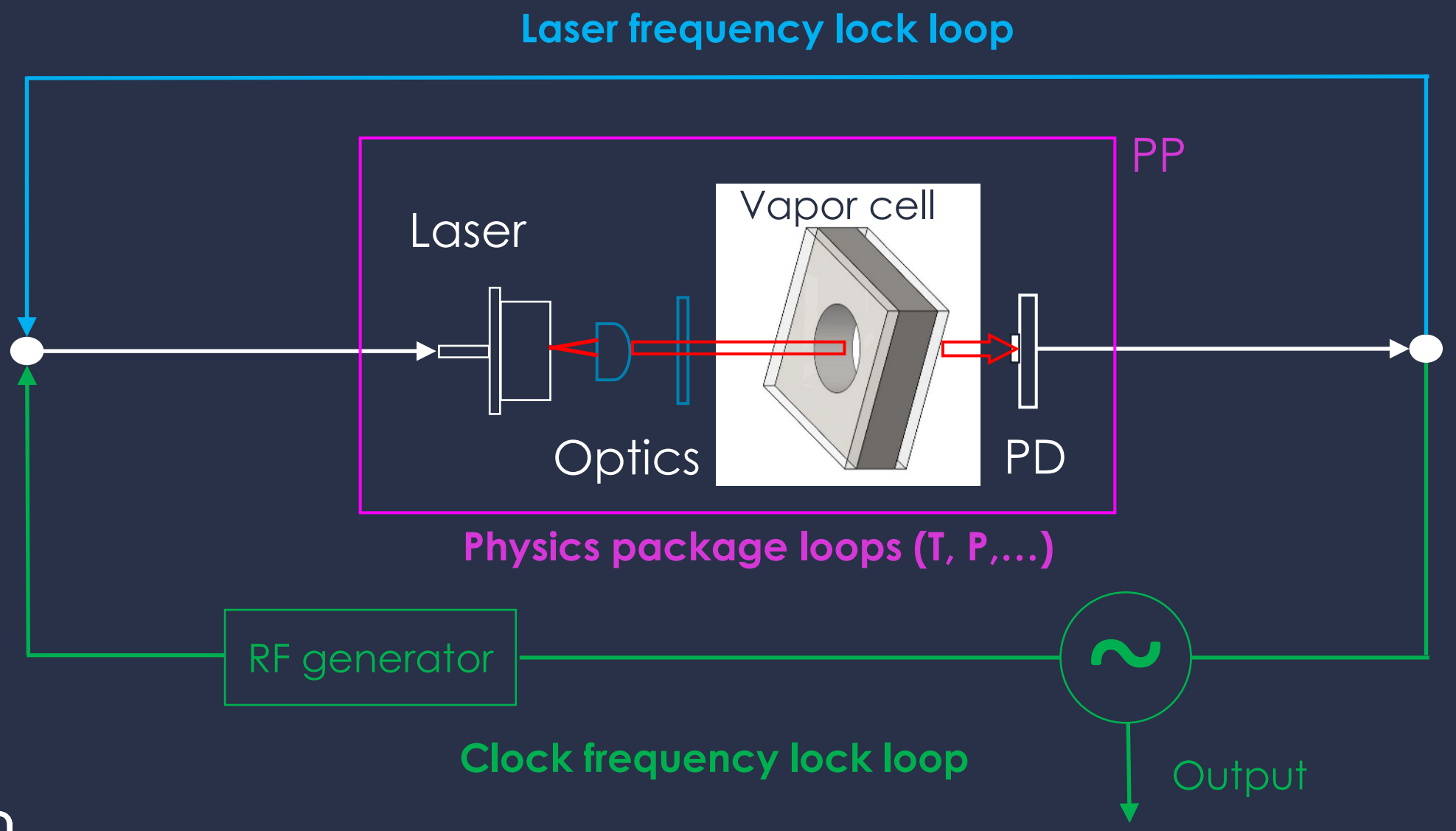
Basics of **miniature atomic clocks**



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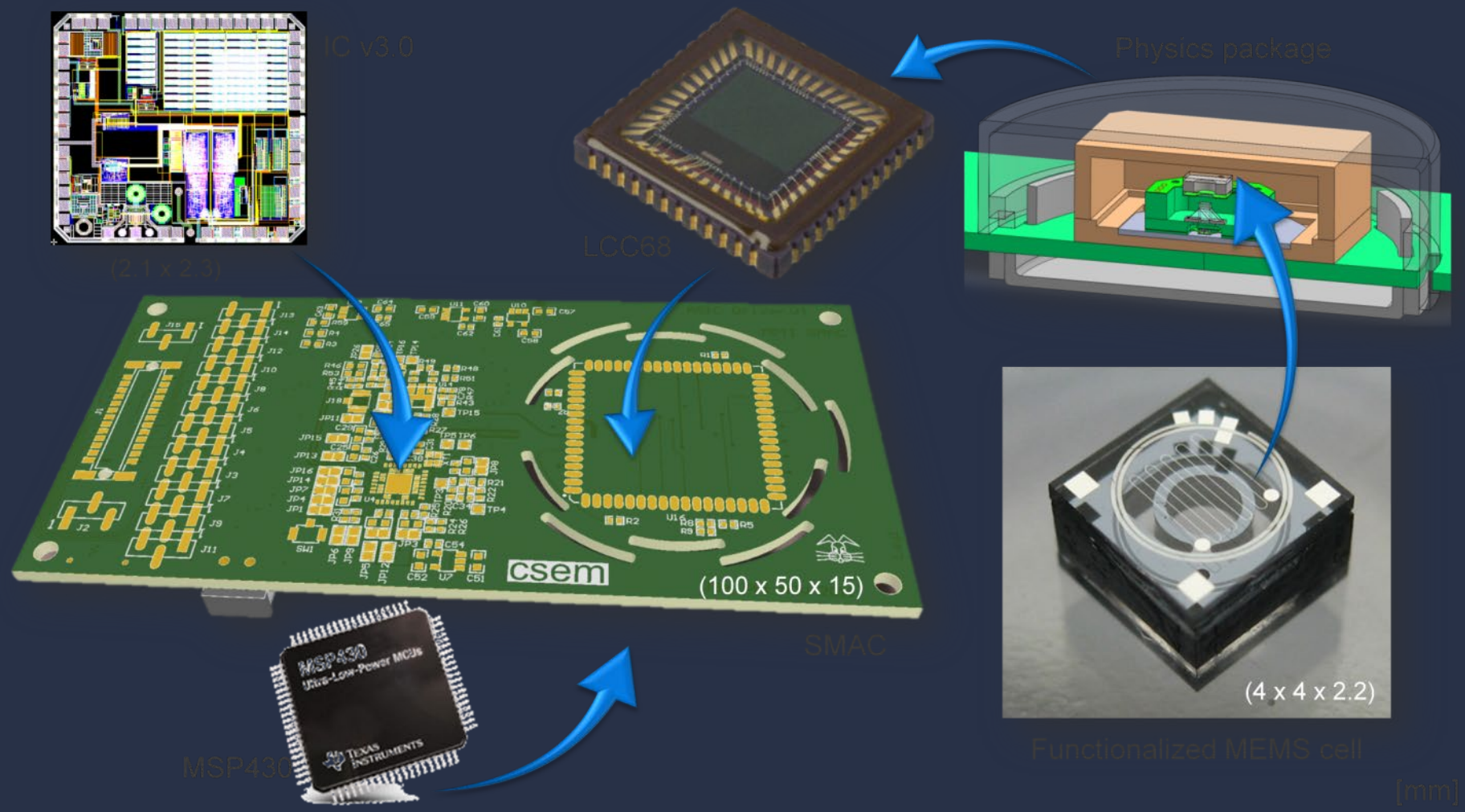
Integration of a miniature atomic clock



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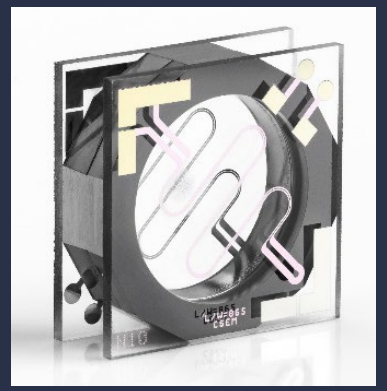
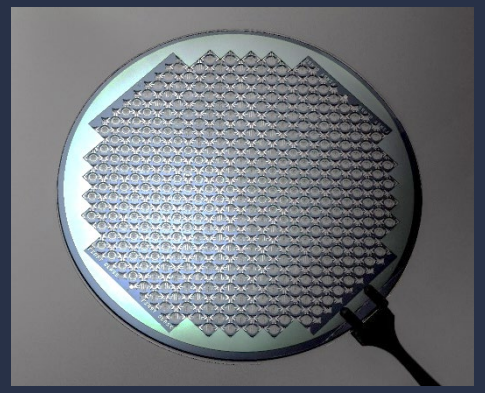
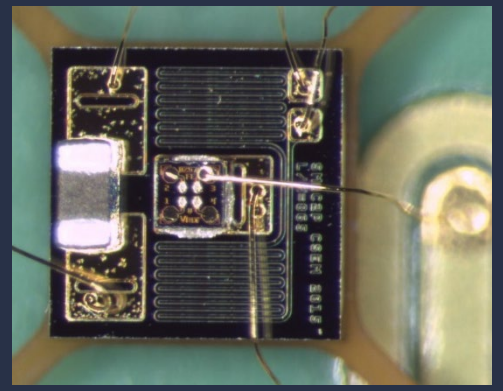
SMAC – Main building blocks

MEMS atomic vapor cells

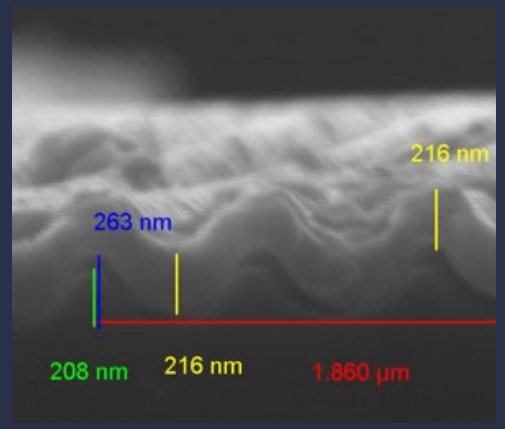




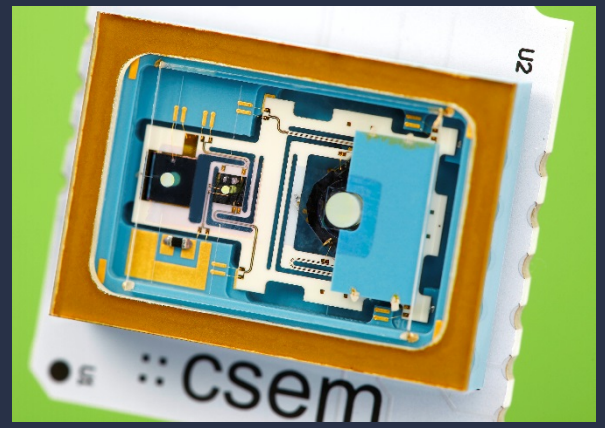
Laser + heater



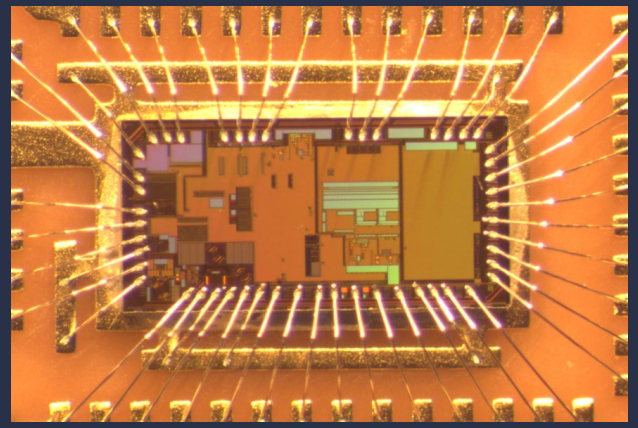
Optics



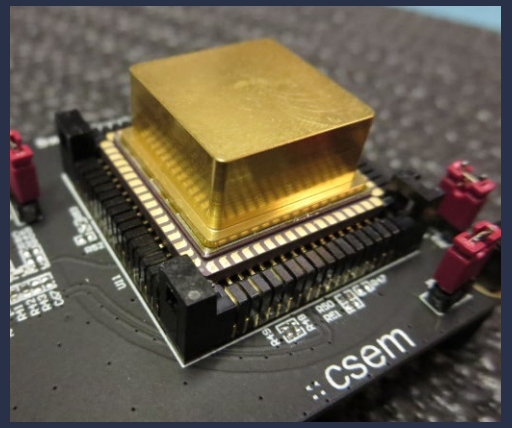
Physics package



Application specific IC (ASIC)



Packaging et assembly



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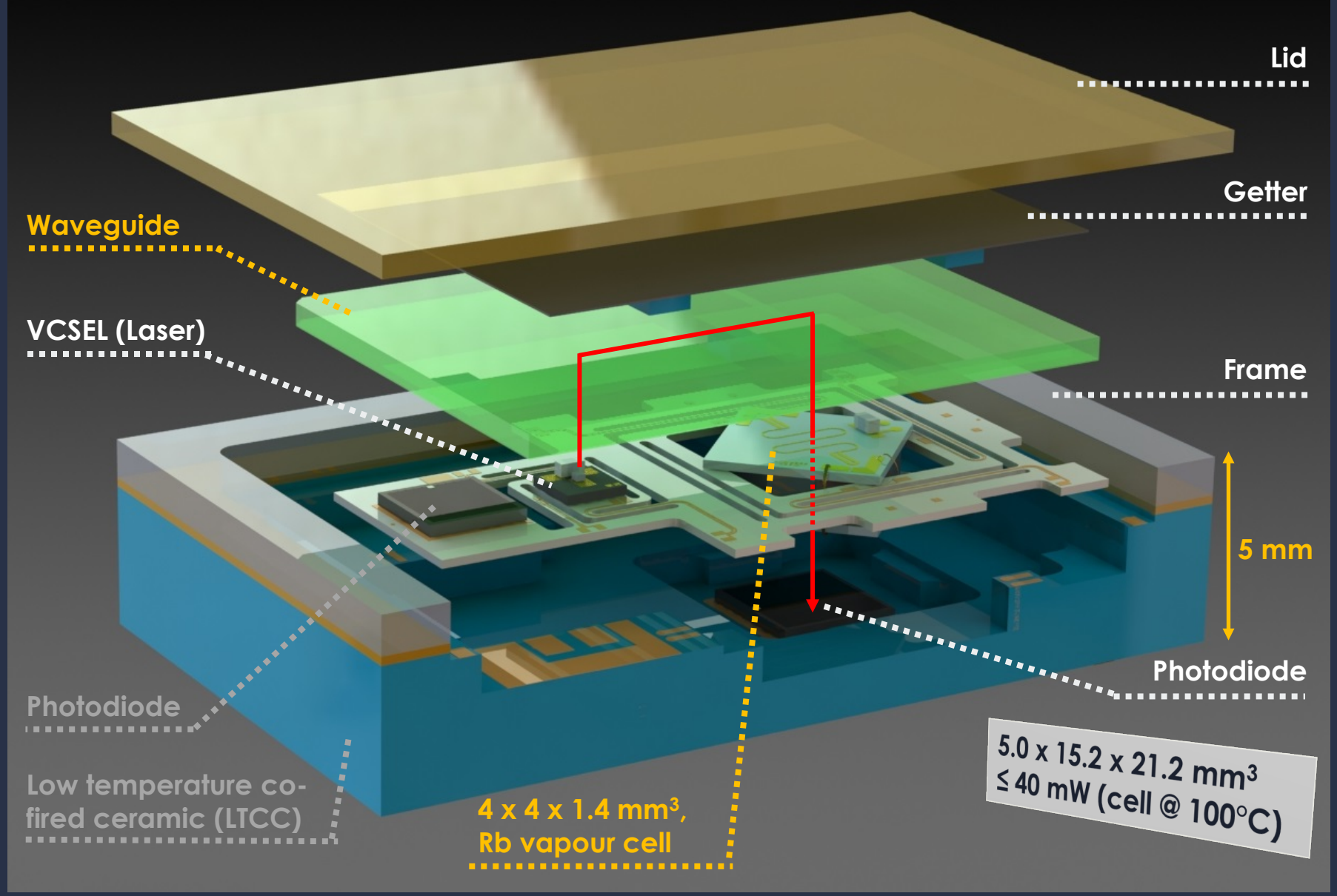
Flat – miniature atomic clock PP



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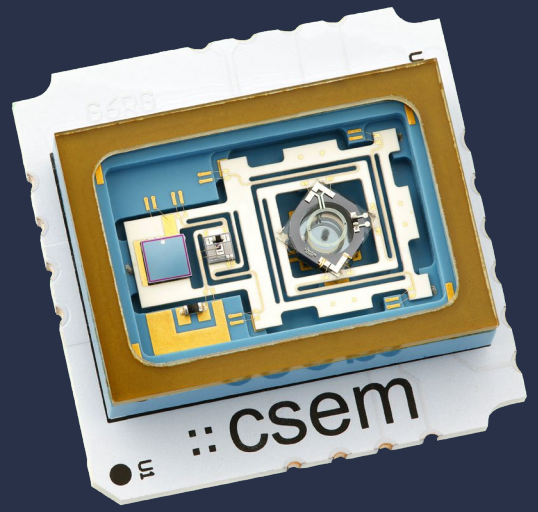
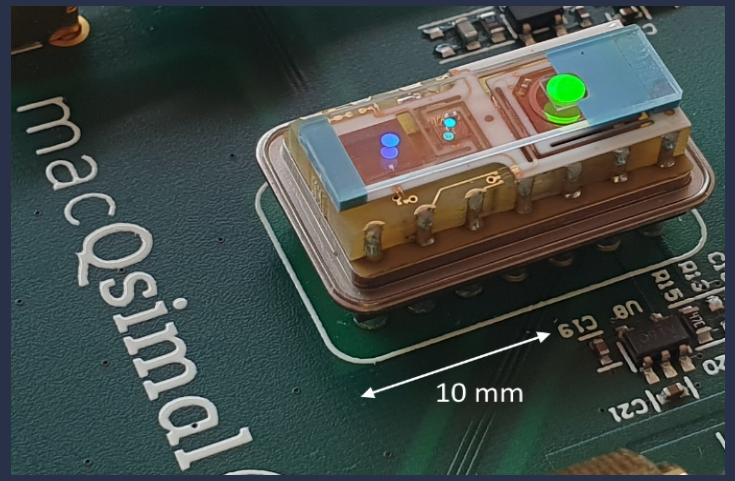
Merging **Orolia's** and **CSEM's** expertises





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macQsimal at a glance

macQsimal

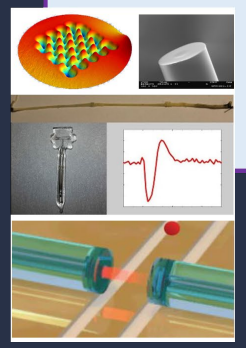
Objectives

ICFO

O1: Miniature Optically Pumped Magnetometers (OPM)

O1.1: Highly sensitive OPM for biomagnetic applications
TRL 2-3 → TRL 4-5

O1.2: Quantum-enhanced OPM concept
TRL 1 → TRL 2-3

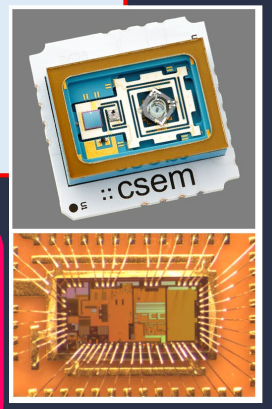


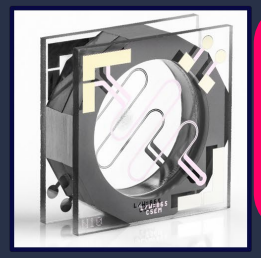
O2: Miniature Atomic Clocks (MAC)

O2.1: Flat form-factor, low-power CPT MAC
TRL 4 → TRL 6-7

O2.2: Quantum-enhanced MAC concept
TRL 1 → TRL 2-3

spectratime
iPrecision Timing Solutions





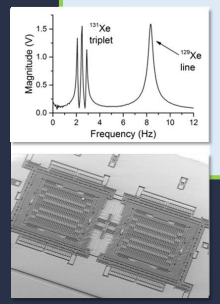
Common platform:
MEMS atomic vapor cells with integrated optics & electronics

BOSCH

O3: Miniature Atomic Gyroscopes (MAG)

O3.1: (Spin) Nuclear Magnetic Resonance Gyroscope
TRL 2-3 → TRL 4-5

O3.2: Quantum-enhanced MAG concept
TRL 1 → TRL 2-3

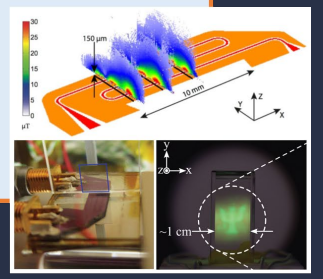


O4: Atomic GHz & THz Sensors and Vector Imagers

O4.1: Calibration-free detection and vector imaging of GHz and THz fields
TRL 2-3 → TRL 4

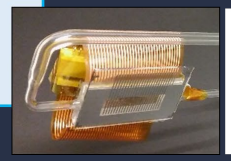
O4.2: Quantum-enhanced GHz sensor
TRL 1 → TRL 2-3

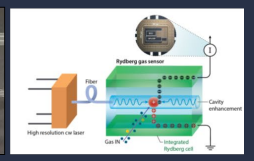
Universität Basel



O5: Rydberg based Gas Sensors

O5.1: NO sensor
TRL 1 → TRL 2-3





Universität Stuttgart

high TRL
lower TRL

QUANTUM FLAGSHIP

QUANTUM Sensing metrology

macQsimal

csem (coordinator), accelopment, VTT, ICFO, University of Copenhagen, Aalto University, Universität Basel, Durham University, Universität Stuttgart, CNRS, unine, BOSCH, MEGIN, spectratime

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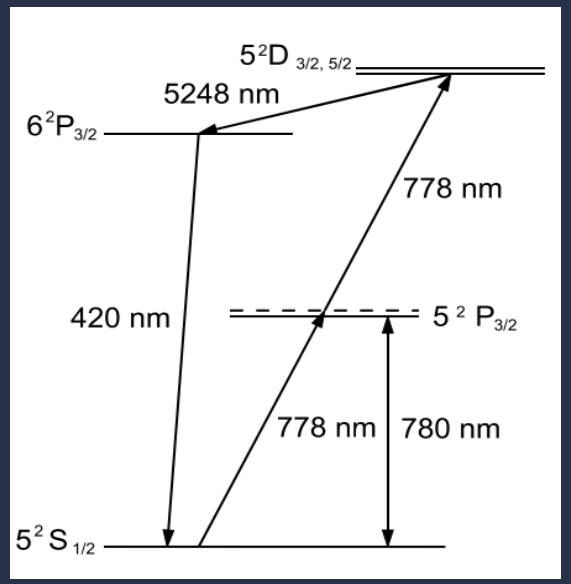
High performance compact clock

- Based on Rb two photon transition at 778.1nm -> move to optical transition
- Potential for compact system
- Focus on clock technology for next generation of Galileo satellites



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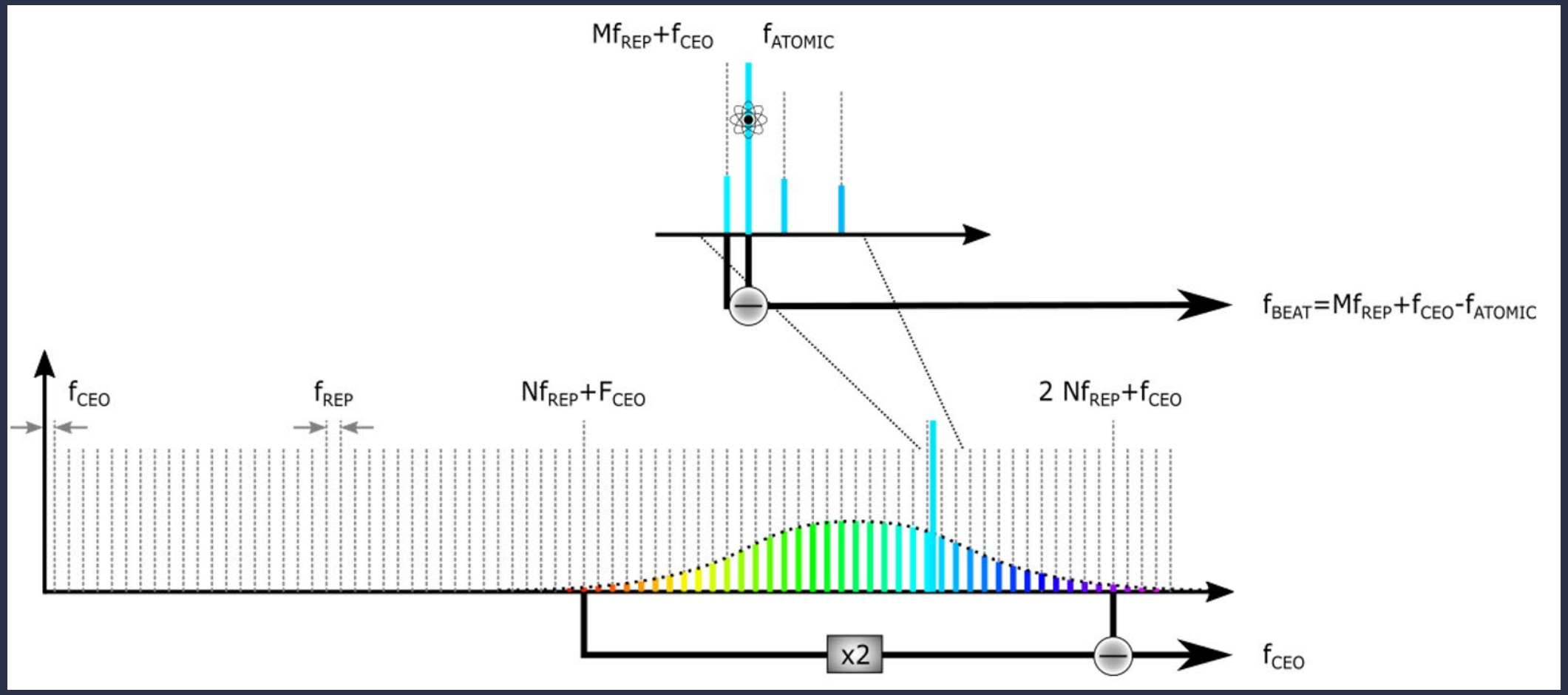
Rb 2 photon clock architecture



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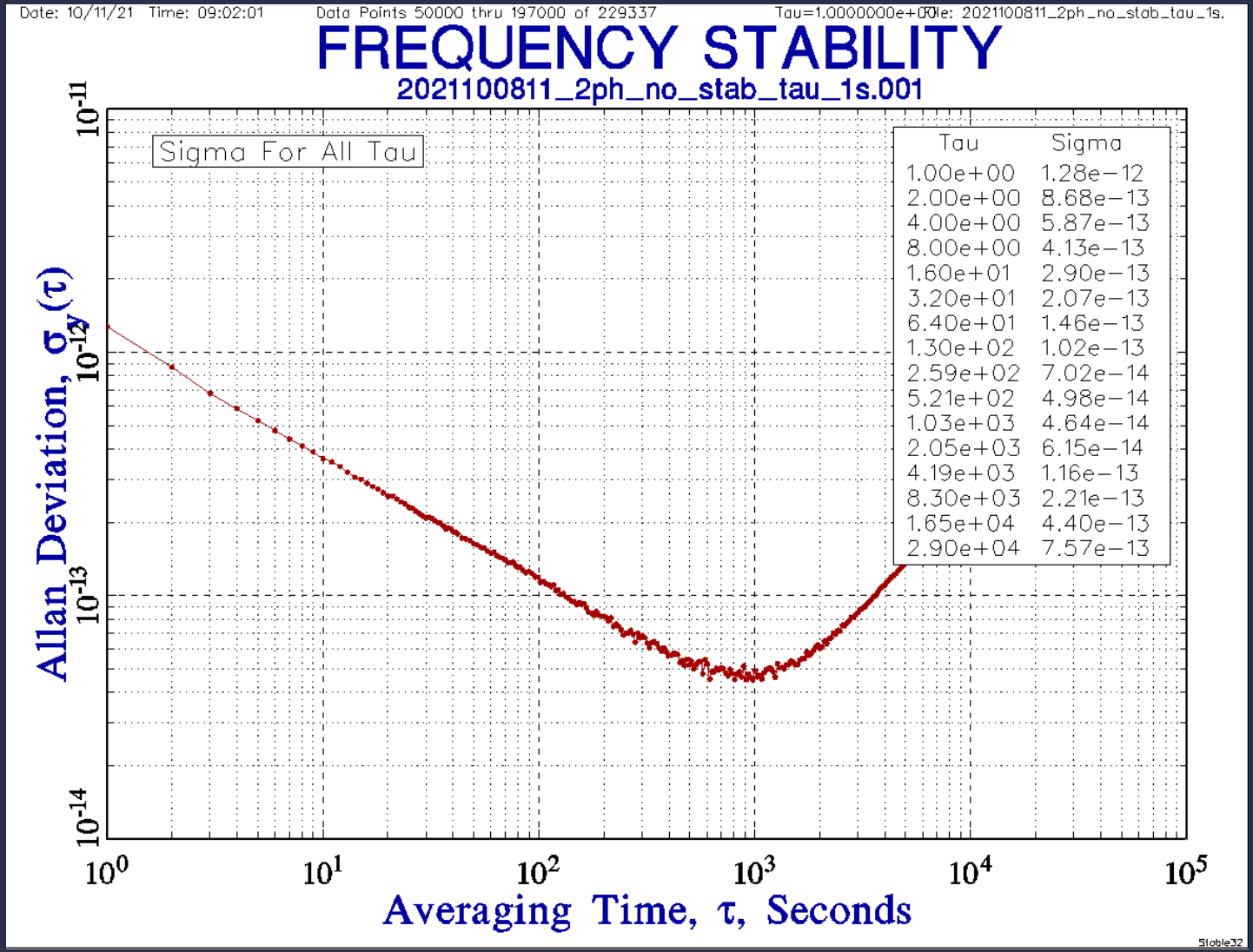
Current frequency stability



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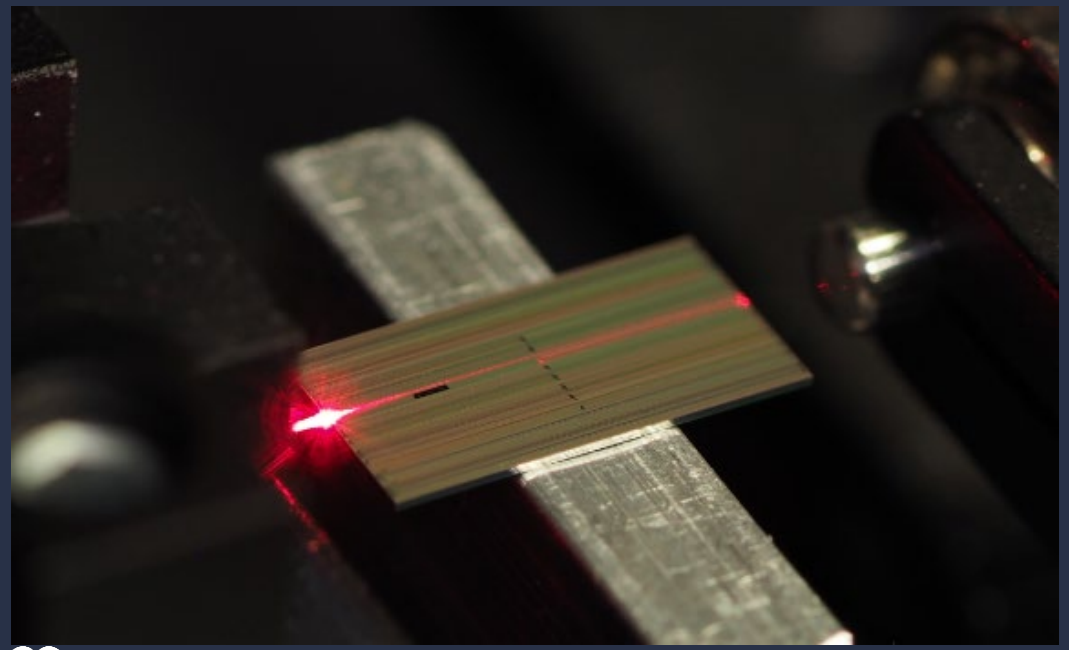
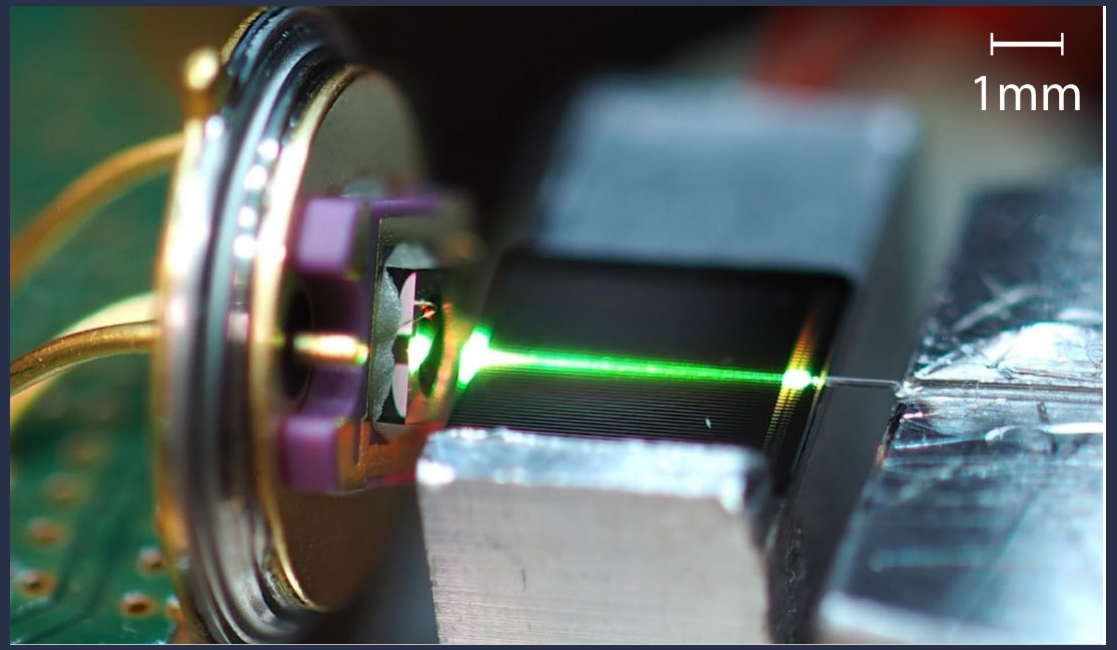
Photonics Integrated Circuits for clocks

- Platforms: SiN and Lithium niobate on insulator (LNOI)
- Nonlinear waveguides for spectral broadening
- Dichroic beam splitter and nonlinear waveguide on chip





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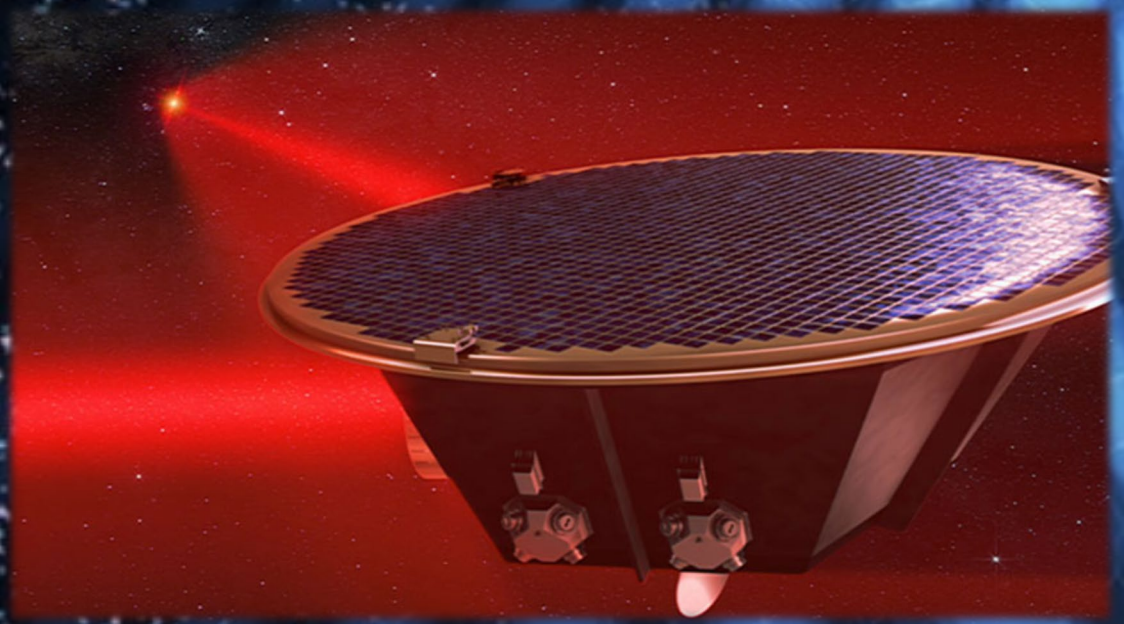
LISA mission to measure gravitational waves in space

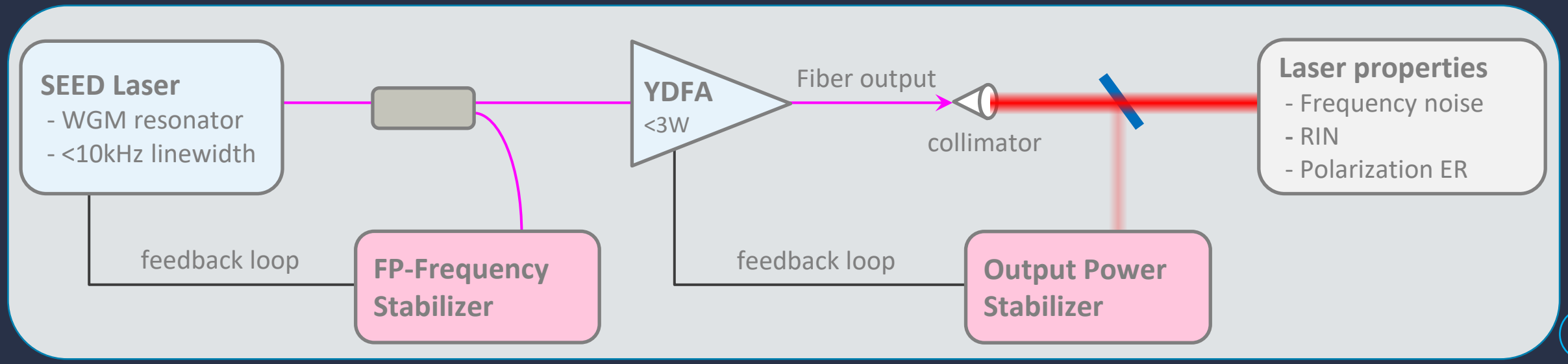
- 3 satellites linked by laser beams over 2.5 millions kilometers
- Satellites trailing Earth orbit
- Joint NASA / ESA mission
- Launch in 2034

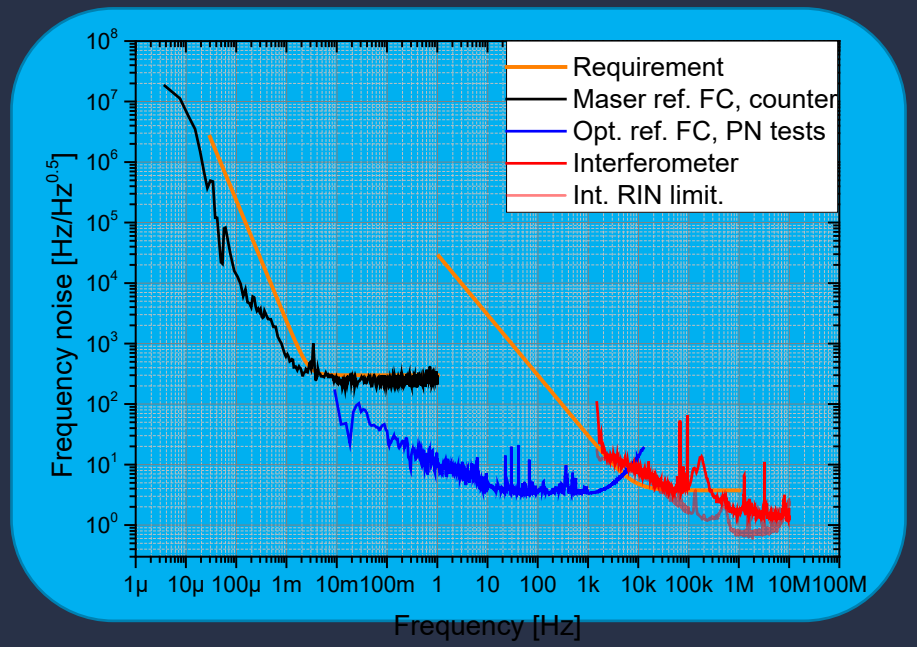


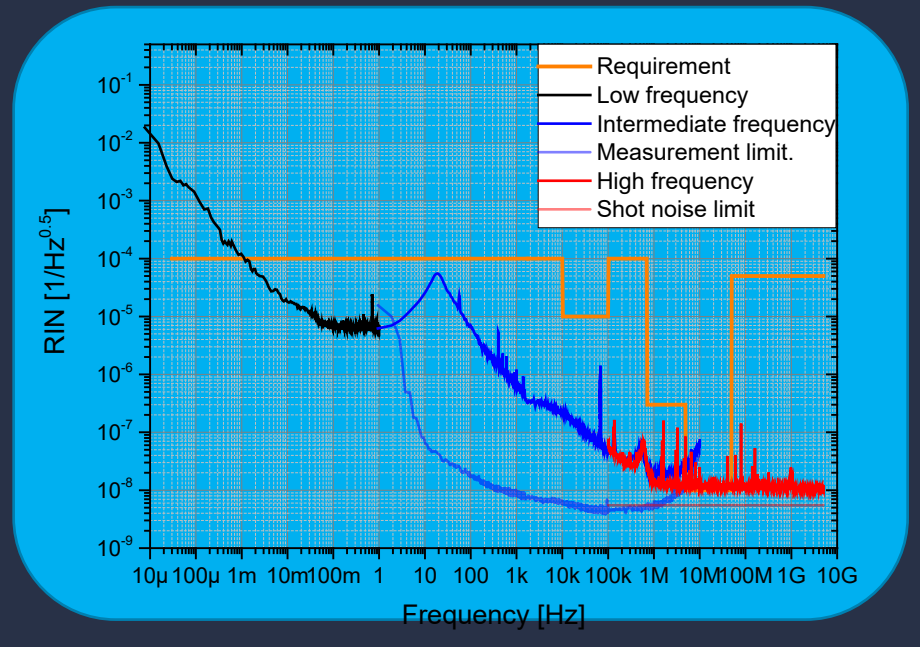
NASA

esa
European Space Agency

CSEM laser breadboard







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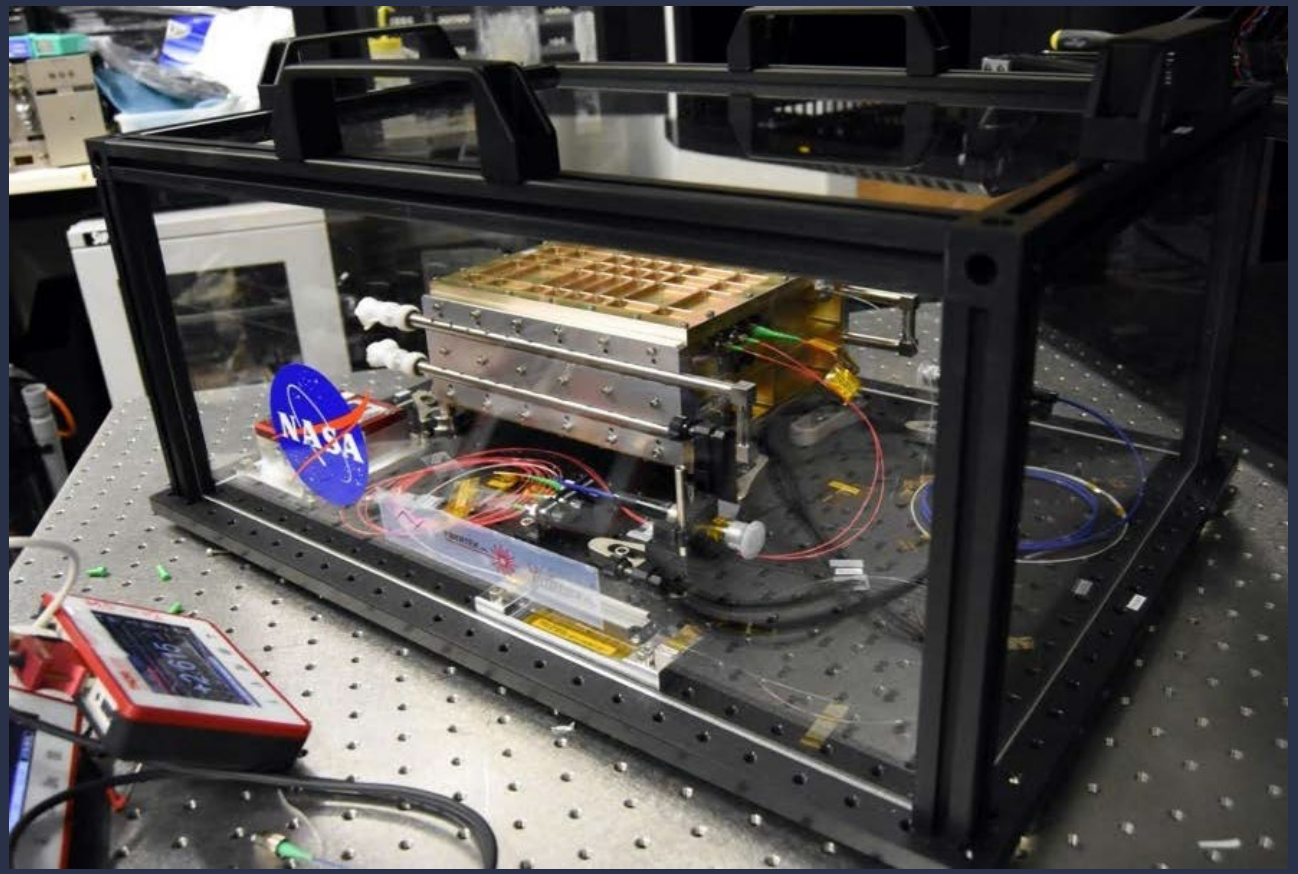
LISA laser metrology center

- CSEM serves as metrology center for ESA
- NASA laser for characterization @ CSEM



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Conclusions & outlook

- Atomic (MEMS) cells at the heart of quantum based instruments
- Atomic clocks, magnetometers and gyroscopes developed at CSEM
- Continuous-wave and femtosecond lasers are essential
- Metrology is key

- Towards high performance, compactness, cost reduction and mass production of quantum instruments

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