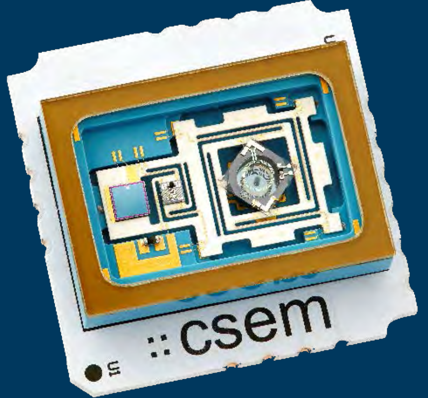
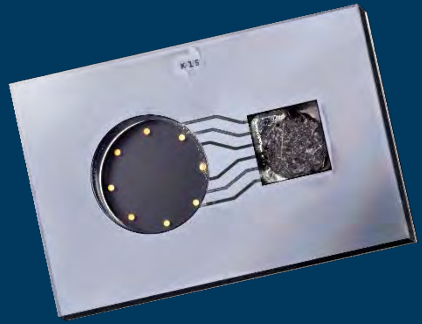
csem

Horloges atomiques Neuchâteloises:



des applications spatiales à la miniaturisation



Jacques Haesler

Trends in Micro Nano

12.12.2018

fsrm

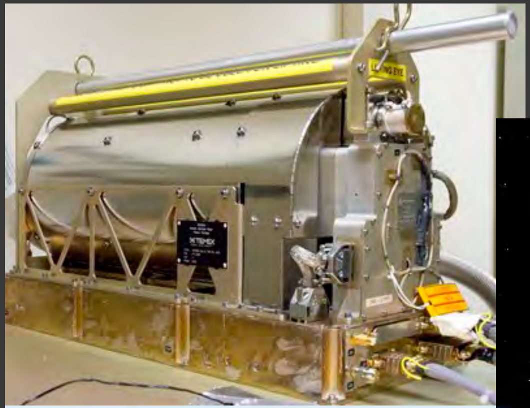
Nous sommes microcity Pôle d'innovation Neuchâtel

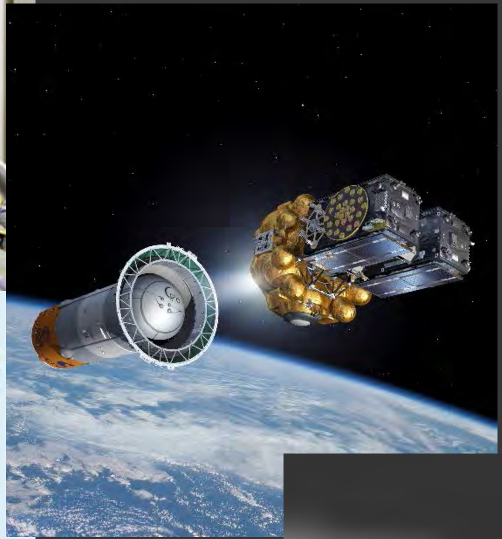
swiss mnt network micro & nanotechnology

jacques.haesler@csem.ch

Agenda

- Horloges atomiques Neuchâteloises
- Application spatiale pour Galileo
- Miniaturisation au CSEM grâce au micro nano
- Prochaines étapes

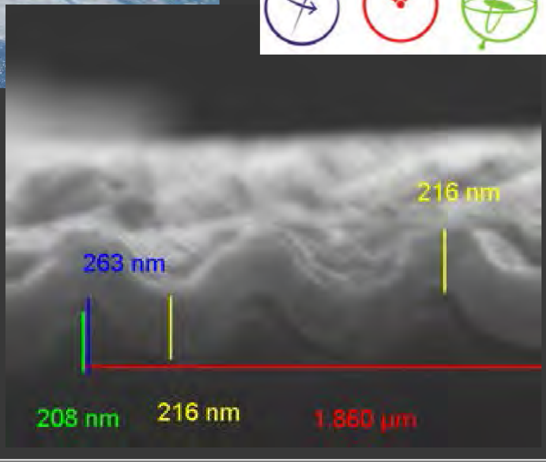




QUANTUM FLAGSHIP

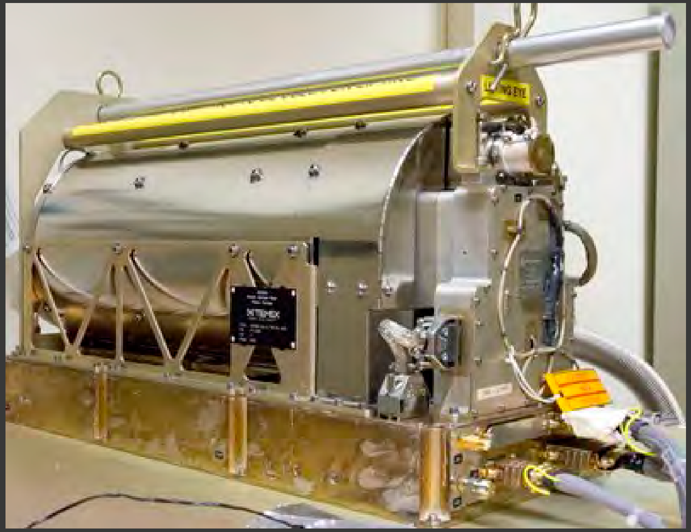
QUANTUM Sensing metrology

macQsimal



Crédits images: Orolia Spectratime SA, ESA.int, CSEM SA

Horloges atomiques Neuchâteloises

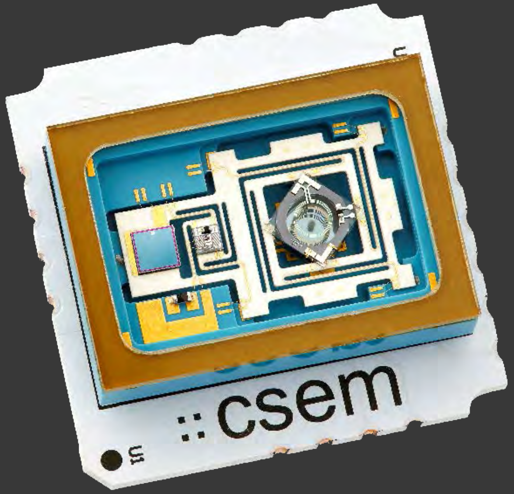


PHM
Maser à hydrogène passif
18 kg
de 2000 à aujourd’hui

Orolia Spectratime SA

RAFS
Horloge atomique Rubidium
3.2 kg
de 1991 à aujourd’hui

Orolia Spectratime SA



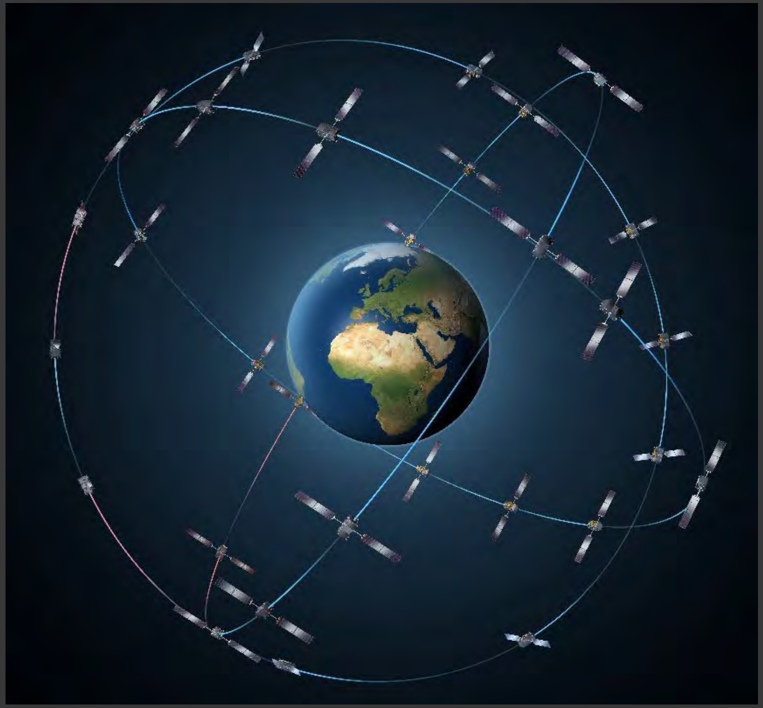
SMAC
Horloge atomique CPT
0.005 kg
de 2007 à aujourd’hui

CSEM SA

Application spatiale pour Galileo

GALILEO

- Positionnement 3D, horodatage (transactions)
- Sychronisation (télécommunications, réseaux d’énergie)
- et bien d’autres…



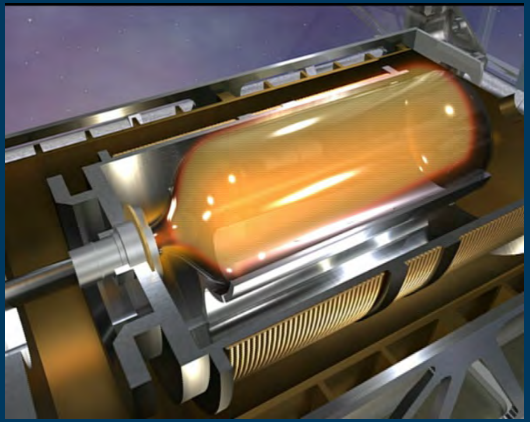
Détails d’un satellite Galileo

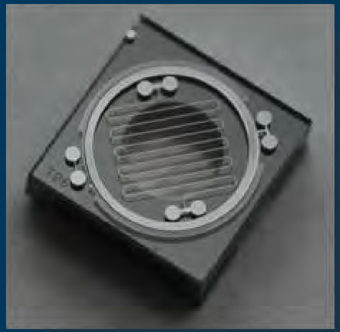
FACTS AND FIGURES

Satellites 1–4	
Launch mass	700 kg
Size	2.74 x 14.5 x 1.59 m (solar wings deployed)
Available power	1420 W
Satellites 5–26	
Launch mass	732.8 kg
Size	2.5 x 14.67 x 1.1 m (solar wings deployed)
Available power	1900 W
Launch vehicles	
Launch site	
Navigation payload	Passive hydrogen maser atomic clocks (two) Rubidium atomic clocks (two) Navigation signal generator unit L-band antenna for navigation signal transmission C-band antenna for uplink signal detection Two S-band antennas for telemetry and telecommands Search and rescue antenna
Orbit	23 222 km, 56°
Operational lifetime	more than 12 years
Satellite control centre	Oberpfaffenhofen Galileo Control Centre in Germany with CNES in Toulouse, Fra support of ESOC in Darmstadt, Germany for launch and early operations, while I performs the in-orbit test campaign
Navigation control centre	Fucino Galileo Control Centre in Italy
	www.esa.int/Our_Activities/Navigation ec.europa.eu/galileo

Miniaturisation des horloges atomiques – pourquoi et comment ?

- Horloges atomiques miniatures pour des applications portables et diverses (récepteur GNSS, nano-satellite,…)
- Neuchâtel comme pôle de compétence des micro- et nano-technologies
- Historique Temps / Fréquence: Observatoire de Neuchâtel
- Couverture de toute la chaîne de développement à Neuchâtel: LTF – CSEM – Spectratime
- Exemple: miniaturisation du cœur de l’horloge atomique – la cellule qui contient les atomes





technologies verre / saphir

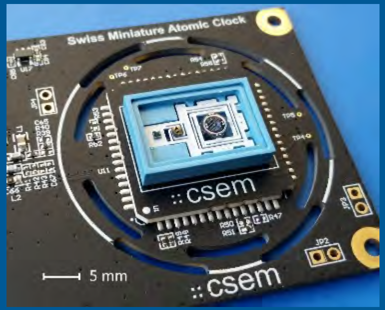
technologies silicum (MEMS)

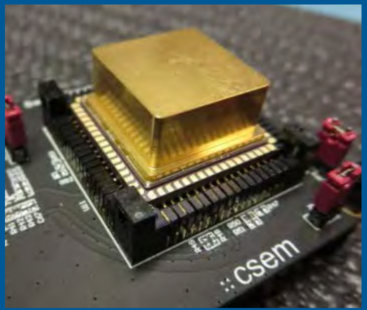
Compétences technologiques CSEM

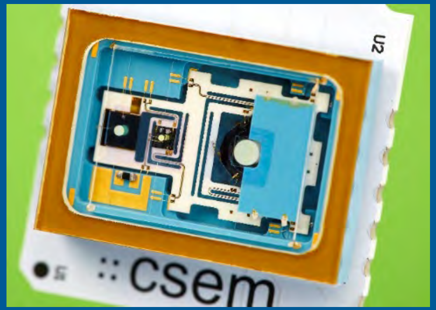
- MEMS
- Surface Engineering
- **Systems**
- Ultra-low-power integrated systems
- PV-center & energy management

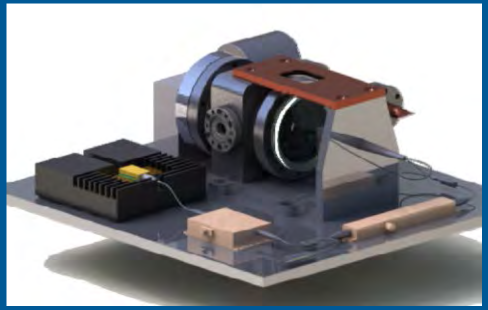
Temps & Fréquence au CSEM

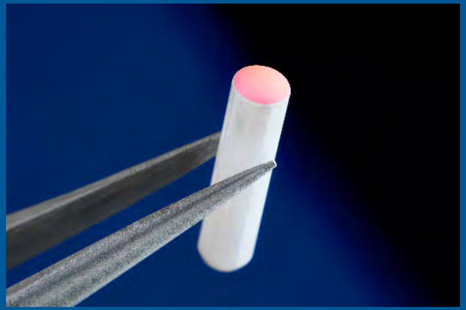
- Temps & Fréquence
  - Micro-ondes
    - Horloges atomiques
  - Optique
    - Lasers
    - LiDARs

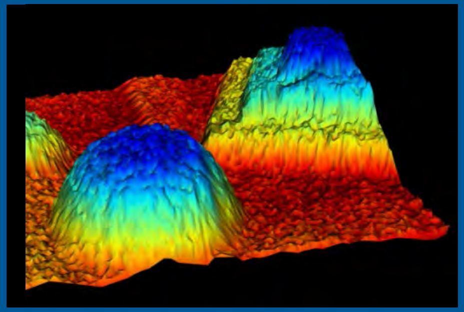




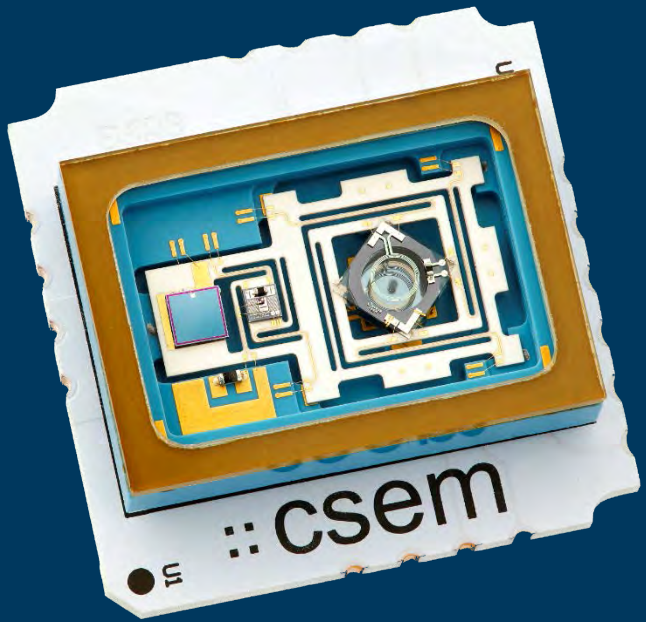


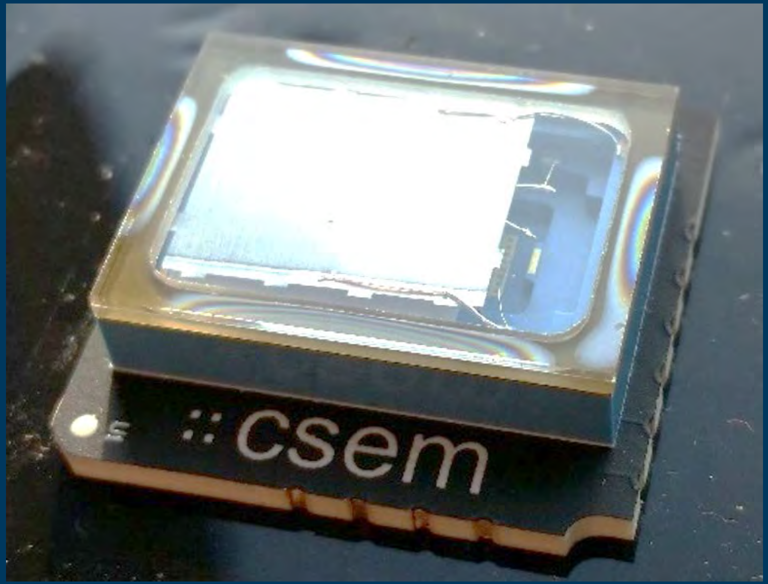


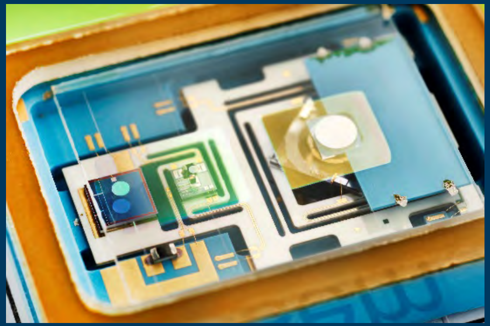


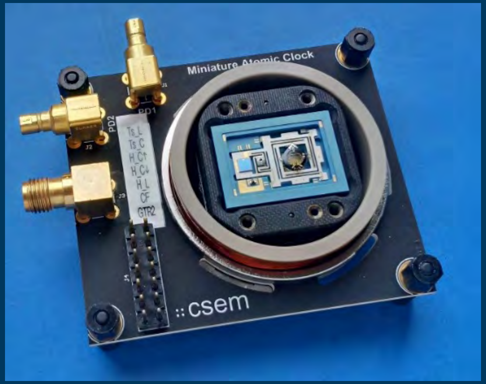



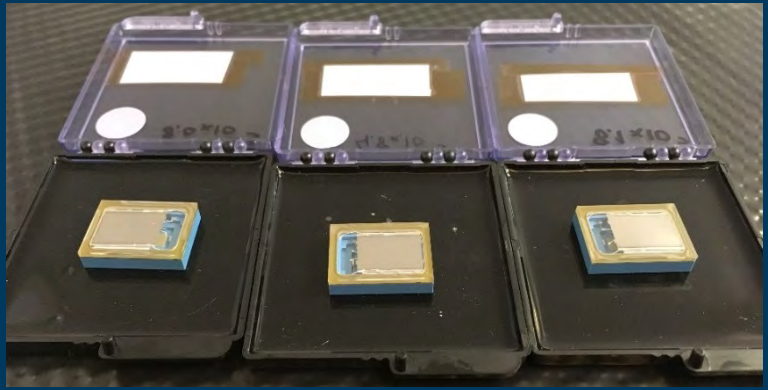
L’horloge atomique miniature du CSEM: SMAC – Swiss Miniature Atomic Clock





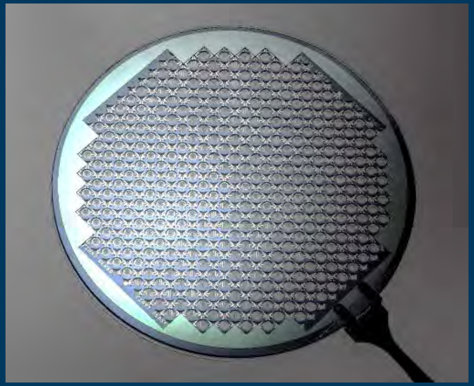




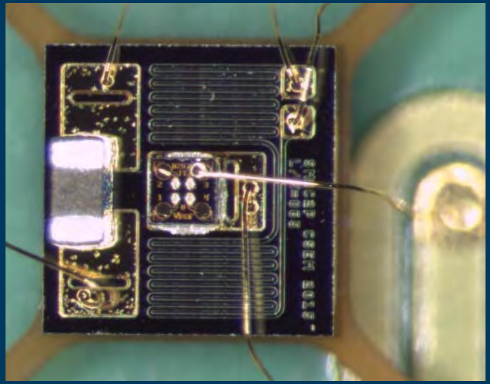


Les blocs principaux de l’horloge atomique miniature

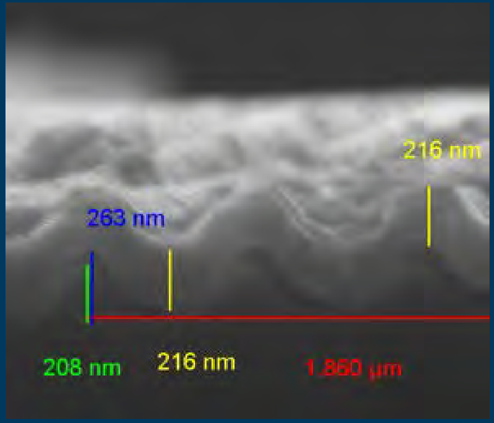
Cellules atomiques MEMS



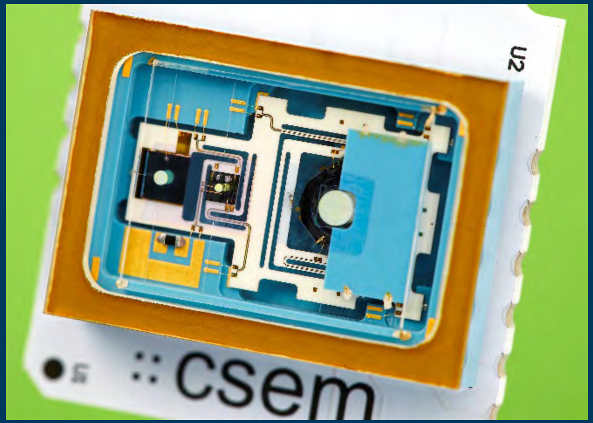
Laser



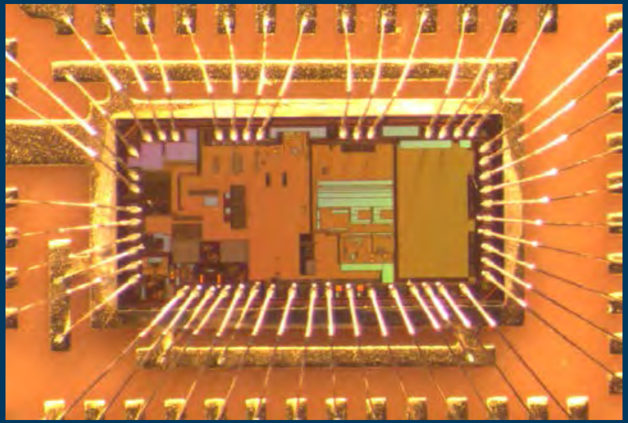
Optique



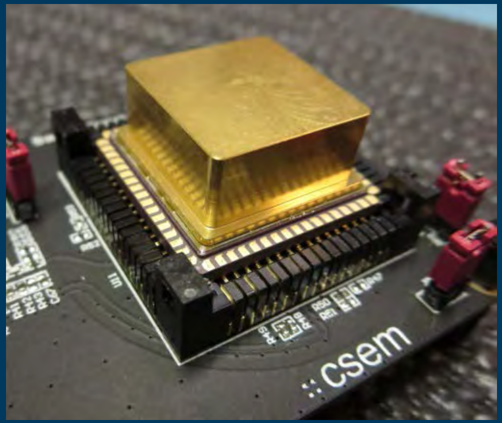
Sytème physique



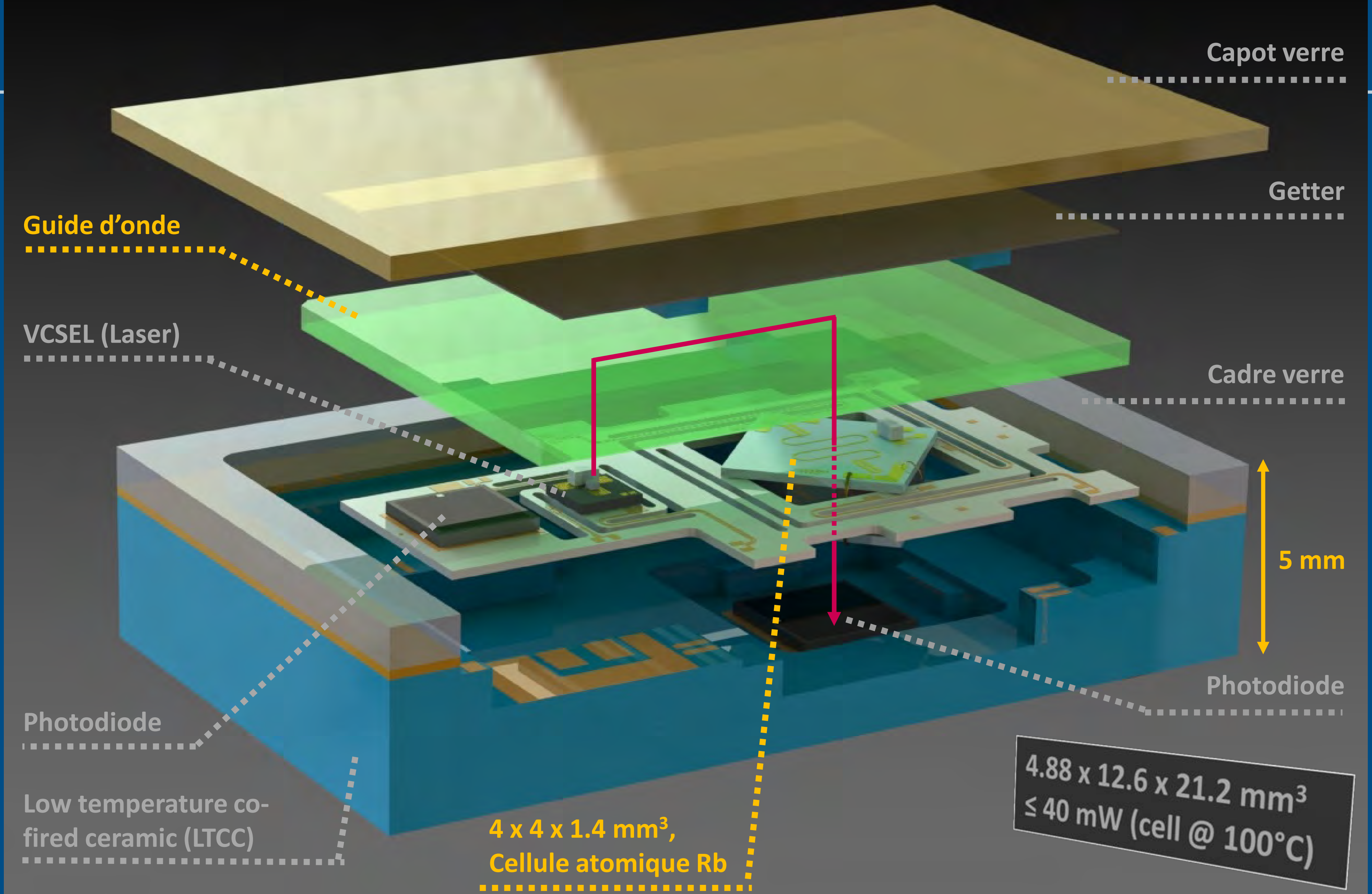
Circuit intégré spécifique (ASIC)



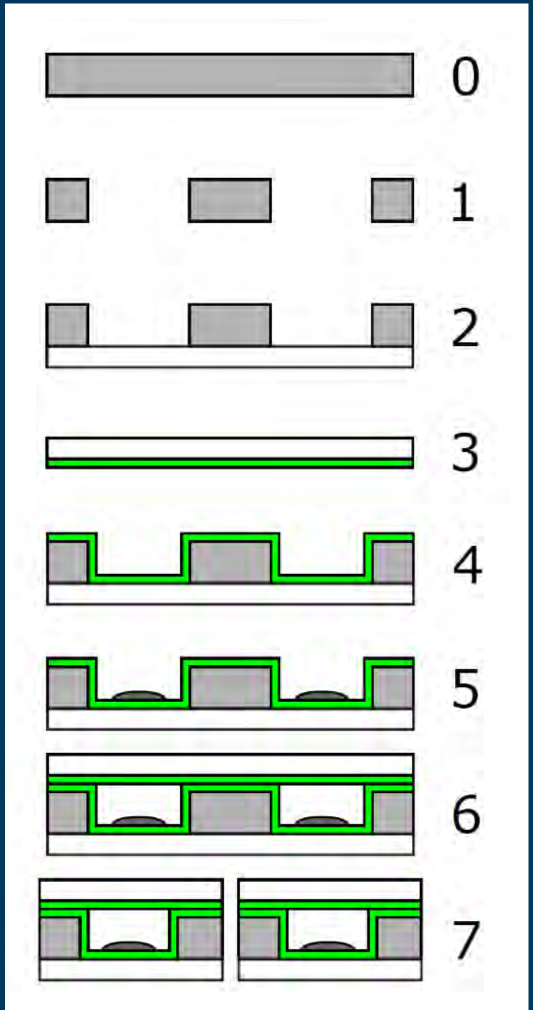
Packaging et assemblage



Swiss Miniature Atomic Clock



Fabrication des cellules atomiques MEMS



Si glass Al_2O_3 RbN_3

Etapes de fabrication:

(0) Substrat Si de 1 à 1.5 mm d'épaisseur

(1) Gravage DRIE de trous traversant

(2) Soudure anodique d'un verre Borofloat®33

(3-4) Couche de protection nanométrique Al_2O_3

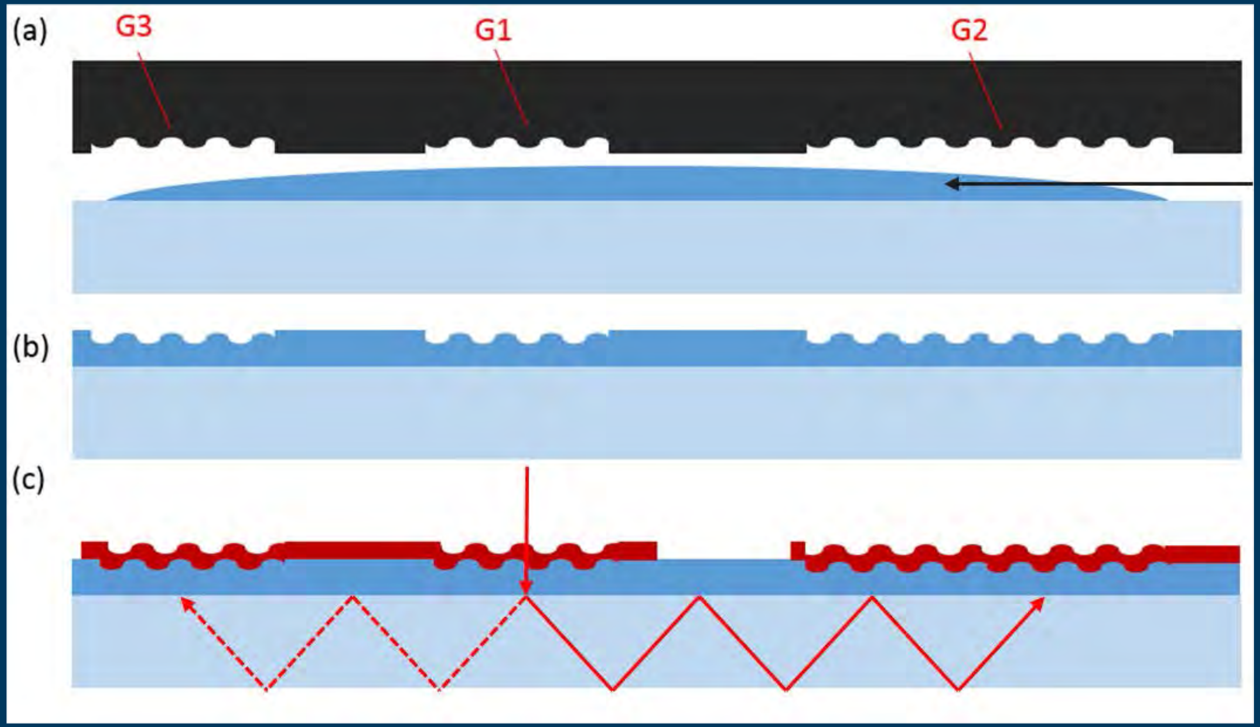
(5) Micro-dispensing d'une solution aqueuse RbN_3

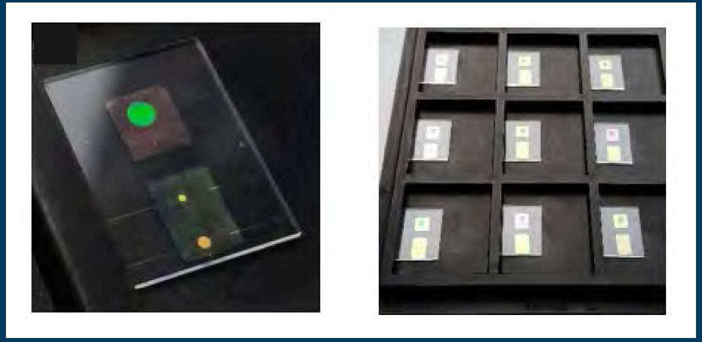
(6) Soudure anodique d'une 2ème fenêtre

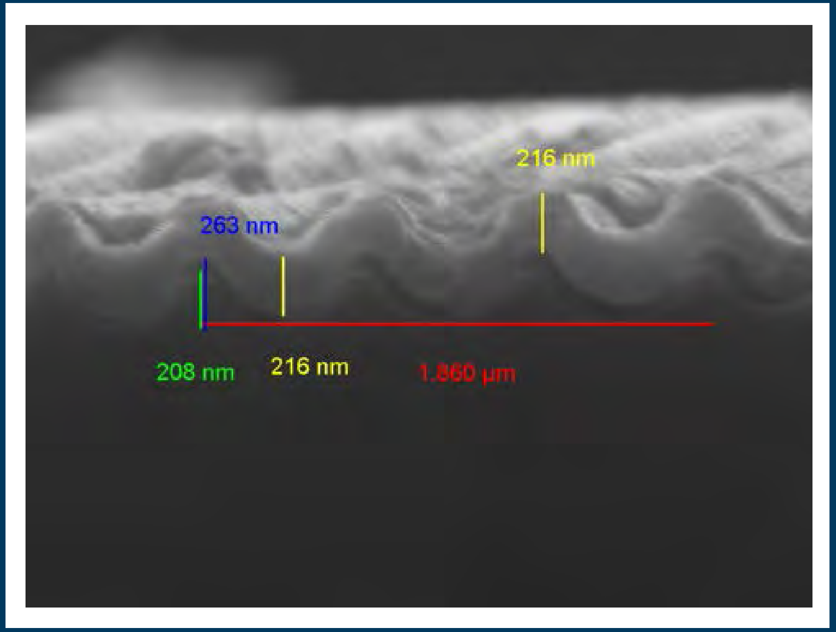
(7) Sciage

+ (8) Activation des cellules par irradiation UV

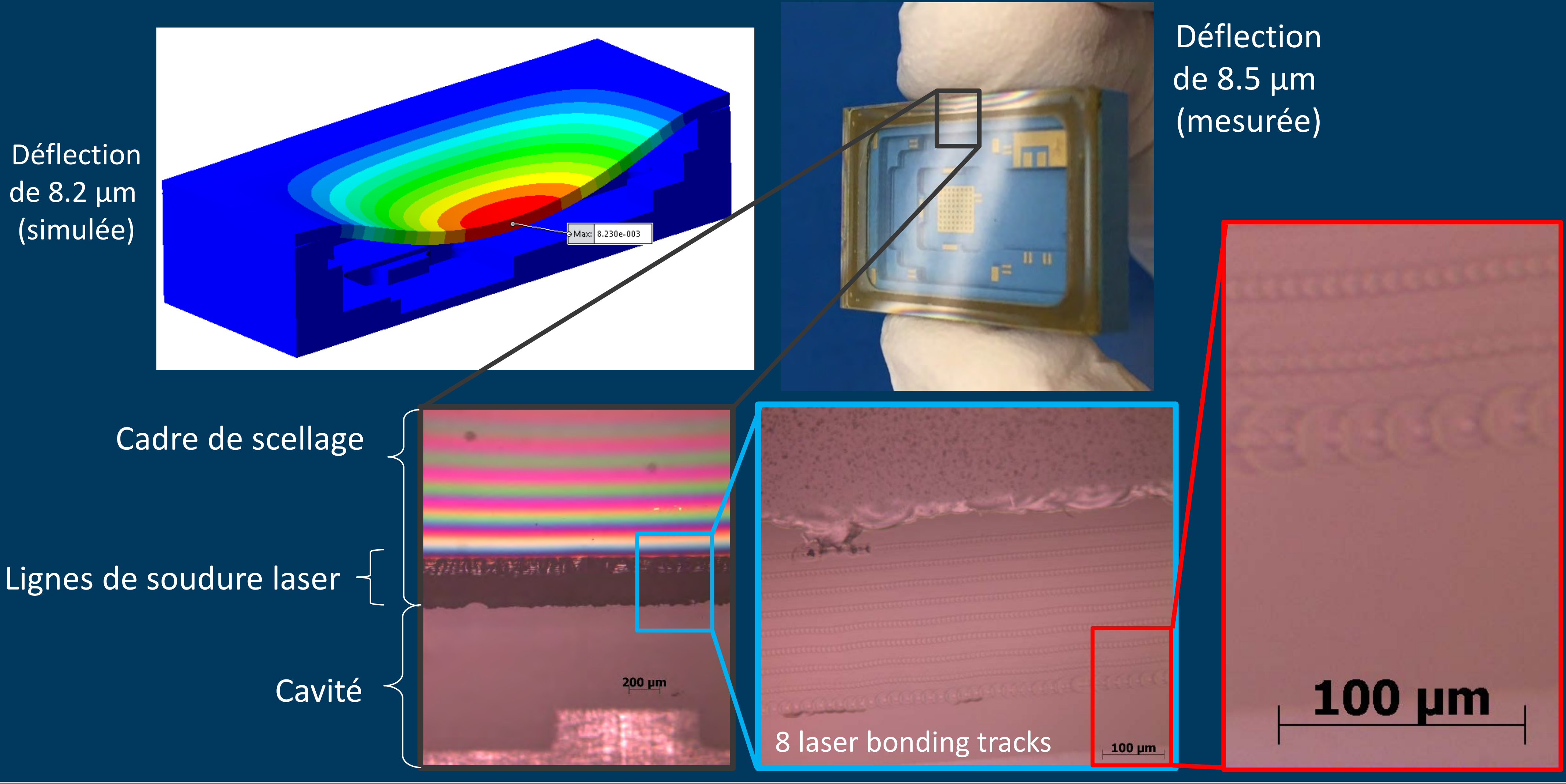
Guide d'onde planaire et réseaux de couplage







Encapsulation: soudure verre-verre par impulsion laser



Prochaines étapes: transfert technologique

QUANTUM FLAGSHIP

QUANTUM Sensing metrology

macQsimal

csem (coordinator)

accelopment, VTT, ICFO, University of Copenhagen, Aalto University, Universität Basel, Durham University, Universität Stuttgart, CNRS, unine Université de Neuchâtel, BOSCH, MEGIN, spectratime

Objectives

Applications

Merci pour votre attention!

Suivez-nous sur

www.csem.ch