Propitious Micro-/Nano-electromechanical system as a key to ultraminiaturization of the microwave atomic clock

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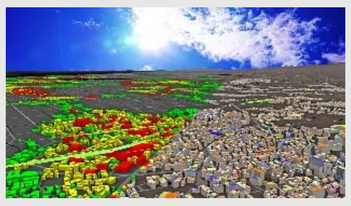
Background

Big data & Digital twin ✖ **Space-time synchronization** ⋙ **Dynamic digital twin**

City scape on digital-twin with high definition

Simulation of urban fire spread



Simulation of solar power generation efficiency

Ref.: PLATEAU supported by MLIT

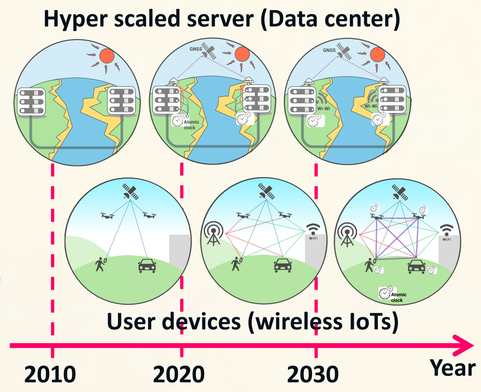
What's "Dynamic".

Adding space-time information to the data that constitutes the digital twin

- ○Near real-time feedback (smart city)
  - → Smart traffic control
  - → Power/Heat/Flood control
- ○High-precision simulations through **data assimilation** due to time series alignment
- ○**Anti-poisoning** and truly diverse data ingestion in AI processing

How do we make dynamic digital twin?

Implementing a stable clock module each user device



<Our activity>

Today's topic

Miniaturized atomic clock

Synchronizer of time and space

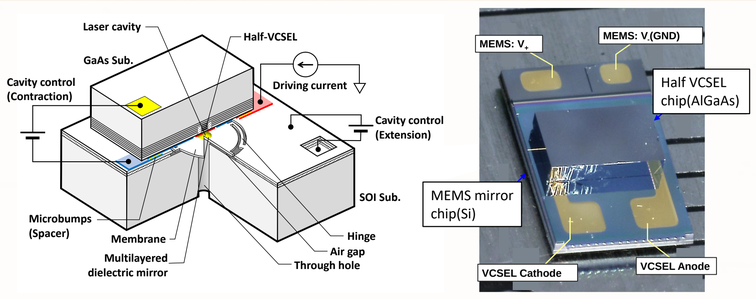
- Time stamper
- Time estimation algorisms

Development Progress of Key Components for Ultraminiaturized Atomic Clock

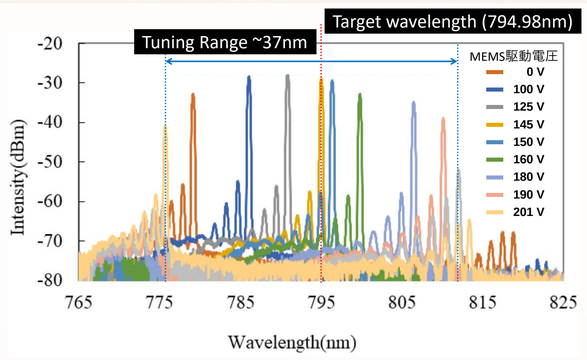
VCSEL

Development of wavelength tuning technology injection current or temperature control for screening cost reduction

<Device Structure>

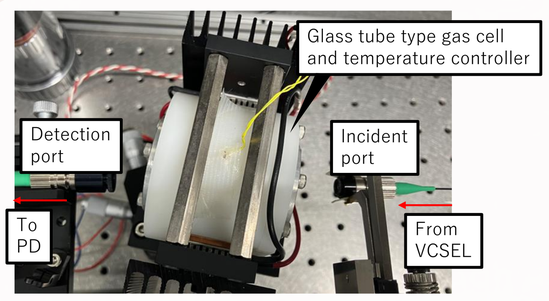


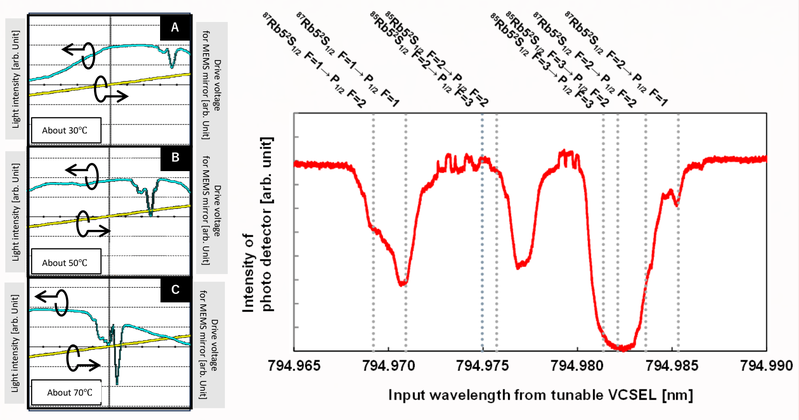
<Wavelength Tuning Range>



Using a mechanically controlled wavelength tuner, we successfully capture Rb absorption lines.

<Observation of Absorption Spectra>





We observed the absorption lines of Rb using a MEMS-based laser sweep.

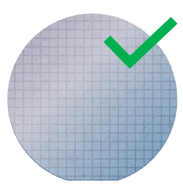
Gas cell

<Fabrication Technology>

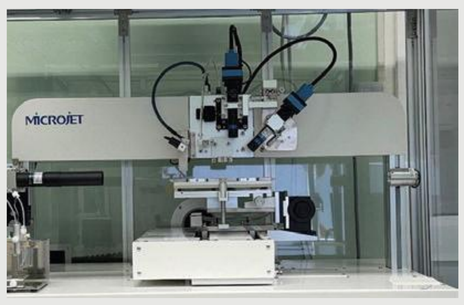
RbN_3 is a clean solid source of Rb that produces only nitrogen, a useful buffer gas, during decomposition.

It is powdery crustal.
- **Clean room handling X**
- **Control Pl/pg order X**

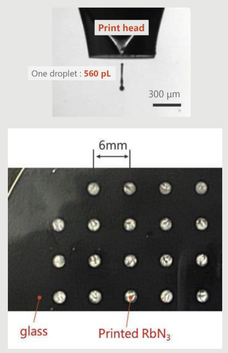
Wafer delivery of RbN_3
Clean room handling O
→RbN_3 is fixed on the wf
Control Pl/pg order O



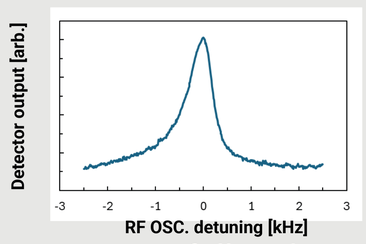
Inkjet printing is the best solution for wafer delivery.



Our RbN_3 printer



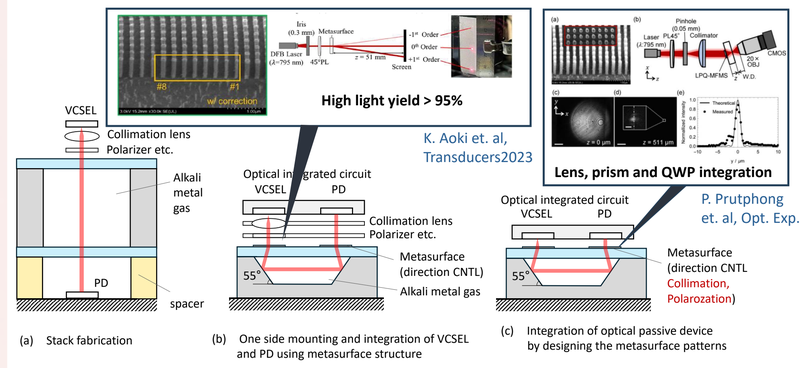
Printed RbN_3 Gas cell



We successfully detect the CPT resonance

<Low Height Gas Cell>

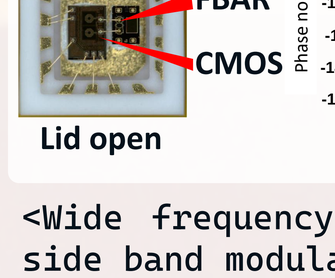
Low loss optical folding is essential to compress the height and increase the integration density



Micro oscillator

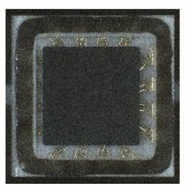
Development of ultraminiaturized RF oscillator for the CPT MW atomic clock

<Ultra compact MEMS resonator>



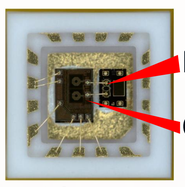
Thin film bulk acoustic resonator(FBAR):
FBAR is a bulk acoustic resonator using piezoelectric film on the wafer
- **○ small size**
- **○ low insertion loss**
- **○ CMOS compatibility**

<LTCC Package>

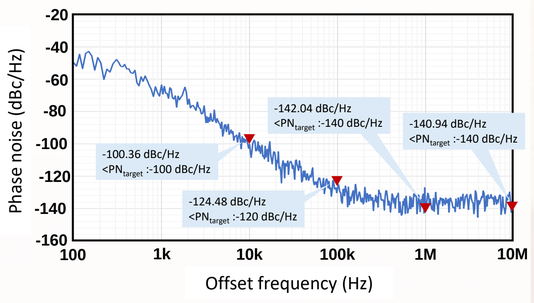


We developed 3 mm x 3 mm LTCC cavity packaged 3.4 GHz band FBAR OSC with very low phase noise.

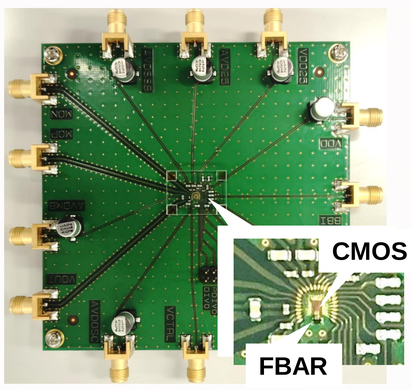
Lid sealed

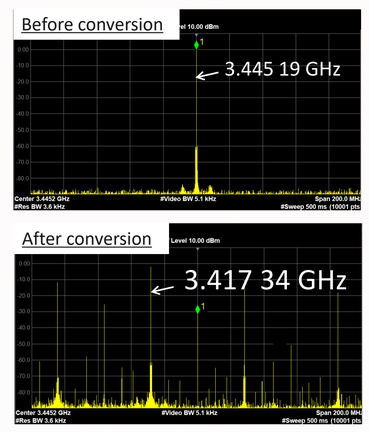


Lid open

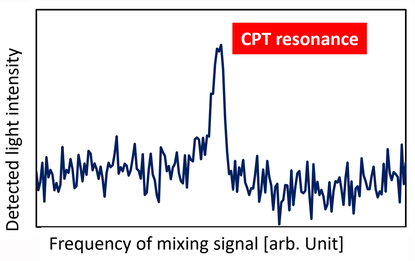


<Wide frequency tuning with single side band modulation (SSBM)>





<Implementation to the atomic clock>



We successfully detect the CPT resonance

<Conclusion> At NICT, to meet various newly proposed technical requirements for 6G, we are developing various technologies that enable time-space synchronization at the device level. In this presentation, we introduced the developments aimed at miniaturizing atomic clocks. In the MEMS wavelength tuner, we adopted a unique MEMS movable mirror stabilization technology and succeeded in obtaining the absorption line of Rb. In the gas cell development, we proposed new manufacturing technology and optical control technology suitable for mass production. In addition, we made good use of MEMS resonators in the control circuit of the atomic clock, proposed RF control technology that is highly compatible with digital technology, and succeeded in obtaining the CPT resonance of Rb.

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