

Study on Resonant-Tunneling Diode THz Oscillators

THz

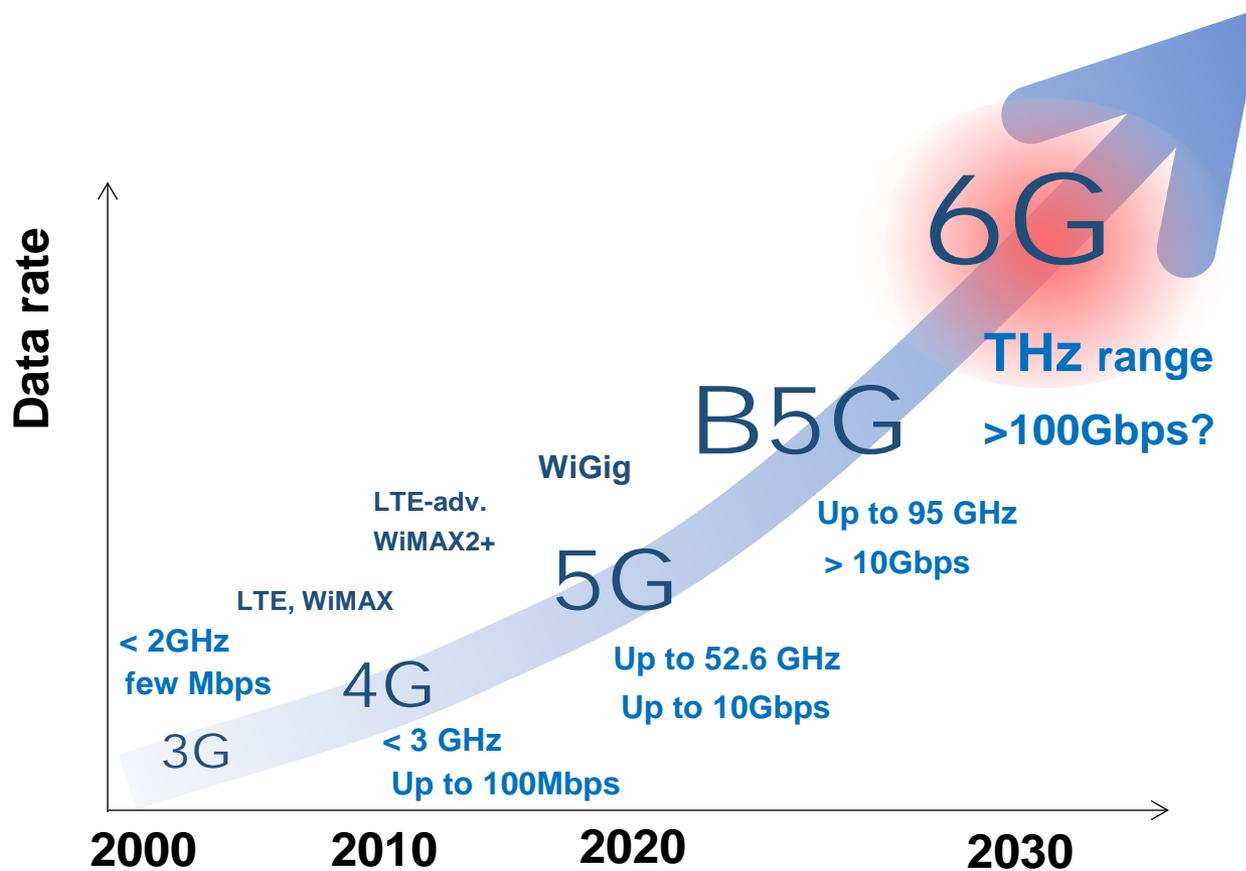


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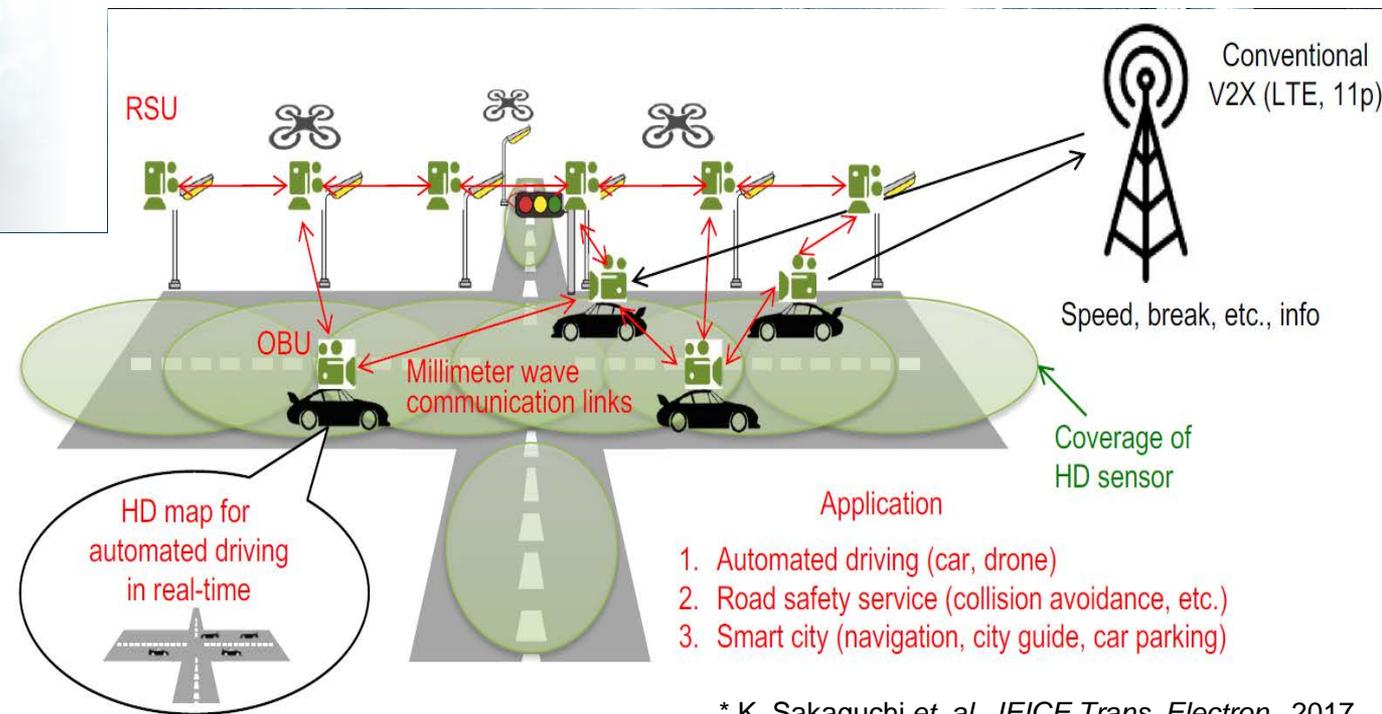
Mikhail BEZHKO



New generation of wireless data transfer systems

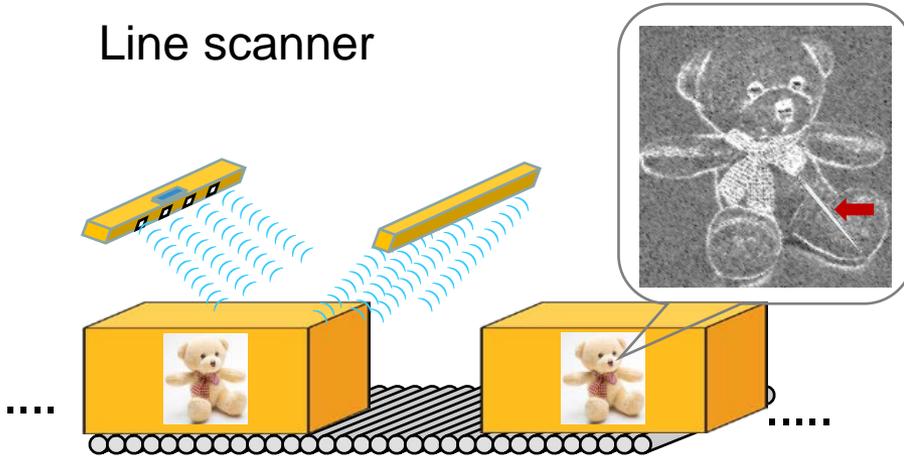


Connected Cars, V2X, IoT

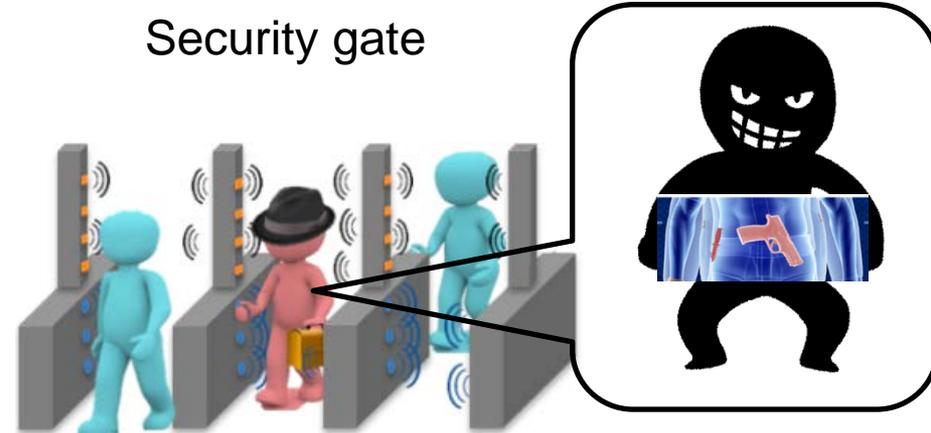


Radar and imaging

Line scanner



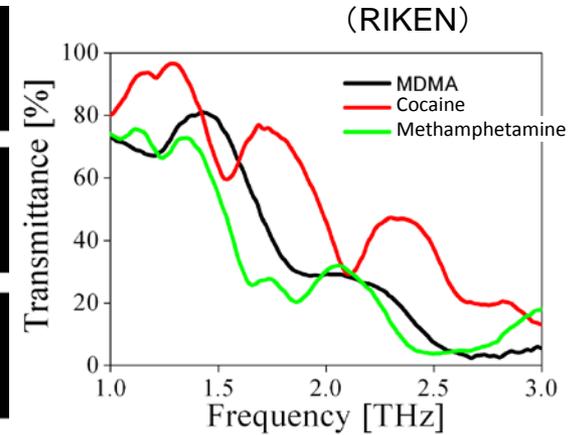
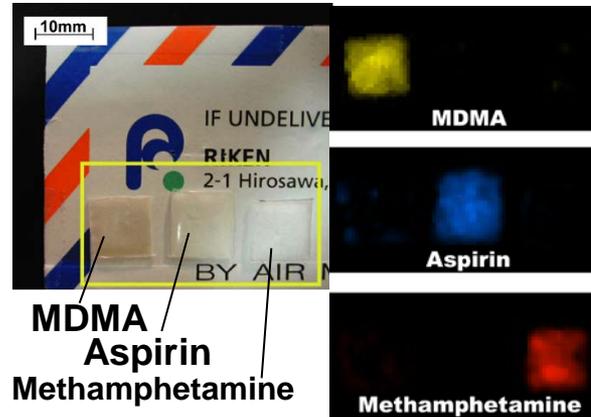
Security gate



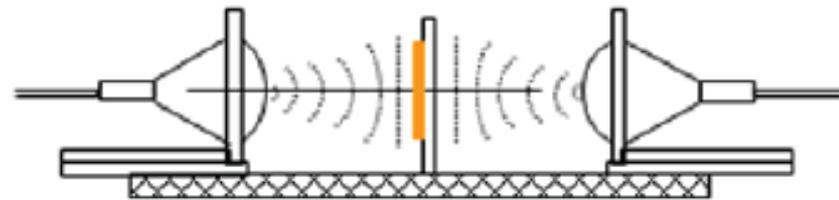
Smart Cars, advanced driver assistance systems (ADAS)...



Material analysis and spectroscopy



*[K. Kawase et al., *Opt. Express* 11, 2549, 2003]



Key performance factors

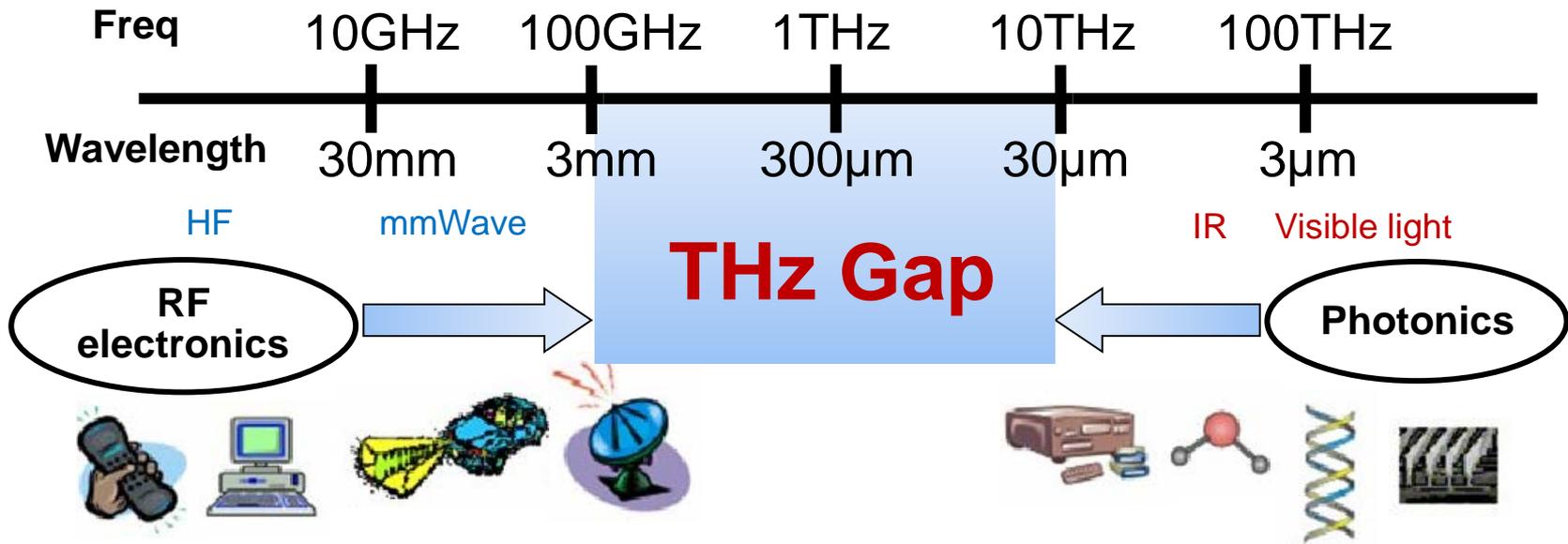
- High (THz) frequency
- High output power
- Compact size

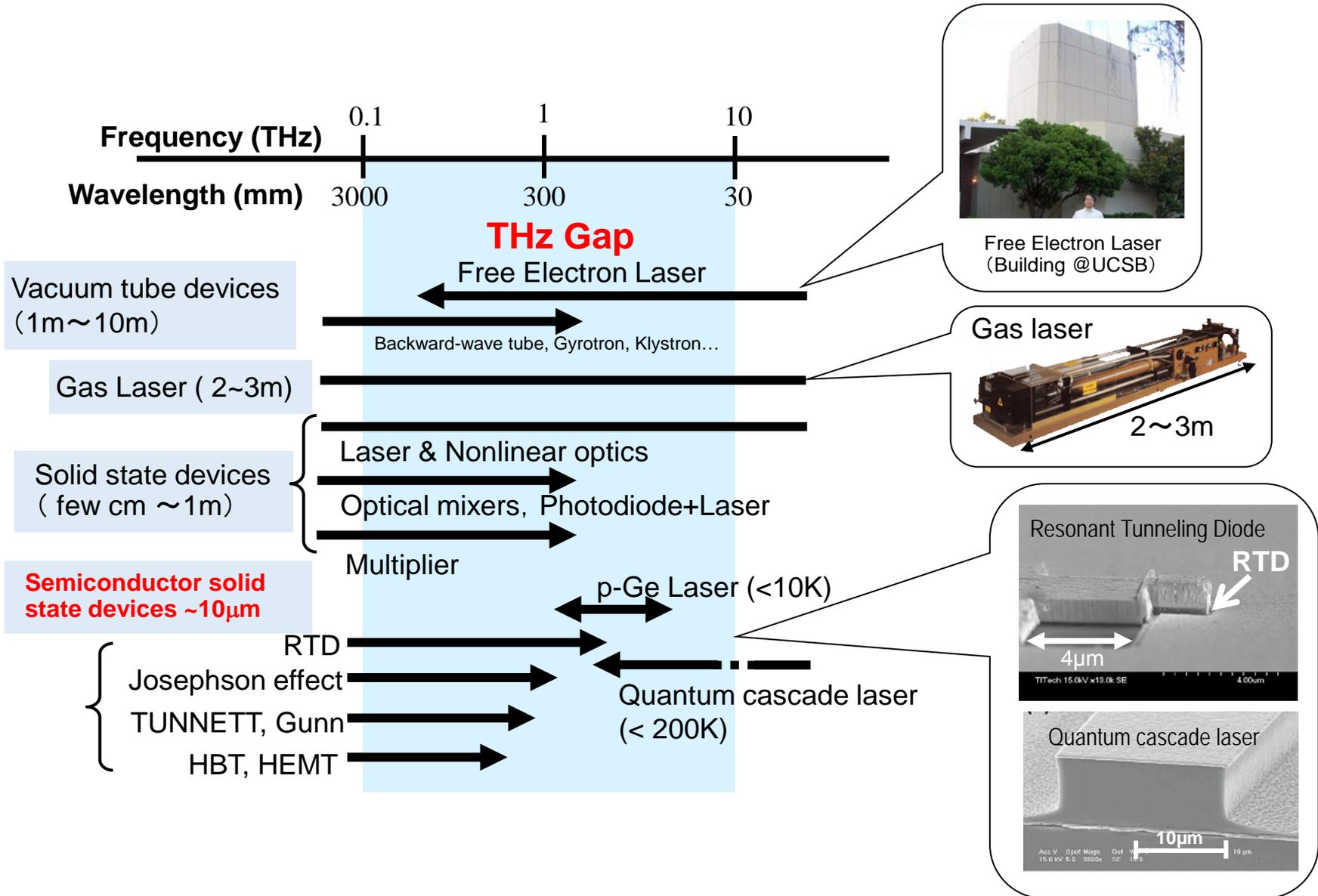


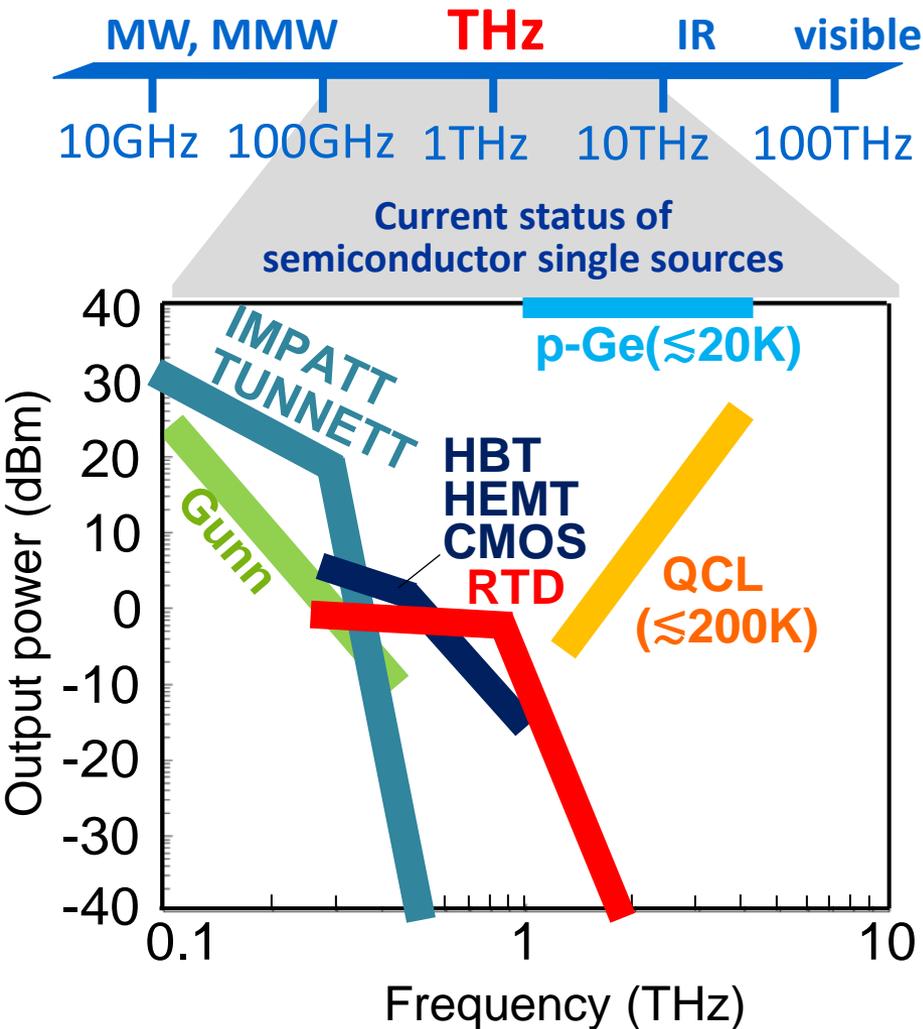
Oscillator (Signal source)

High frequency signal sources are key component in new technologies

Frequency of an electromagnetic wave







► Quantum Cascade Laser (QCL)

- 1.2mW @ 4THz, 206 K
(L. Bosco et al., *Appl. Phys. Lett.* **115**, 2019)
- 0.36mW @ 1.34 -1.58THz, 10K
(Walther, et al, *Appl. Phys. Lett.* **91**, 2007)
- 8.5 μ W @ 4.1 THz, Room Temp
(Q. Y. Lu et al., *Appl. Phys. Lett.* **99**, 2011)

► Transistors (HBT, HEMT, CMOS)

- 1mW@530GHz, triple, 16-el.
(Pfeiffer, et al, ISSCC, 14.5, 2014)
- 80 μ W@1THz, 4th harmonic, 42-el.
(Hu, et al, IEEE Radio Freq. Cir. Symp.RTU2B-2, 2017)

► Resonant Tunneling Diode (RTD)

- 1.98THz, Fundamental
(Izumi, et al., IRMMW, MA3.1, 2017)
- 0.73mW @ 1THz, Fundamental, 89-el
(Kasagi, et al, JAP, **125**, 151601, 2019)

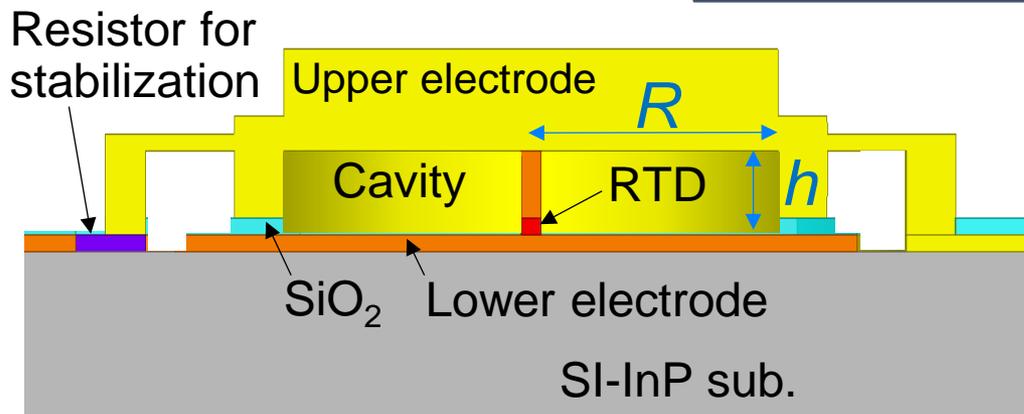
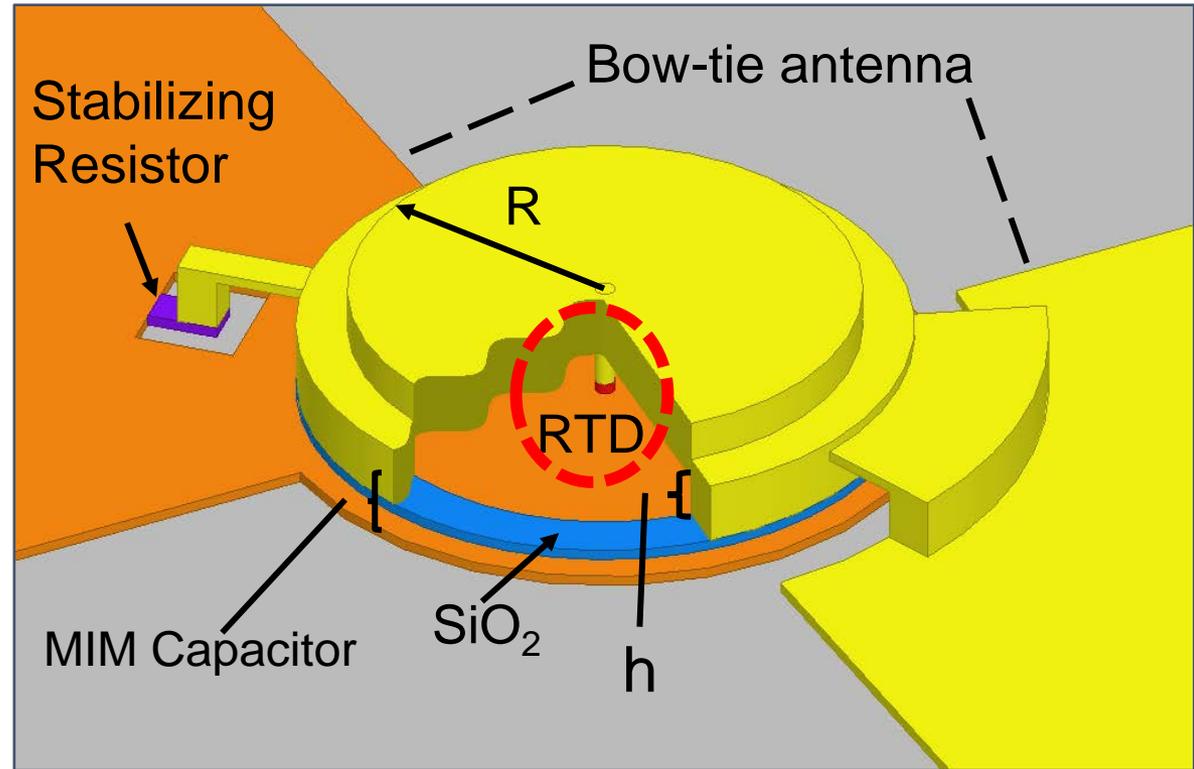
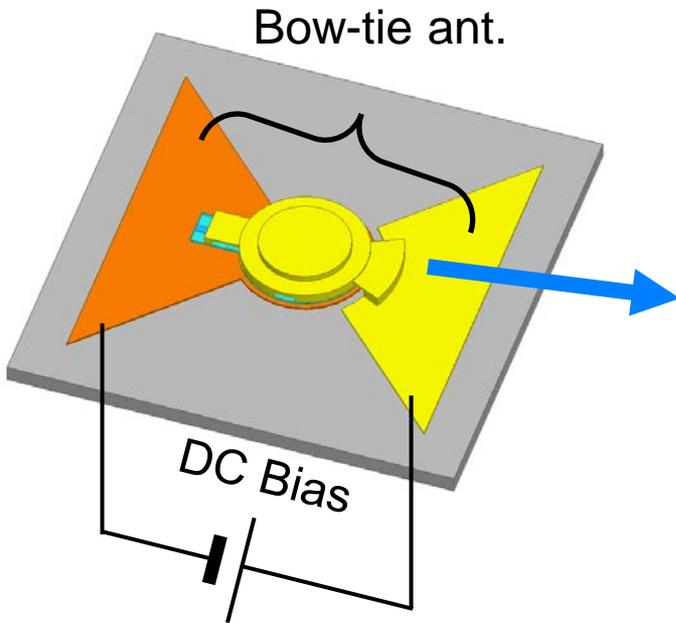


Frequencies $> 2\text{THz}$

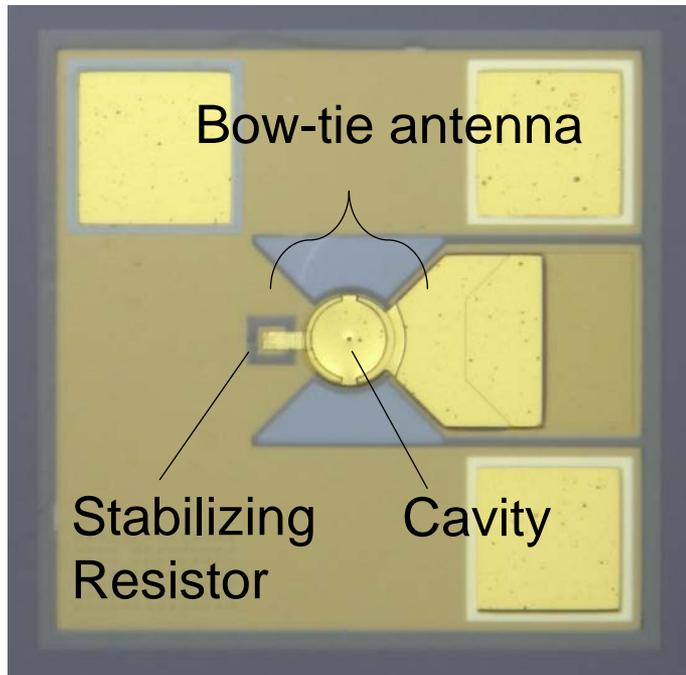
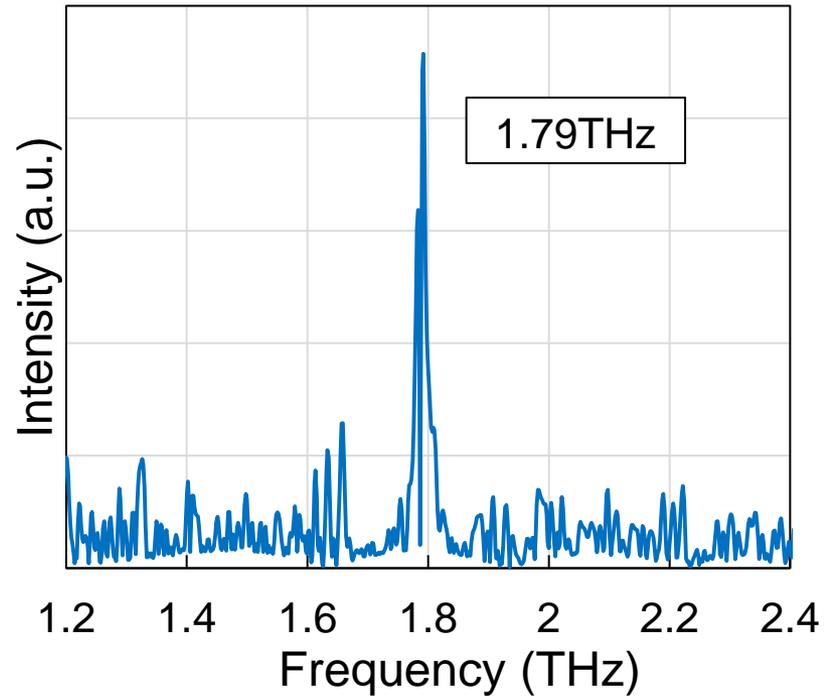
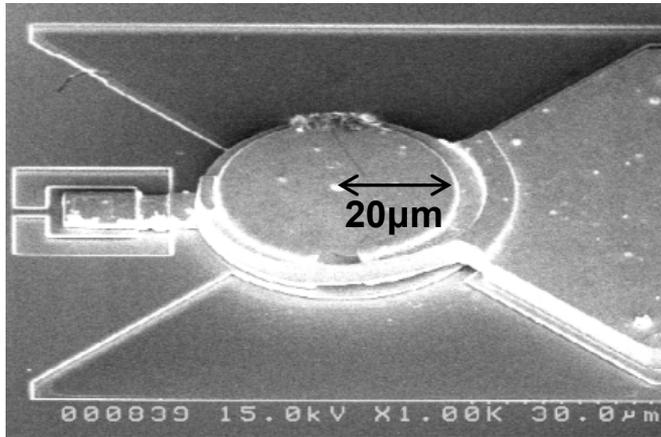
from a compact solid state source?

Purpose of the study:

Study on the oscillation frequency limitations in RTD oscillators to achieve frequencies $> 2\text{THz}$



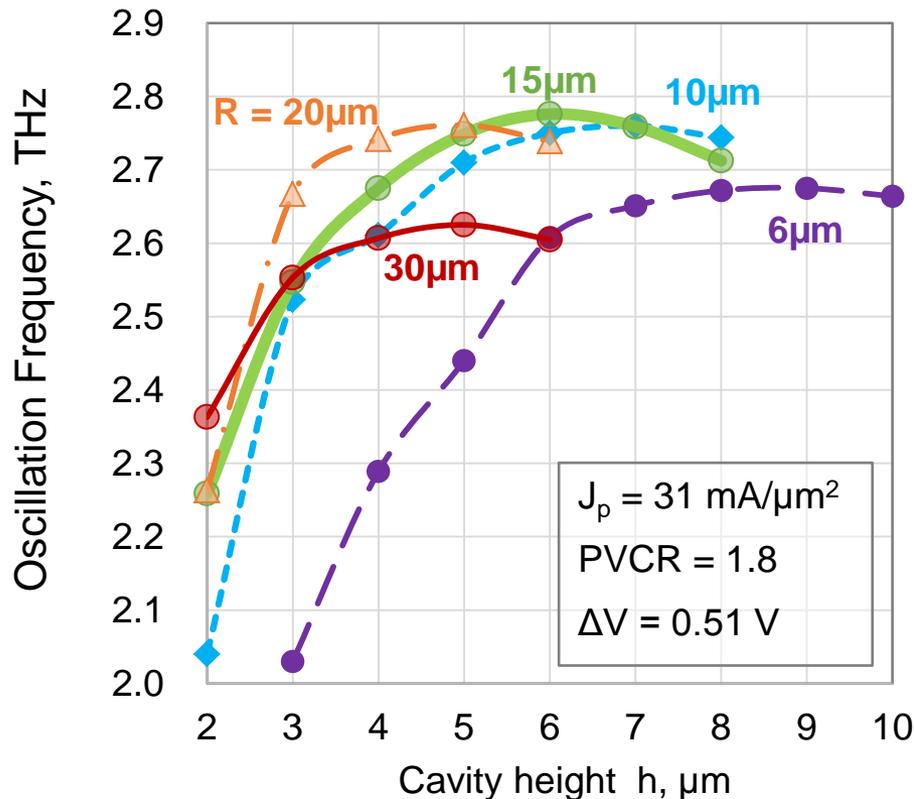
RTD integrated with low-loss cylindrical cavity



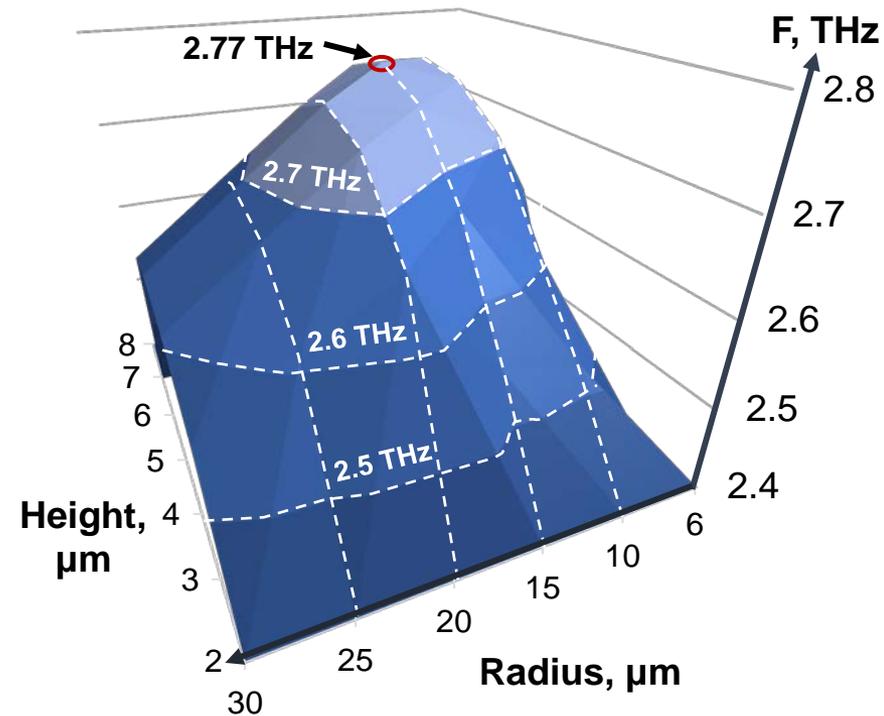
- Oscillation frequencies up to 1.79 THz were achieved at room temperature. [Izumi, et al., ., IRMMW, MA3.1, 2017]

Oscillation Frequency

Upper limit of oscillation frequency in dependence on the cavity height (h)

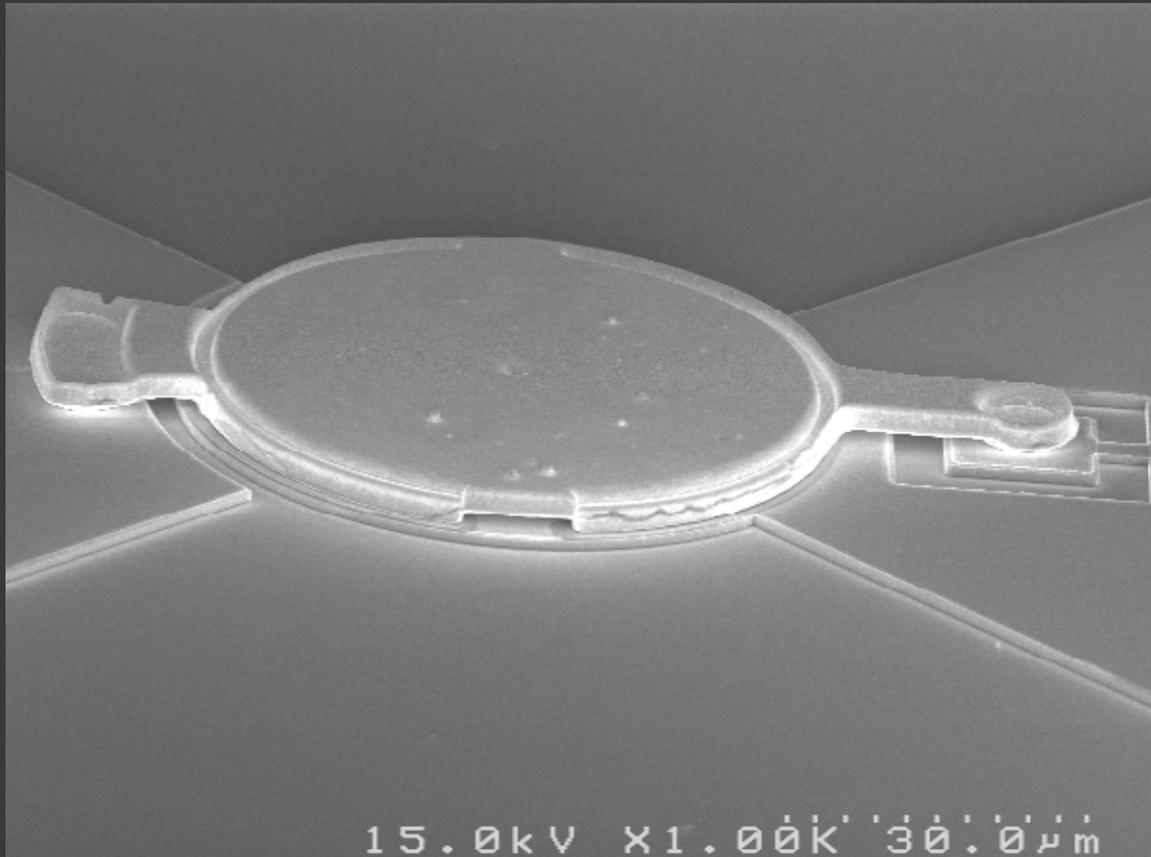


Upper limit of oscillation frequency in dependence on the R and h

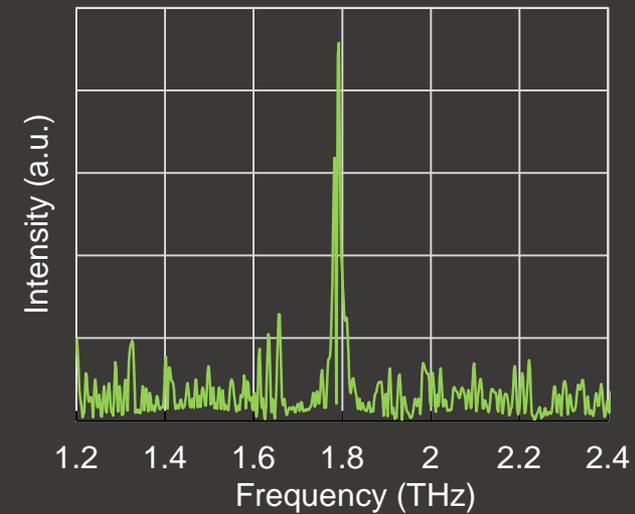
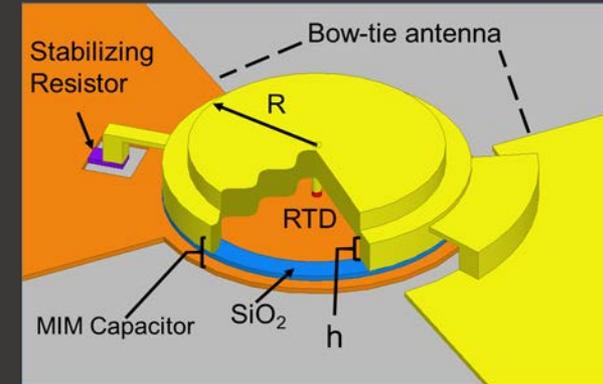


Oscillation frequencies up to 2.77 THz could be expected with cavity radius $\sim 15 \mu\text{m}$ and cavity height $\sim 6 \mu\text{m}$.

SEM image

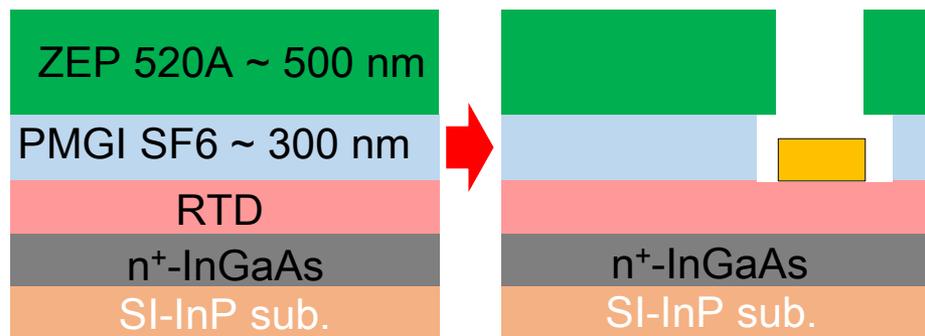


Six-stage Device Process

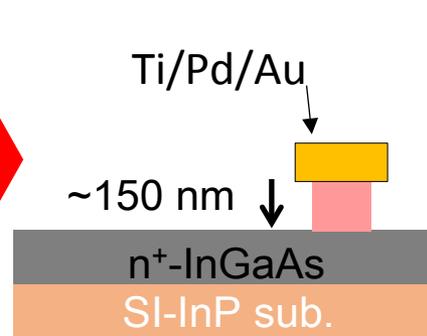


Six-stage process

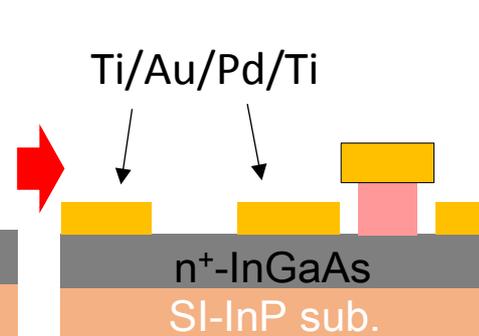
1. RTD Top electrode



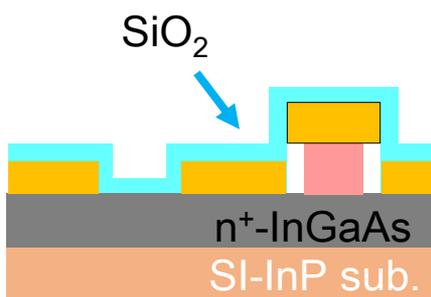
2. RTD mesa fabrication



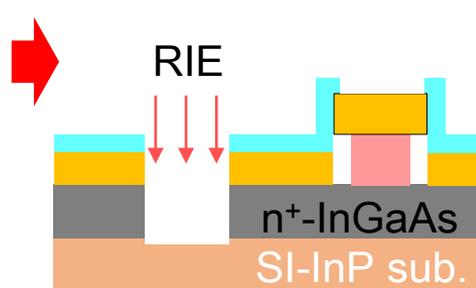
3. Bottom electrode Evaporation



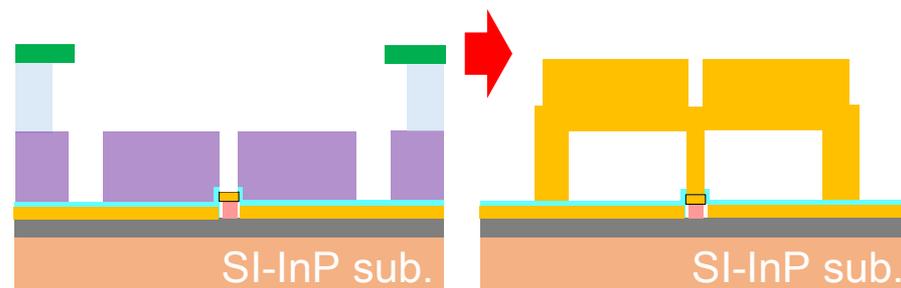
4. SiO₂ film by PCVD



5. Element separation



6. Cavity fabrication





- THz sources is one of the key component in novel technologies and applications
- RTD is one of the most promising candidates for compact size THz frequency source
- Oscillation frequencies above 2 THz could be reached by using low-loss cavity resonator
- Oscillation frequencies up to 2.77 THz could be expected with cavity radius $\sim 15 \mu\text{m}$ and cavity height $\sim 6 \mu\text{m}$.
- Fabrication process optimization is necessary to achieve calculated performance of the device



Tokyo Institute of Technology

Thank You!