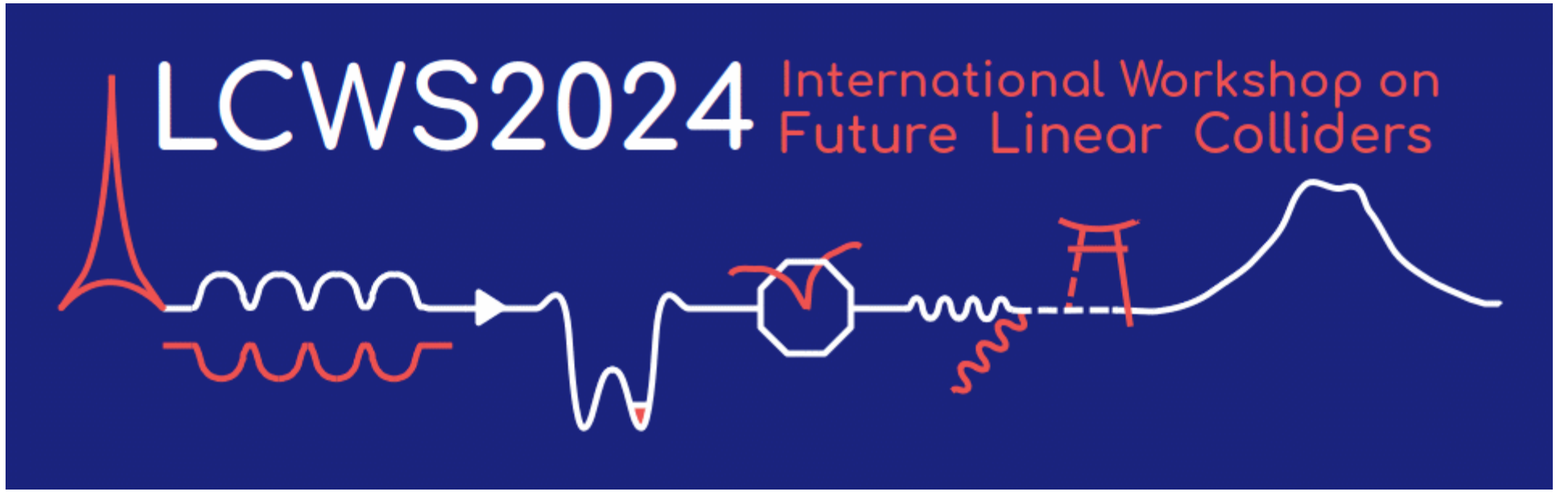
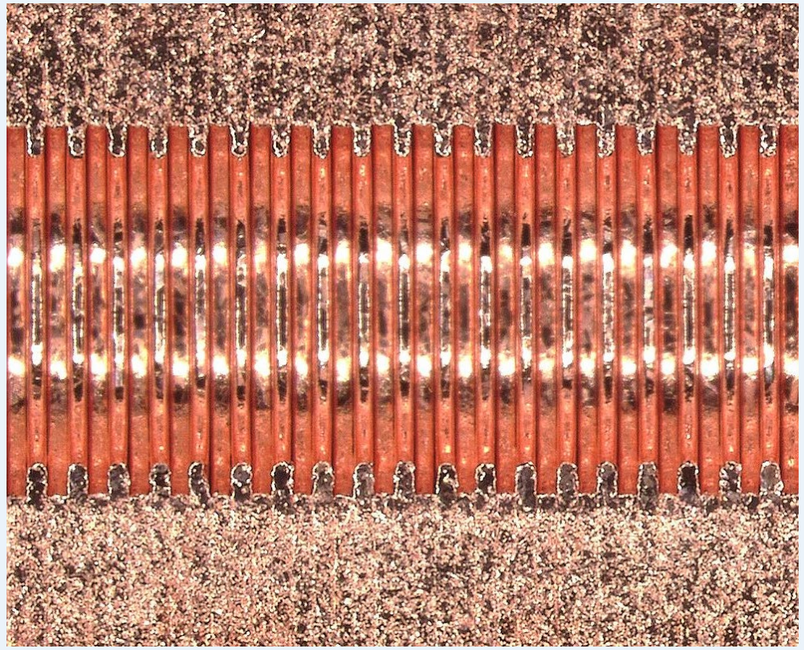
Progress of research on corrugated wakefield structures in PAL working group



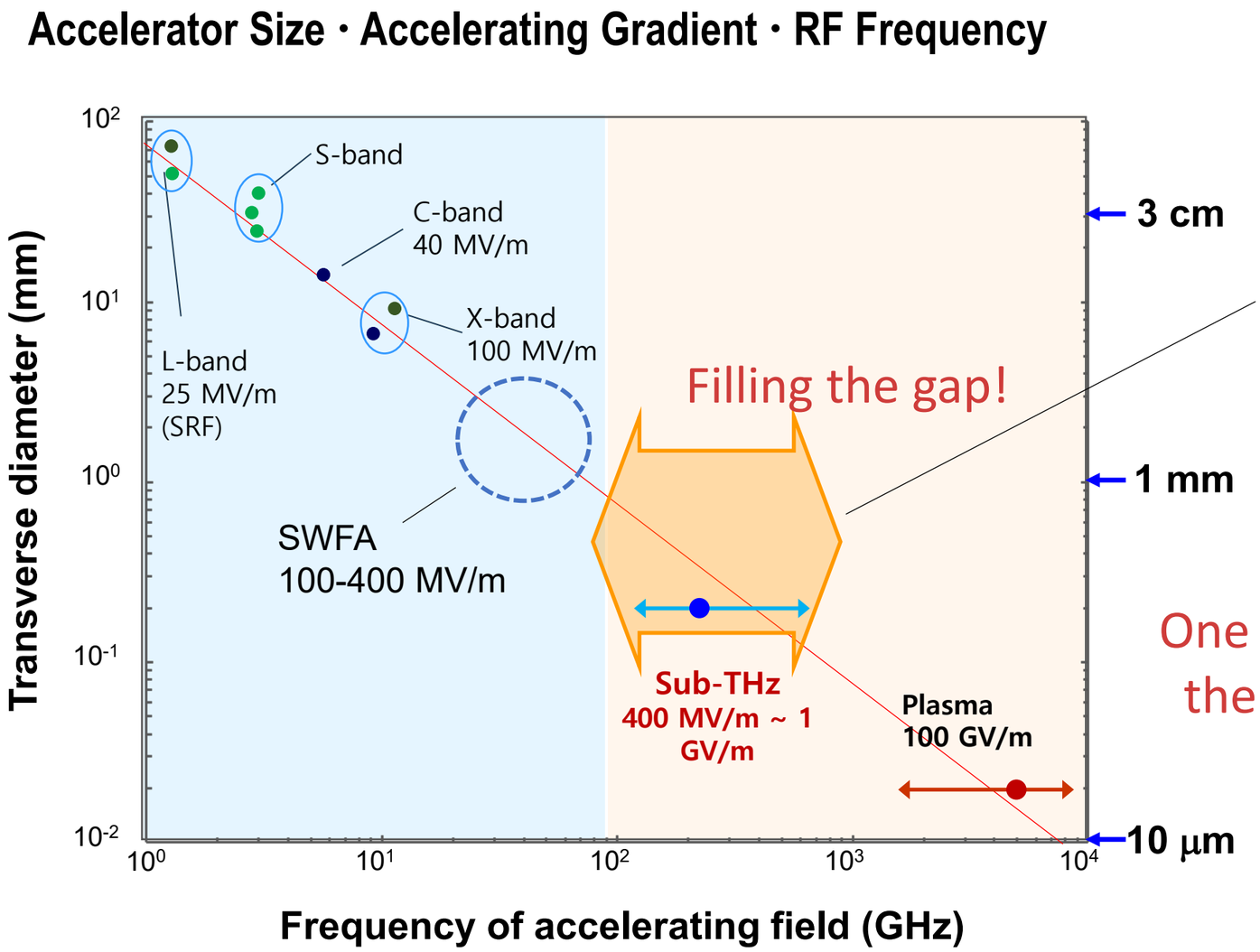


2024. 07. 10

Overview

1. Motivation
2. Fabrication method development
3. Previous experiment result
4. Future plan and upcoming experiment

Motivation



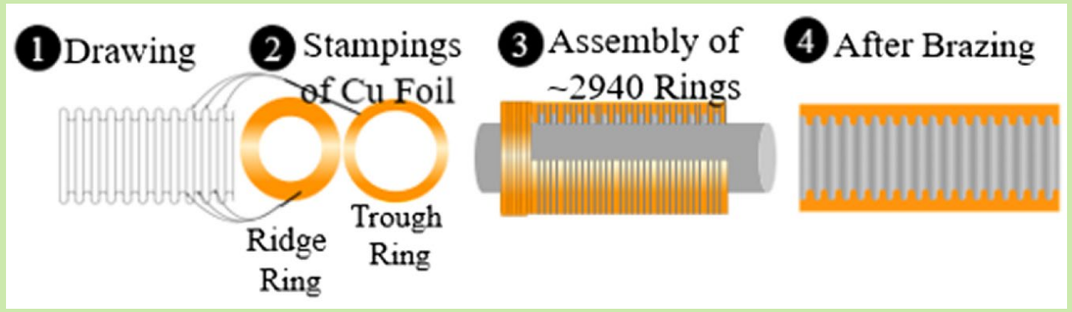
Could be…

- Higher gradient than GHz-SWFA
- Higher stability than plasma
- Compatible with nC charges

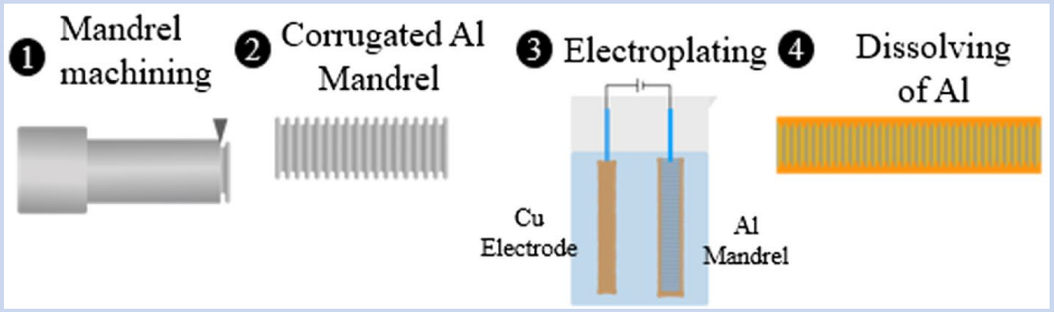
One of major challenges is the fabrication of micro-structures

Fabrication methods of corrugated structure

Stacking micro-structures



Electroforming

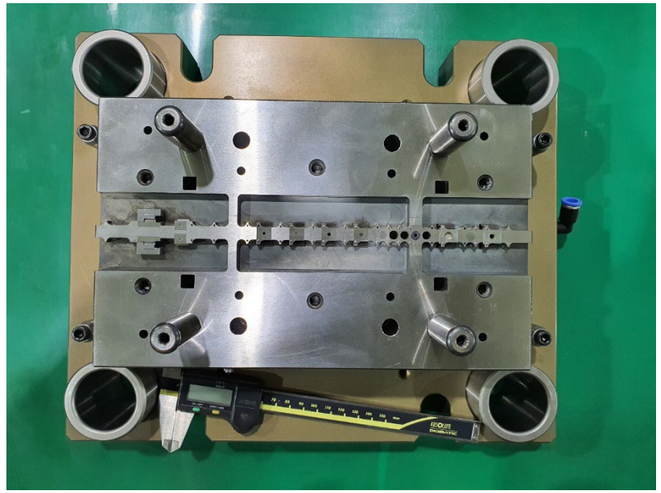


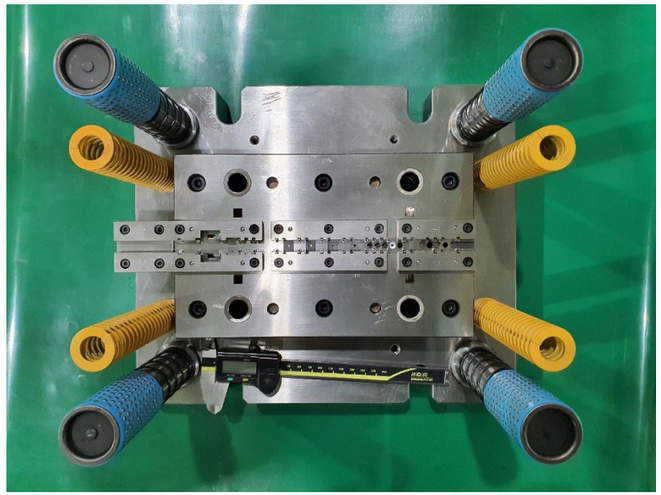
Siy, A., et al. "Fabrication and testing of corrugated waveguides for a collinear wakefield accelerator." *Physical Review Accelerators and Beams* 25.2 (2022): 021302.

- We used and studied a method of **stacking micro-structures**.
- Using a method of stacking makes it easy to create long and high frequency structures.
- It is important to align the micro-structures, minimize deformation, and ensure tight bonding.

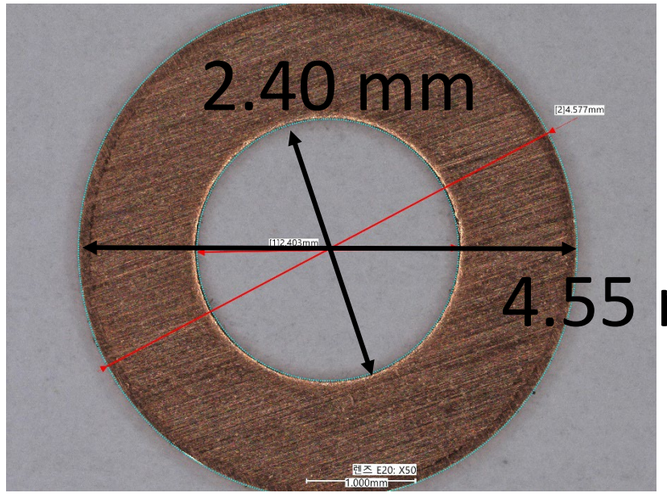
Fabrication of micro-structures (Die stamping)

Die & mold

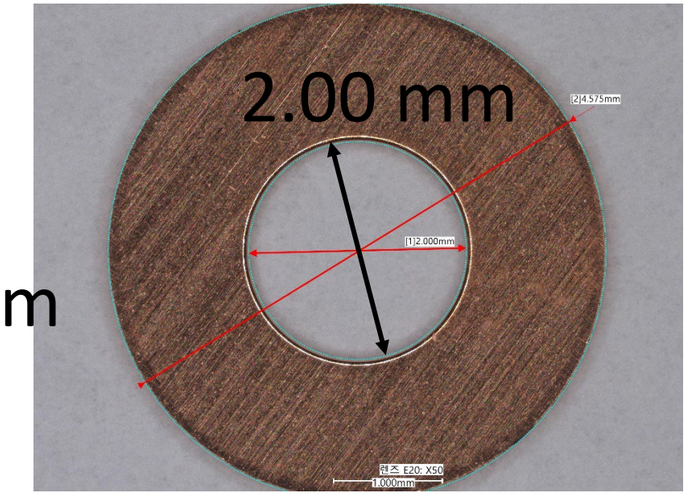




Trough ring



Ridge ring



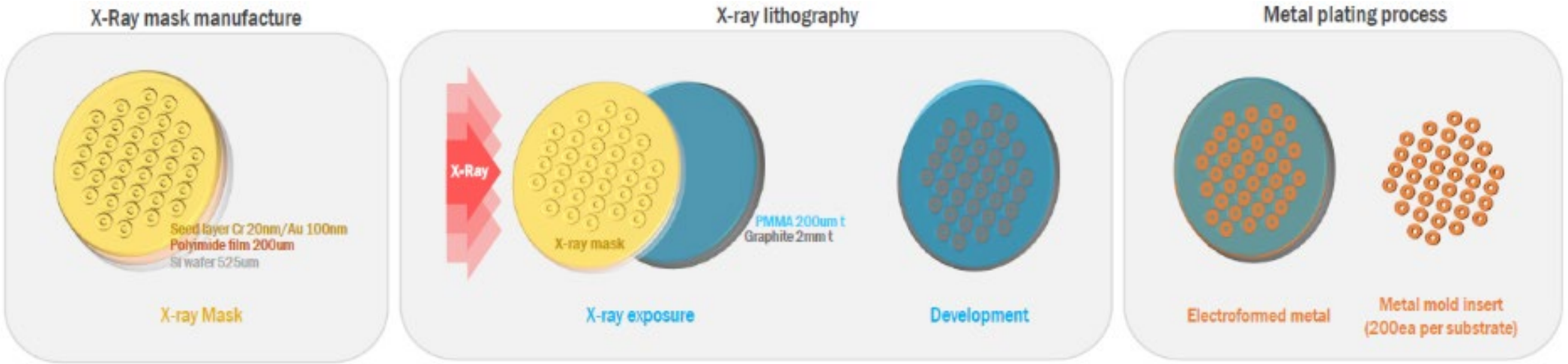
- Die stamping is very good for mass-production
- We fabricated 10k of each part with 0.15 mm thickness
- Even when using flat sheets for fabrication,

  the final product were not perfectly flat

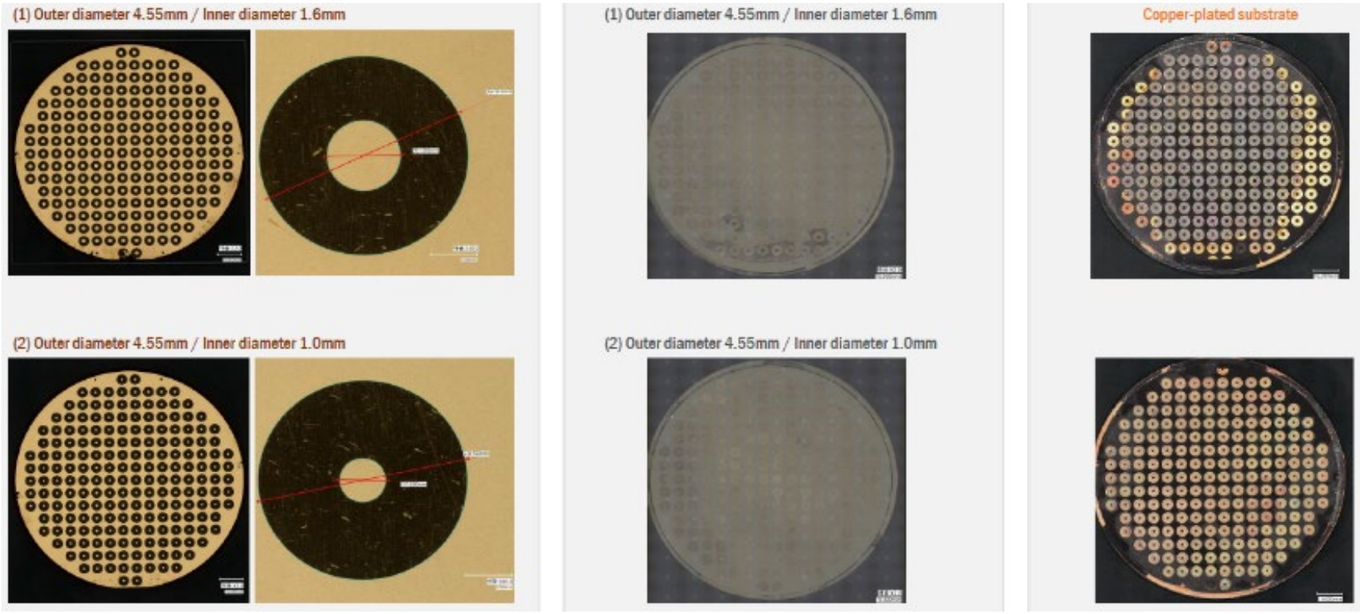
  due to deformation of stamping process

Fabrication of micro-structures (Lithography)

PLS-II 9D beamline

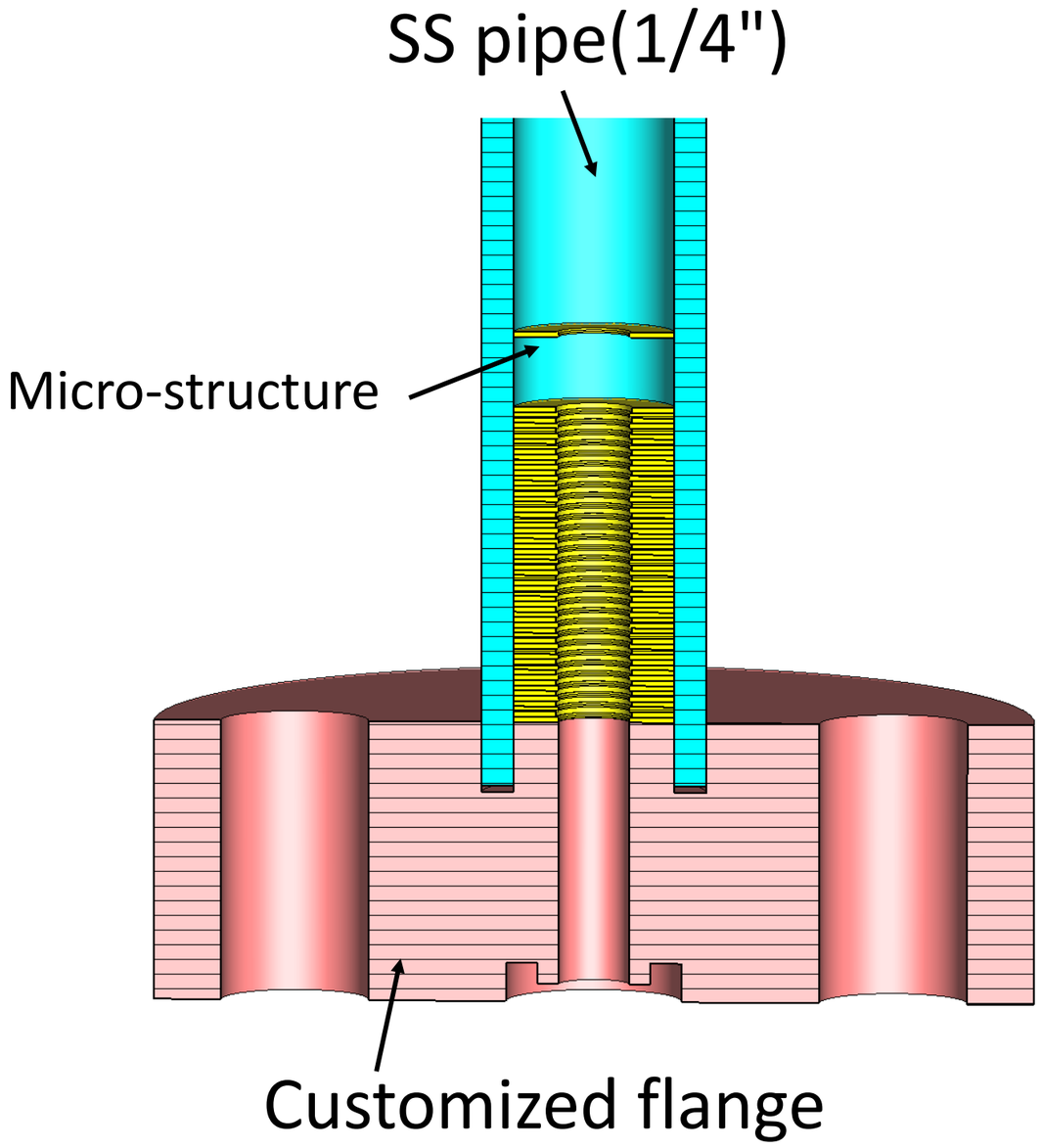


Outer diameter 4.55 mm
Inner diameter 1.60 mm



Outer diameter 4.55 mm
Inner diameter 1.00 mm

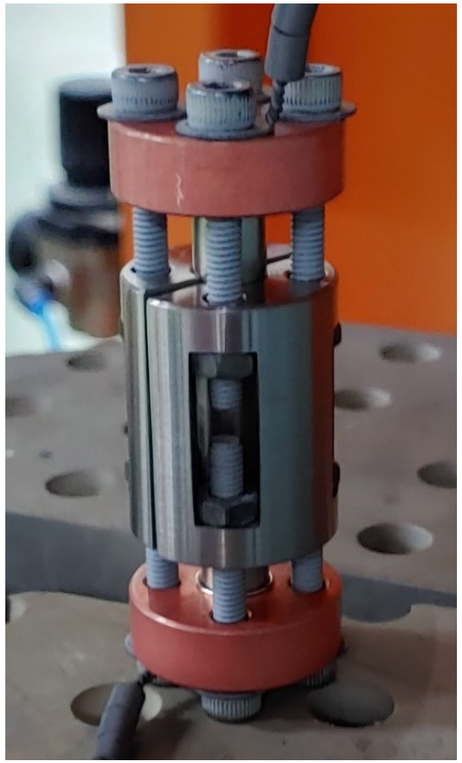
Alignment of assembly



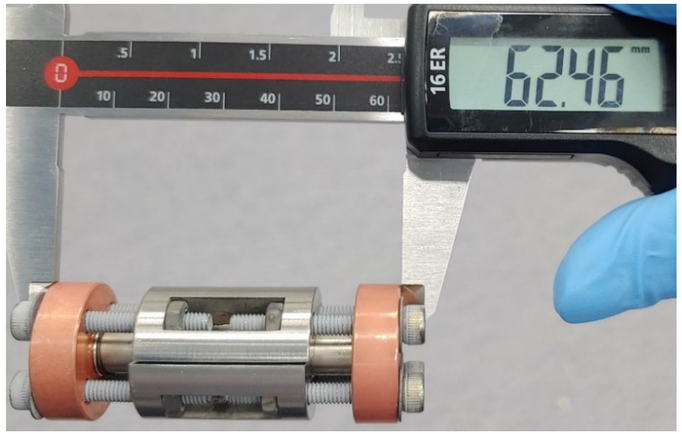
- SS pipe is a guide for alignment and stiffness.
- OD of micro-structures are fitted to SS pipe ID.
- The difference of both diameters are around 10 μm.

Bonding of micro-structures

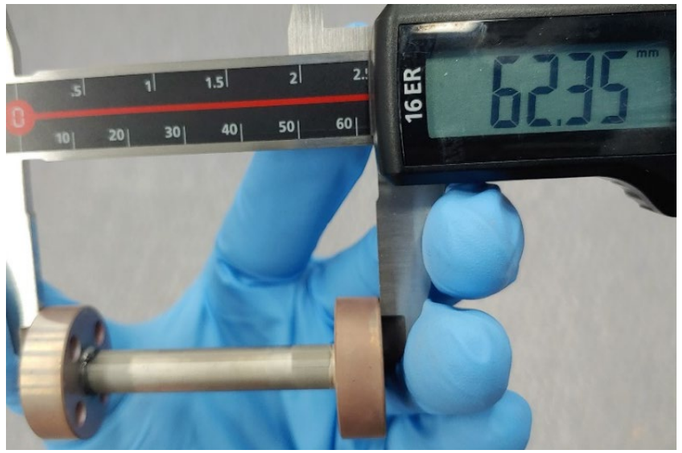
Hot diffusion bonding + brazing



Before bonding

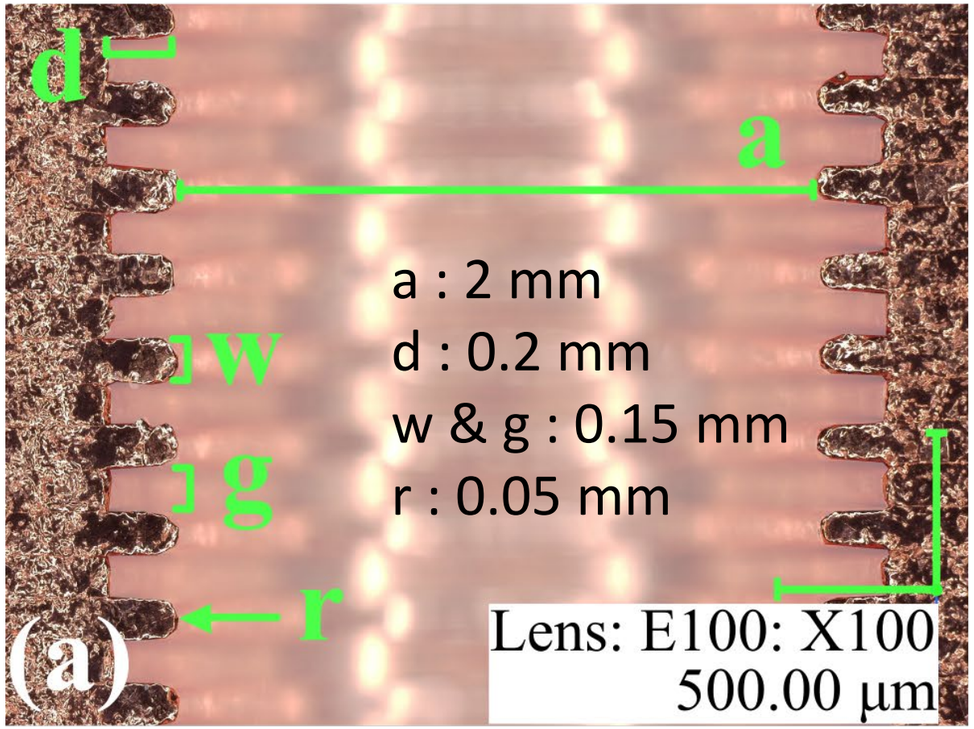


After bonding

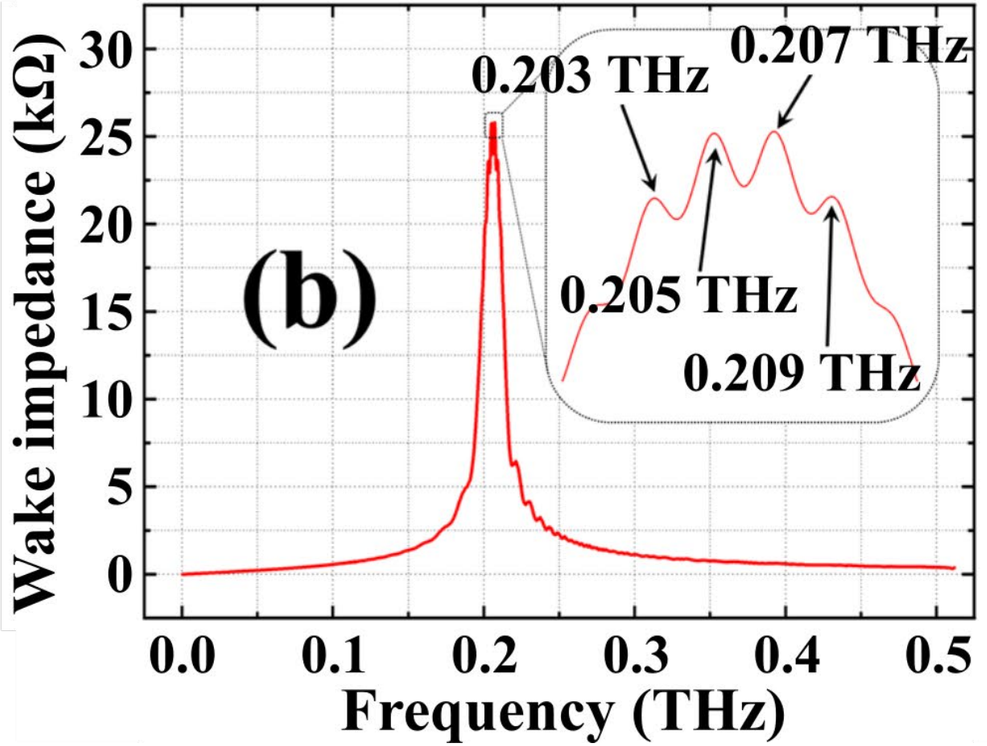


Fabricated structures (die stamping) and simulated characteristic

Half cut view (die stamping)



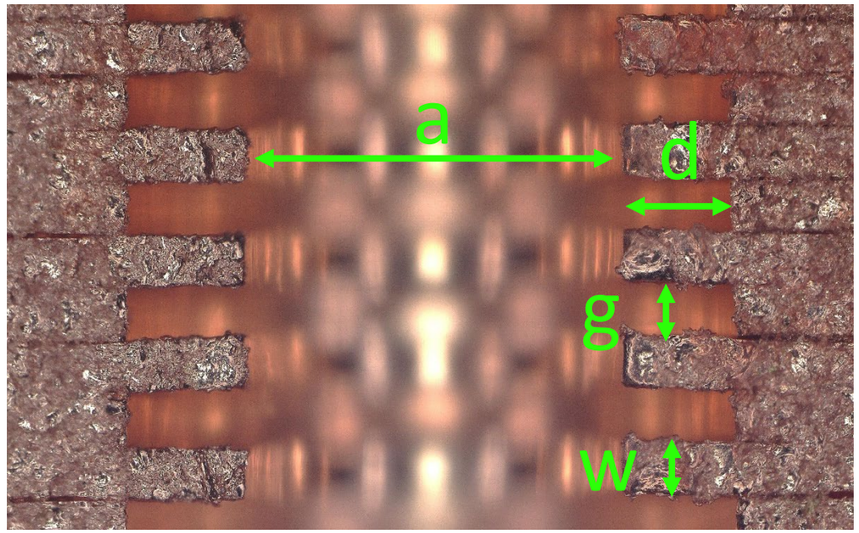
Simulation results of the structure



- Two of the prototypes using die stamped micro-structures were used on beam-based test in AWA

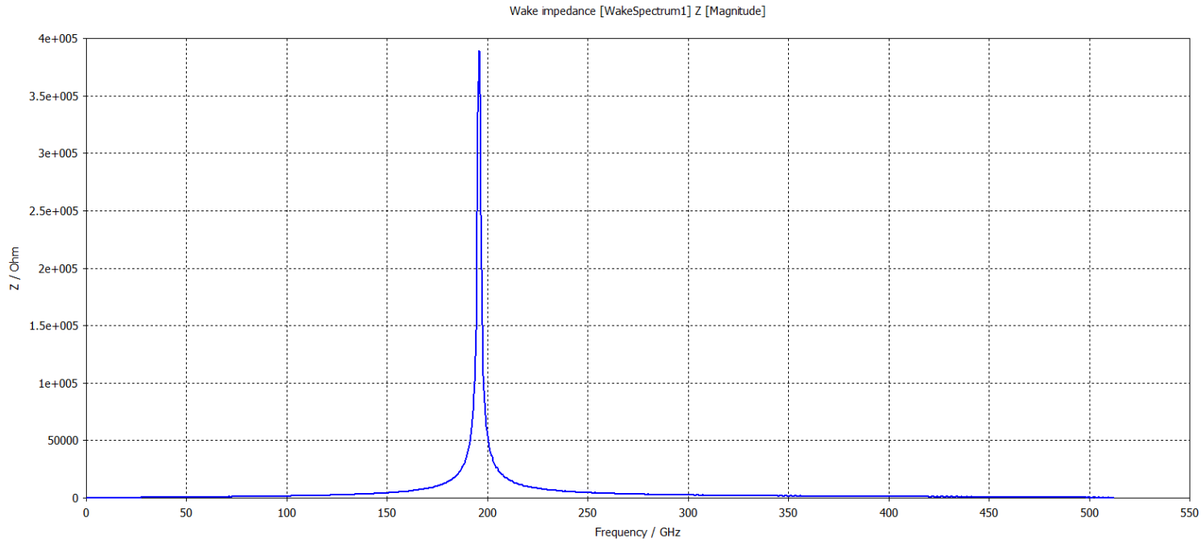
Fabricated structures (lithography) and simulated characteristic

Half cut view (Lithography)



a : 1 mm d : 0.3 mm w & g : 0.15 mm

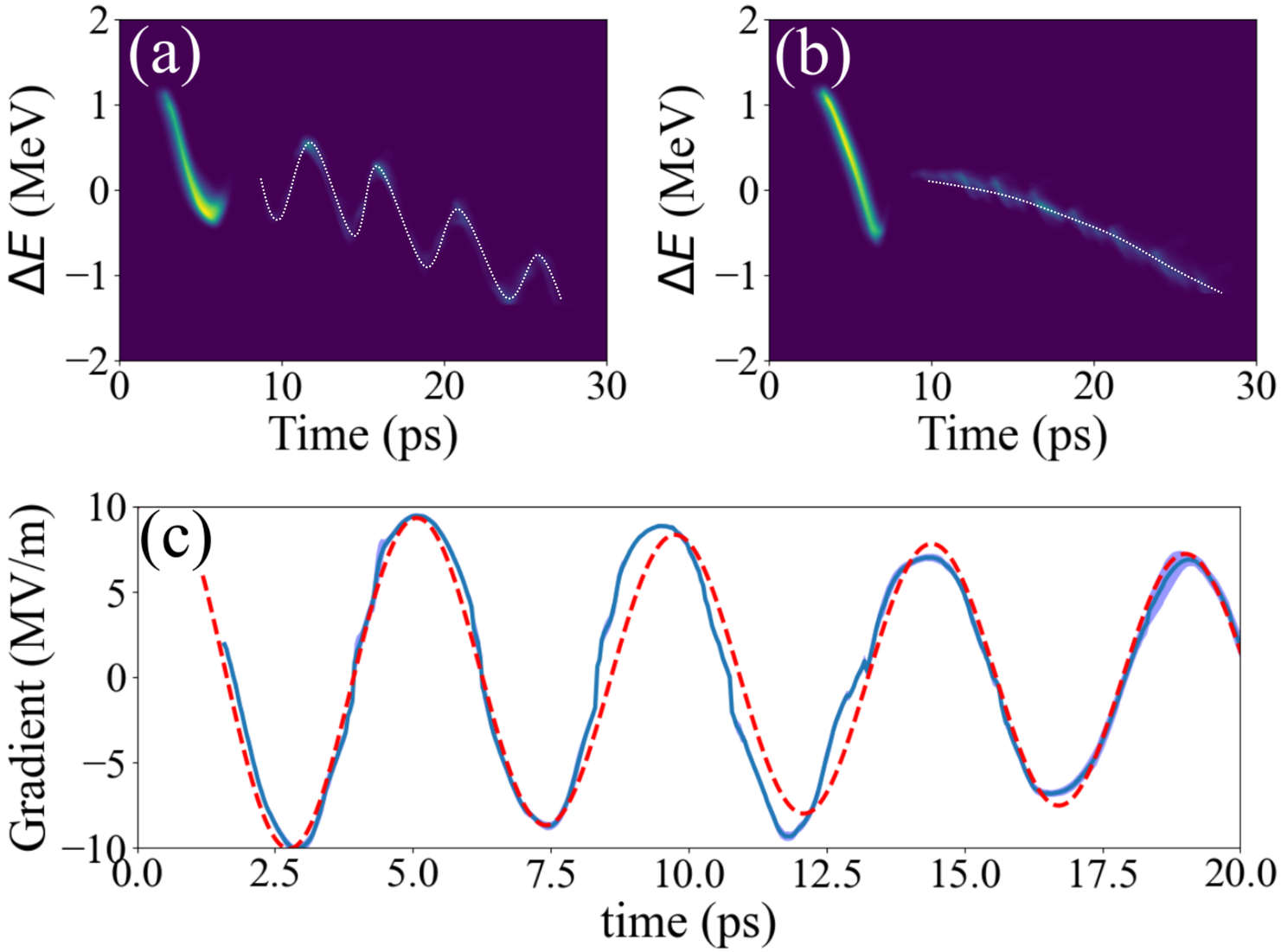
Simulation results of the structure



195 GHz

- A prototype using lithography discs was fabricated and cut for inspection

Beam-based characterization results (Die stamping)



The results were introduced in Scientific Report 13,3207 (2023).

- (a) is the energy profile w/ structure.
- (b) is the energy profile wo/ structure.
- Blue in (c) is the gradient of experiment. Red in (c) is the gradient of simulation.

- The results of the first phase matched well with the simulation.
- The results make us to proceed to the next phase.

Next step

- Fabrication of sub-THz structure was successfully accomplished.
- The next step is utilizing developed method for real applications.
- Collaboration is ongoing to develop THz two-beam acceleration, which could have advantage over GHz -TBA and THz-CWA.

Demonstration of core technologies (e.g., High-power PET, Drive BBU, etc.)

↓

Integration and Proof-of-Principle exp.

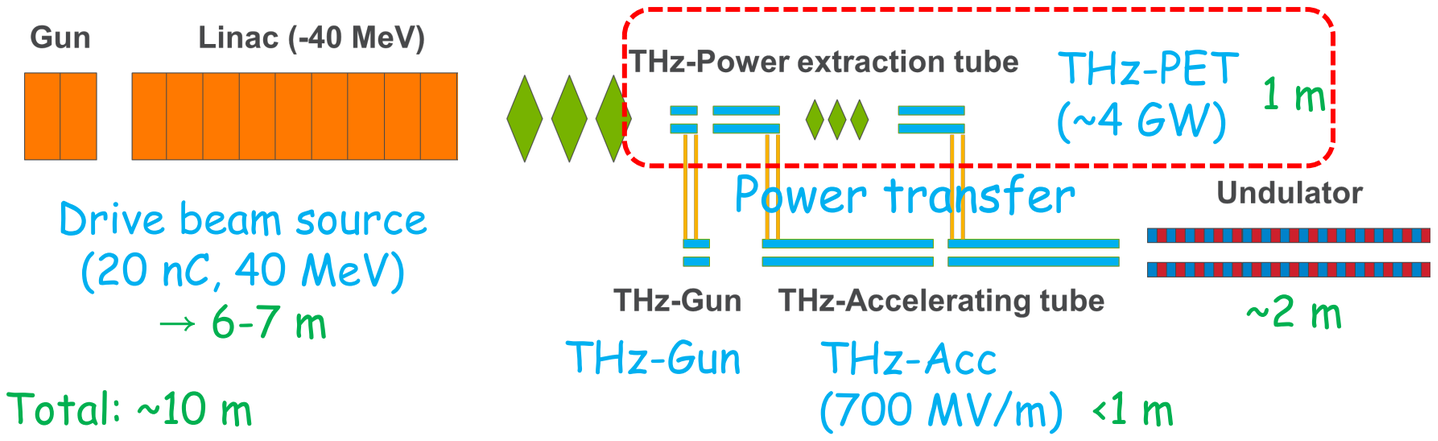
↓

Conceptual design of real facility

↓

Demo

Integration demo facility layout



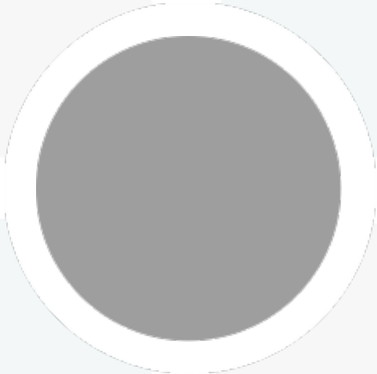
Collaboration groups

Pohang Accelerator Laboratory

RF design
Fabrication R&D

Organizing project
Demonstration planning
Beam dynamics R&D
Application R&D

Northen Illinois University



Korea University

Organizing project
Application R&D
Optics design

Demonstration planning
Beam experiment
RF and optics design
Beam dynamics R&D

Argonne National Laboratory

Short term plan

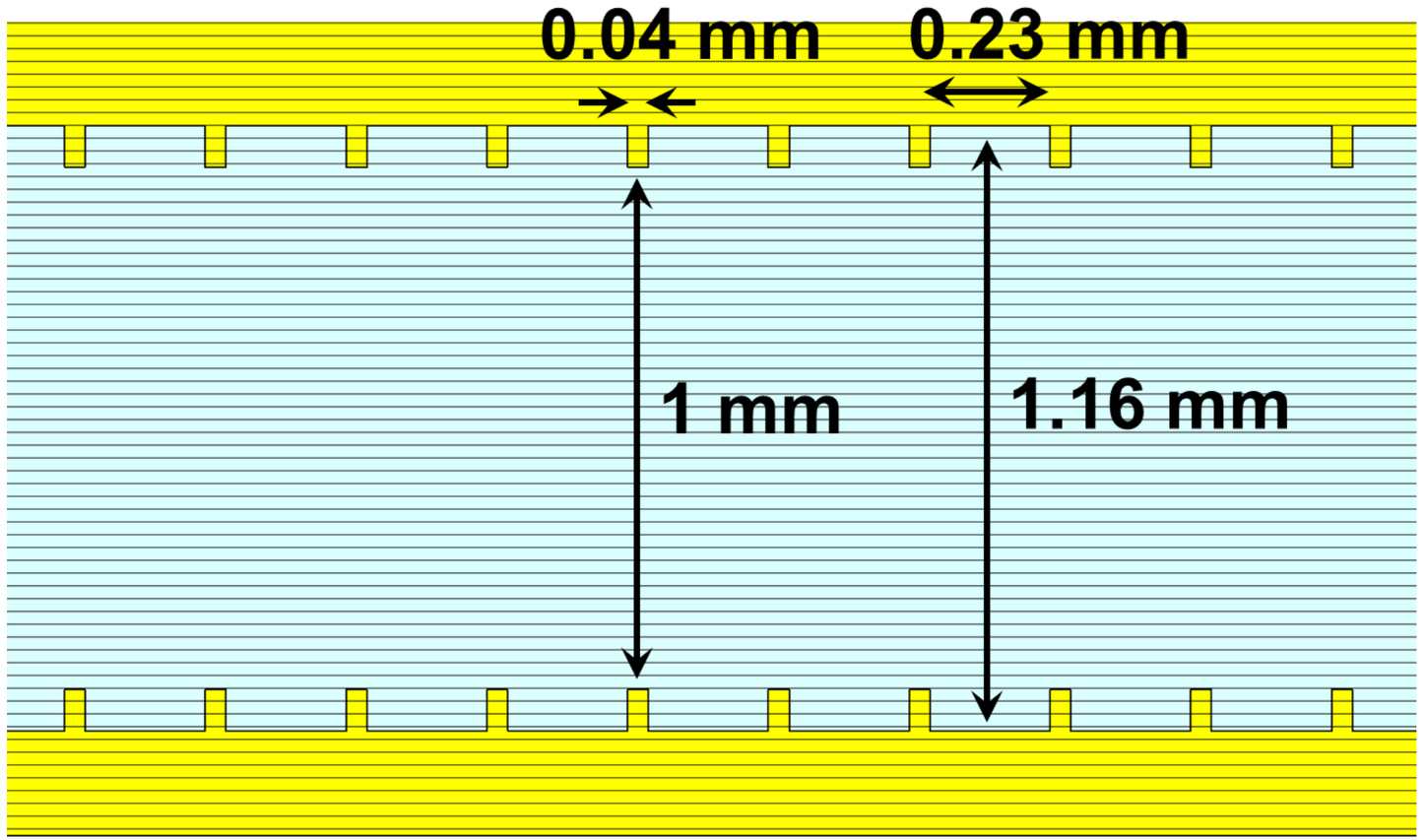
Short term goal is generating >1 GW peak power

- Design of PET for > 1 GW (done)
- Engineering design of PET for > 1 GW (done)
- Fabrication of PET for > 1 GW (Early August)
- Beam-based test (Early September)

- Power extraction design
- Engineering design for measurement setup
- Measurement of > 1 GW

} Early of next year

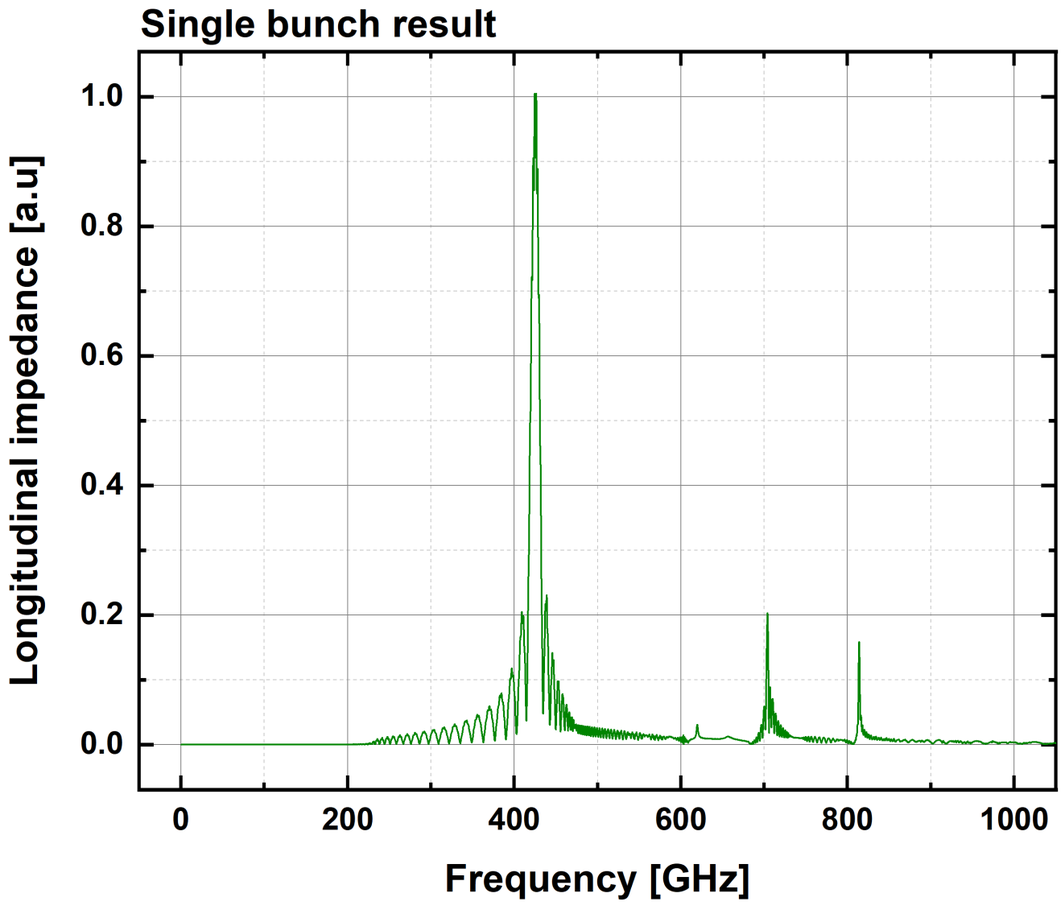
New design of THz PET

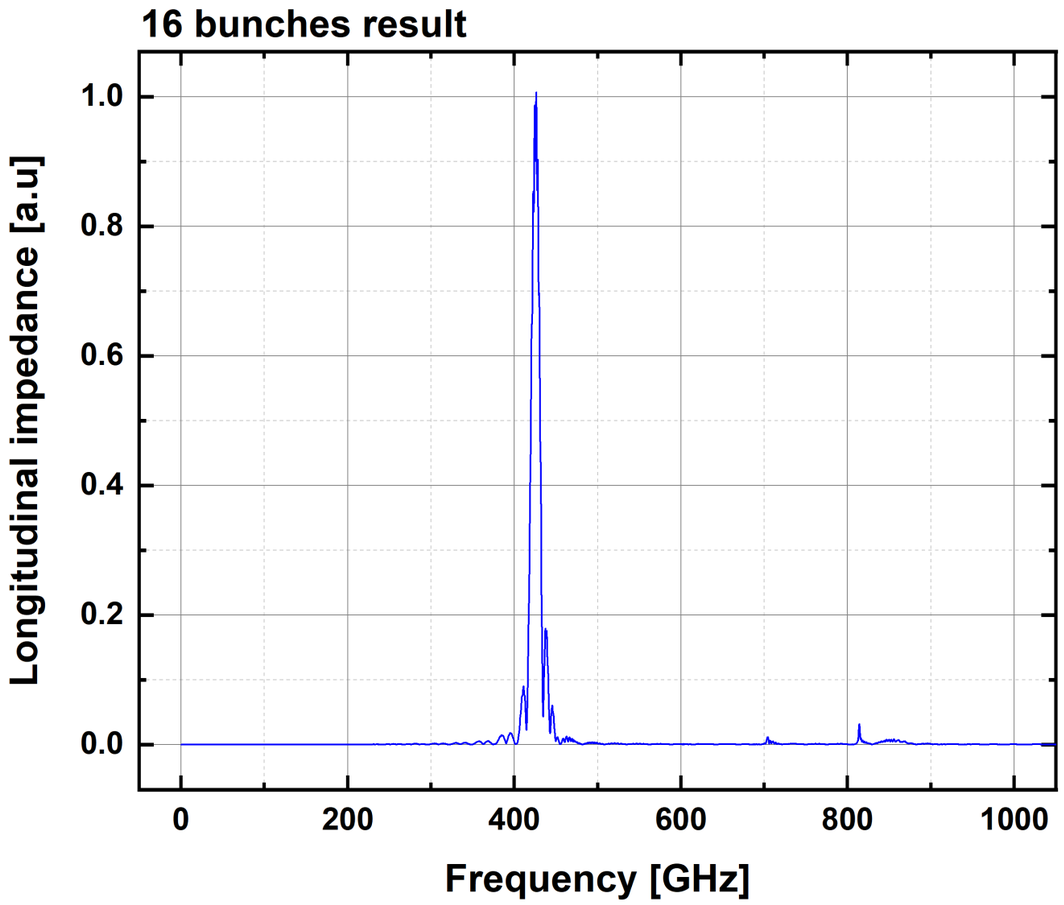


Beam requirement : rms σ 0.1 mm

1 nC, 16 bunches

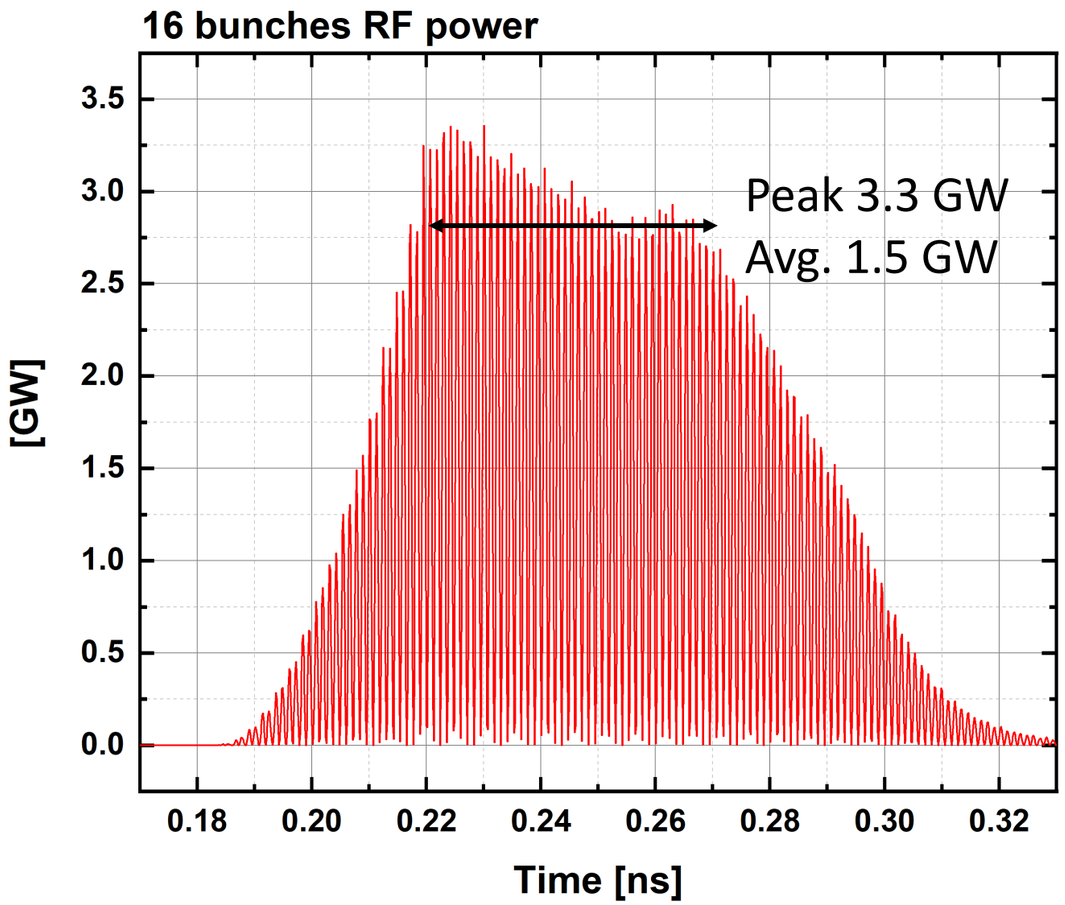
Wake impedance of new THz PET (simulation)





- There are HOMs in a single bunch result.
- But when the bunch spacing is set to the fundamental mode frequency, only the fundamental mode is amplified in multi bunch result.

THz power of new PET (simulation)

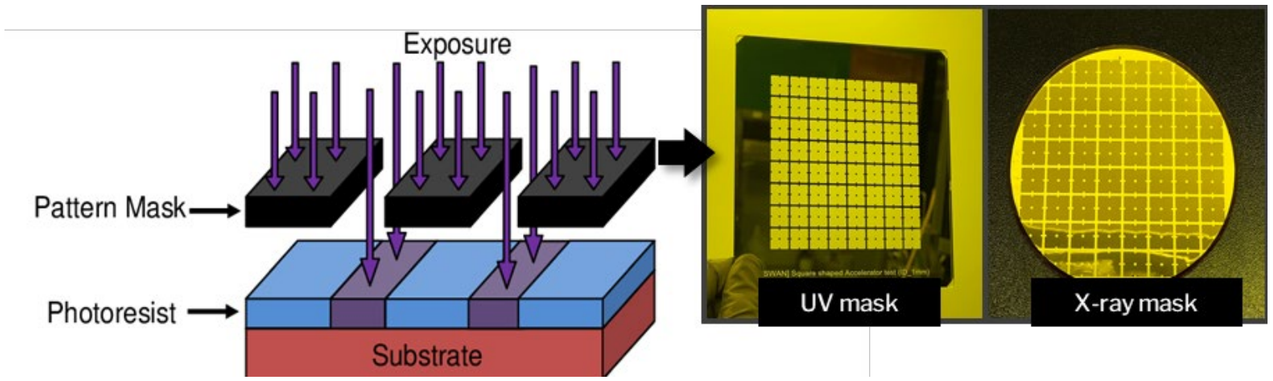


Coupler + horn radiation

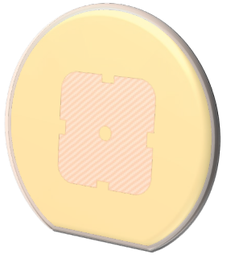
Wakefield generation by 1 nC x 16 bunches (PIC simulation)

Fabrication of micro-structures for new design

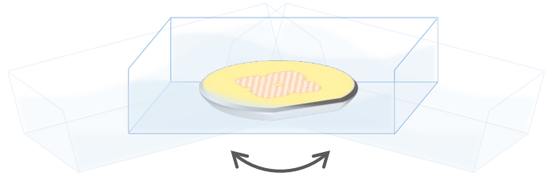
PLS-II 9D beamline



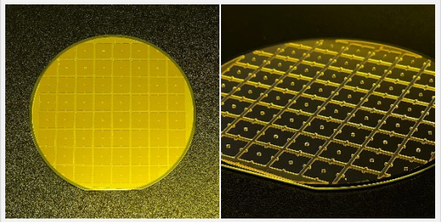
Expose to X-ray



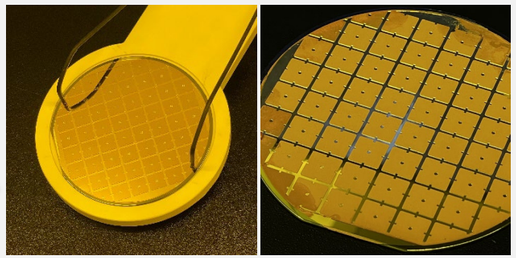
Before development



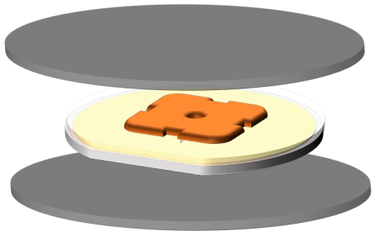
Development



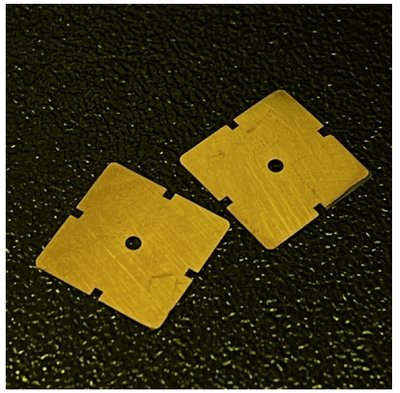
Patterned substrate



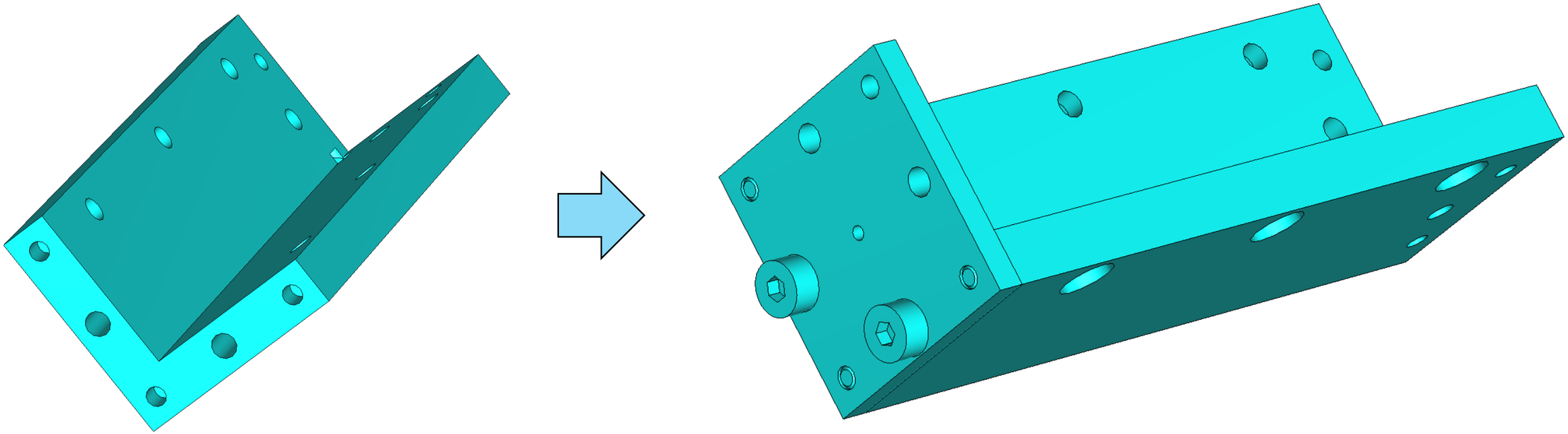
Electro-forming



Double side polishing

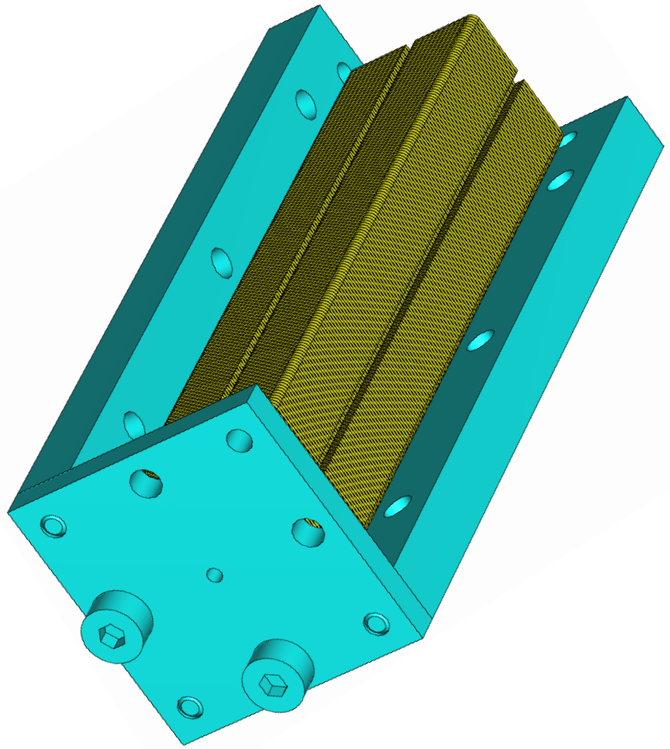


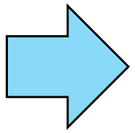
Assembly model of new design (1)

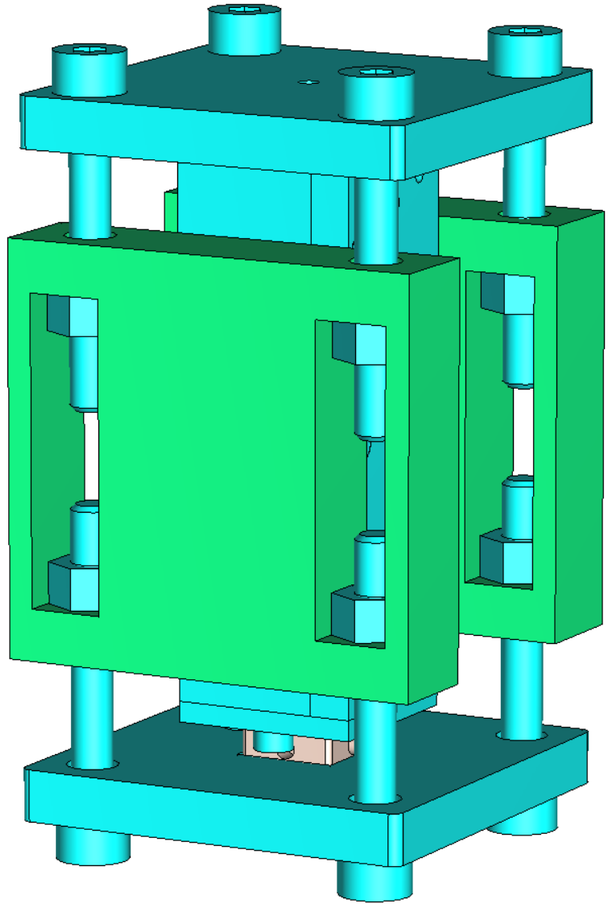


- SS outer pipe is replaced to SS V-blocks.

Assembly model of new design (2)





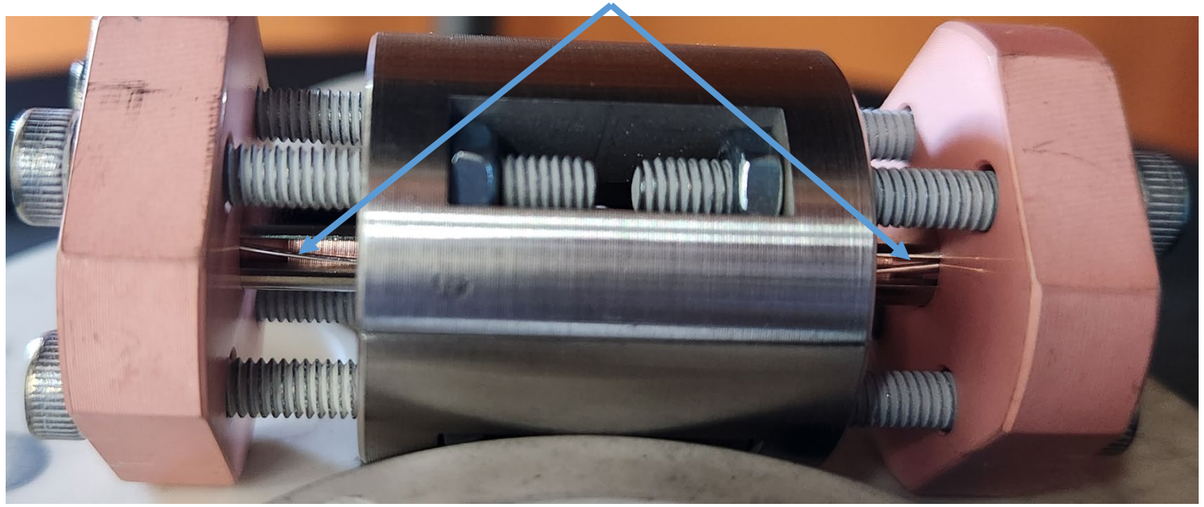


- Stack micro-structures 1 by 1

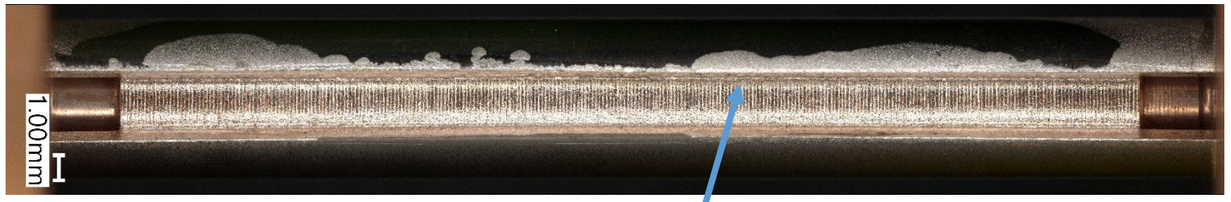
- Hot press and brazing of micro-structures

Study of hot press and brazing

Brazing filler

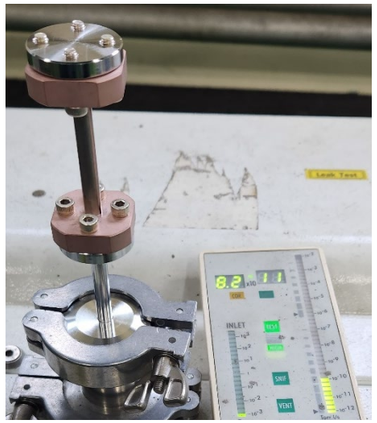


- Using half pipes to open the outer of micro-structures
- Brazing fillers to the outer of micro-structures
- Inner side of micro-structures is OK

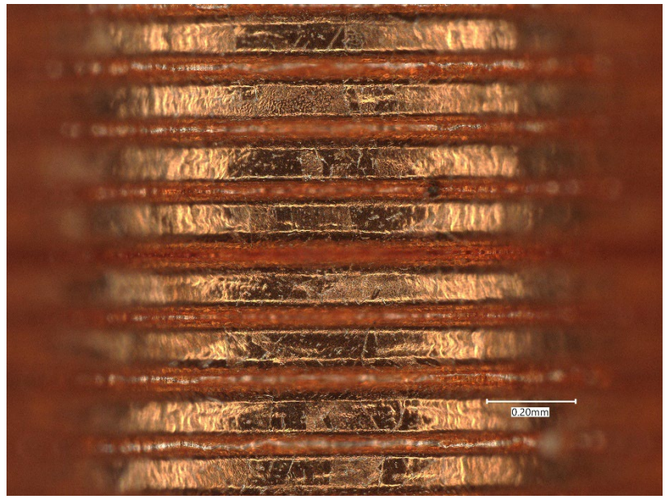


Brazing filler spread

Vacuum tight sealing is OK



Half cut view of inner side



Summary

- Pohang Accelerator Laboratory developed a method to fabricate sub-THz structure.
- The fabricated structure was characterized by electron beam-based measurement and showed good agreement with simulations.

- Four institutions are collaborating to develop THz-TBA technology.
- Currently, R&Ds for core methods and technologies are actively ongoing.

- Demonstration for high-power generation is underway.
- Structure is being fabricated, and the beam-based test is planned in early September.

End of presentation

Thank you very much