Development of 3 GHz cavities at KEK

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Motivation

- We have the surface preparation and vertical-test facilities for 1.3-GHz single-cell and 9-cell cavities at KEK. But the budget and resources for the thin-film studies are limited, and the 1.3-GHz system is too large for our thin-film studies.
- If we utilize 3-GHz single-cell cavities for the tests of thin-film coated inner-surface, we can save the budget and resources of the surface preparation and vertical tests.
- The scale of 3-GHz cavity is about half of 1.3-GHz cavity. This means that the volume of 3-GHz cavity facilities is about 1/8 of 1.3-GHz cavity facilities. (the volume of facilities, and also EP acid, BCP acid, liquid He, etc.…)
- Utilization of 3-GHz cavities might speed up the studies of thin-film coated cavities.

Fabrication of 3 GHz single-cell Cu and Nb cavities.

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FABRICATION OF 3.0-GHz SINGLE-CELL CAVITIES FOR THIN-FILM STUDY

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Abstract

We fabricated 3.0-GHz single-cell cavities with Cu and Nb materials for testing thin-film creations on the inner surface of the cavities in collaboration between Jefferson Laboratory (JLab) and KEK. The cavity was designed at JLab. According to the design of cavity, the press-forming dies and trimming fixtures for the cavity-cell were also designed and fabricated at JLab. These dies and trimming fixtures were transported to KEK, and the rest of fabrication processes were done at KEK. Nine 3.0-GHz single-cell Cu cavities and six 3.0-GHz single-cell Nb cavities were fabricated finally. Two 3.0-GHz single-cell Cu cavities were mechanically polished at Jlab. Three 3.0-GHz single-cell Nb cavities were transported to Jlab for inner-surface preparation. All these Cu and Nb cavities will be utilized for the tests of various thin-film creations at JLab and KEK. This presentation describes details of the fabrication of these cavities.

INDRODUCTION

S-I-S (Superconductor-Insulator-Superconductor) thin-film multilayer structure has been proposed by A. Gurevich to enhance the effective H_{c1}, and T. Kubo has proceeded with an advanced theoretical study to predict an optimum thickness of each layer which achieves the maximum effective H_{c1} [1–3]. Alternative superconductors for thin-film structure, such as NbN, NbTiN, Nb_3Sn and so on, are proposed to achieve higher gradient and/or higher quality factor than bulk-Nb cavity. Nb thin-film on Cu cavity will provide drastic cost-reduction of SRF accelerators. Therefore, the thin-film technology will have an obvious and enormous impact to SRF accelerator facilities in terms of high-performance and/or cost-reduction. And the impact might be larger if the technology is applied to large-scale facilities, for example, the International Linear Collider (ILC), Continuous Electron Beam Accelerator Facility (CEBAF) and so on.

Series of studies have been done for the creation of thin-film structures with Nb, NbN, NbTiN, Nb-Sn and so o… a… p… e… w… experimental trials with thin-film test-cavities might be required to achieve the aimed extreme SRF performance.

SRF2019
T. Saeki, MOPO54

Consequently, we considered that the small-size 3.0-GHz cavity might be suitable for such thin-film experiments, because the Nb material procurement, facilities of cavity fabrication, setup of inner-surface preparation, film-creation, and performance tests can be done and obtained in relatively low-cost, compared with large-size 1.3-GHz cavity of ILC and/or 1.5-GHz cavity of CEBAF. We have good cavity-fabrication facilities at KEK and good companies for cavity fabrication in Japan in connection with KEK and Kyoto University. We have the inner-surface preparation and performance-test facilities for 3.0-GHz cavity at JLab. In such situations, the design and fabrication of 3.0-GHz cavities with Nb and Cu materials were done in collaboration between JLab and KEK.

PRESS-FORMING AND TRIMMING OF 3.0-GHz CU AND NB CUPS

The design of 3.0-GHz single-cell cavity was done at JLab. The total length of cavity is 170.8 mm with the cell length of 50.7 mm, and the inner equator diameter of the cell is 90.5 mm. The outer diameter of flange is 88.9 mm and the inner diameter of beam-pipe is 33.8 mm. The material of flange for Cu cavity is stainless steel and that of Nb cavity is NbTi. Cu disks were cut out from Cu plates (C1020) and the Cu disks were annealed in vacuum furnace (520 degrees C x 2 hours) at KEK. A picture of the Cu (C1020) disks set in the vacuum furnace for annealing process is shown in Fig. 1.

Figure 1: A picture of Cu (C1020) disks set in the vacuum furnace for annealing process.

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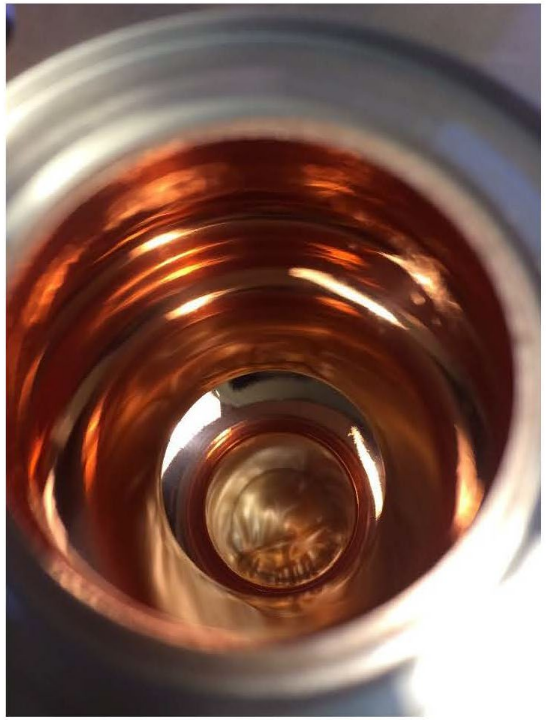
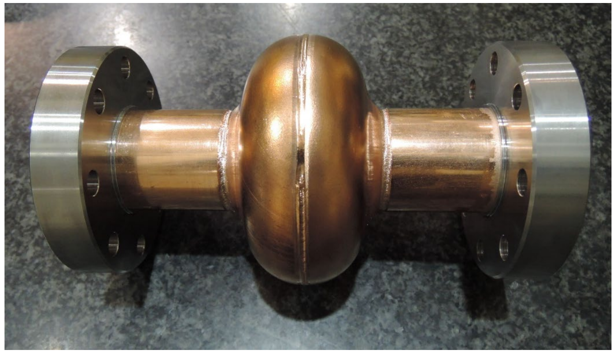
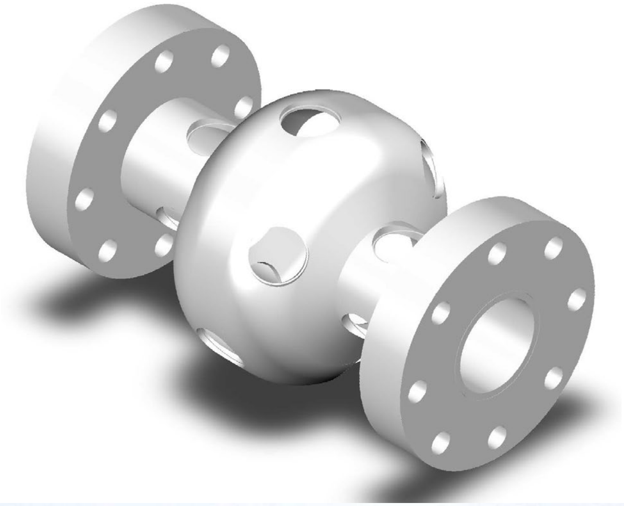
Cavities - Fabrication
fabrication

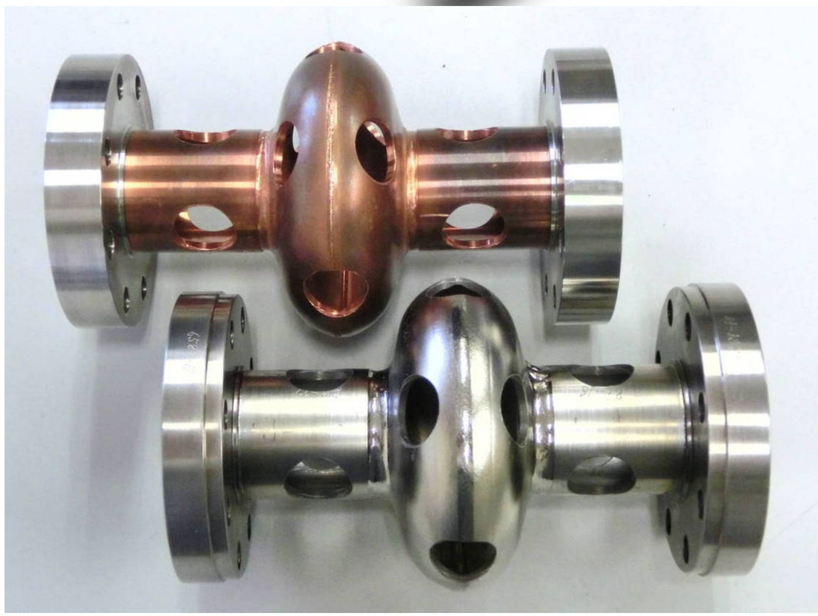




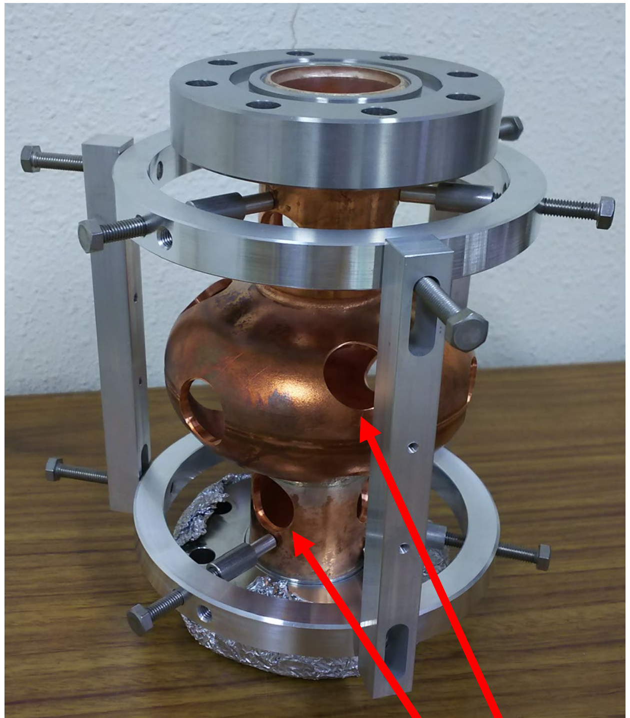
Cavity for thin-film study is designed by Jlab and fabricated by KEK.

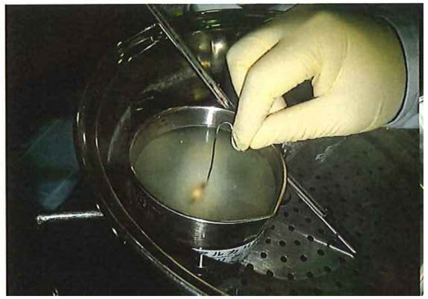
Coupon 3-GHz single-cell cavities





Coupon 3GHz single-cell Cu and Nb cavities



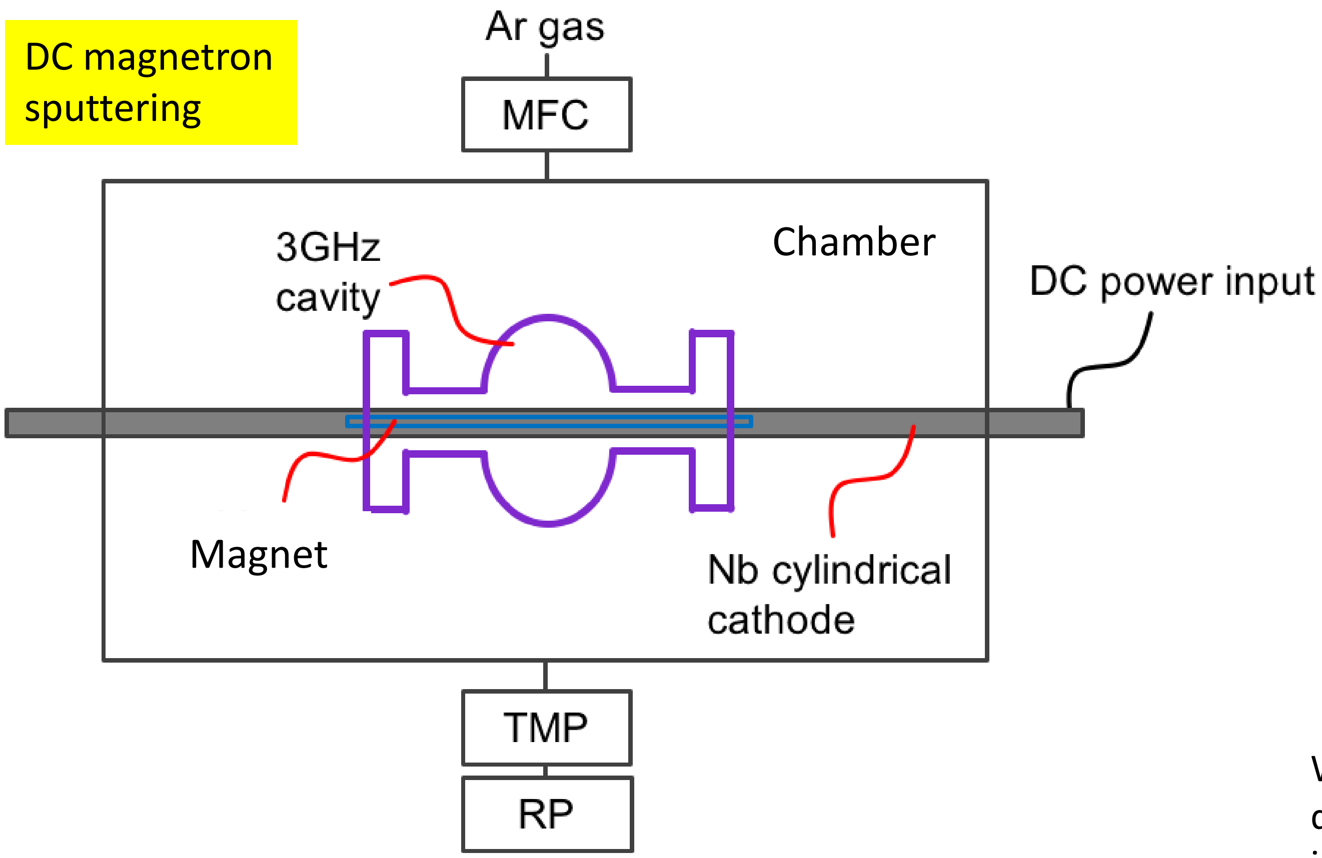


Coupon samples can be set on the holes of cavity

Plan

- An apparatus that can deposit Nb or NbN thin-film on Cu or Nb cavity is being prepared in collaboration with ULVAC, Inc..

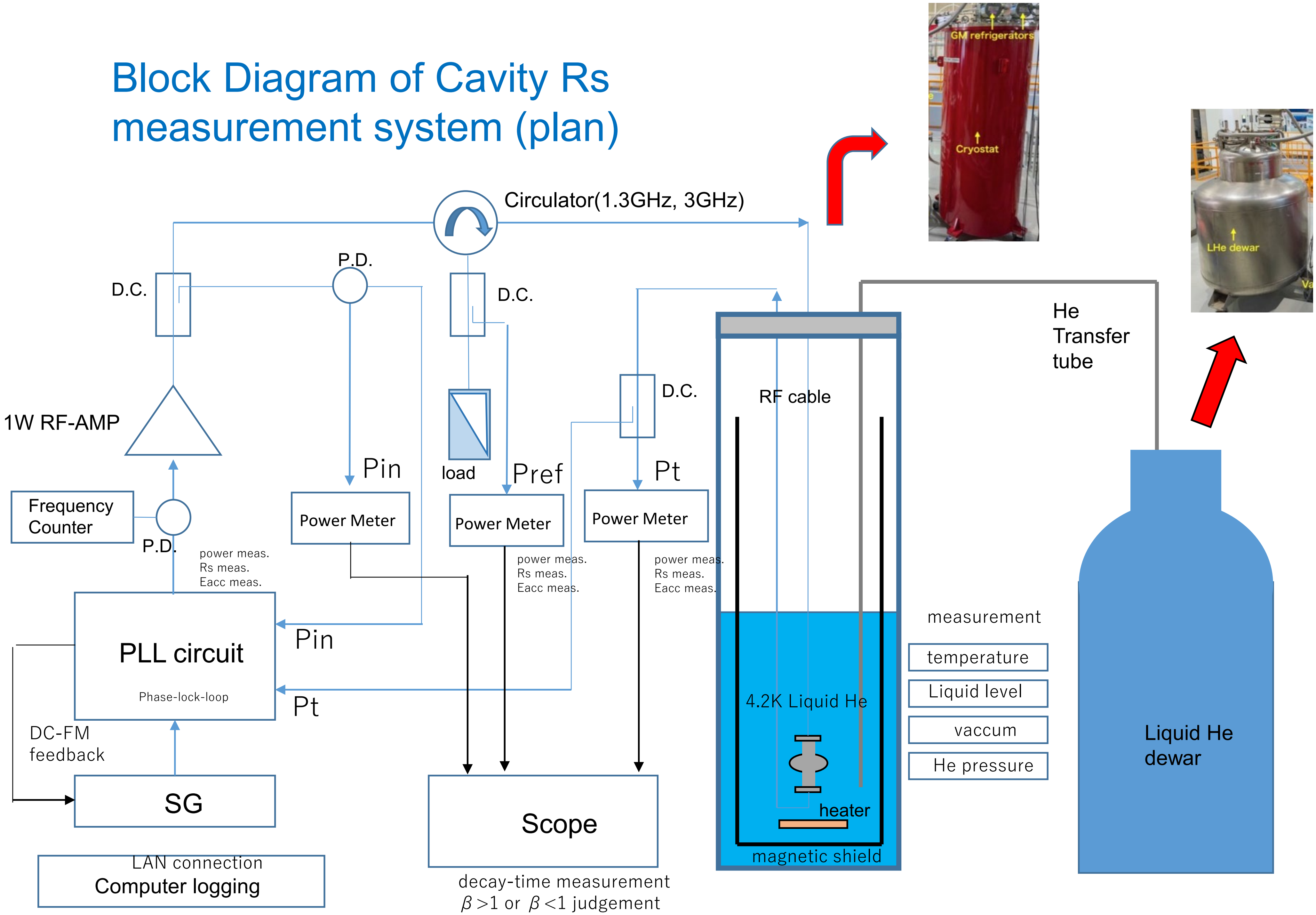
DC magnetron sputtering



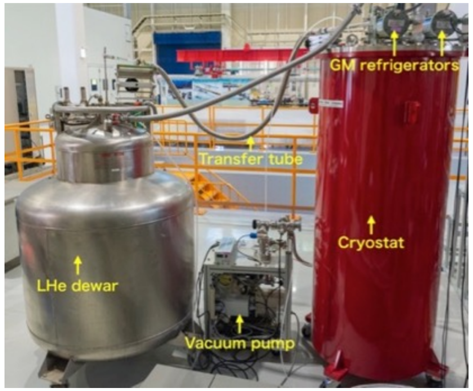
We have already successfully deposited Nb thin-film on the inner wall of Cu tube (Φ35mm).

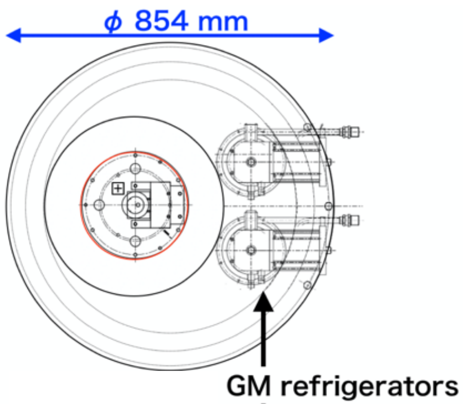
Preparation of 3GHz cavity vertical test stand at KEK

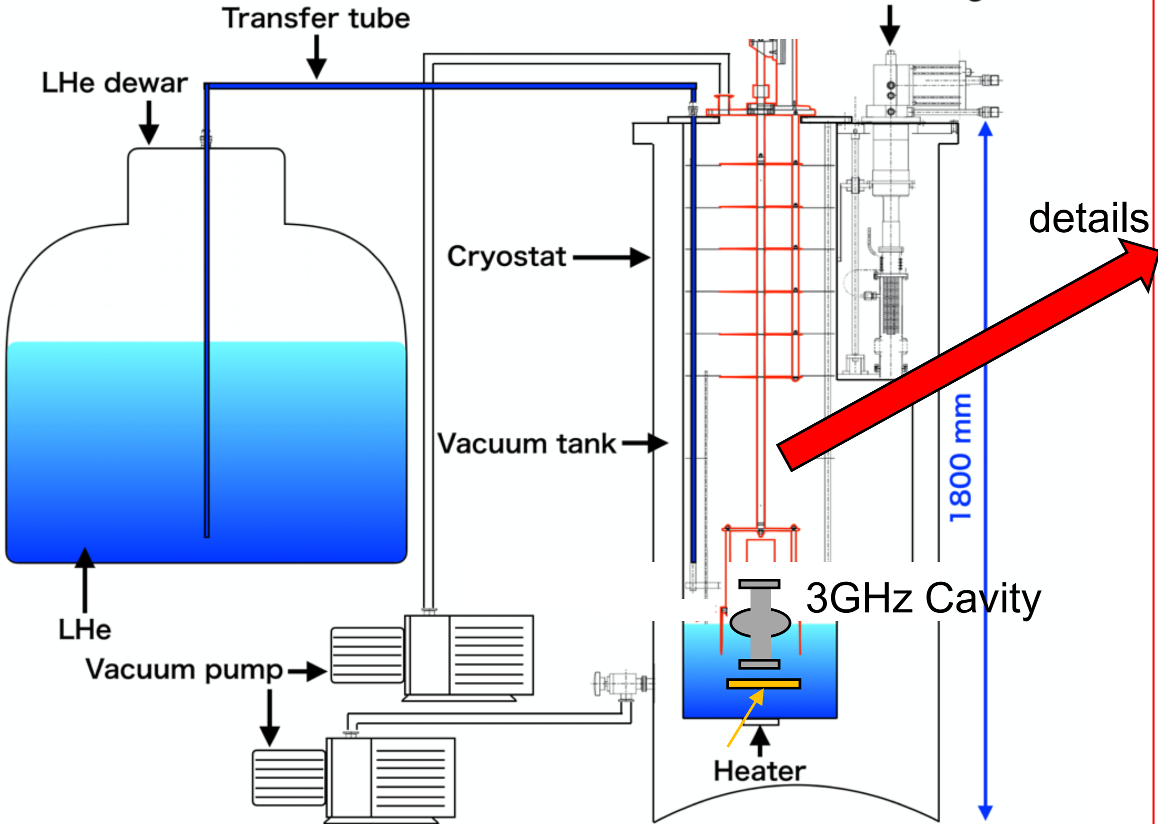
Block Diagram of Cavity Rs measurement system (plan)

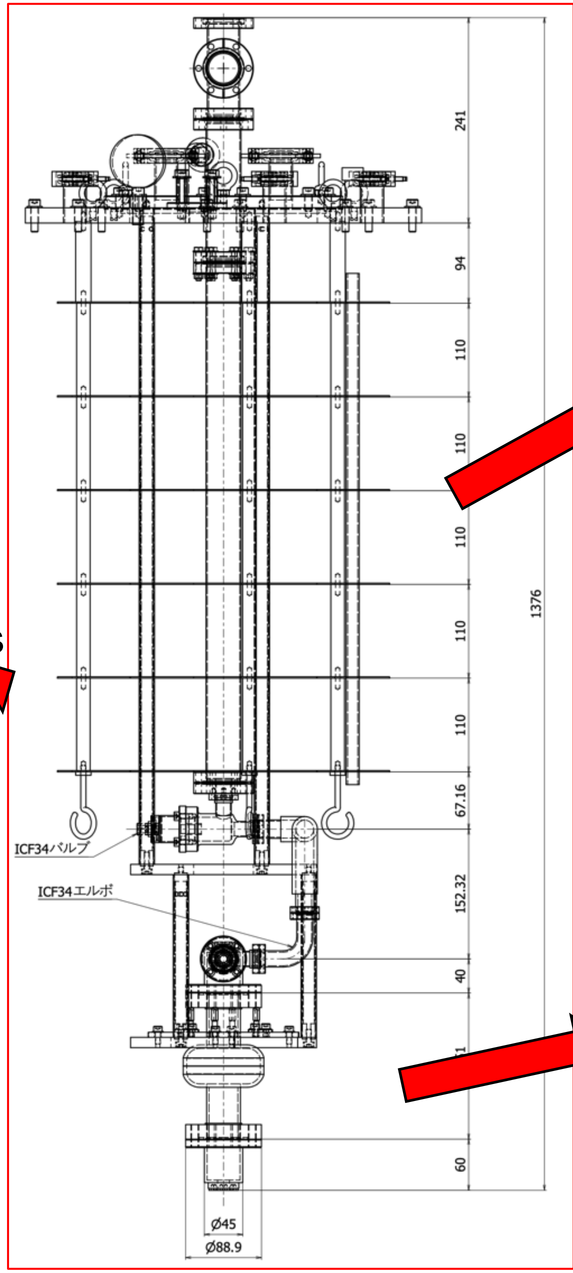


Cryostat arrangement (plan)

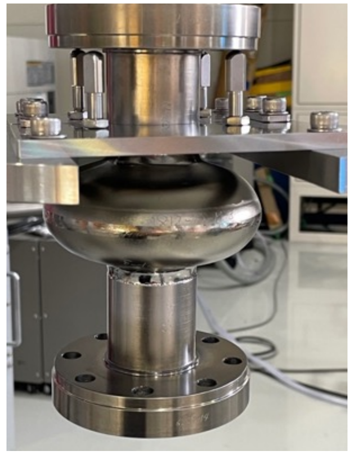




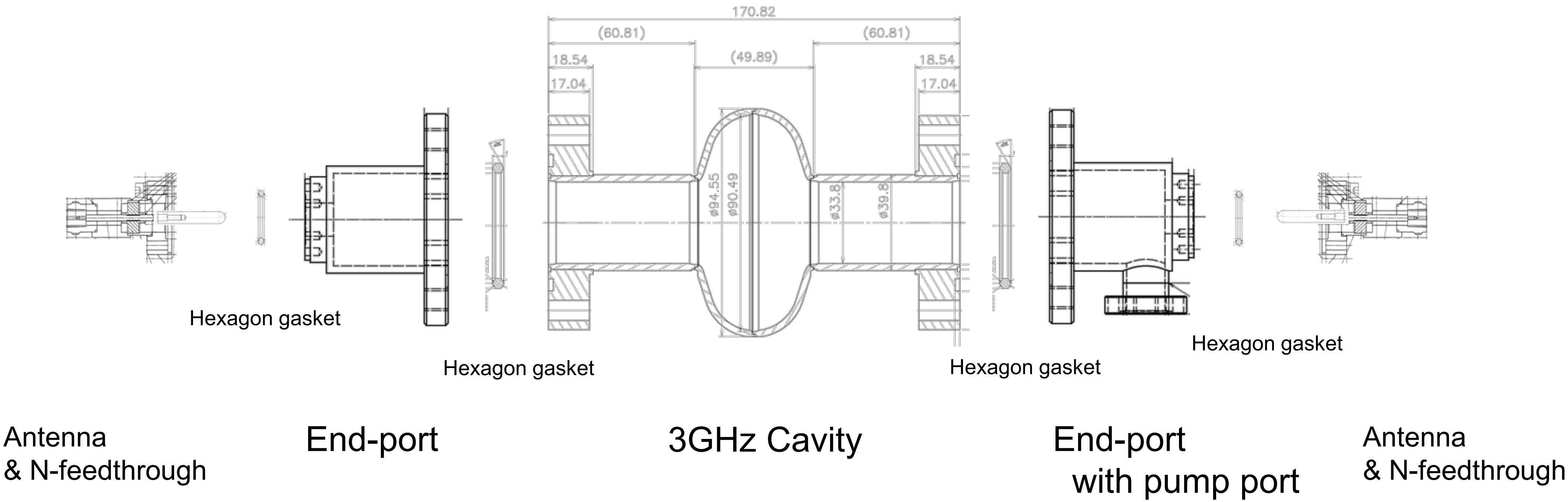




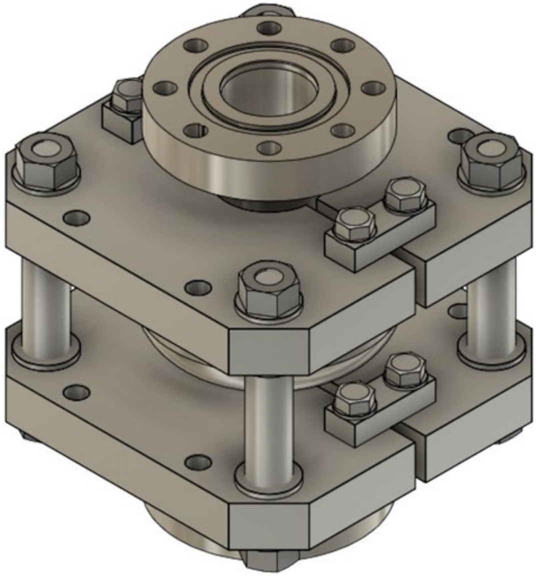
under fabrication

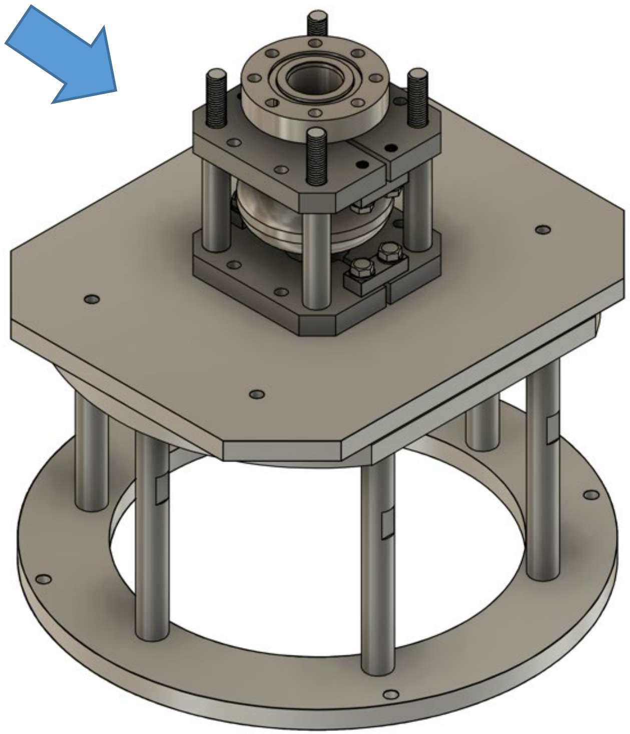


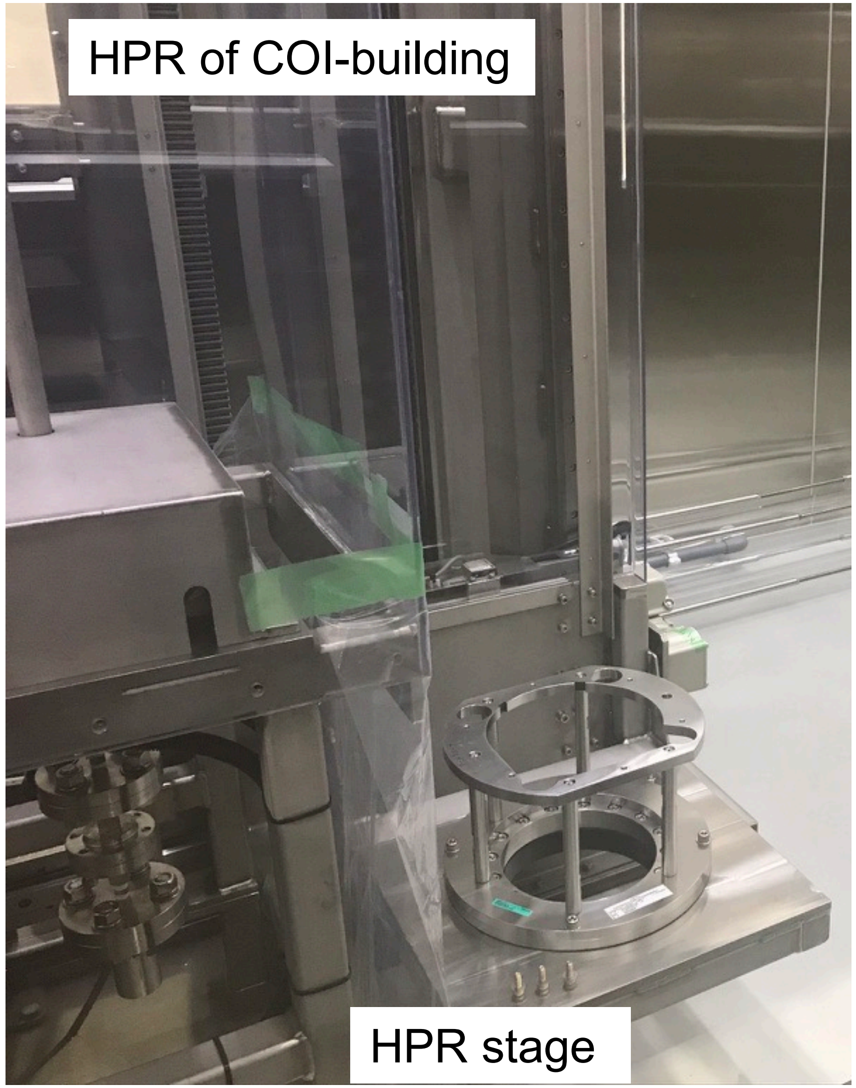
3-GHz Cavity End-port & Antenna arrangement (plan)



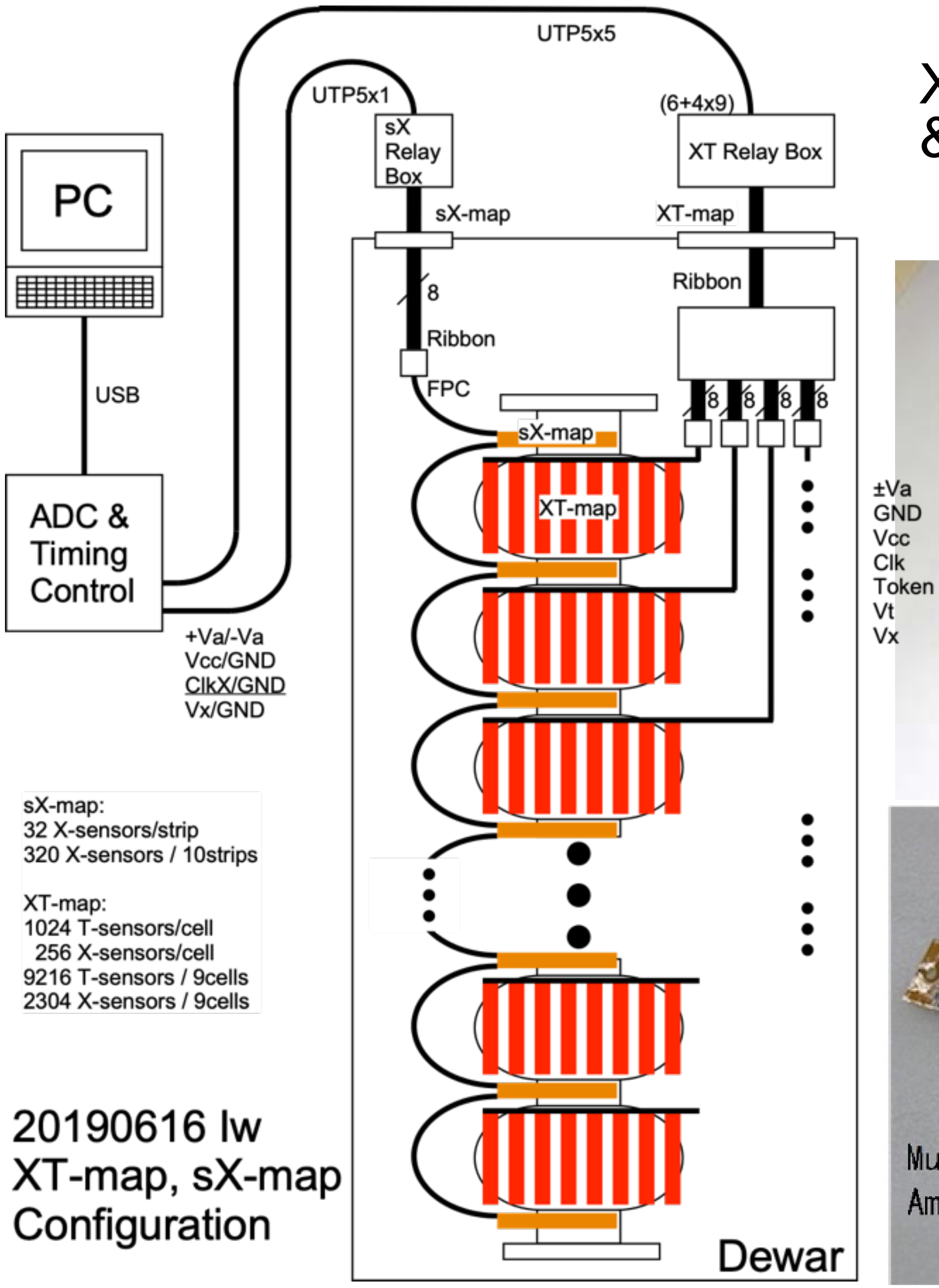
3-GHz Cavity holding frame and HPR stage adapter



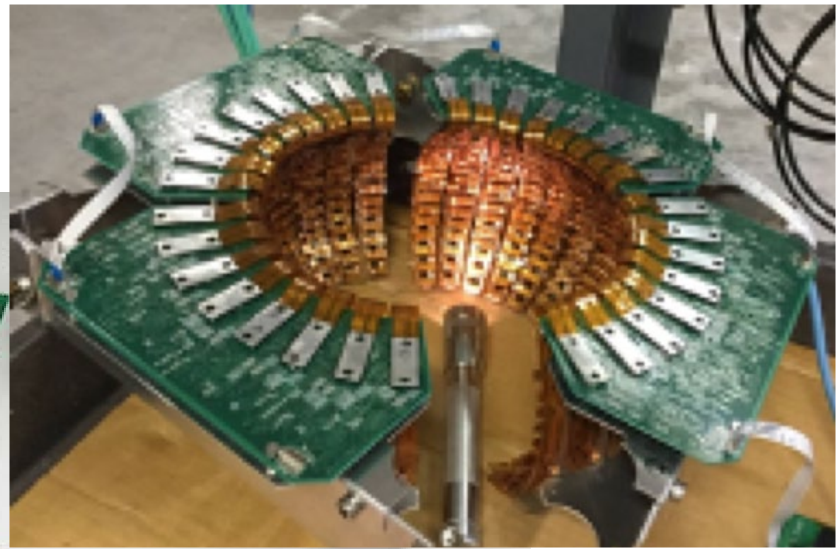


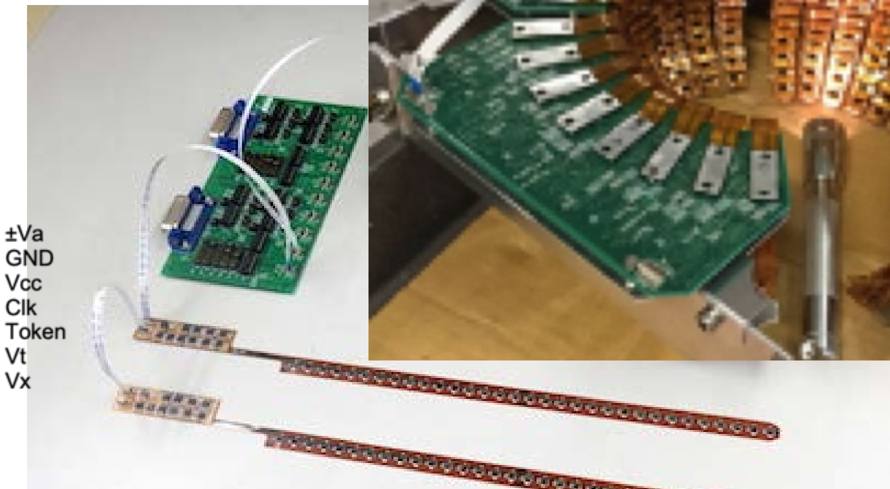


High Density XT-Mapping for 1.3-GHz cavity developed at Kyoto University

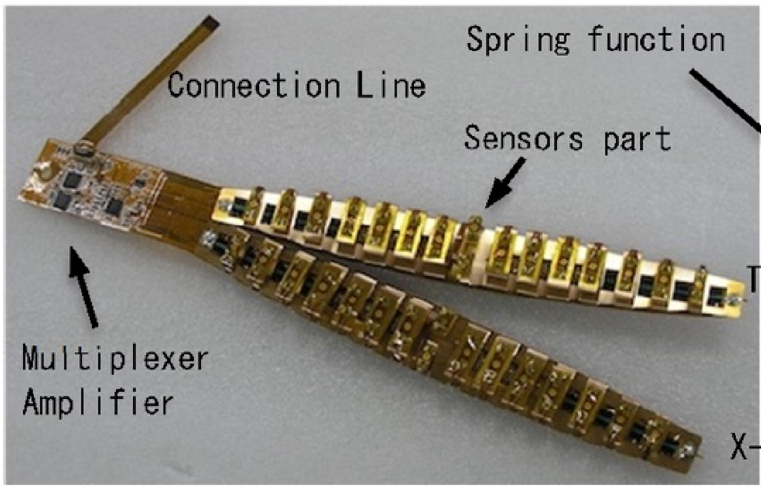


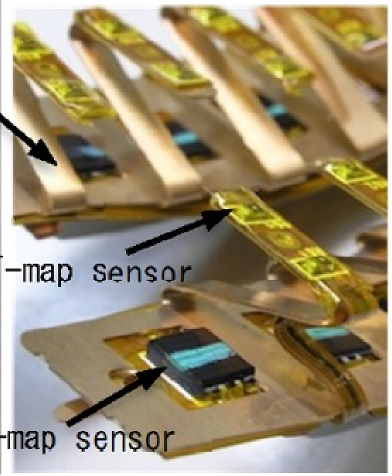
XT-map & sX-map





stiffener(strip) X-map

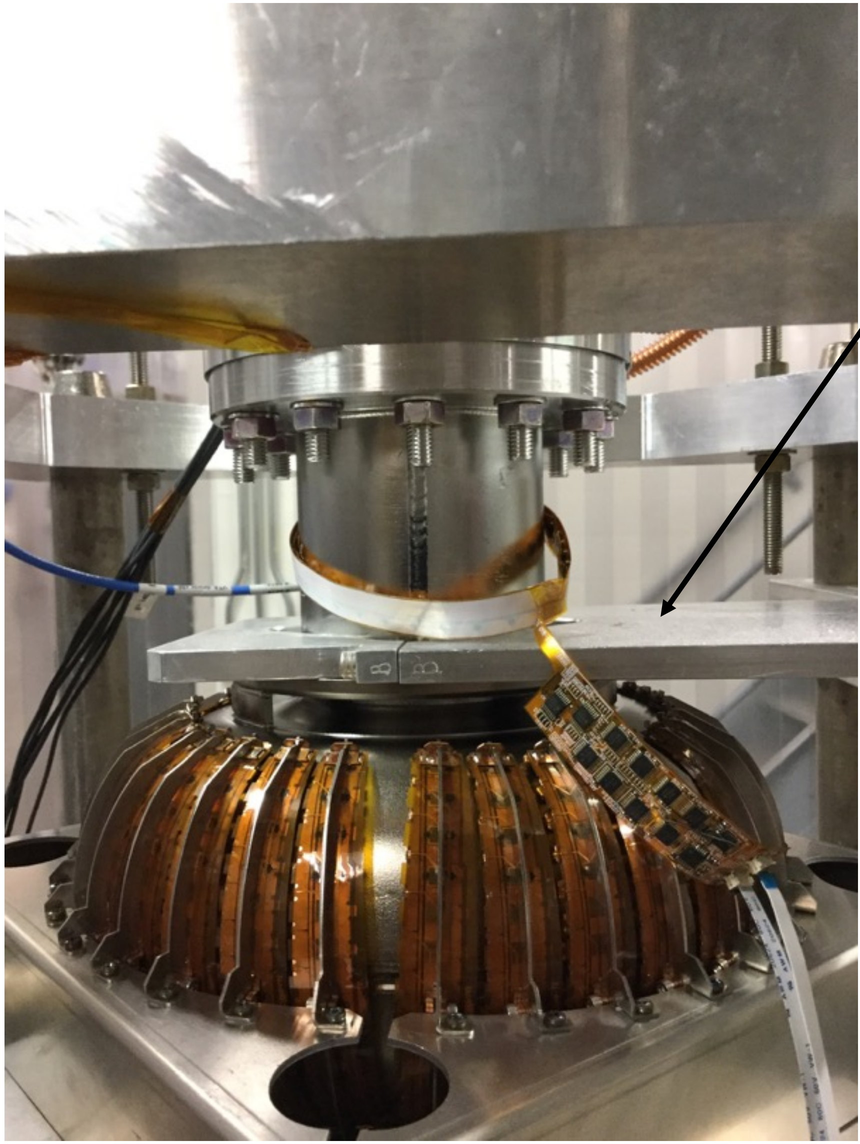




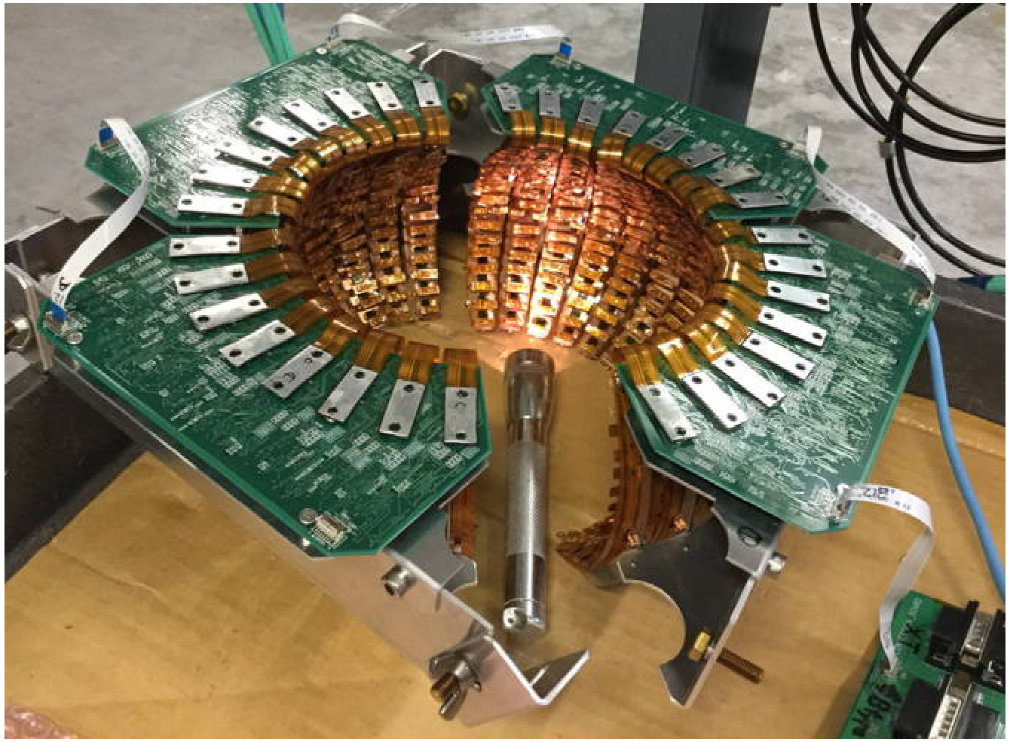
1.3GHz XT-map system test at Jlab (Nov. 2019)
1.3GHz 5-cell cavity / LSF5-1

T-sensors fit on the cavity surface.

1.3GHz XT-map system test at Jlab (17 Feb. 2020)
1.3GHz 9-cell cavity / LSF9



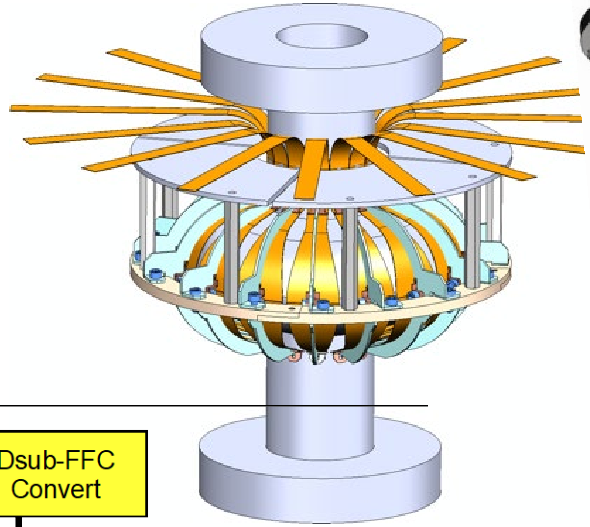
Installed upside down to avoid the interference.

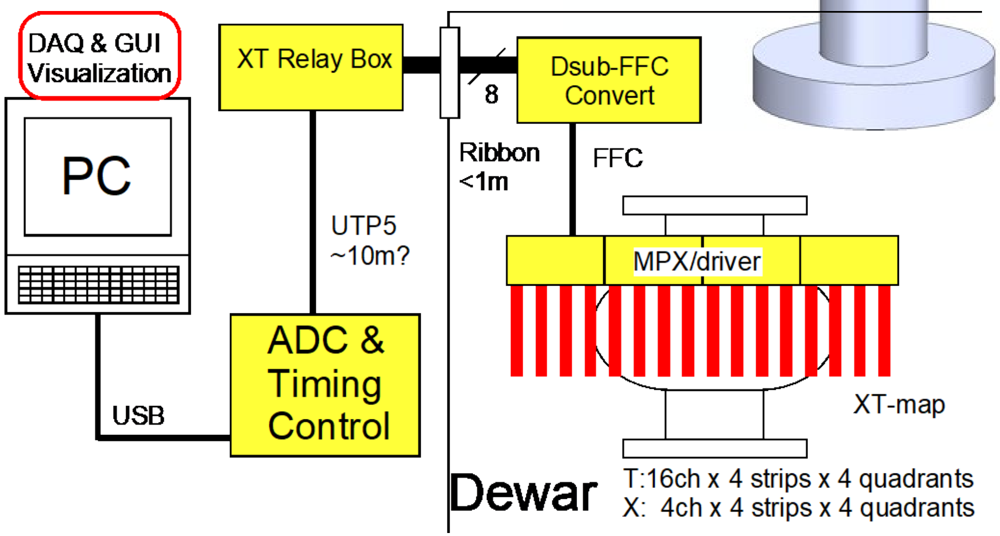


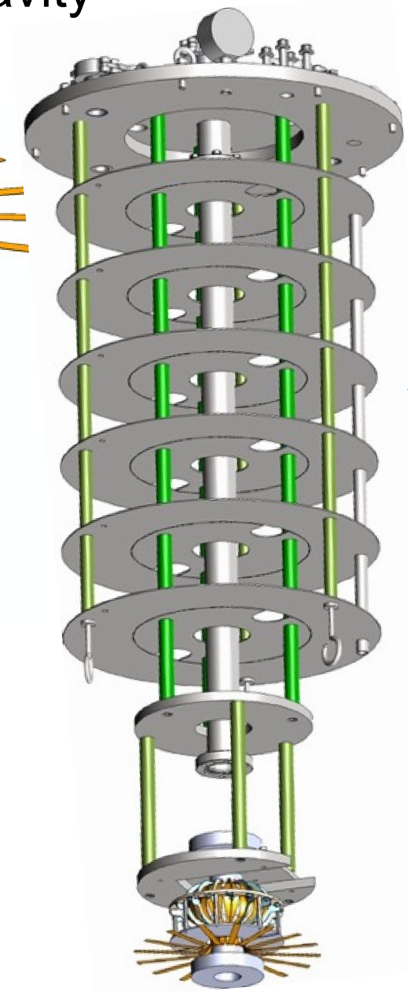
3GHz XT-map @ Kyoto U.

Test setup under preparation:

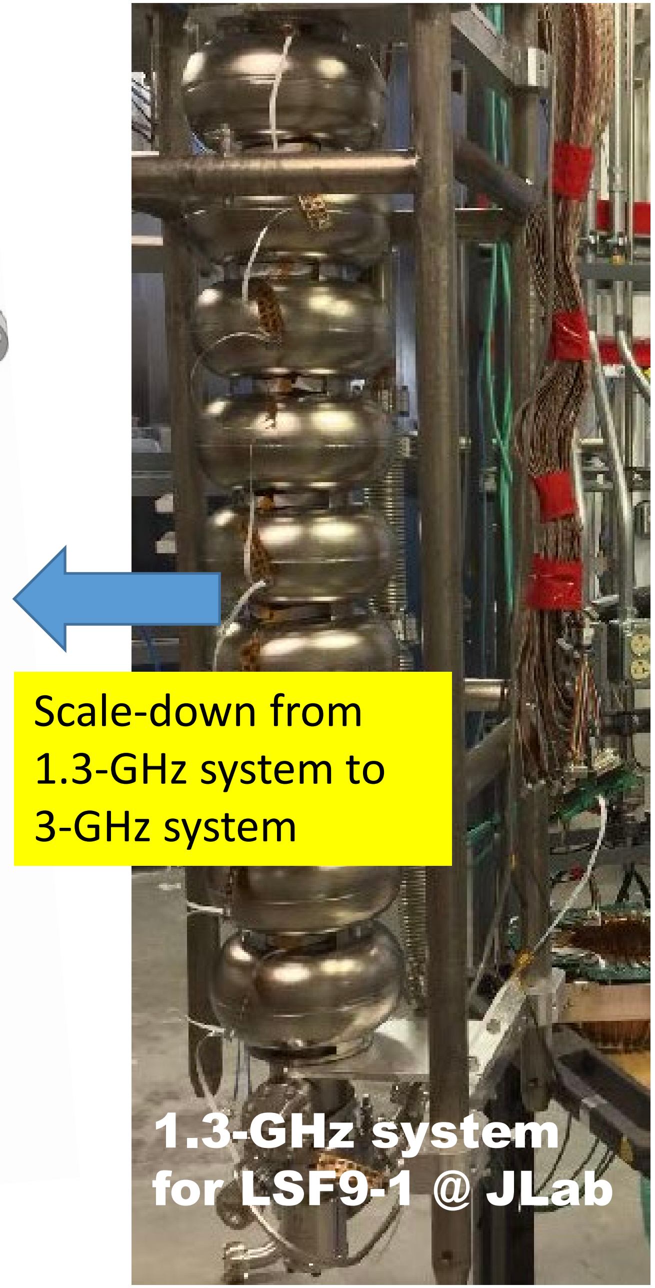
- Scaled down for 3GHz cavity.
- 4 X-sensors on a strip x 16 strips around the cavity
  → 64 X-sensors
- 16 T-sensors on a strip x 16 strips on the cavity
  → 256 T-sensors
- update rate:
  <10 scans/s
- 8 wires (UTP5)



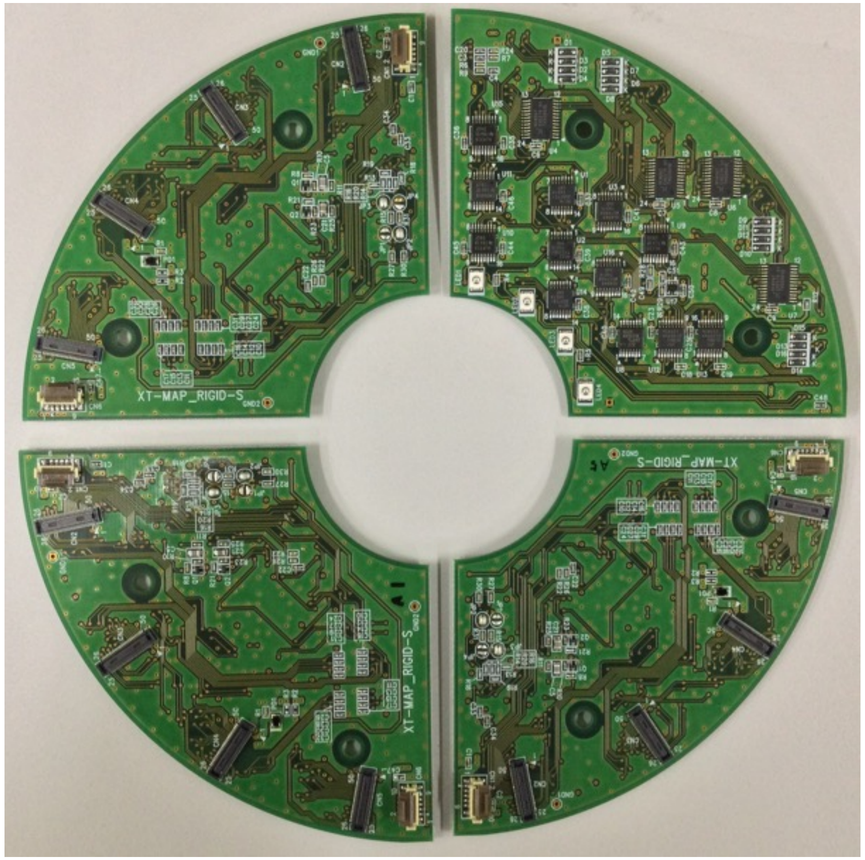


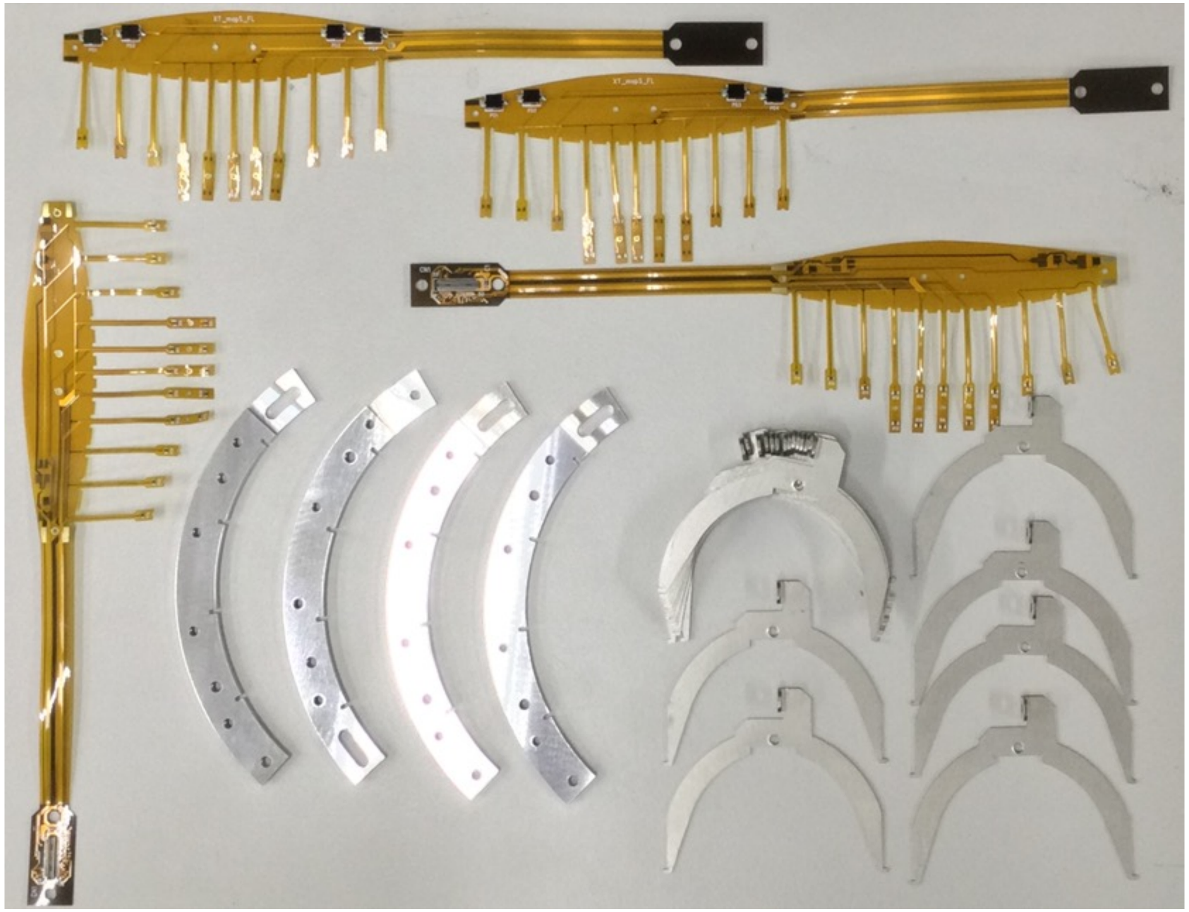


3GHz@KEK



Prepared Parts for 3-GHz XT-map system (Mar. 2021)





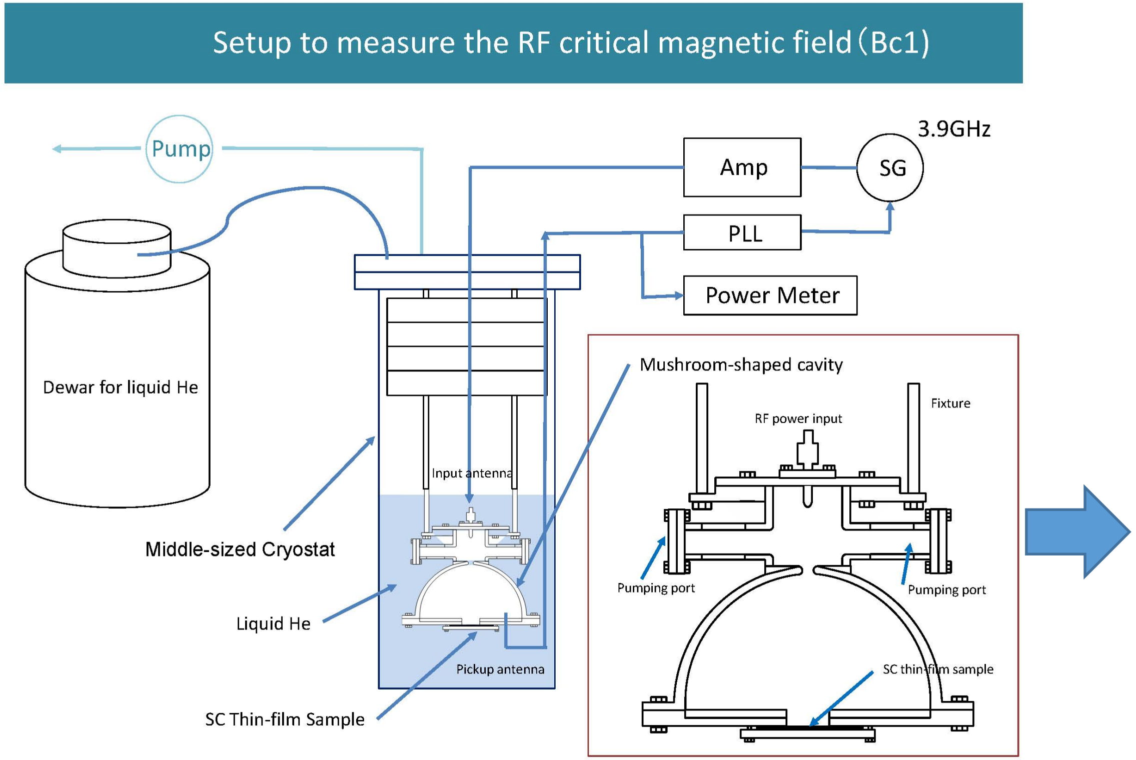
Multiplexer Board for 3-GHz cavity

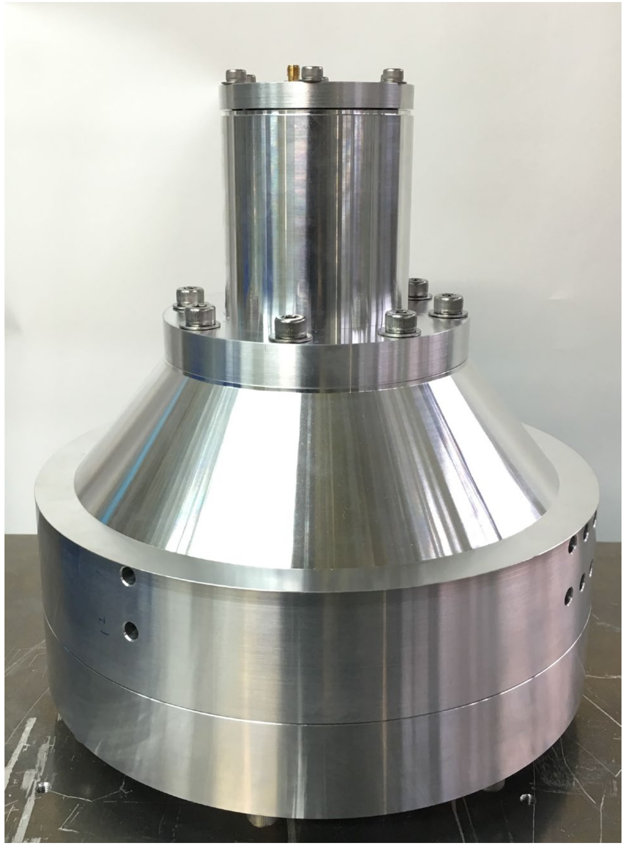
Sensor FPC

Fixing Jigs for 3-GHz cavity

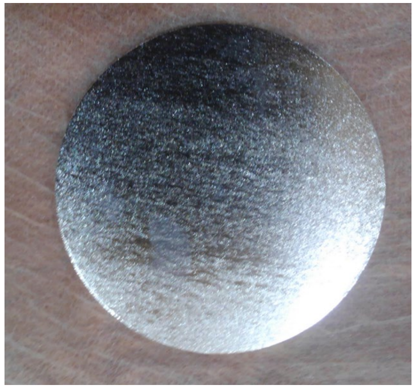
Plan of test by Nb-disc sample with mushroom cavity at KEK

Mushroom cavity test with disc sample for RF electromagnetic field is in-between third-harmonic DC test and SRF cavity test.

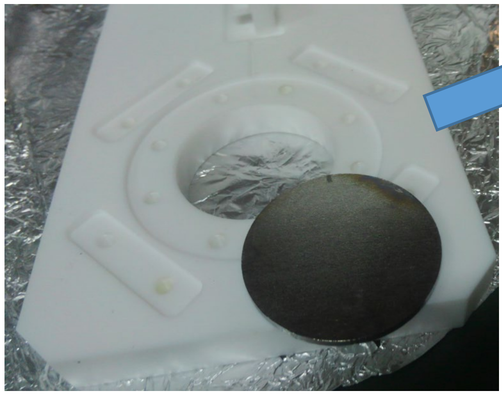


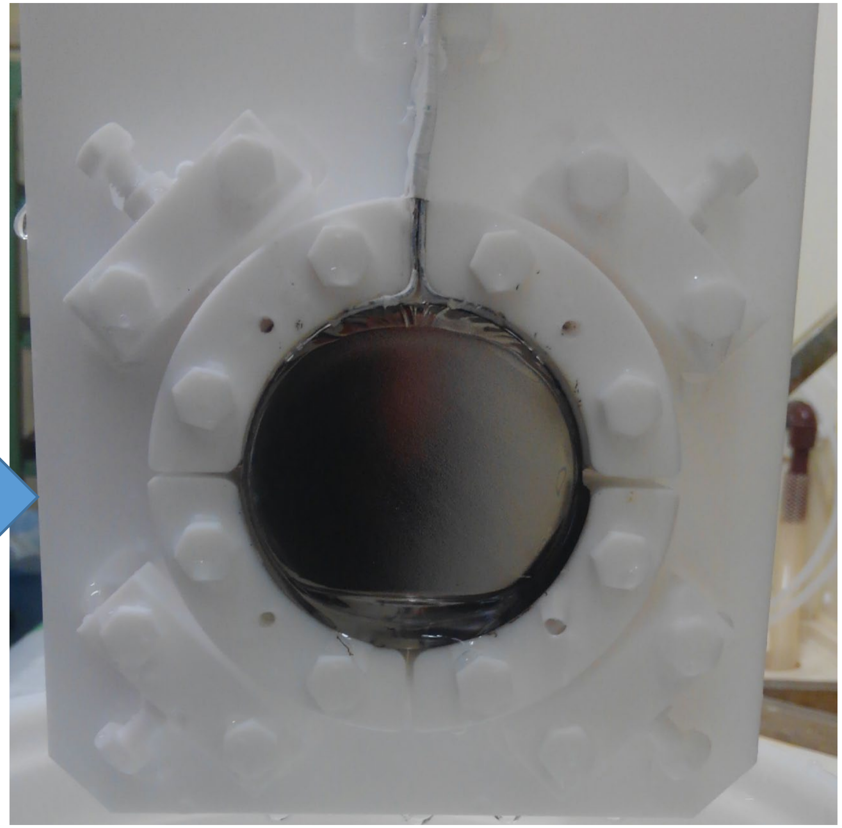


Development of special EP fixture for Nb-disc sample of mushroom cavity



After BCP processes





After EP process, smooth surface was obtained on Nb disc sample.

Summary

- Utilization of 3-GHz cavities might save the budget and resources of studies compared with the studies by 1.3-GHz cavities. And it might speed up the studies of thin-film coated cavities.
- Fabrication of 3-GHz single-cell Cu and Nb cavities in collaboration of Jlab and KEK is shown.
- Fabrication of coupon 3-GHz single-cell cavities is shown. And plan is explained to use it for the thin-film creation test at ULVAC.
- Preparation of 3GHz cavity vertical test stand at KEK is reported.
- Development of 3-GHz XT-map system at Kyoto university is reported.
- Special EP setup for Nb disc sample for mushroom cavity test is developed at KEK.