Bus Extender Status

Takashi Hachiya

Nara Women's University & RIKEN BNL

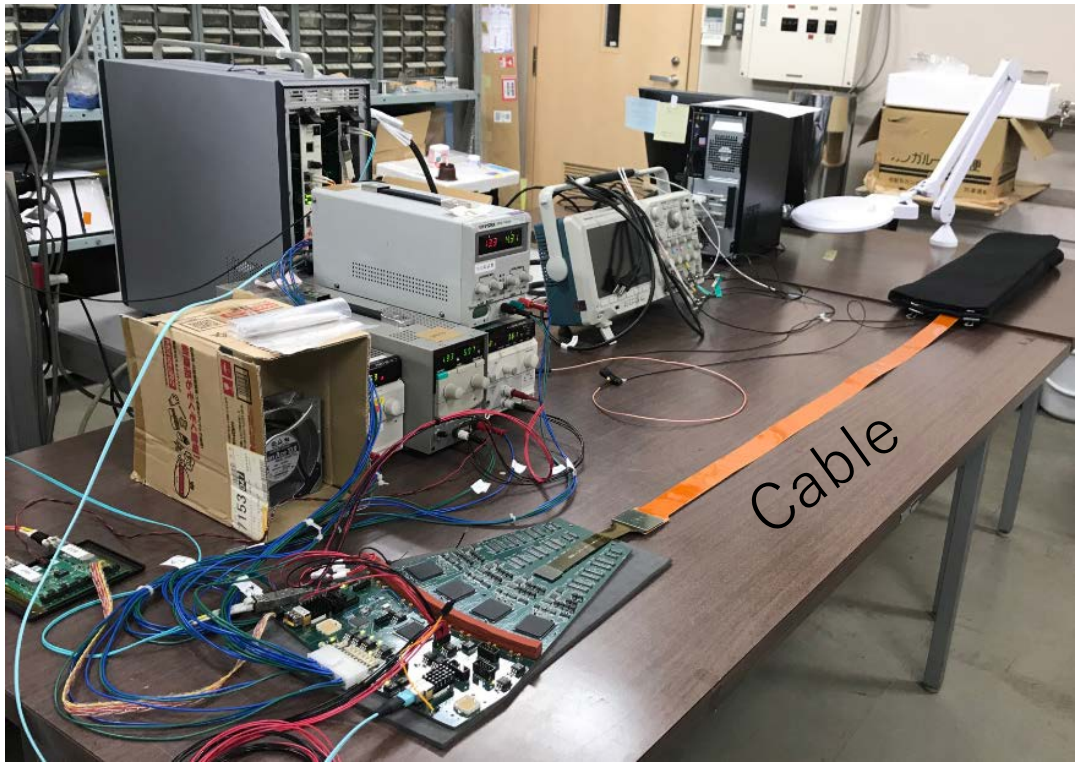
Bus-Extender = Very long data cable

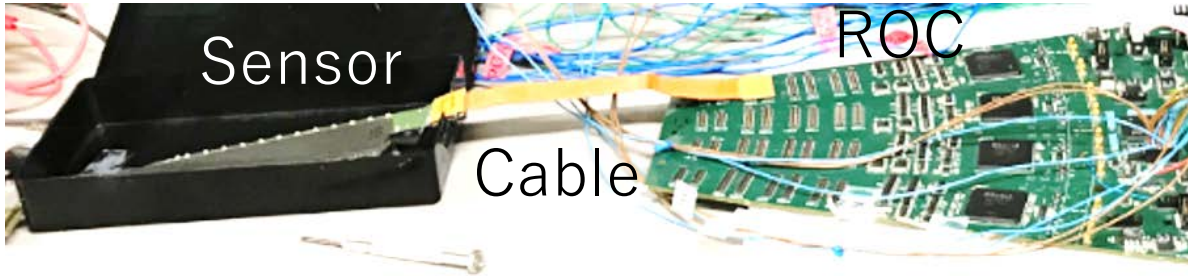
- Follow the FVTX tech -- FPC
- Status
  - Design completed
  - Prototype tested at FNAL beam test
  - Performance looks OK

- Issues
  - Remain in the production

	FVTX	INTT
Length	10~30 cm	**120cm**
Layer	7	4
Signal	62 pairs (LVDS)	62 pairs
Power	V-a, V-d, GND	V-a, V-d, GND
Substrate	Polyimide	LCP
Impedance	50	50

There are some remaining issues



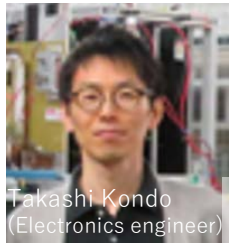


Short summary

INTT R&D team in Japan including Bus-Extender R&D (7 stuff and 8 students)


Itaru Nakagawa

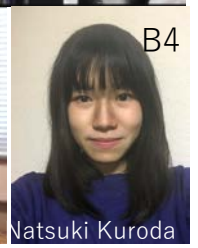

Shoichi Hasegawa


Takashi Kondo
(Electronics engineer)


Daisuke Yanagawa
(Mechanical Engineer)


Genki Nukaduka


Takashi Hachiya



- R&D for remaining issues
  1. Through hole issue we found recently was studied

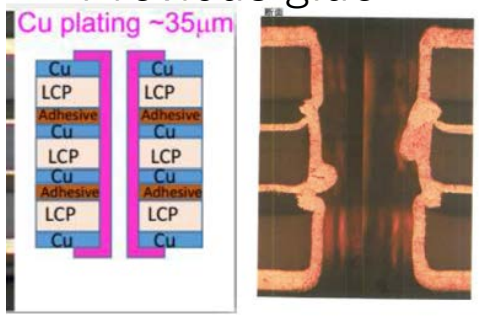
  2. Radiation hardness
     - FPC samples are exposed with 5k, 500k, 1000kGy with strong ^{60}Co source

  3. Yield rate issue – currently 20~30% (4 / 12)
     - Single lines are so thin and 1% of lines is failed (124 lines per bus-extender)
       - Line becomes short and open circuit.
     - Preparing new testing fixture to find open/short circuit

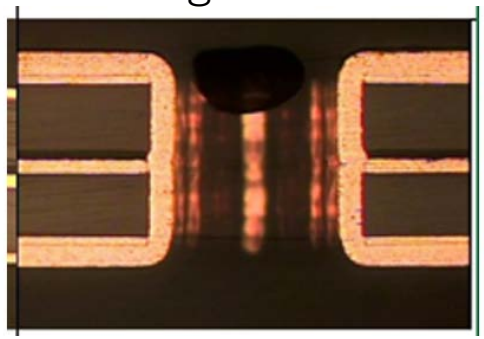
1. Through hole issue

- Through hole issue was fixed with new glue
  - Nodules and cracks with previous glue were disappeared
- We recently found there are small bump with new glue
  - The cross section of the hole shows that LCP pushes the surface
- To confirm if it is OK or not, we re-did the thermal shock test

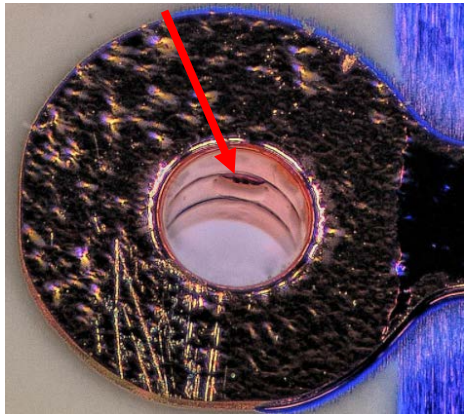
Previous glue



New glue



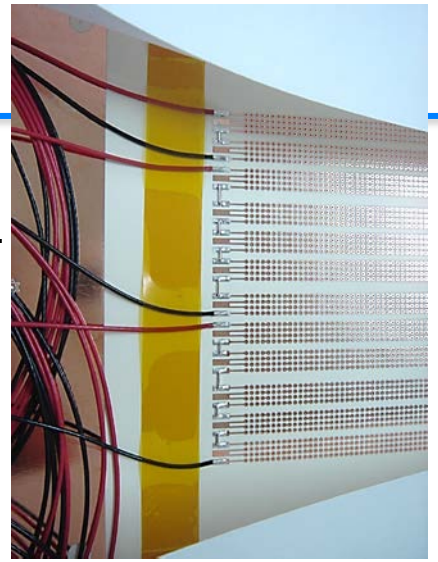
Small bump with new glue

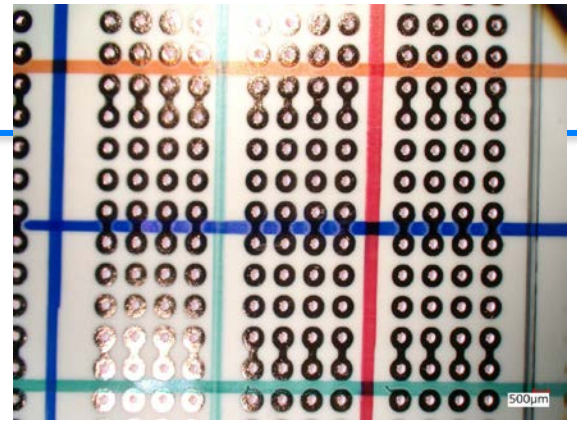


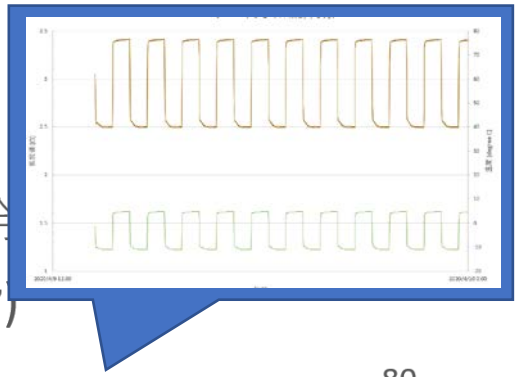
Cross section

Thermal Shock Test

- Temperature cycle (same as before)
  - -15 (30min.) ~ 75°C (30min.) with 1~2min. transition.
    - Equivalent to -50～125°C(30min.) for polyimide
    - Thermal expansion of LCP is ~2x than Polyimide. Temperature is set so that the thermal expansion is the same
      - LCP:206ppm/°C、Polyimide:～100ppm/°C
  - 1000 cycles (40 days)







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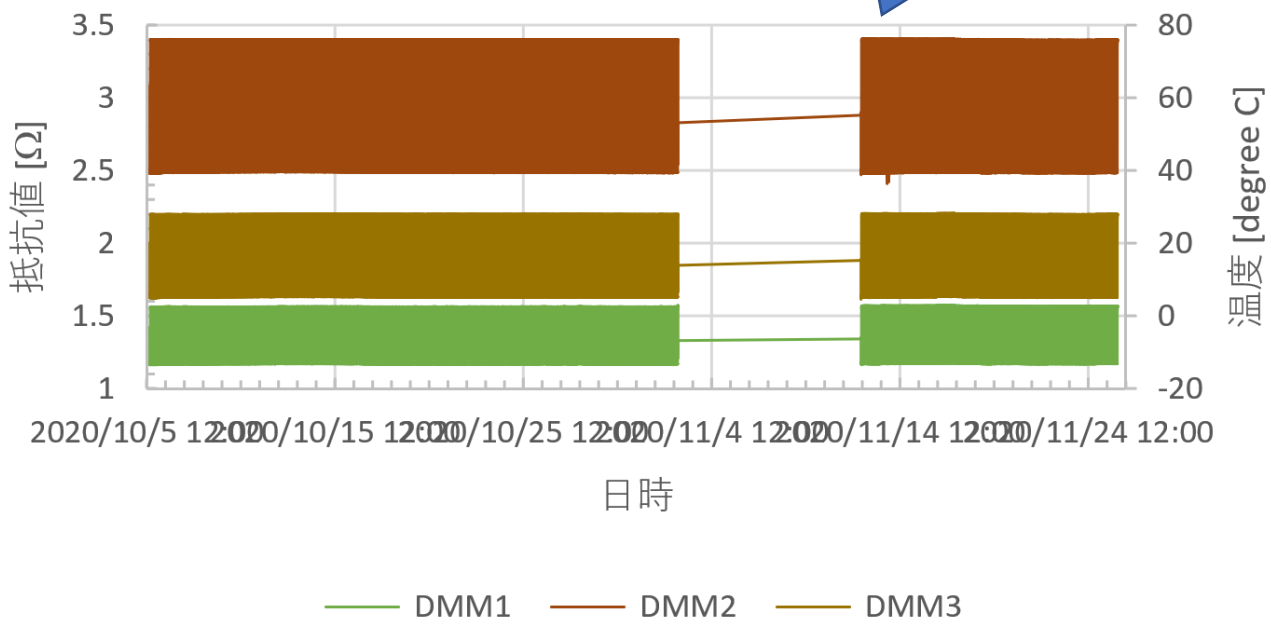
(2020/10/05~)

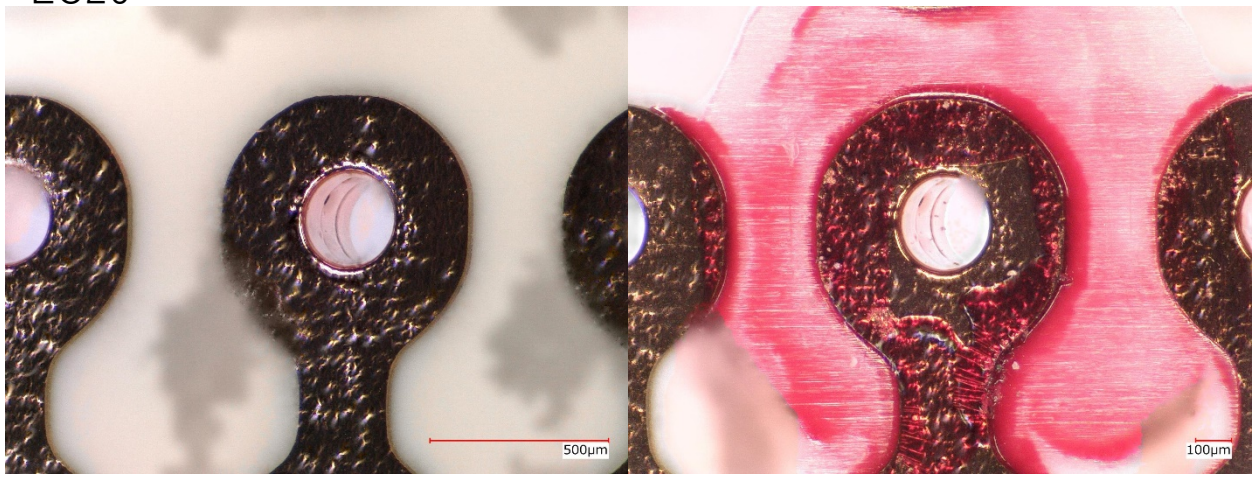


- Test FPC
  - 4 layers, same as bus extender
  - 400, 600, 1000 holes are daisy chained respectively and continuously monitored the resistance of the chain.

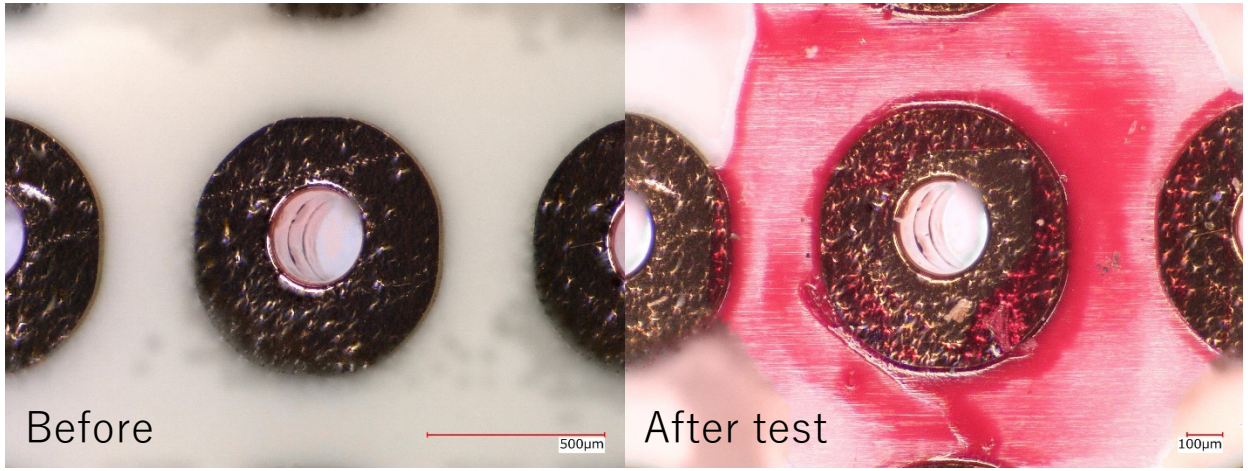
- Results
  - Resistance changes with temperature
  - All chains are healthy after 1000 cycles.

Visual check before and after the test

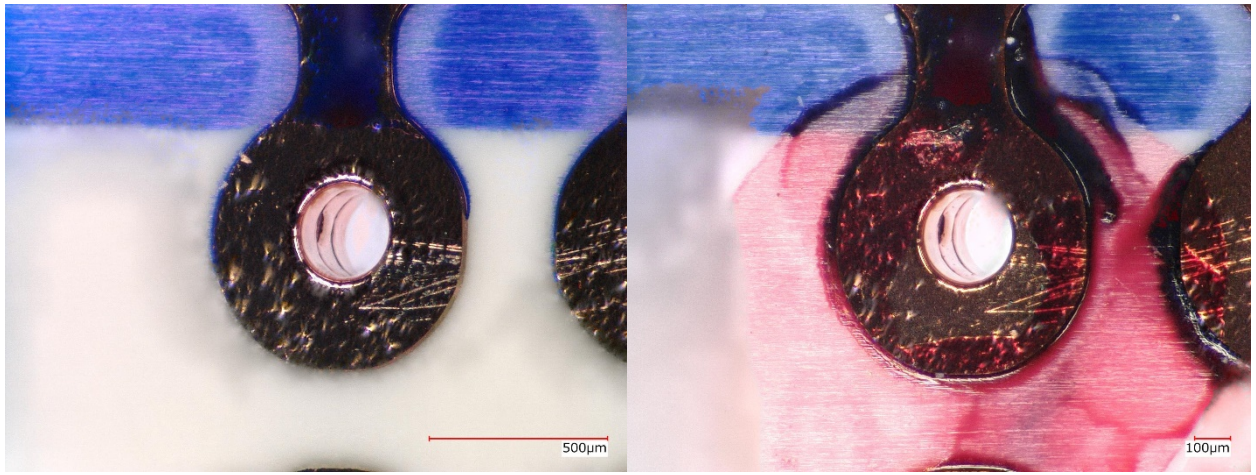
EC20



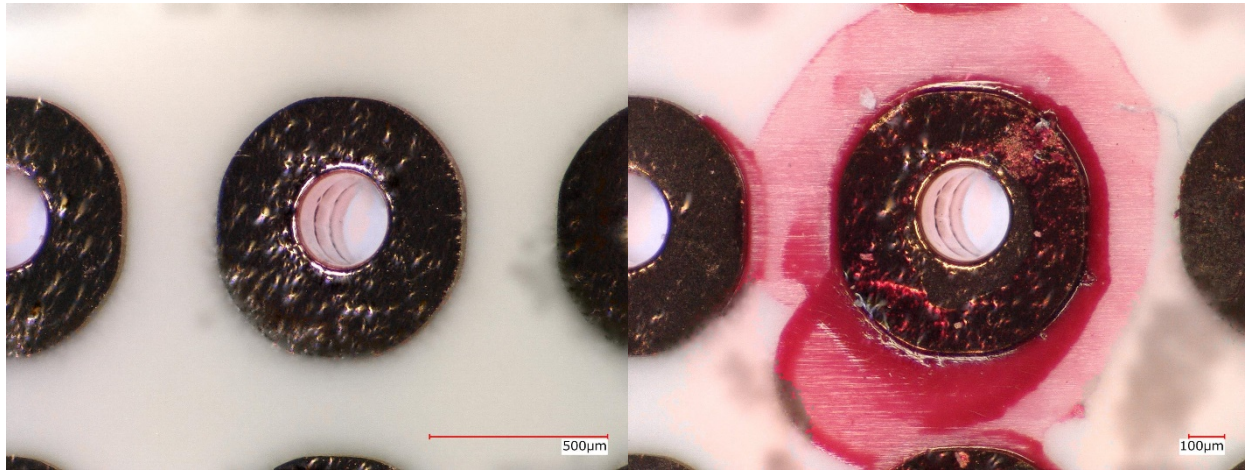
EC26



HA29



HB26

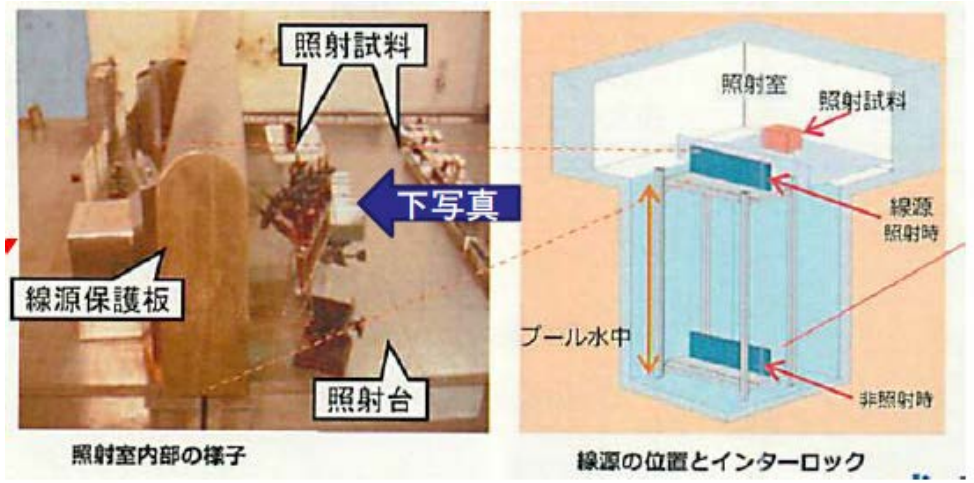


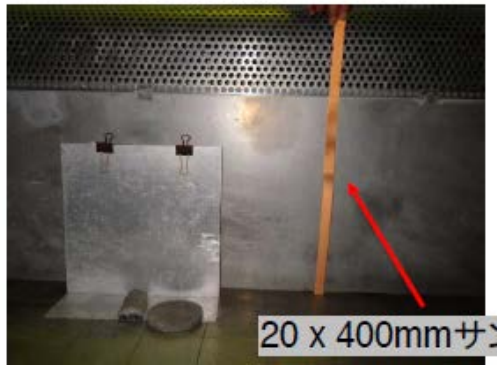
- No (visible) change after the test.
- We conclude the module we found is not problem, OK for use

Radiation hardness test

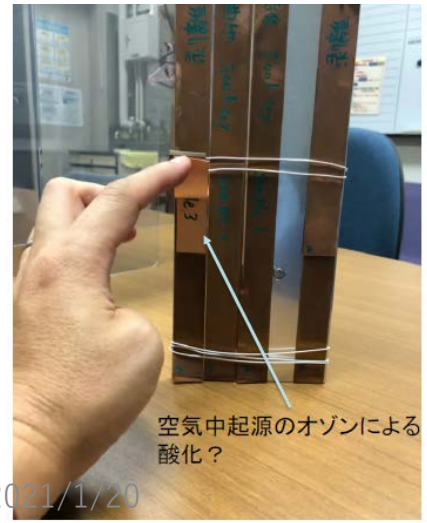
- Radiation from data taking period may damage the physical characteristics of bus-extender
  - 5kGy is typical dose from the expected luminosity with 5 year run of sPHENIX

- FPC samples are exposed with 5k, 500k, 1000kGy
  - Test facility has very strong ^{60}Co source in Japan (Takasaki QST)
    - Took a week for 1000kGy
    - After the exposure, FPC sample get dark because oxidized by Ozon

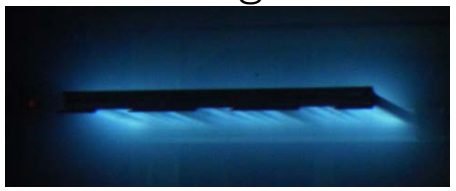


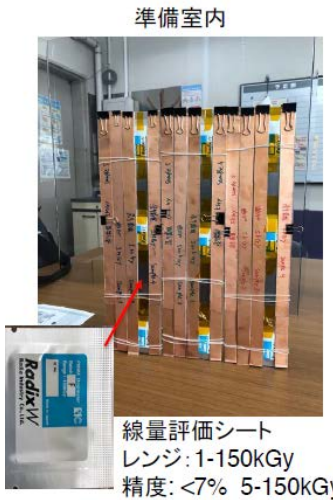


FPC sample after radiation exposure



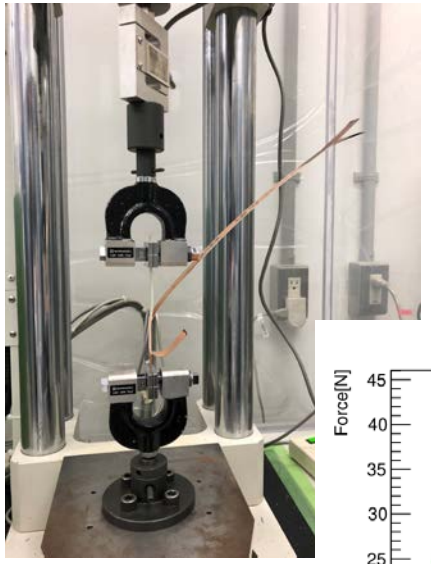
Cherenkov lights in water

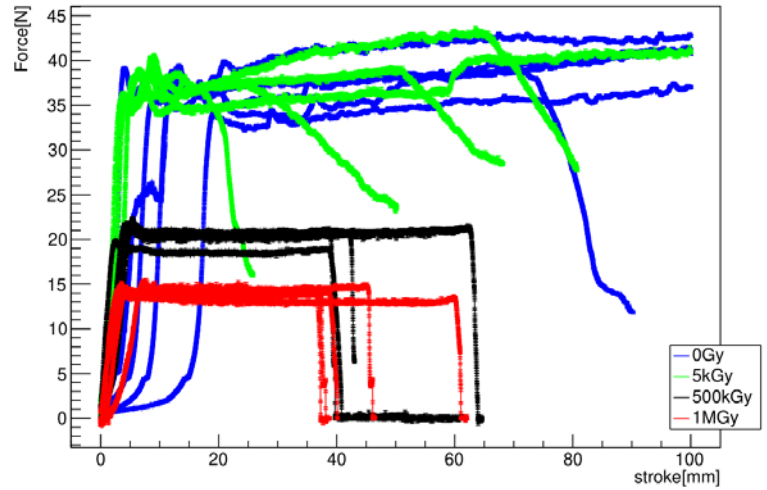




Radiation hardness test

- We tested the radiation hardness by measuring:
  - Peel strength
  - Bending elastic modulus
  - Itaru, H. Imai, D. Imagawa, M. Morita measured them

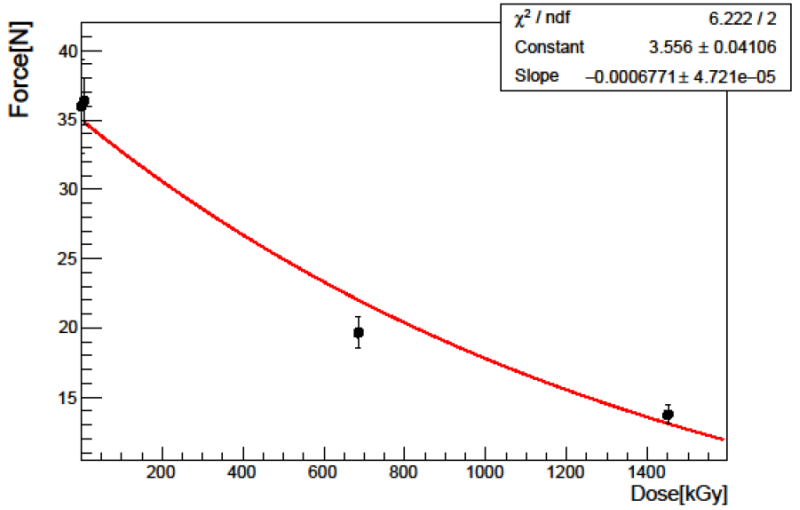




- Peel strength by tensile test
  - Snapshot of the analysis

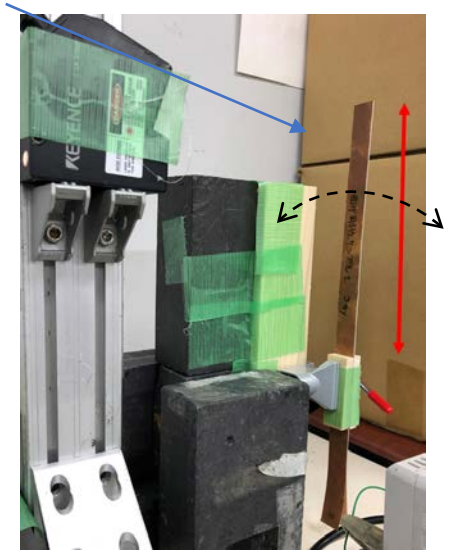
Miu Morita

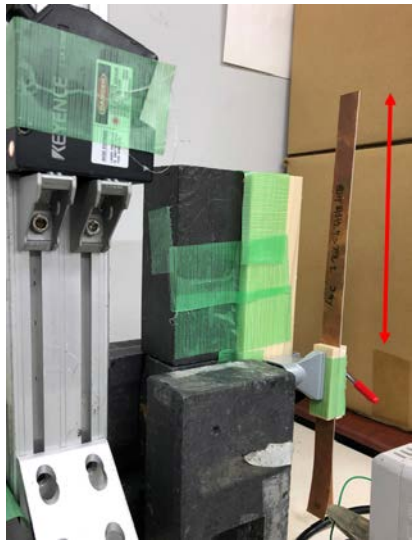
  - Peel strength look no change with 5kGy and get reduced with higher dose.
    - ~15N(/2cm) at 1000kGy
      - Could be OK
      - Polyimide shows ~20N(/2cm) without dose



Radiation hardness test2:

- Bending elastic modulus
  - the natural (proper) frequency is measured
    - FPC sample is flicked by finger to vibrate

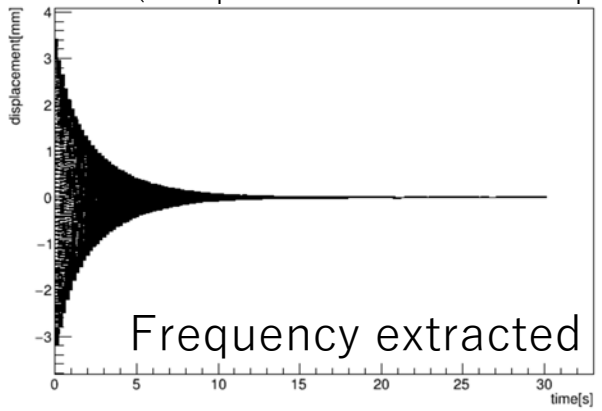


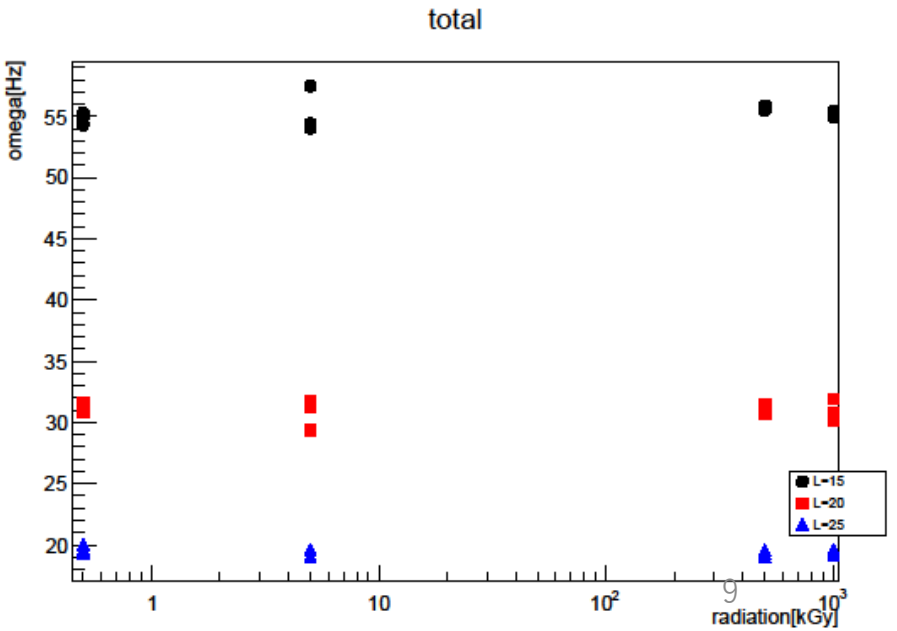


$$f_n = \frac{\lambda_n^2}{2\pi l^2}\sqrt{\frac{EI}{\rho A}}$$

$f \rightarrow$ frequency
$l \rightarrow$ length
$\rho \rightarrow$ density
$A \rightarrow$cross-section
$\lambda \approx 1.875$

Raw data (Dumped vibration of the sample)





  - To check if the measurement is OK, we measured the sample several times with the different arm lengths (15, 20, 25cm)
- Result shows same value of the bending elastic modulus

Radiation hardness test2:

- Bending elastic modulus
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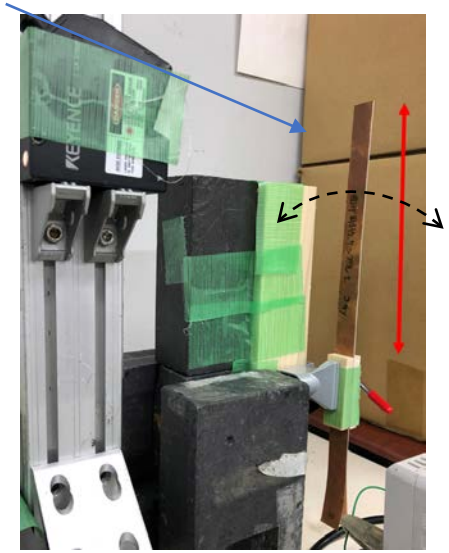
    - FPC sample is flicked by finger to vibrate



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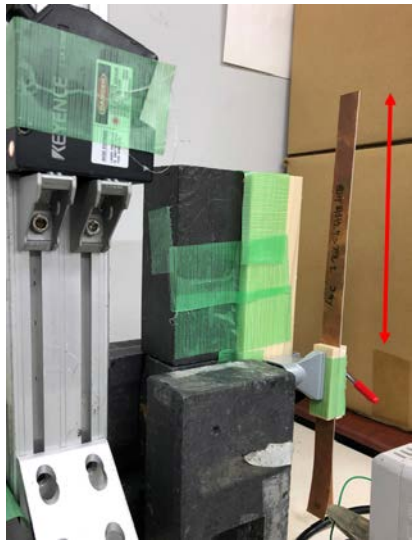

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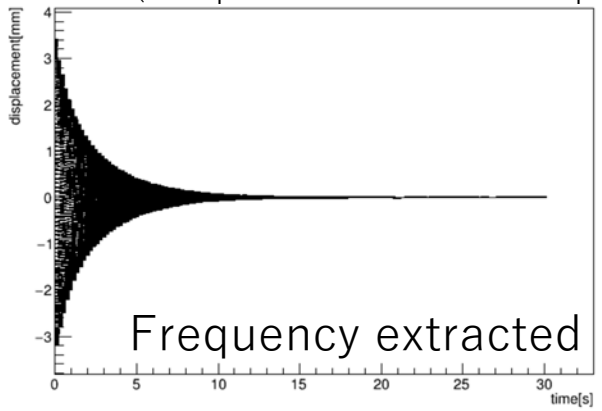
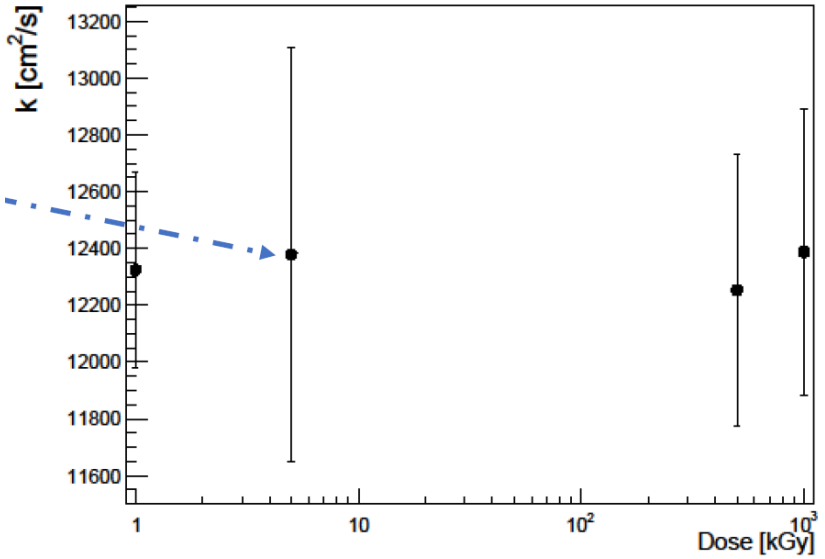


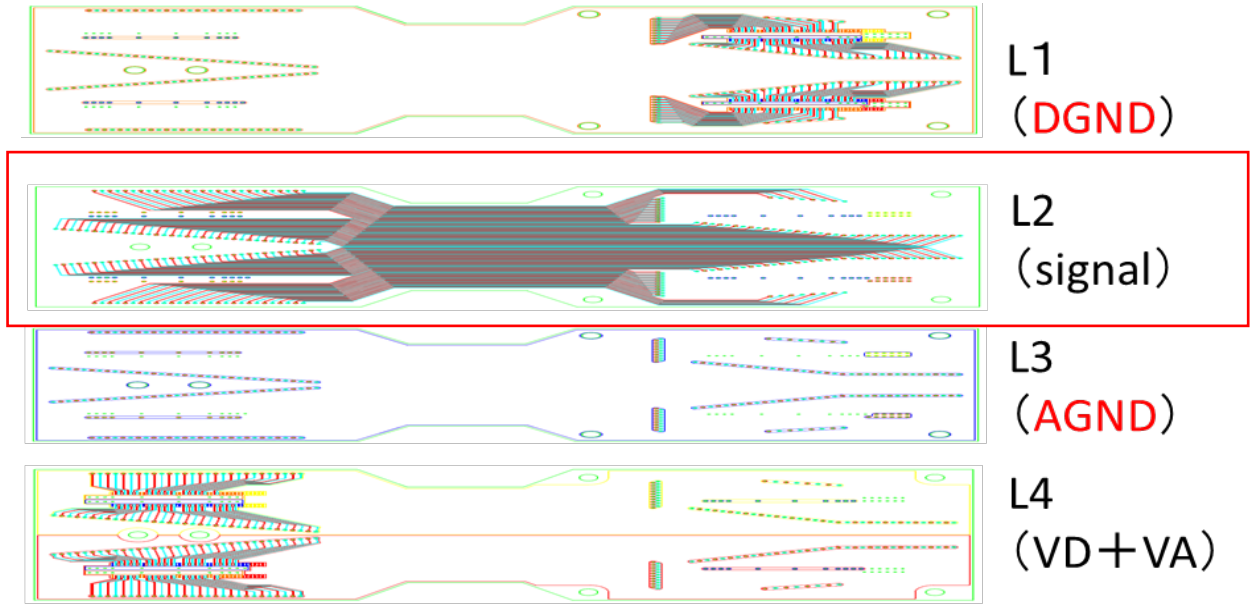
$$K = fl^2 = \frac{\lambda^2}{2\pi}\sqrt{\frac{EI}{\rho A}}$$



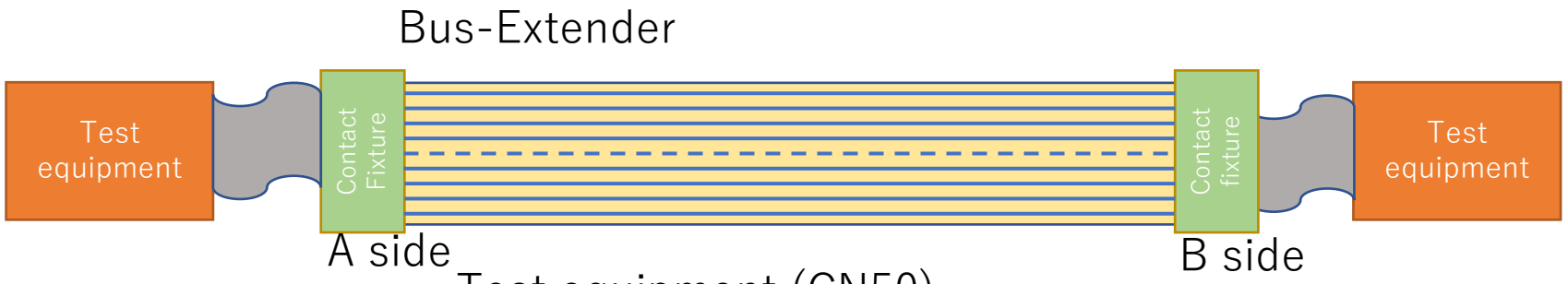
  - To check if the measurement is OK, we measured the sample several times with the different arm lengths (15, 20, 25cm)
- Result shows the bending elastic modulus seems to be flat
  - No effect by radiation

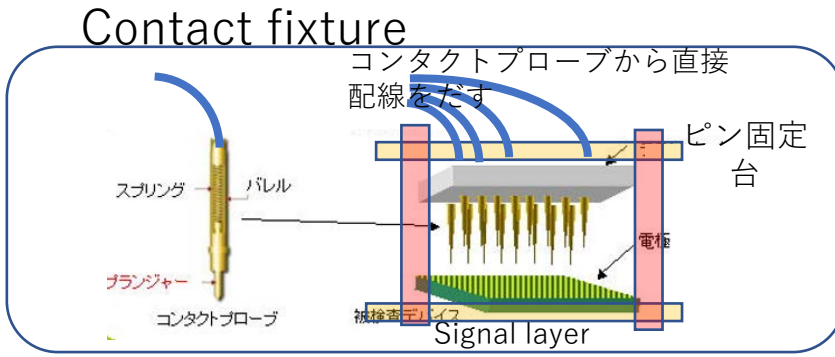
Continuity check of Bus-extender

- Yield rate issue
  - Yield rate is low because some signal lines gets short/open.
    - The situation was improved but still the short/open lines happens ~1% level, at least 1 line / 1 bus-extender (124 lines)
  - Check the continuity of all signal lines at L2 layer during the production
    - Fixture & test equipment is under preparation



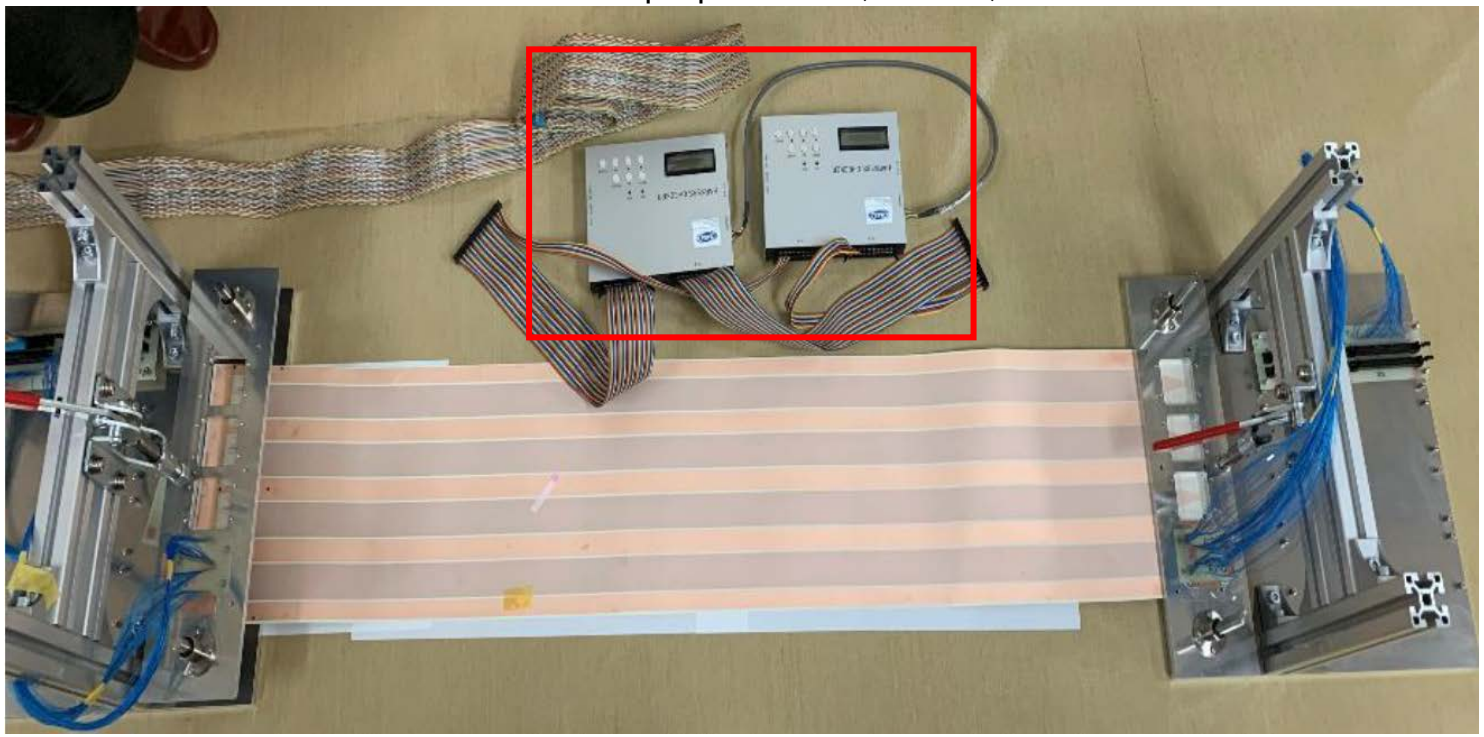
Test equipment and fixture





Contact probe (spring pin)

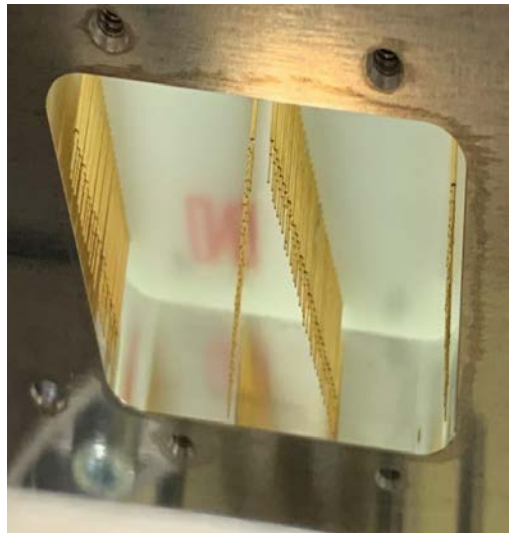
Test equipment (CN50)



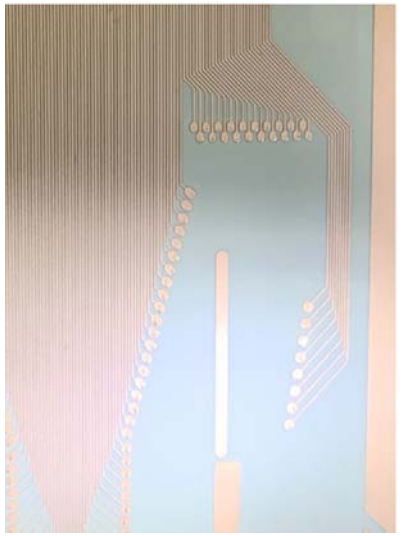
CN50 check open/short status of 100x100 combination

- A x B, and A x A, B x B as well,
- Takes ~10s for scan, so quick. Results can be recorded by PC

Contact probe (spring pin)



2nd layer (signal lines)



The contact probes touch the lands for through hole.

First result

B side

1: connected (short), 2: disconnected(open)

A side

- Diagonal part =1 means “connected”, others =0
- This test equipment works nicely.

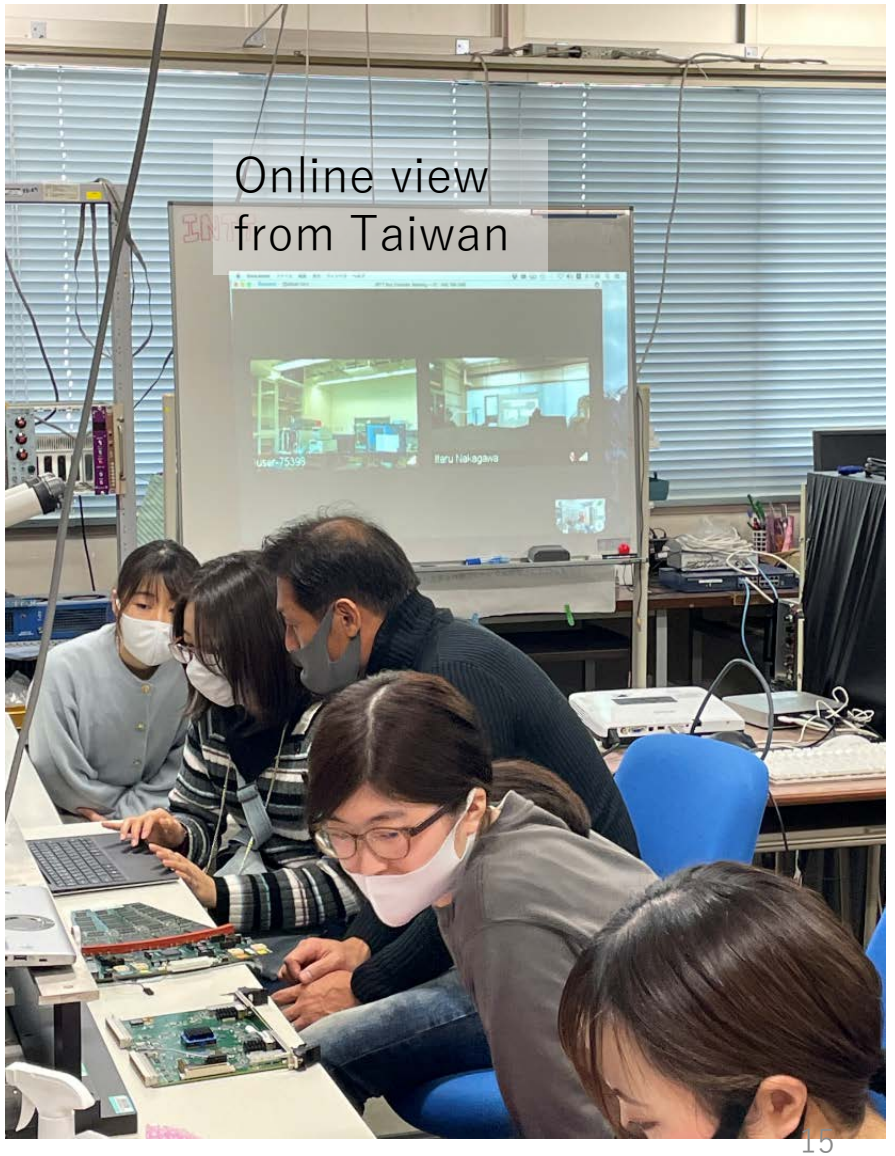
Test equipment for the final BE

- Plan to use the same equipment to check the continuity of the final BE products
  - Just connect with DF18 connector instead of the contact probes

Taiwan – Japan (NWU) Online Workshop Dec. 7 – 9, 2020

- Keep online for 3 days to work together on the issues of the test bench and/or INTT sensor module
  - Discussed what to do
  - Took data with the same condition and check
  - Finally found some causes of the issues – Voltage drop

- The online workshop is useful even though under the severe CORONA situation
  - Similar with what we do in the in-person workshop



Short summary

- R&D status
  - Through hole issue we found recently was studied
    - Did thermal cycle test again
    - Comfirmed the current through hole is good to use
  - Radiation hardness
    - FPC samples are exposed with 5k, 500k, 1000kGy with strong ^{60}Co source
      - Peel strength looks reduced with higher radiation dose
      - Bending elastic modulus doesn't change
    - Bus-Extender has good radiation hardness
      - The more detailed analysis is on-going
  - Yield rate issue – <1% of lines gets problem(open/short)
    - New test system checks the continuity of signal lines one by one
    - is almost ready to use