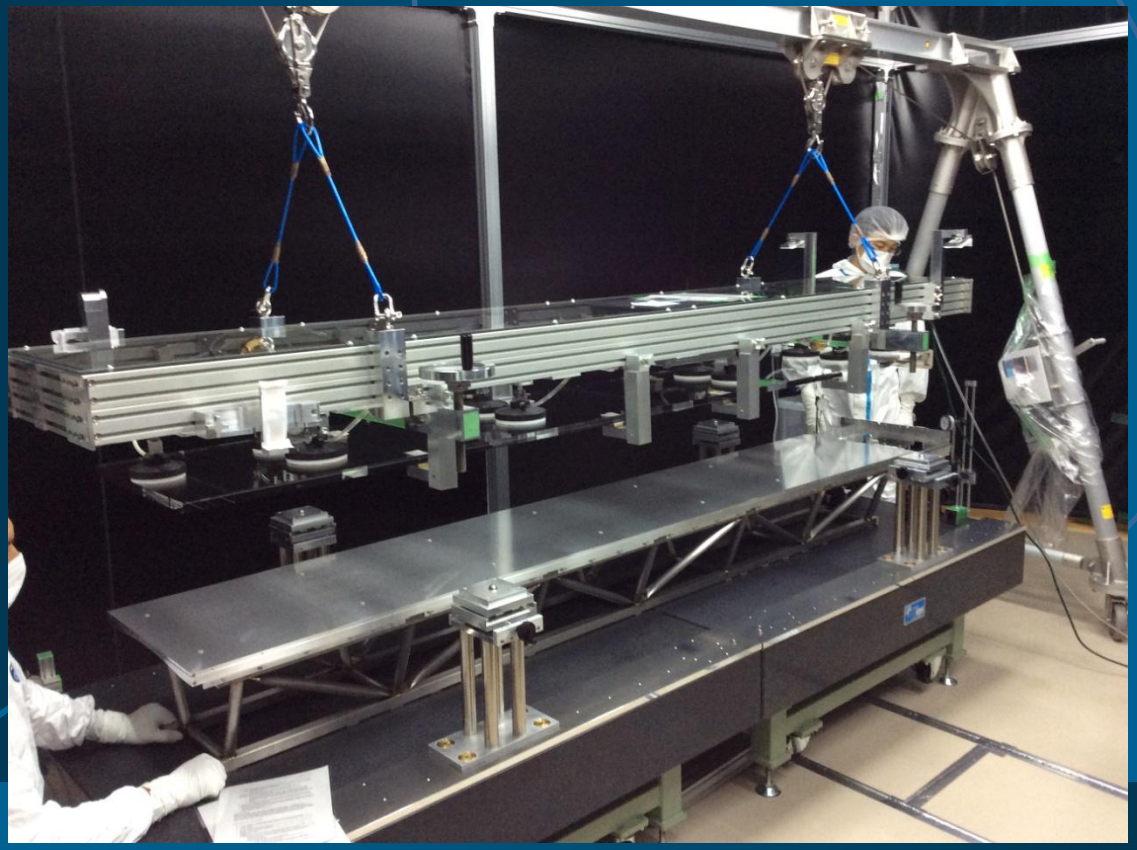
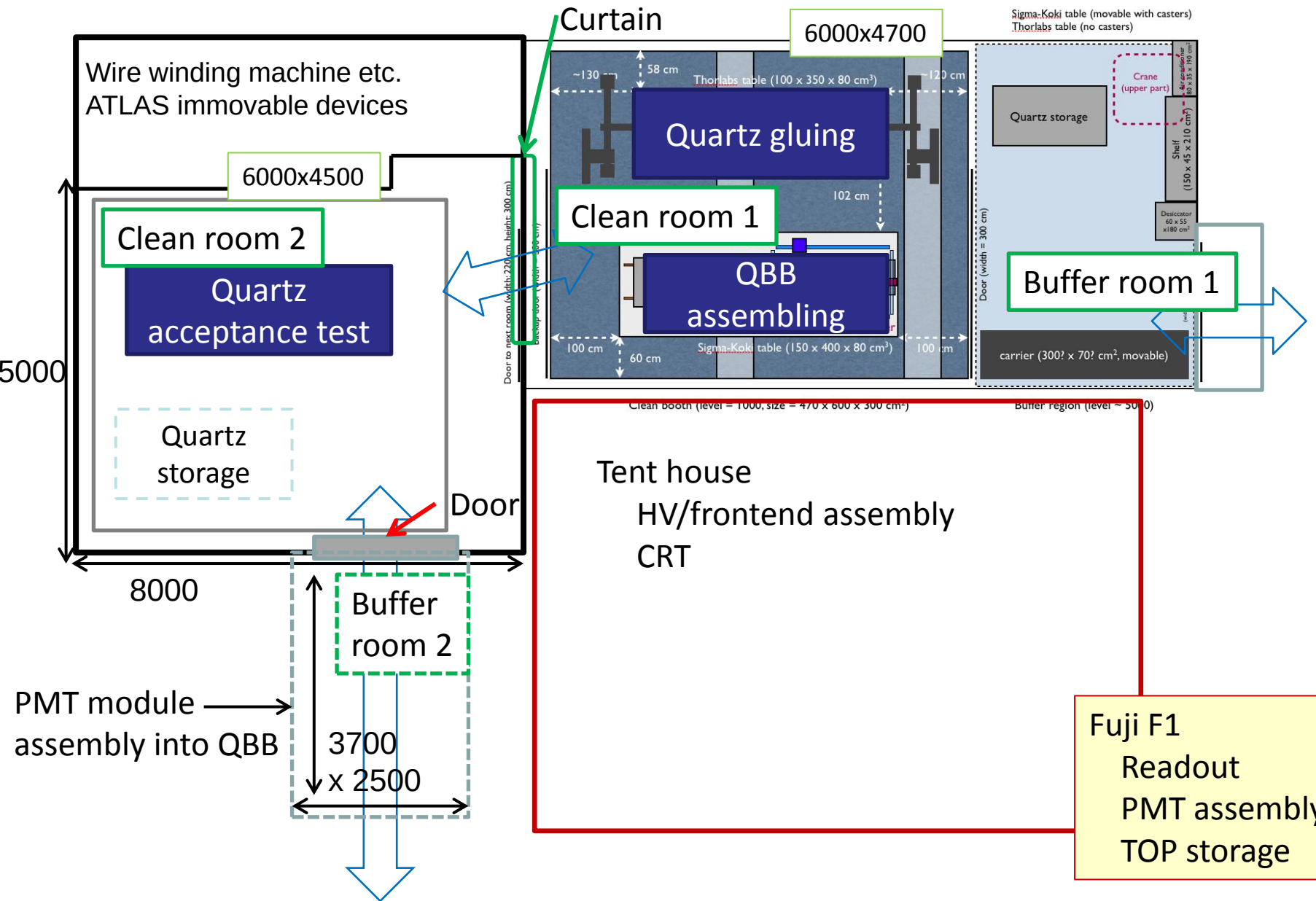
Optics and module assembly +MCP-PMTs

K.Inami



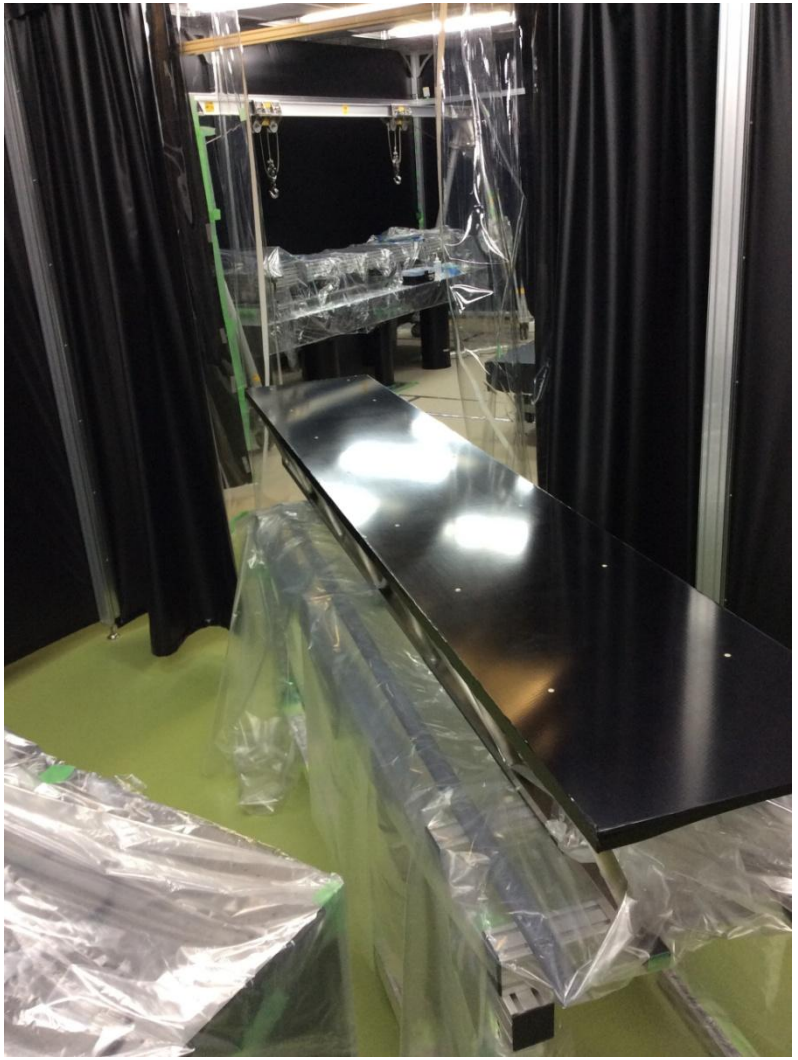
Room for module production



Clean room for quartz assembling

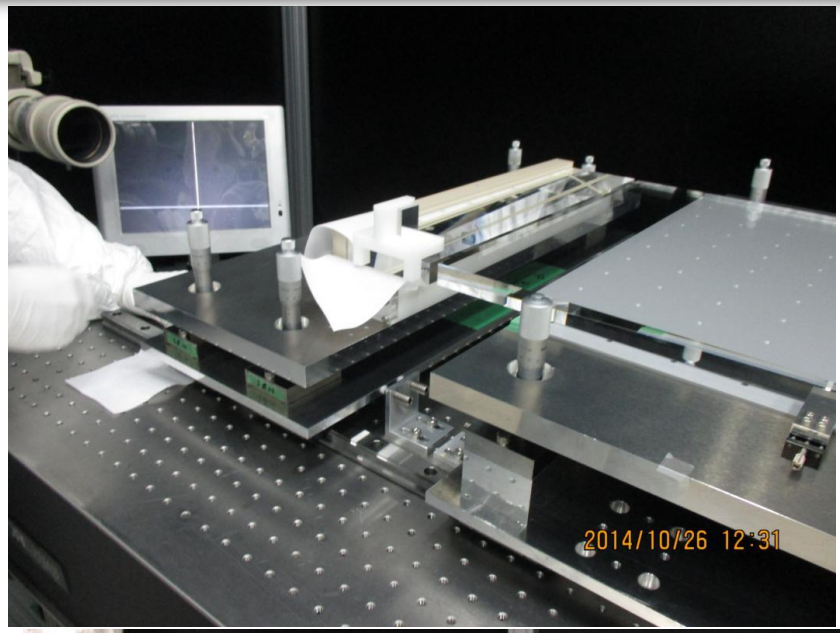
- Quartz acceptance test at room2
- Quartz glue at room1
- Optics and QBB assembling at room1
- Clean level is 100~1000.

From clean room 2 to clean room 1



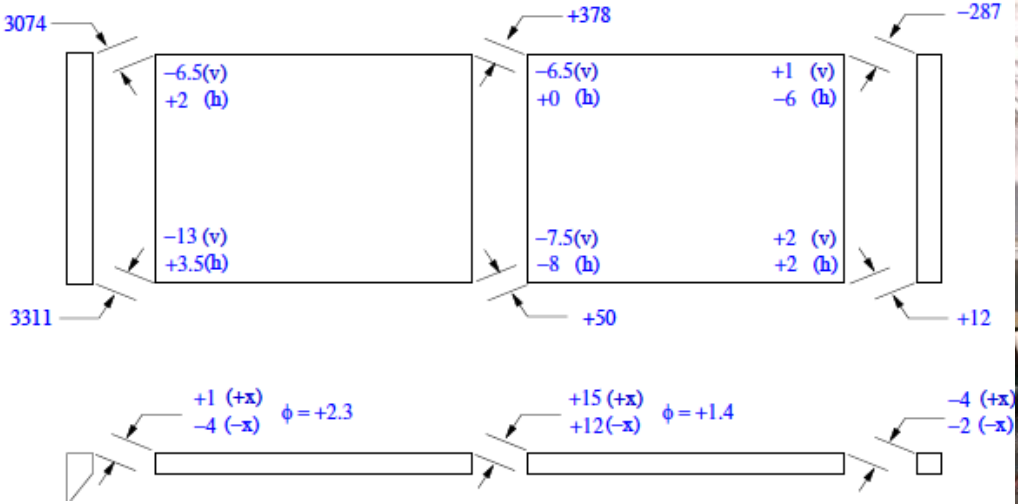
Quartz Alignment

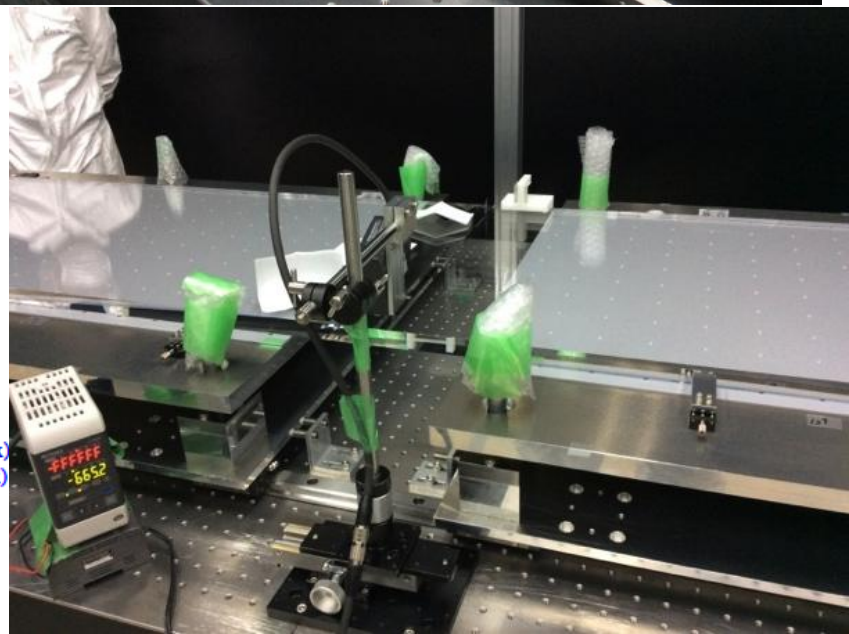
- Quartz alignment with gluing stage, autocollimator, and laser sensors, with procedures based on dry runs.



Module: 01 Units: microns/arcseconds Angle sign convention: AC at prism (+z) side

prism: 449006 base bar: OOW 3 front bar: OOW 1 mirror: SN002

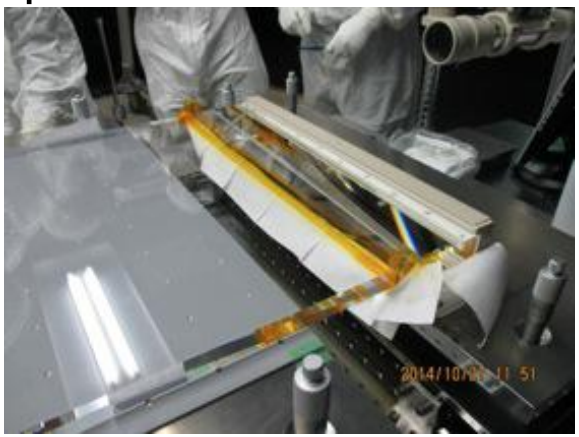




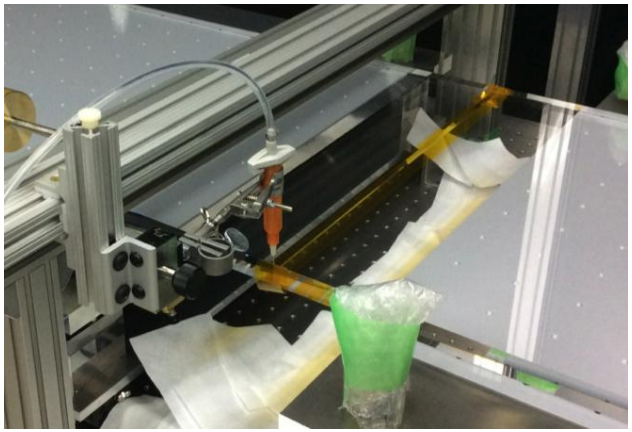
Quartz Gluing

- Gluing procedure is based on dry runs + some R&D for details
  - Taping (+ curtain for prism-bar joint)
  - Centrifuge for eliminating bubbles
  - Glue injection with a trolley
  - Cleaning, curing, …

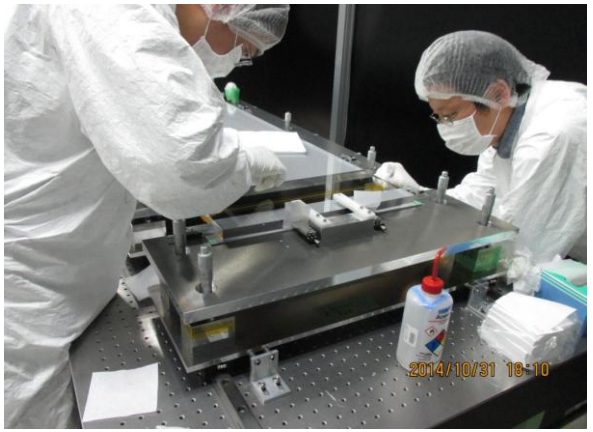
prism-bar



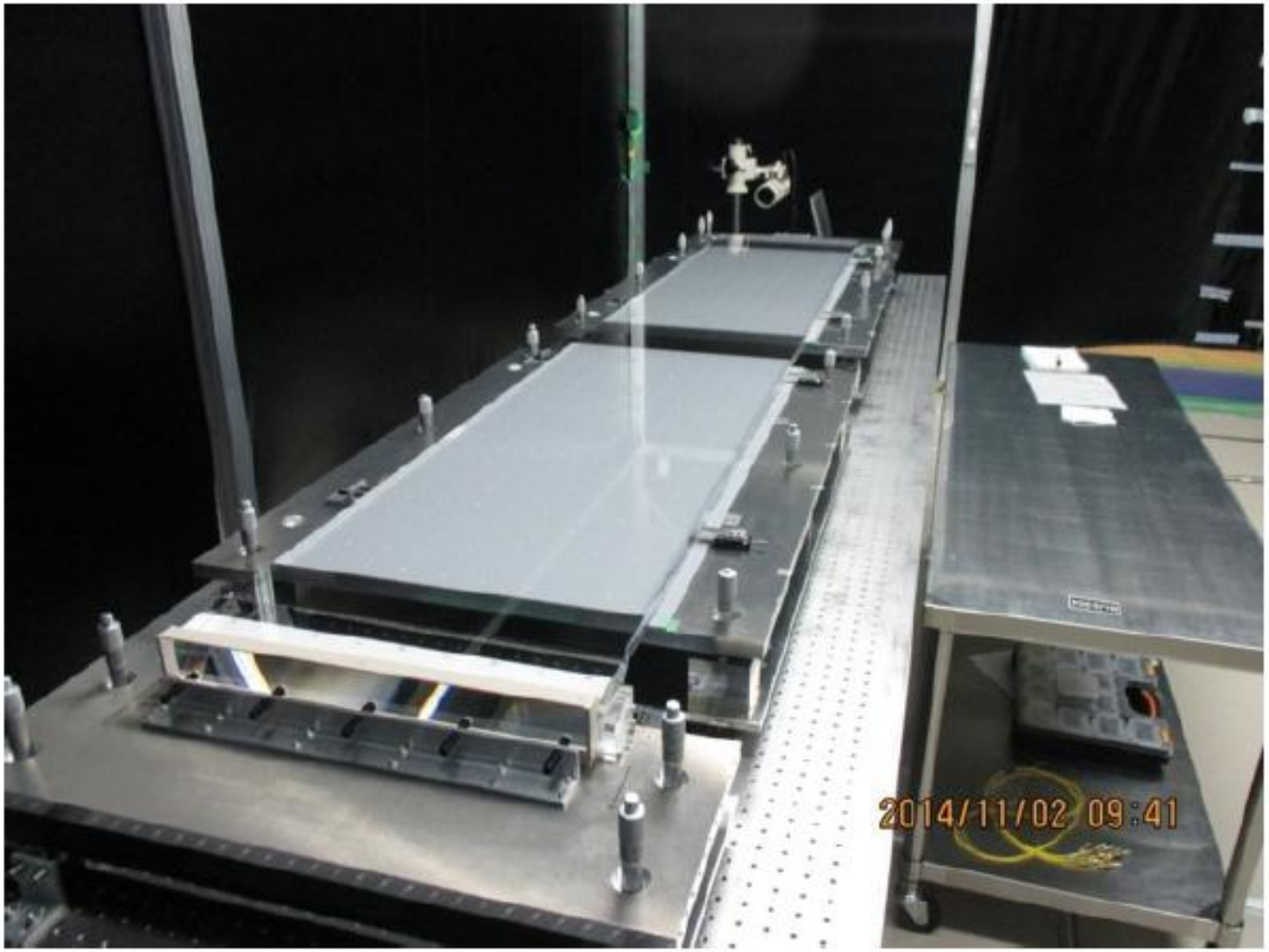
bar-bar



Bar-mirror

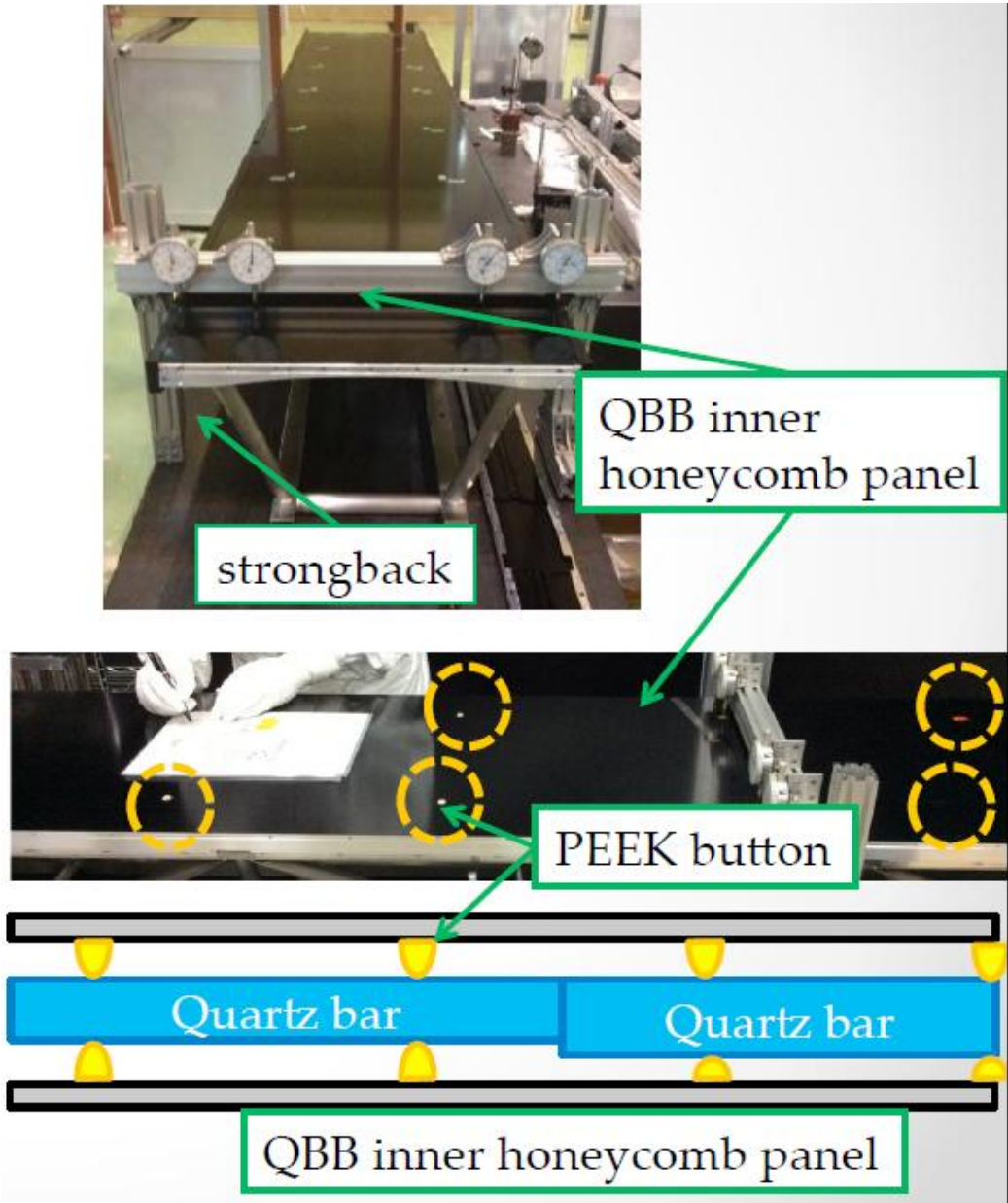


Glued Optics (Module01)



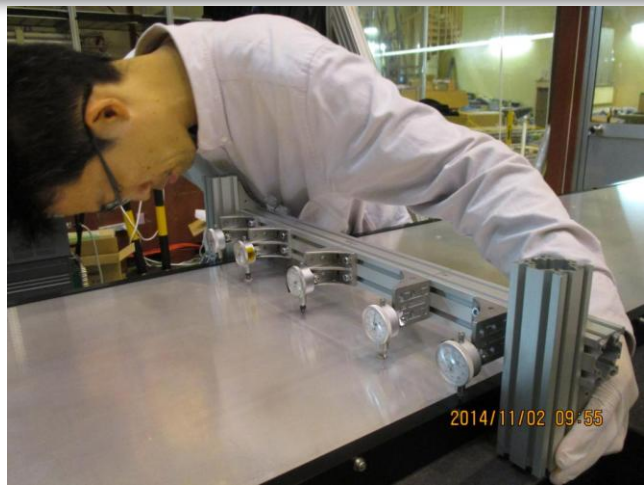
QBB preparation

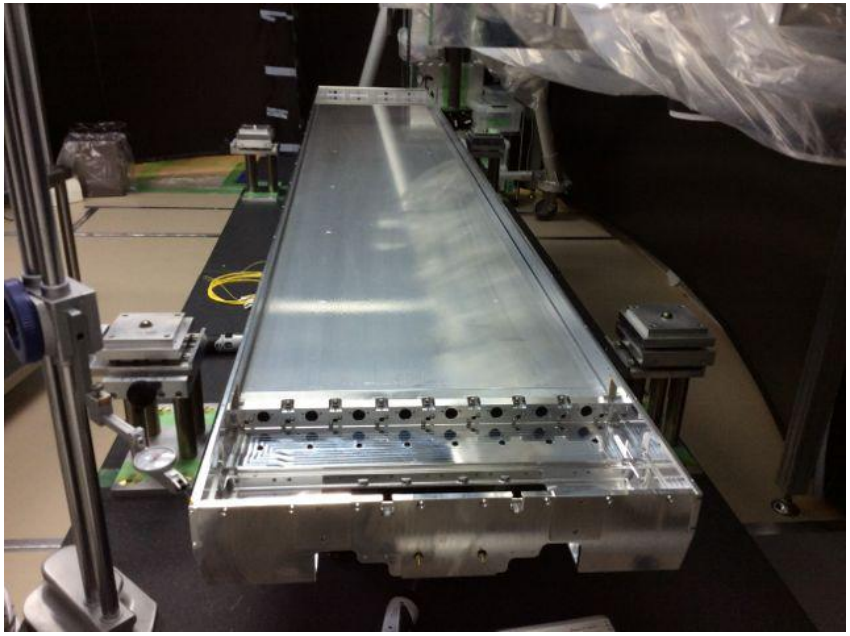
- Honeycomb panel attached to Strong back.
  - Put on stone table
  - Flatness is ~50micron.
- PEEK buttons are glued.
  - 14 buttons/panel
  - Considering height difference of dummy glass
  - ~30micron precision

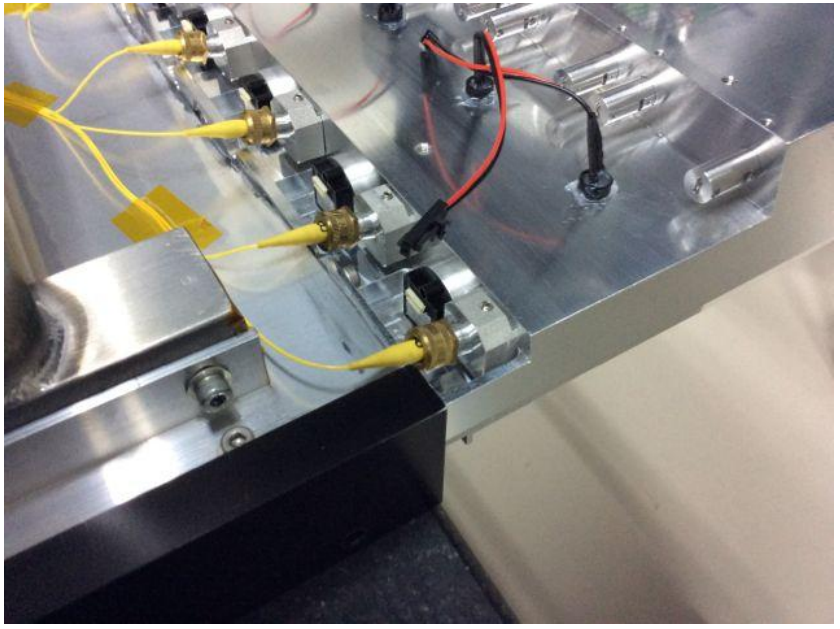


QBB preparation

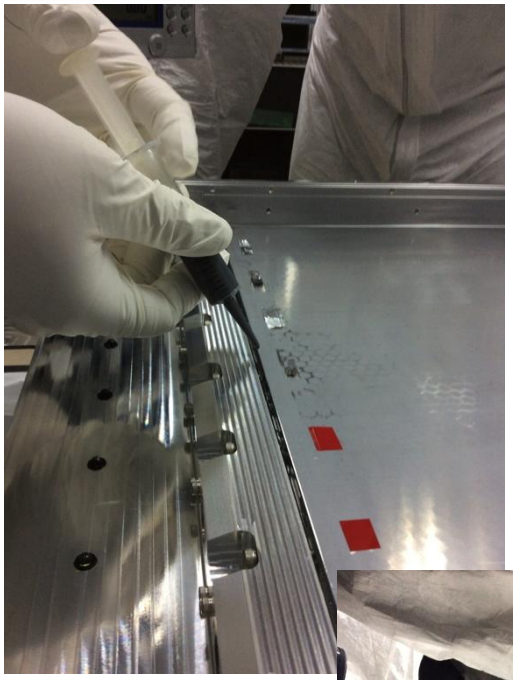
- Measure flatness of the honeycomb panels.
- Attach strong-back, tune and test stability.
- Assemble enclosure
  - Align inner-panel and enclosure < 0.06mm.
- Install LEDs, cameras, spring holders, fiber holders

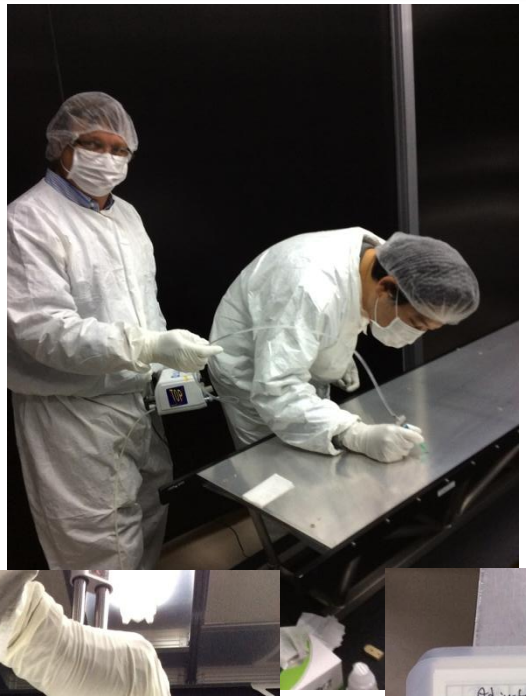


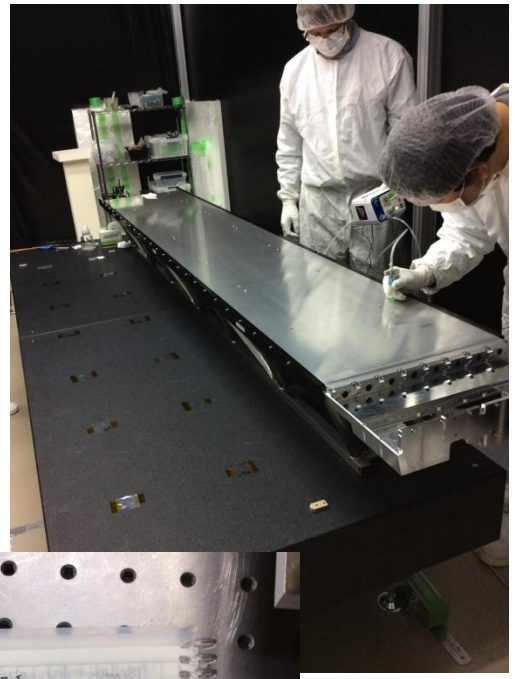


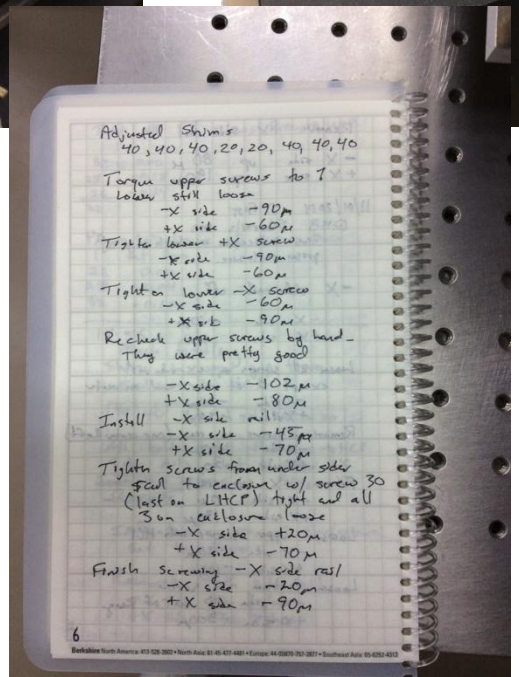


More Pictures from QBB Preparation



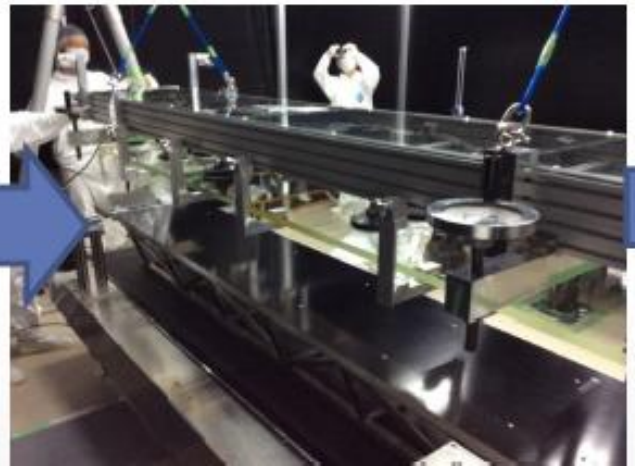
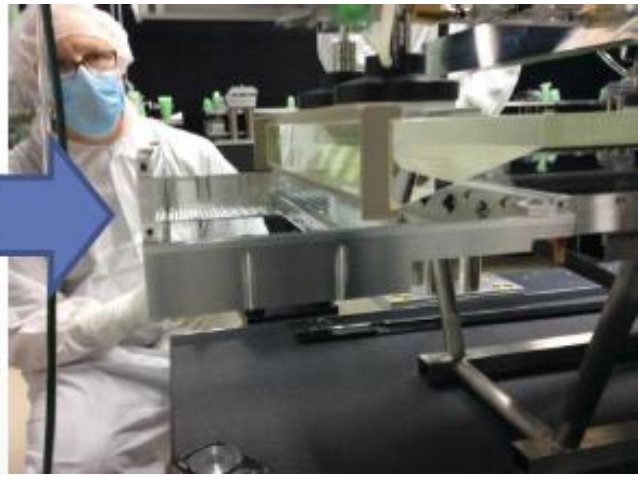




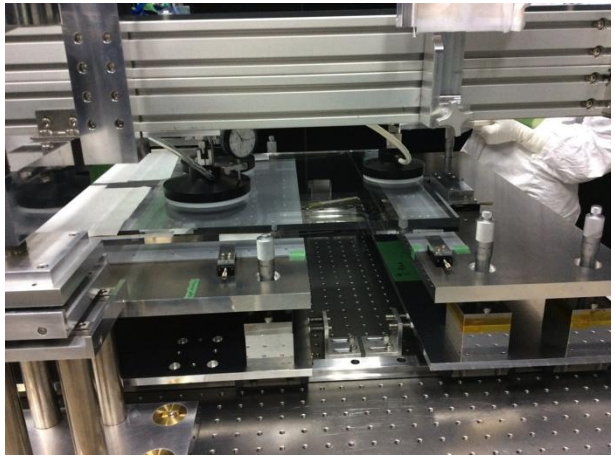


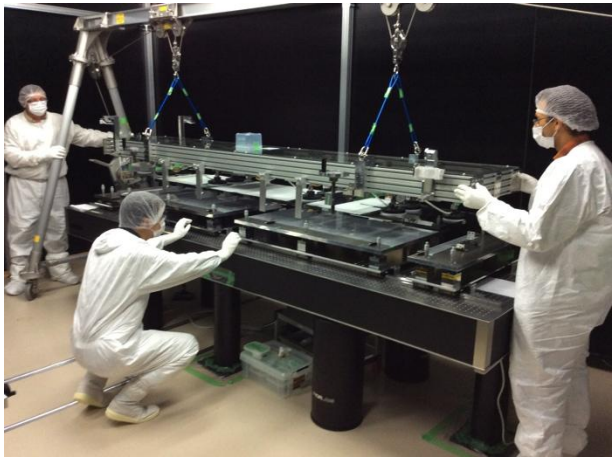
Lifting jig operation

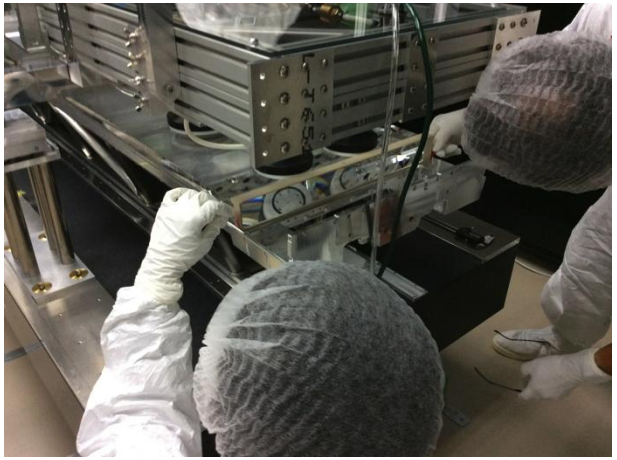
- Successfully lift up dummy glass from gluing stage to QBB stage
  - Need to refine crane path, flooring
  - Small improvement to make easier operation
- Touch down to QBB
  - Need to check clearance
  - Need many jigs to guide quartz
  - Check assembling procedure after cups off

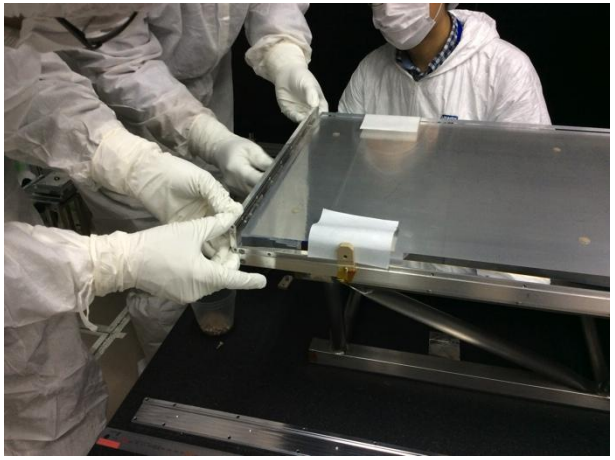




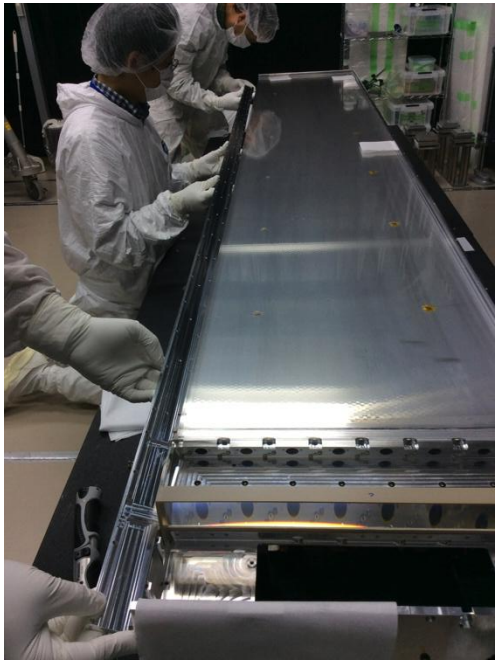
Installation of Optics to QBB



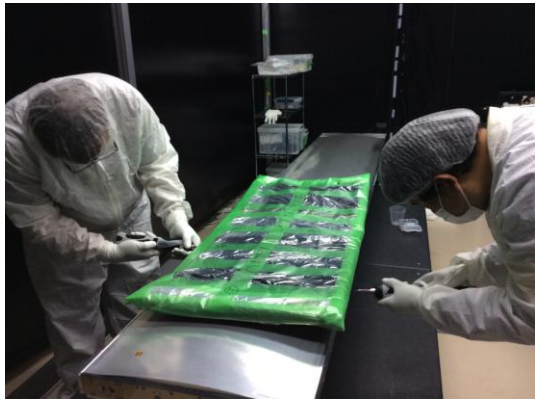


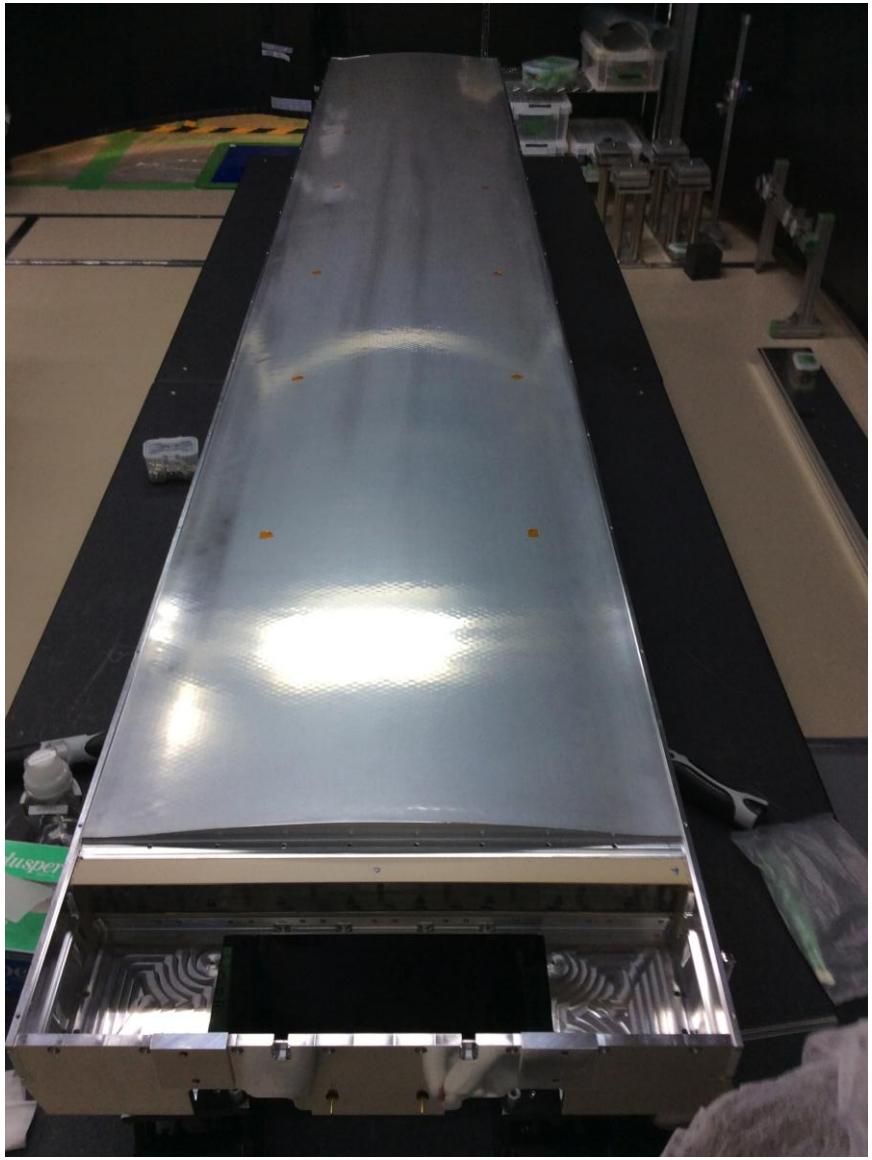






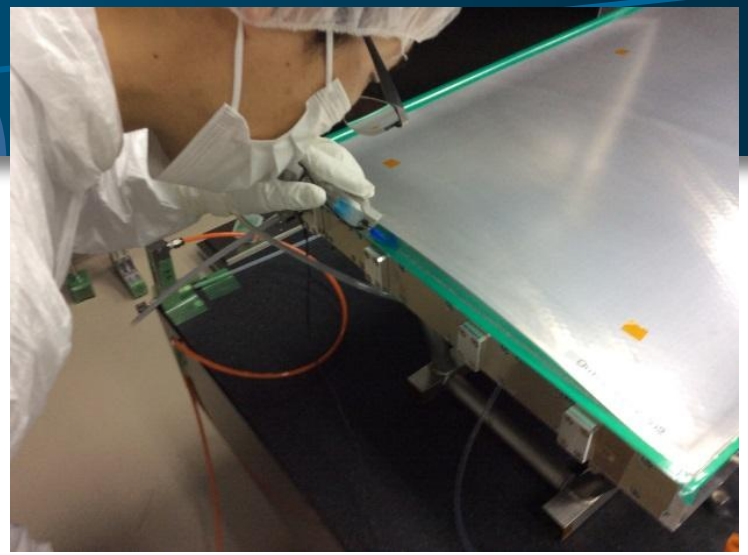
Completion of Optics + QBB

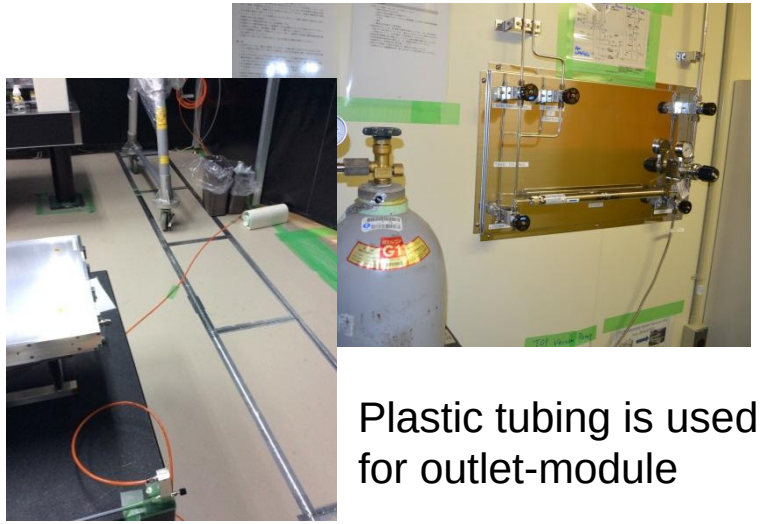




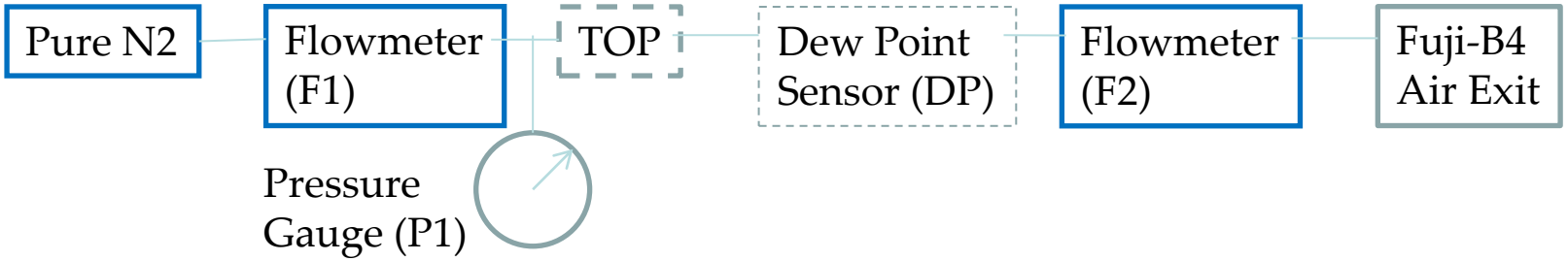
Gas sealing

- QBB panels, side Rails, FWD endplate, prism enclosure were sealed with Si glue.
- Tested with Restek Electronic Leak Detector + Pure N2 (& G1 Ar)
  - Significant leaks were found in the prism enclosure through the mounts for CCD cameras, LED, fibers and others (fixed now).
- Started to flow pure N2, and measure dew point.
  - < -51 degC. (34.31ppm) achieved
  - Target is - 60 deg (11 vol.ppm) with the inlet flow rate of 0.5L/min. and pressure < 1kPa.



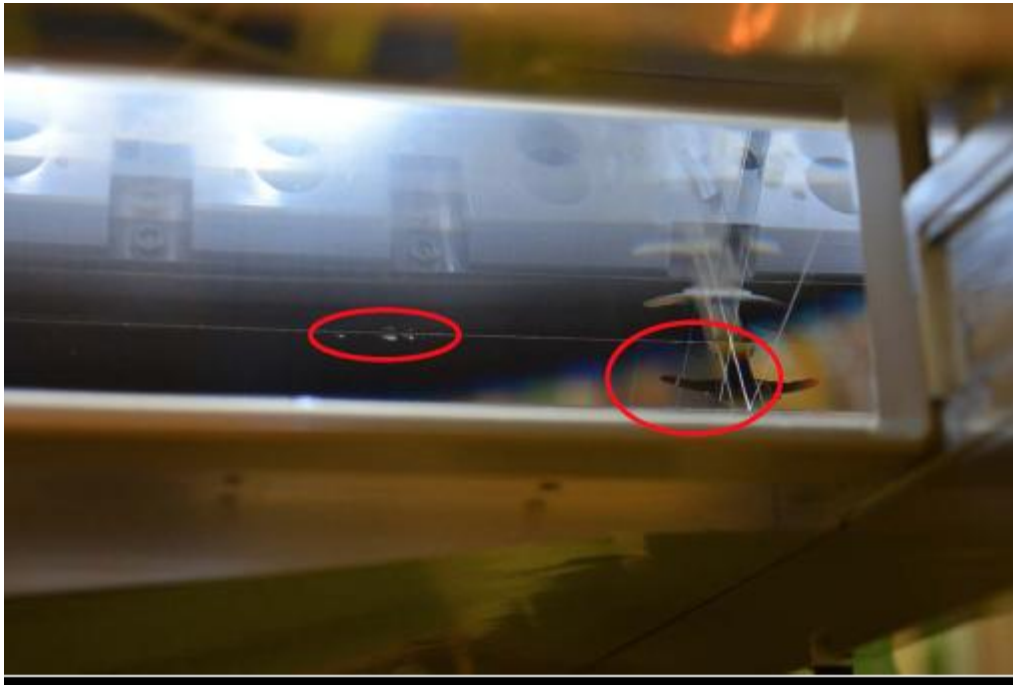


Plastic tubing is used for outlet-module



Issue in gluing

- We found small regions of adhesion failure in the prism - bar glue joint.
- The peeled part is the side of bar, which is the side the glue was leaked and striae like structure seen at the corner.
- Unusual steps were taken to remove the excess glue leakage.
- The gluing process for module 02 has been stopped to investigate the issue.



⇒ Check whether the crack develop or not, by normal operation (moving, rotation for several times etc.).

⇒ No change was found.

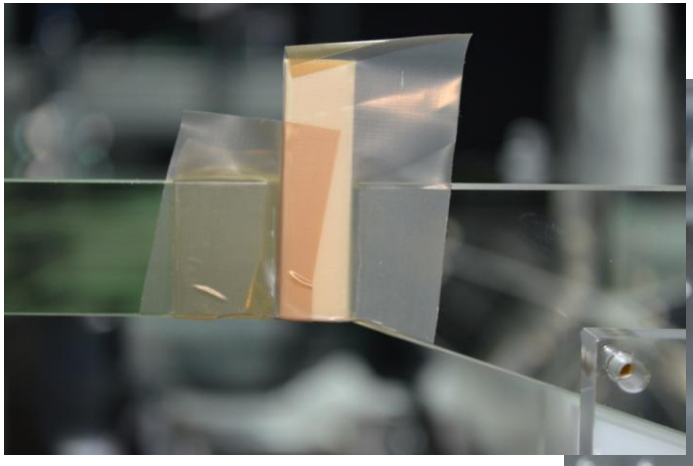
Glue studies

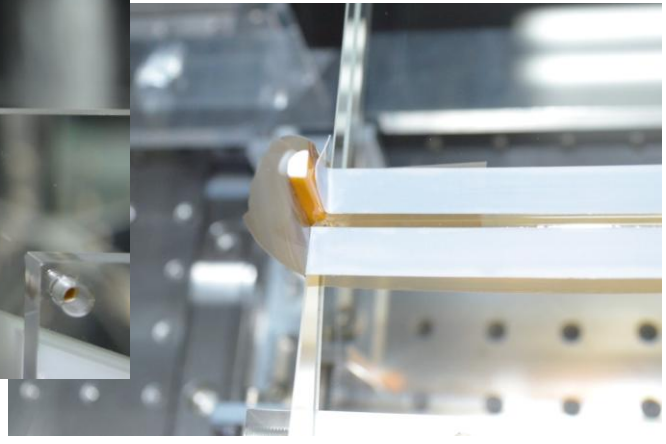
- Before resuming the optics assembly, we have studied on:

- Reasons of failures
  - No change by normal operation, applying load on the enclosure.
- Gluing methods (many know-hows).
  - Need reduce leak to make more stable joint (optimization of gap, taping etc.)
  - EPOTEK company suggested to use a promoter AP-100 for highly polished surfaces
  - Got many suggestions from DIRC group and company technicians (Epoxy Technology, Sydor, Norland, and Photon Gear Inc.)
- Strength tests
  - Prepared small quartz pieces (5x5x2cm^3) with polished surface
- Test with large sample
  - Put EPOTEK between the dummy mirror glasses and check the situation
  - Two well-polished dummy mirror quartz from Sydor as final check

Taping method development for EPOTEK

- Striae like structure was appeared in the case of glue leakage. We need to improve the taping method for the stable glue curing.
- Use Teflon tape (softer than Kapton tape)
  - Easy to fix the leakage around the edge
- Test Teflon block and tape for prism part with glue
  - Difficult joint due to the difference of width
    - Prism (456mm), bar (450mm)
  - No leakage happened for 4 trials.
- Enabled to align/tune after taping

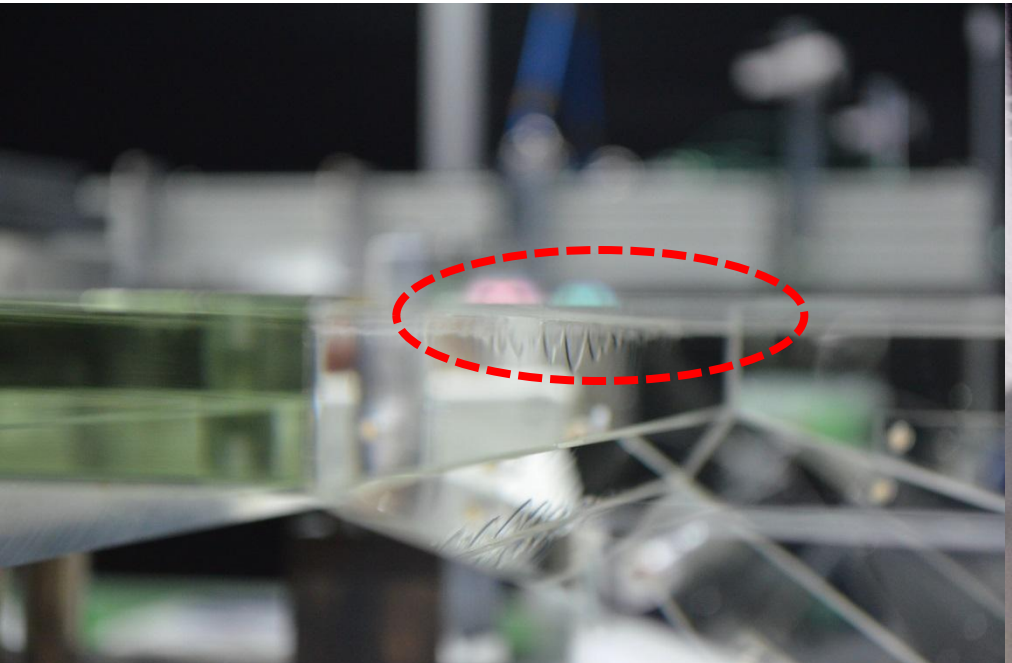


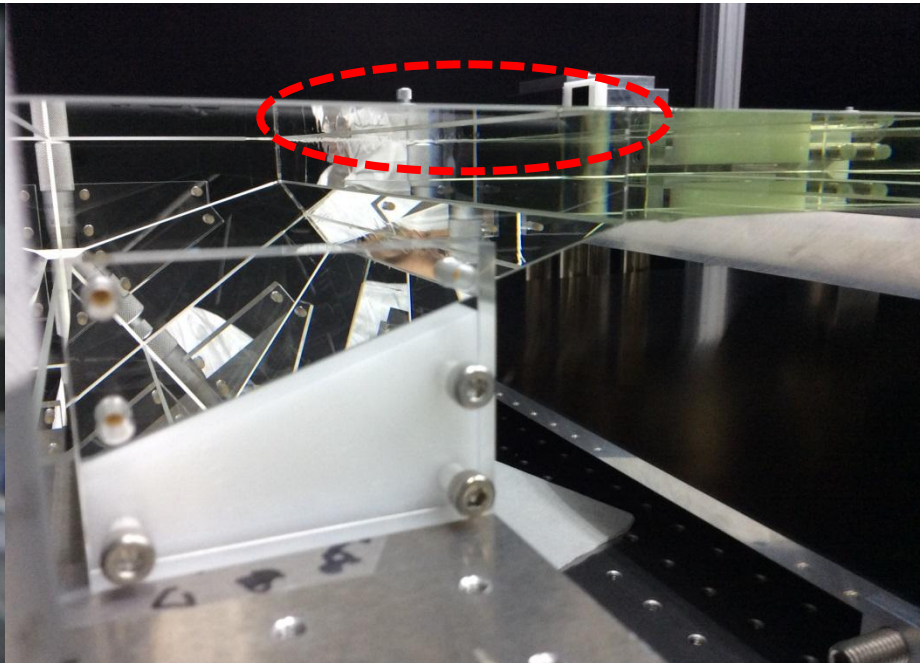


Glue test with large glass

- Found typical striae-like structures in the 3rd trial of prim-bar gluing R&D
  - Tiny index change ➔ Difficult to find this structure on small pieces.
    (Large (wide, long) optics, large angle of view, angle of incidence, … needed)
  - The observed “drop”-like striae corresponds to
    - Extra glue on upper surface.
    - Glue applied in the latter half of gluing (~30mins)
    - The “drop”-like glue was cured (more sticky) than glue, when we have cleaned the surface

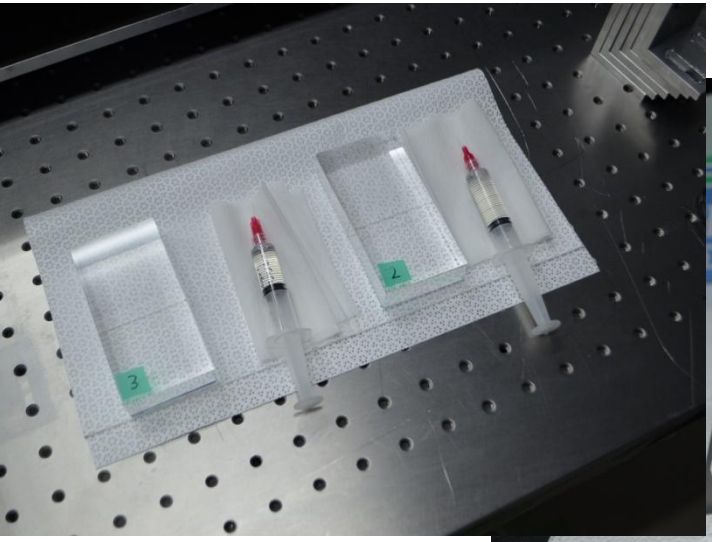
  ➔ It seems that difference of the curing status of glue makes this structure.

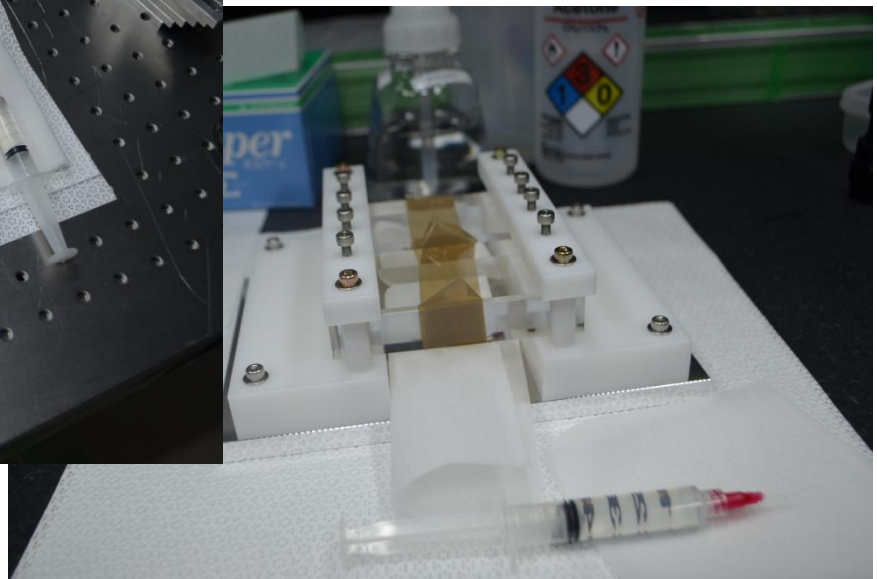


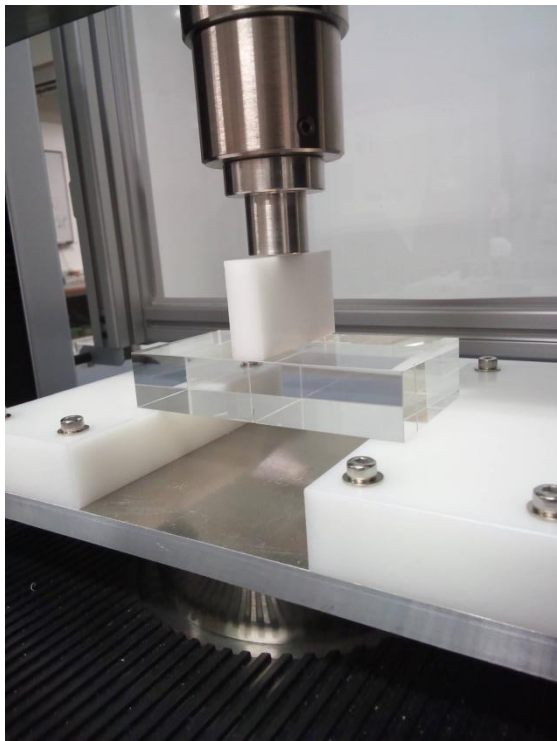


Small polished quartz

- Made several types of EPOTEK samples and NOA63 sample as a reference
- Check the strength with the “normal” procedure
  - Alignment, taping, putting glue, curing, un-taping, cleaning the excess
- Tried to make bad samples
  - With index fluctuation by glue leakage
  - Remaining acetone residue on quartz surface
- Performed the bending test

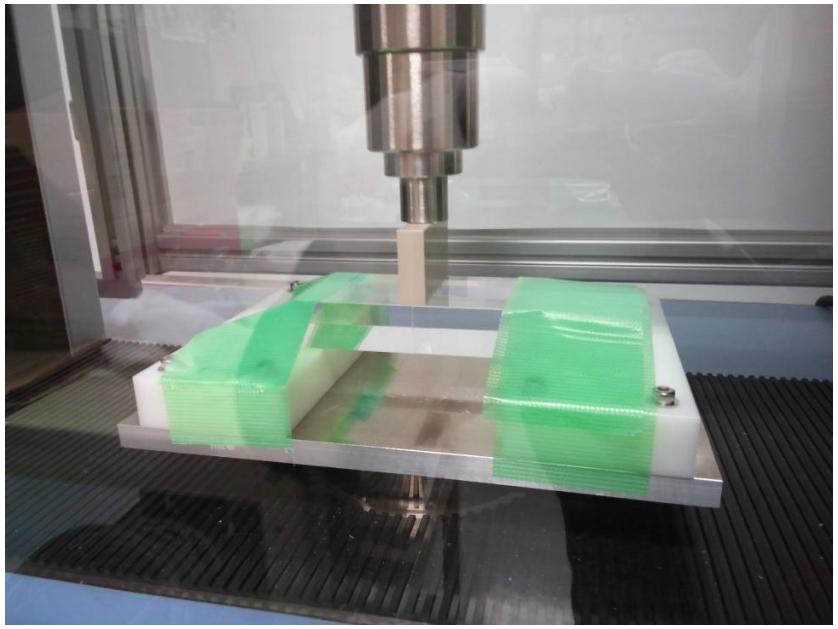






Bending test with small polished quartz

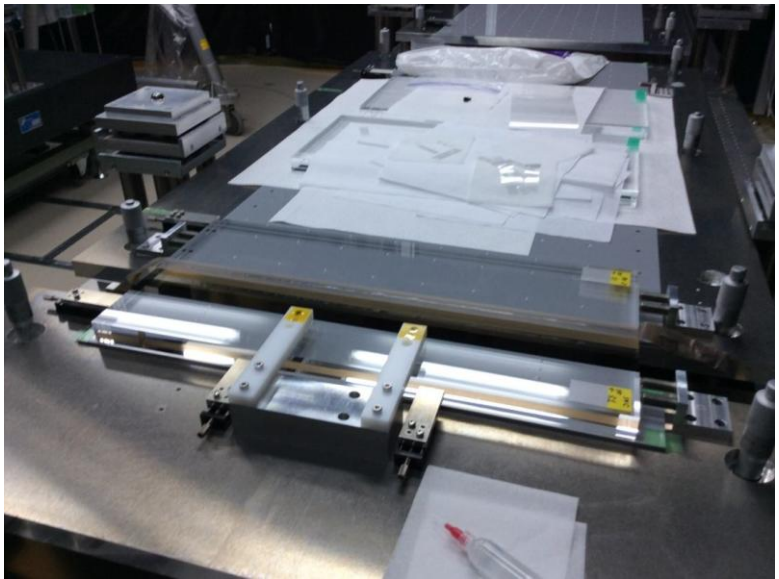
- Tested 10 samples
  - 841N; corresponds to the maximum stress by the self weight of 2.5m quartz bar supported at the end point without QBB. (extreme case)
- Glue applied by the current procedure shows good strength.
  - No strange delamination was seen during the test.
  - AP100 shows less strength.

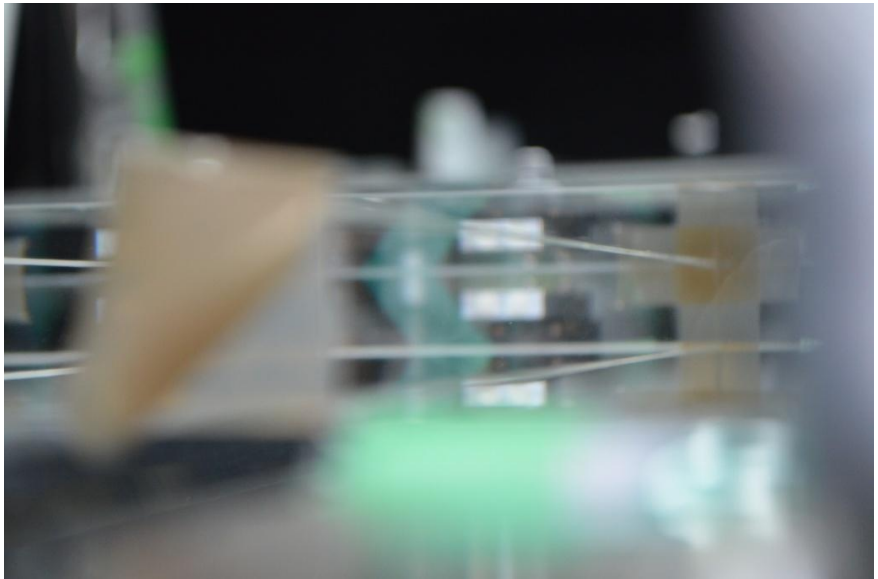


	Break at (N)
EPOTEK-1 (“normal” procedure)	6000
EPOTEK-2 (“normal” procedure)	6600
EPOTEK-3 (“normal” procedure)	6200
NOA63-1	3000
NOA63-2	2000
EPOTEK with weak striae 1	6500
EPOTEK with weak striae 2	6000
EPOTEK with acetone residue 1	5000
EPOTEK with acetone residue 2	5000
EPOTEK with AP100	4300

Test with large polished quartz

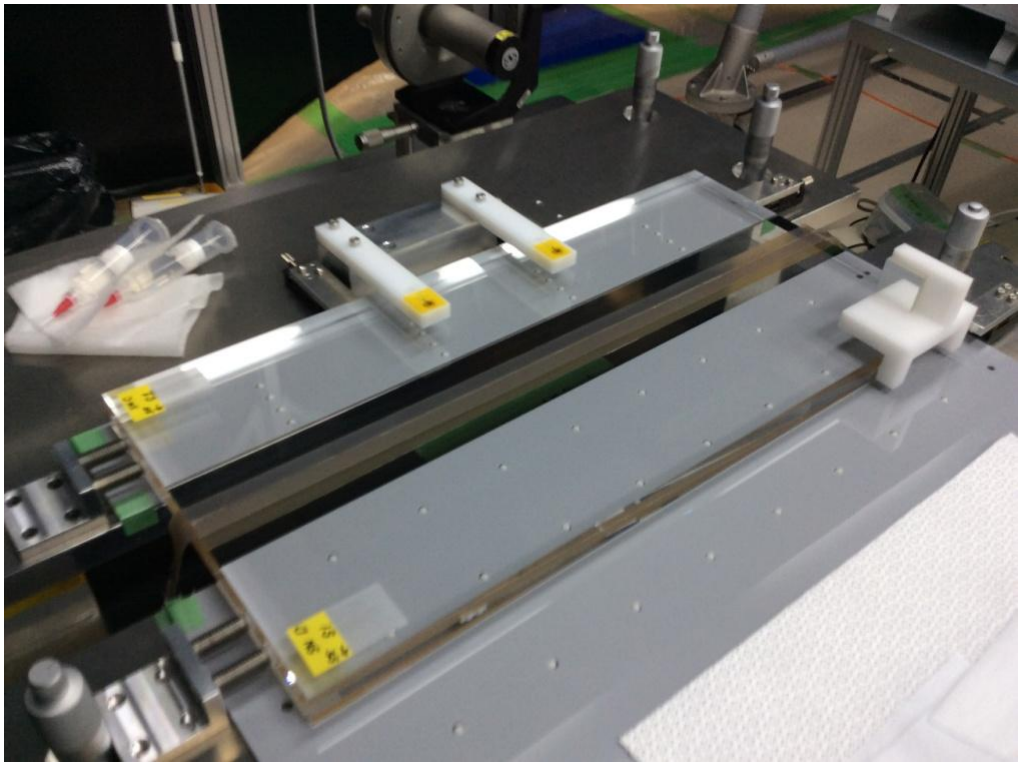
- Fortunately we got “polished quartz” with the same size of dummy mirror
  - The requirement for polished surface is same with the real quartz.
  - The material is quartz, but low grade to save money and time.
- Check glue status using similar surface condition
  - Gap: <20micron at min. 50micron at max.
  - There was visible stripe-shape striae at begining
    - After several hours, become strong.
    - After full cure, it became very weak.
  - The cured surface looks fine. No strange issue found.





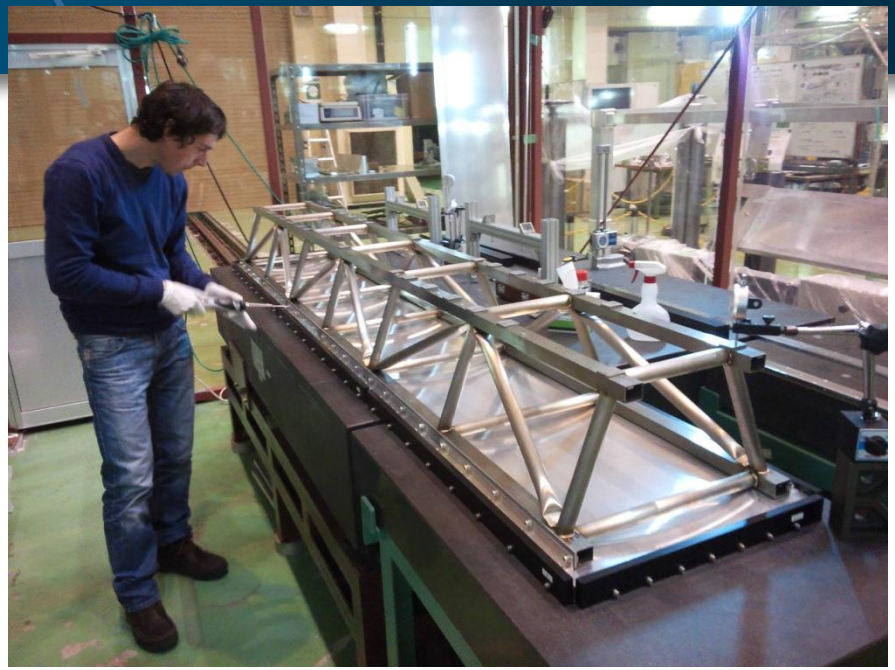
Final test with mirror sample

- Glue cured with Sydor sample (same quality with mirror)
  - Found strange smudge entered from top and fall down to middle
    - After several hours, it disappeared.
  - Again, visible stripe-shape striae found at beginning, but become very weak after full cure
    - This type of striae looks OK for the strength as tested by small sample.

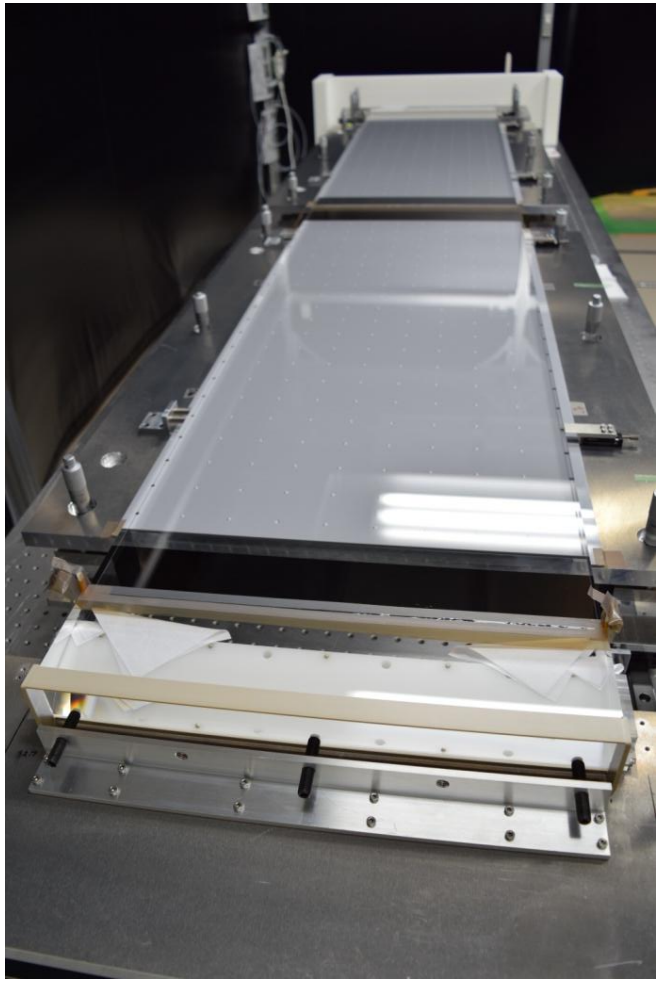


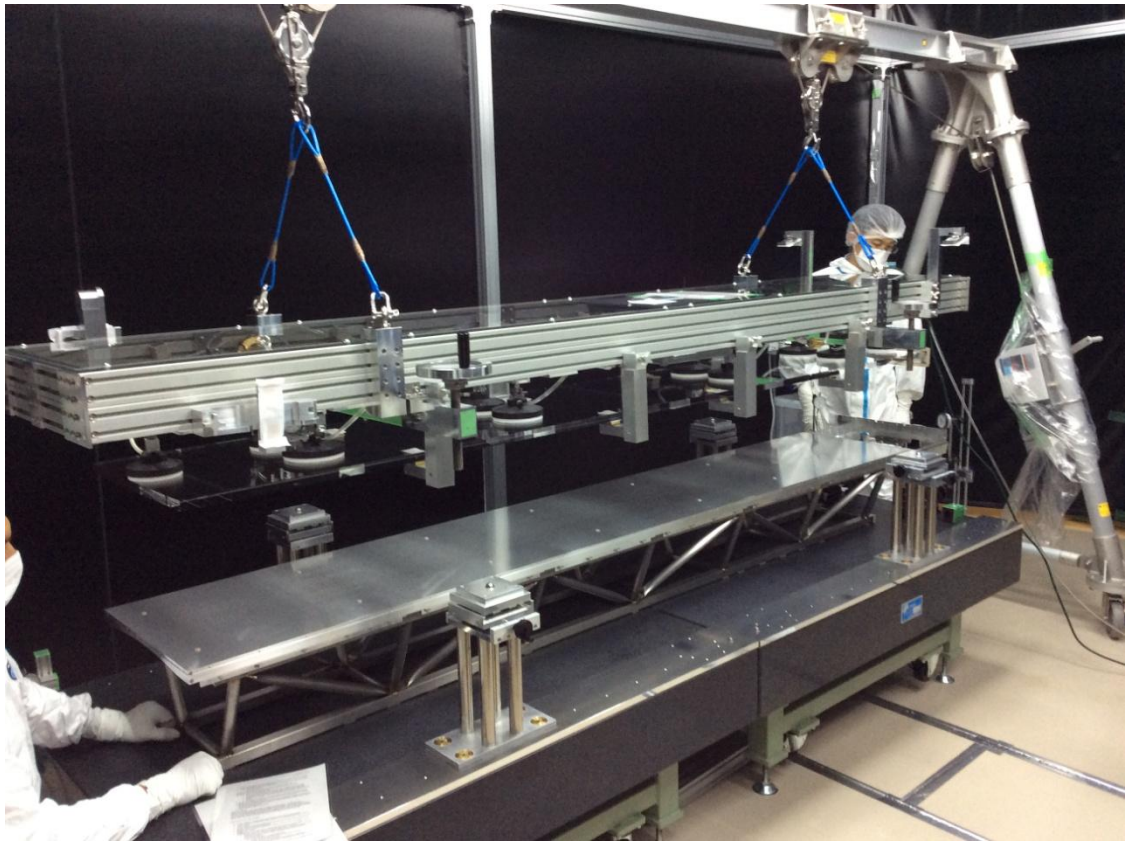
Module production

- Resumed module production after glue studies.

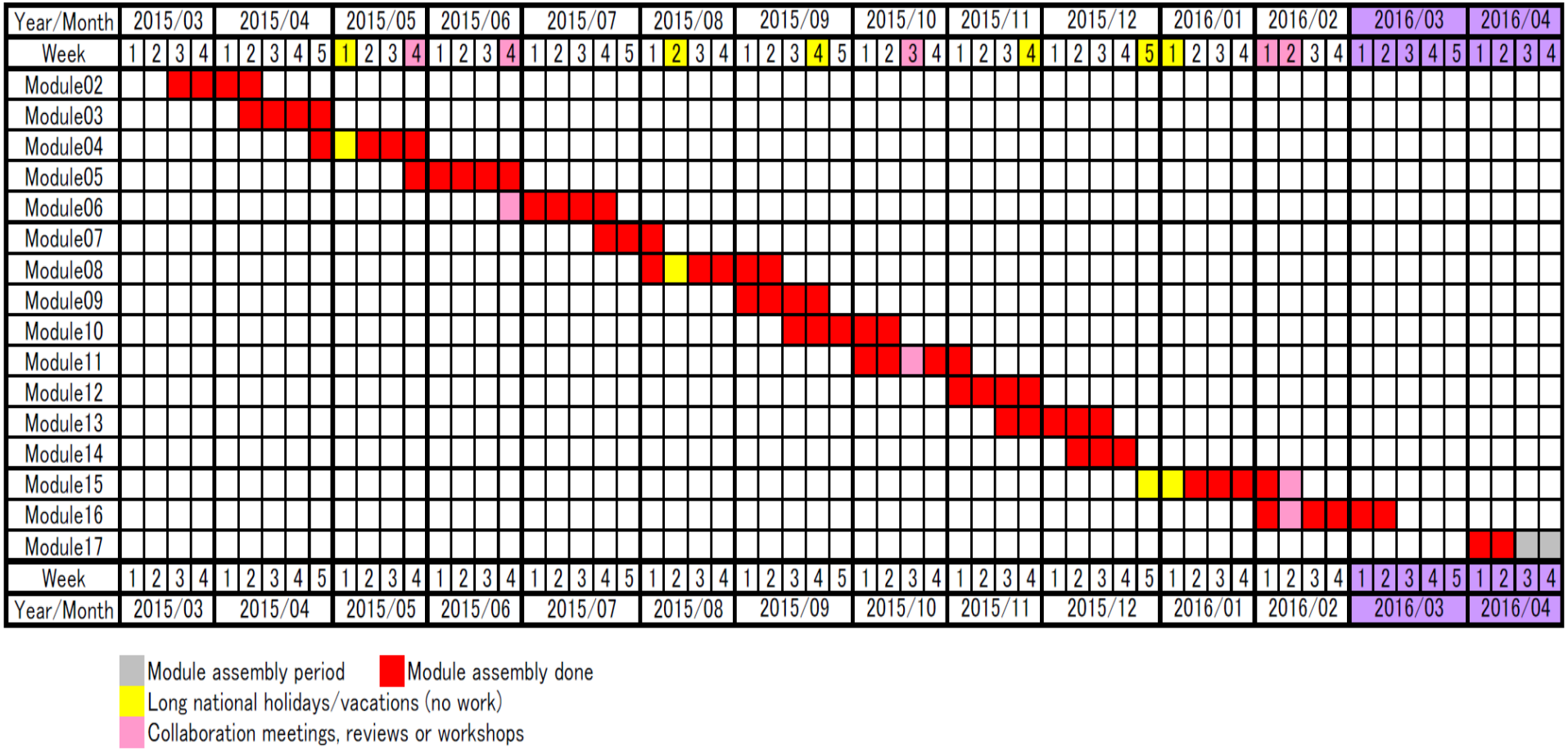


Module production





Module production schedule



- Module production moved smoothly; ~3 weeks per module
- Last module finished by the end of April

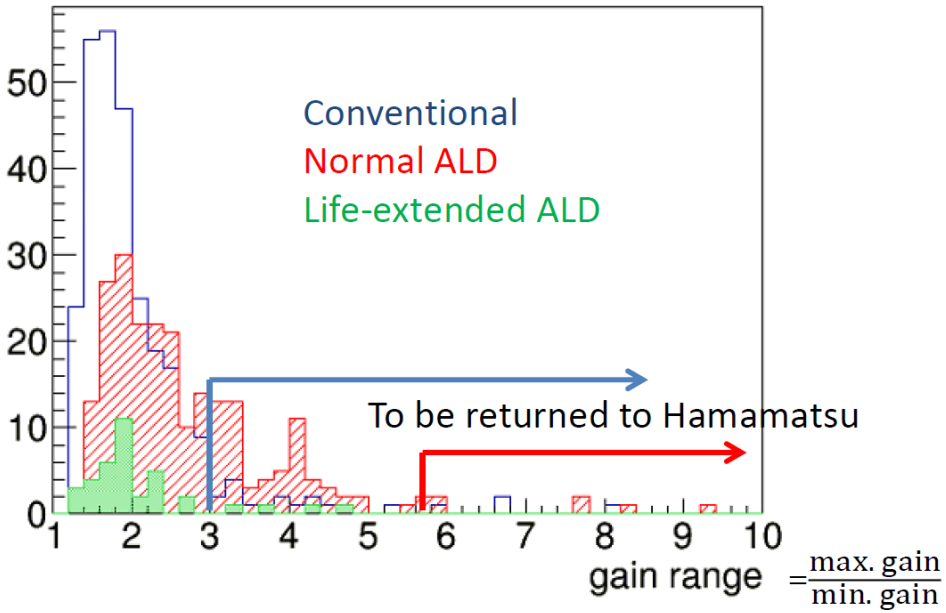
MCP-PMTs

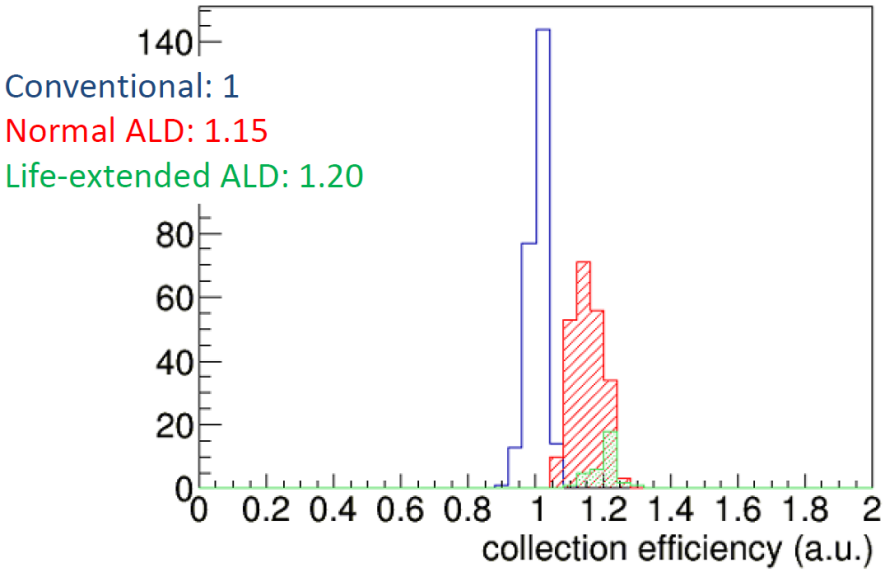
As of Apr. 22, 2016

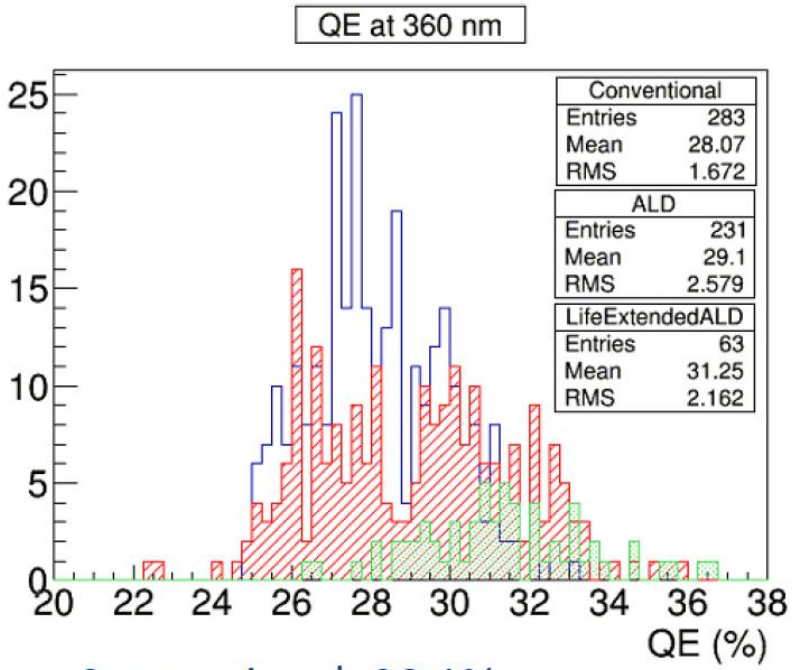
	Conventional			ALD			Life-extended ALD		
Delivered	**308**[*1]			**238**			**65**[*2] **(+28)**		
Inspection item	Done	Returned	Undone	Done	Returned	Undone	Done	Returned	Undone
• Visual	282	(5[*3])	4[*5]	238	(26[*3])	0	65		0
• QE	304	16[*1]	0	236	2	0	65		0
• HV test	298	7[*1]	0	238	4	0	65		0
• Gain/TTS	290	1(+16)	0	234	1(+7)	0	65		0
• 1.5 T magnet	283	1	0	230	0	0	65		0
• Other		5[*4]							
Total returned		30(+16)			7(+7)			0	
Delivered —returned	278 **(262)**			231 **(224)**			65 **(93)**		
As required	**255**			**221**			**64**[*6]		

*1 16 PMTs by Nagoya KAKENHI included; 1 rejected for QE and 1 for HV
*2 10 PMTs by Nagoya KAKENHI included
*3 Re-potted
*4 Bent pins (4), potting yellowed (1)
*5 3 PMTs already installed in the spare module (TOP01), 1 in USA
*6 In addition, 4 life-test samples are used

Performance of MCP-PMTs





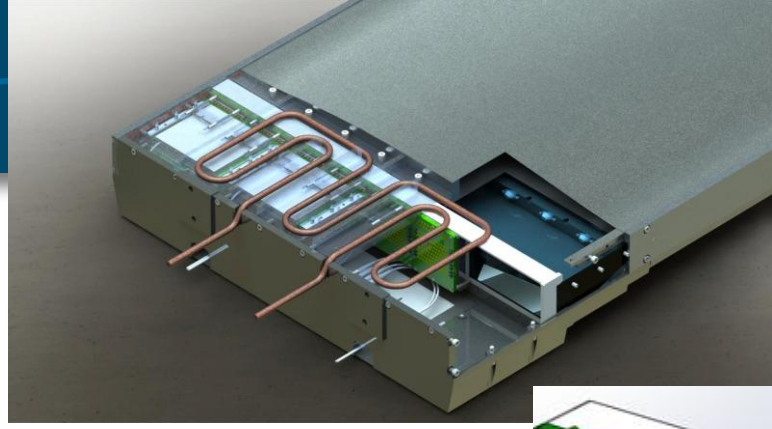


Conventional: 28.1%

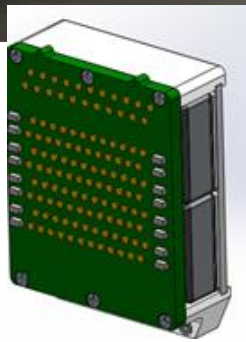
ALD: 29.1%

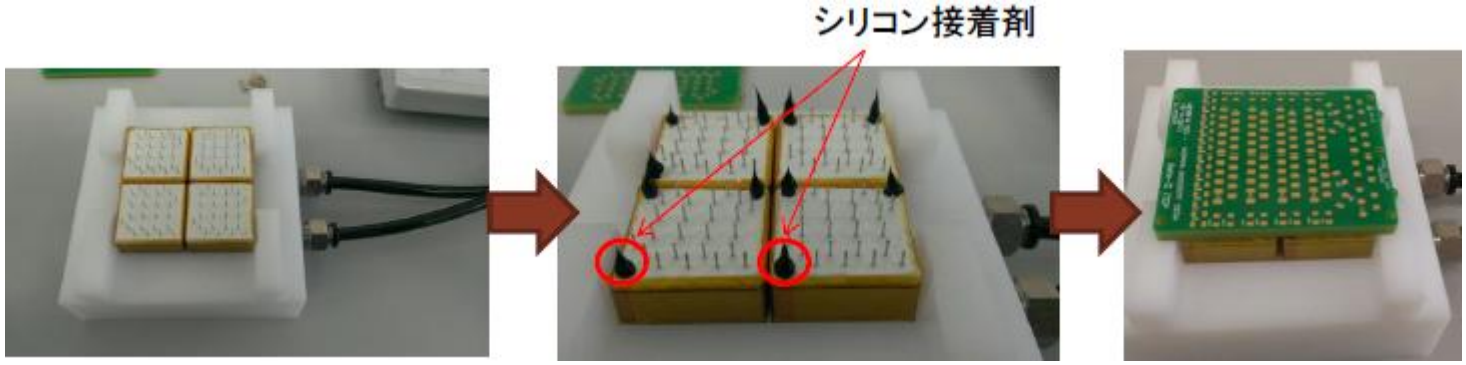
Life-extended ALD: 31.3%

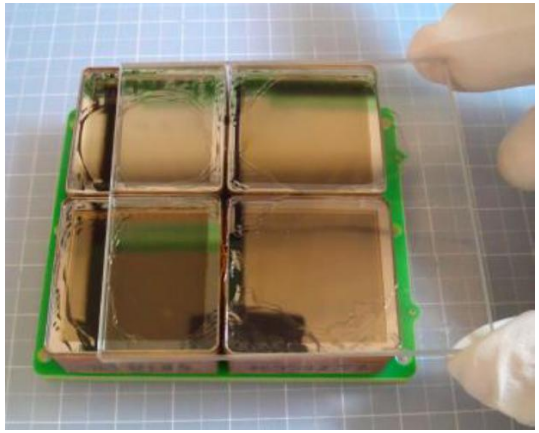
PMT module assembly

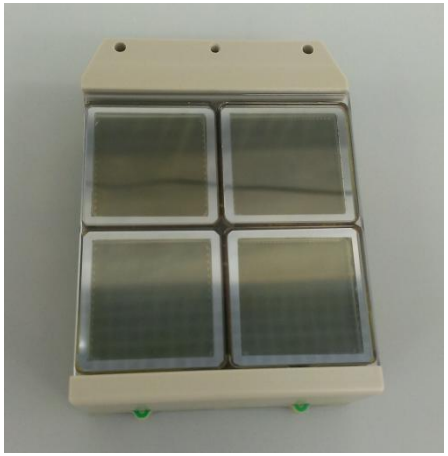


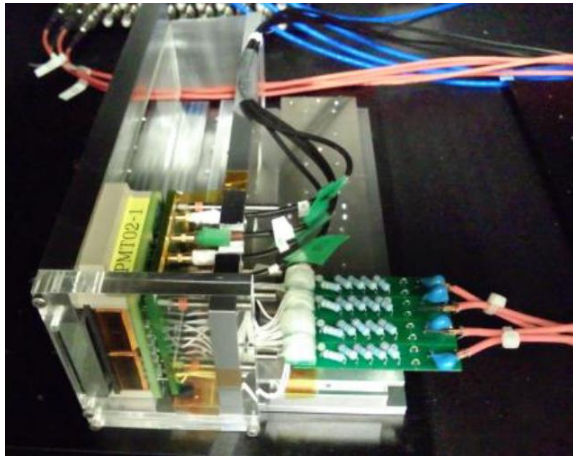
- 4 MCP-PMTs assembled into one module
  - Fixed by silicone glue on optical filter using vacuum chuck
  - Glue wavelength-cut filter
- Check HV discharge





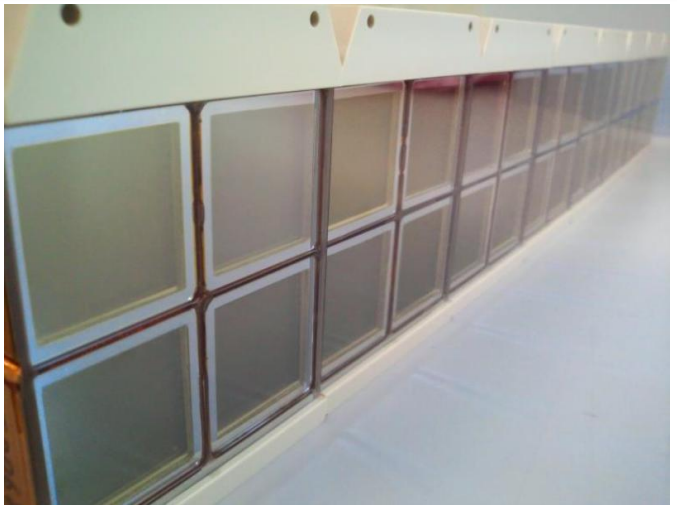


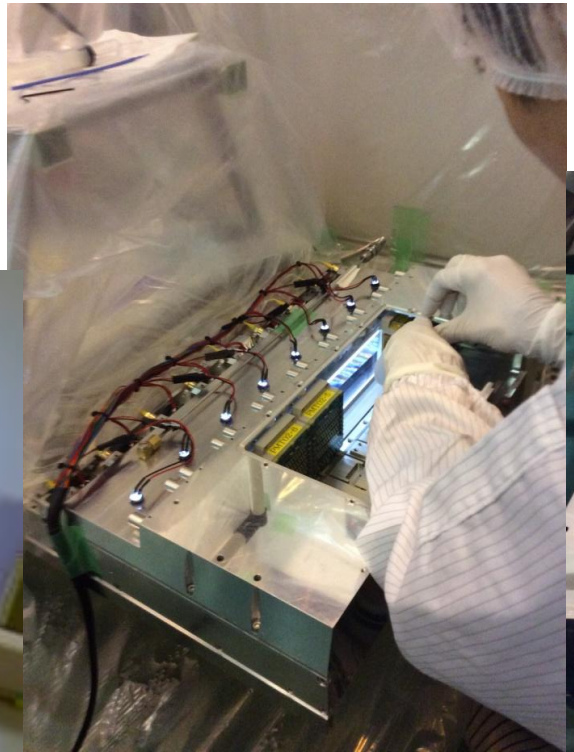


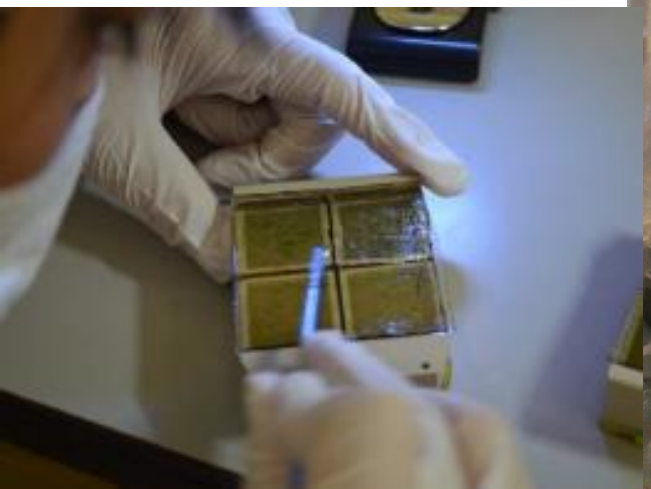


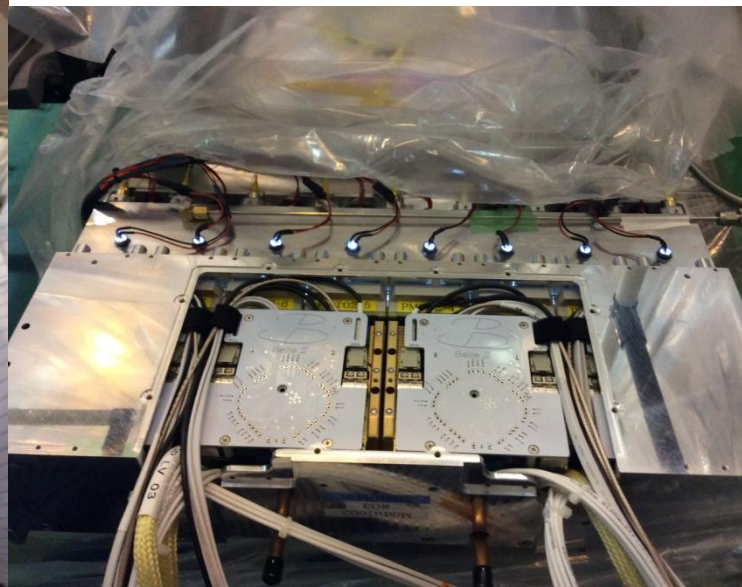
PMT/HV/Frontend assembly

- Tested PMTs assembled to PMT modules
  - Produce optical cookies
- Install into TOP module
  - PMT modules
  - HV/Frontend electronics from US

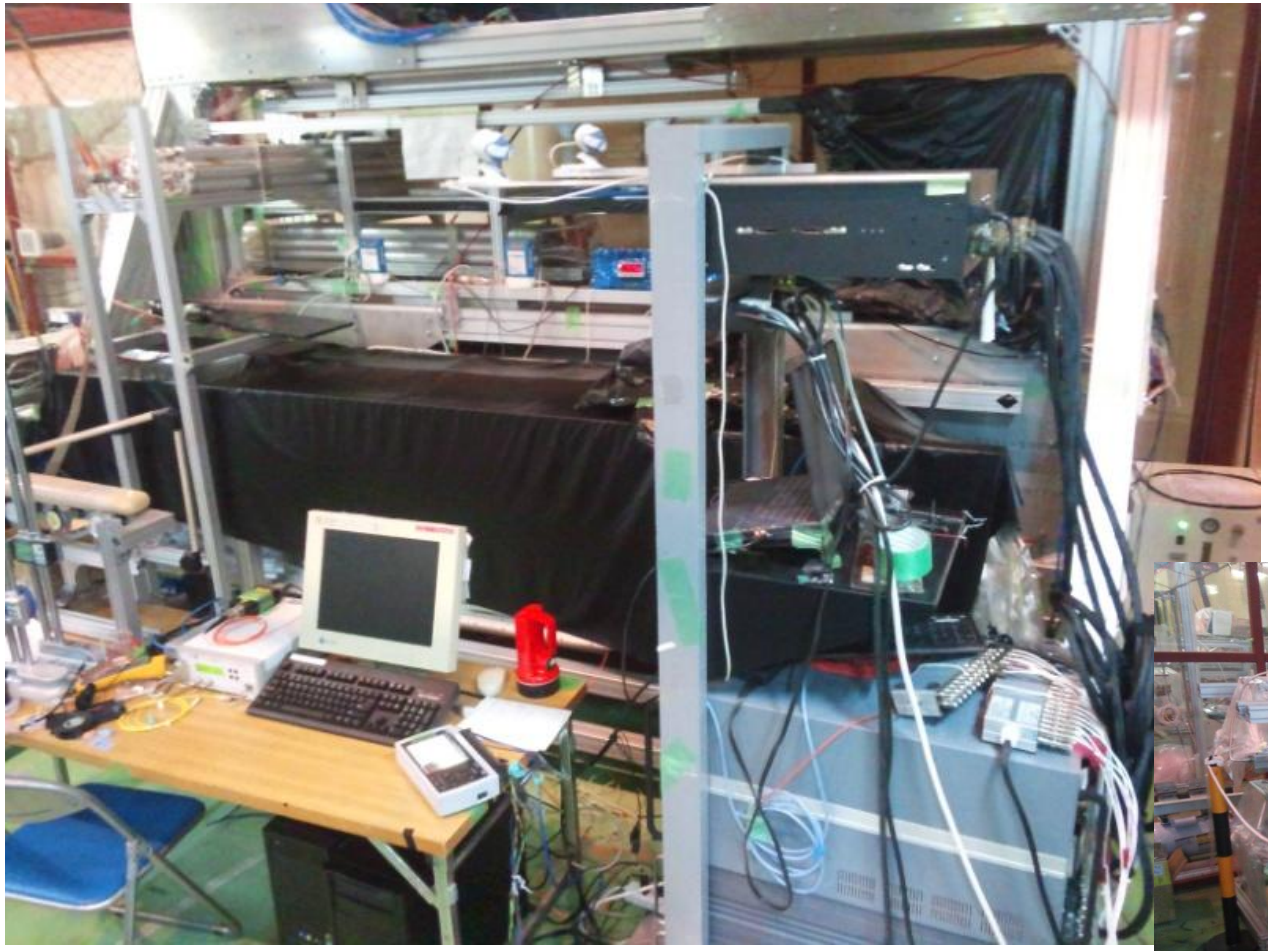








Test of assembled modules



Module03,04
at Fuji B4 tent
in testing for
installation

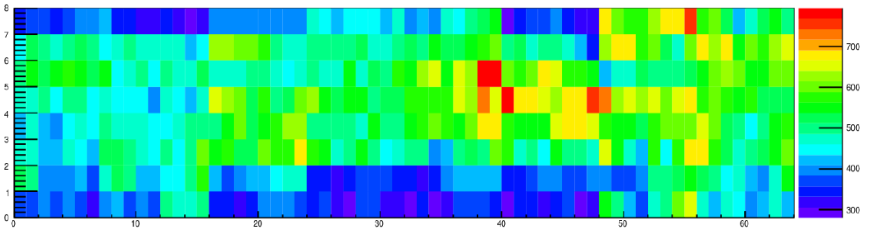
Module02, 05-07 at Fuji B4 tent

Module test

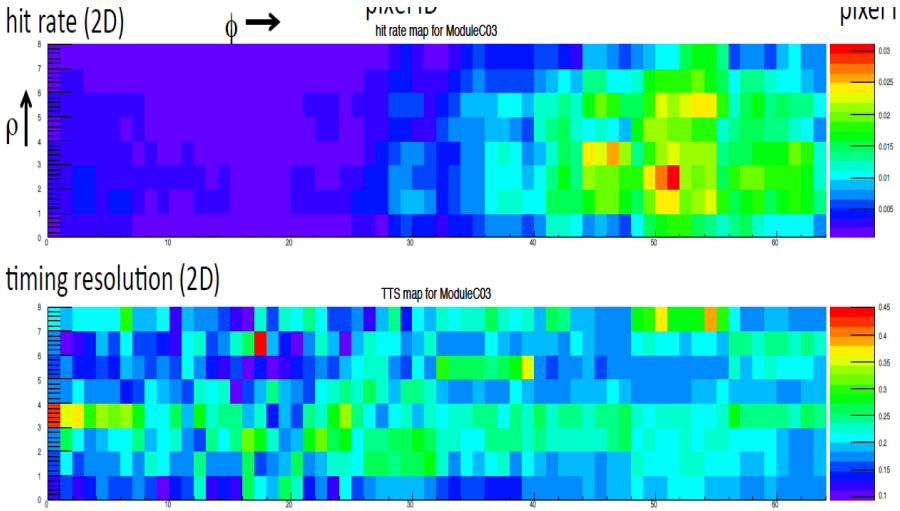
- Assembled modules tested with laser signals and cosmic-rays.
  - Could take hit data
  - Reasonable number of hit by cosmic-ray
- Preparing for the tests with Belle-II software

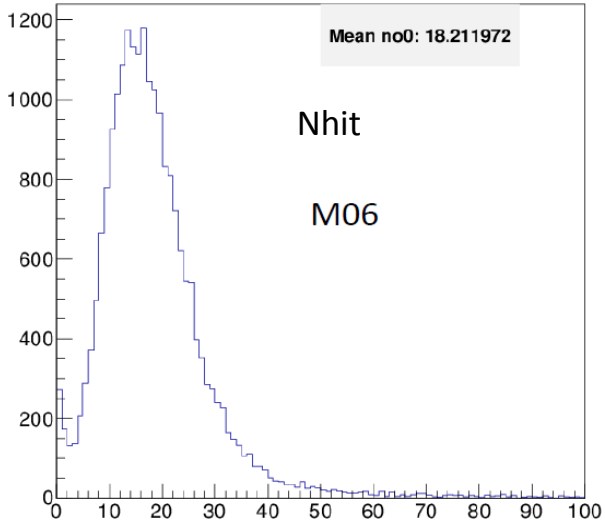
M06 cosmic-ray data

Hit map



M03 laser data





Summary

- TOP module assembly went smoothly and finished in ~1 year.
  - After several development of procedure, especially gluing

- We studied many procedures using slide-glasses, small prisms, small quartz sample and large quartz sample.
  - We could not reproduce the similar delamination.
  - Improved understandings for the striae phenomena and improved the procedure to reduce it.
  - Confirm good glue strength with our procedure
  - No problem found for larger samples with the improved procedure

- After module assembly, the performance was confirmed by laser pulses and cosmic-rays, before installation.