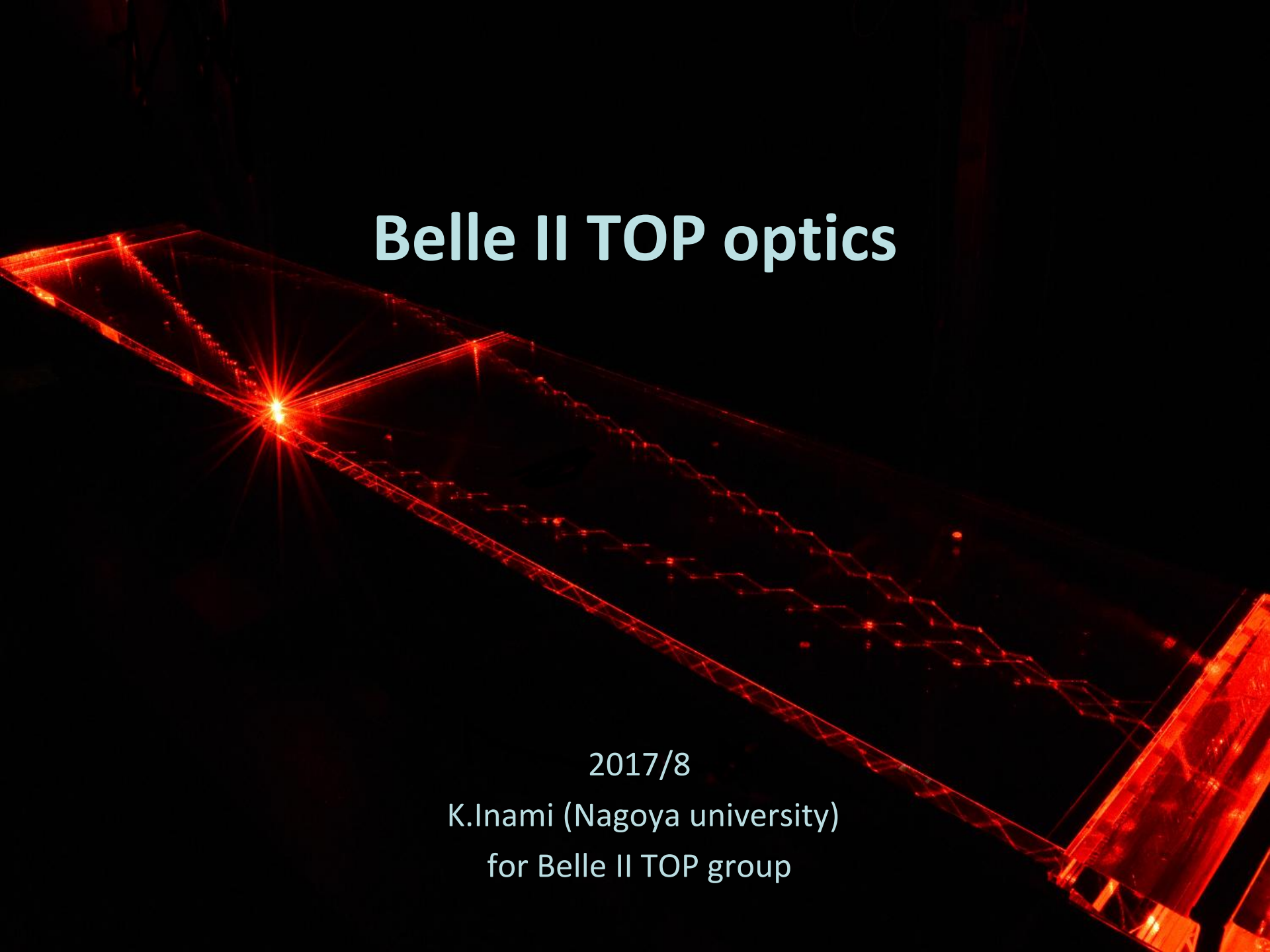


Belle II TOP optics

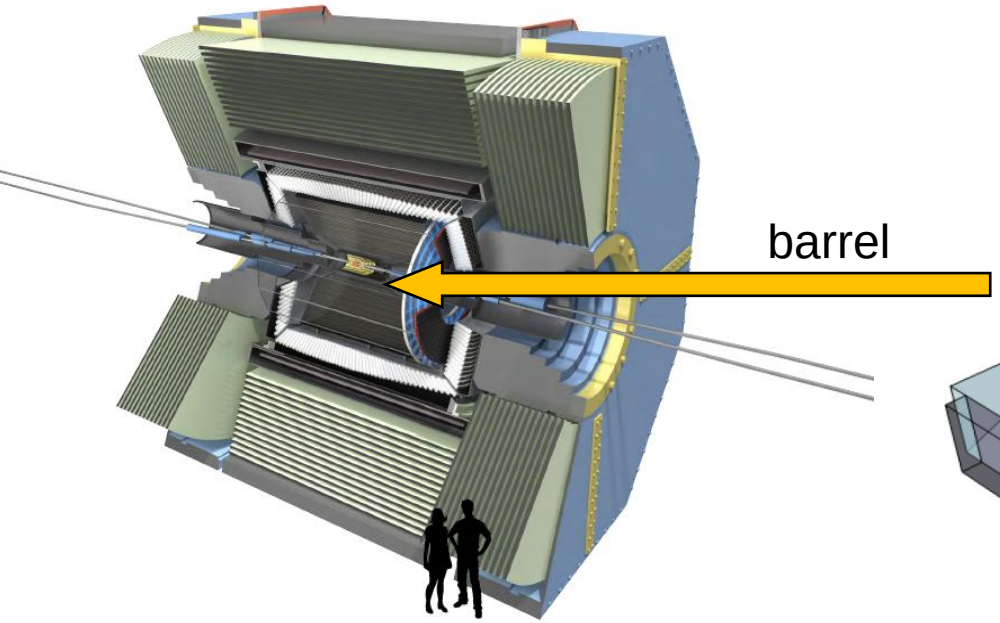
2017/8

K.Inami (Nagoya university)

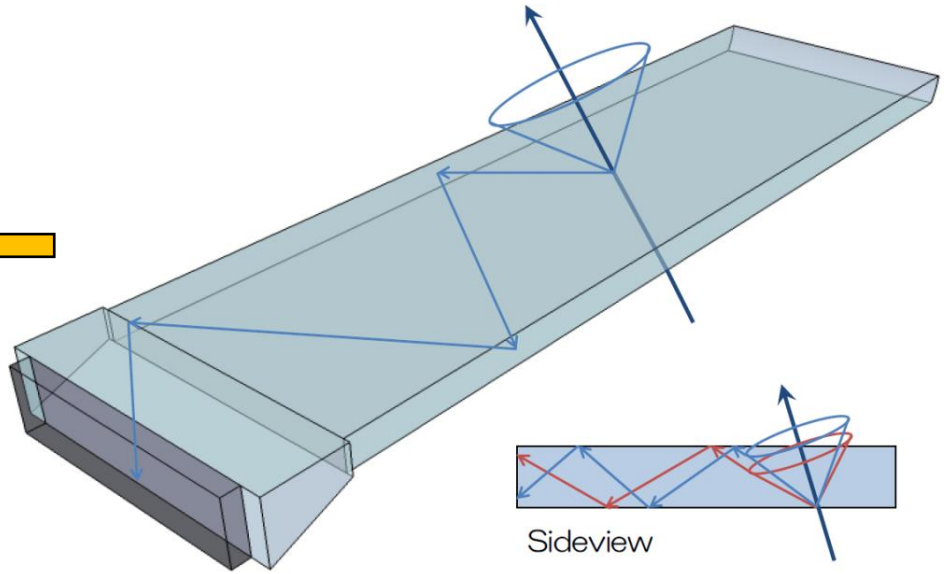
for Belle II TOP group

Belle II TOP detector

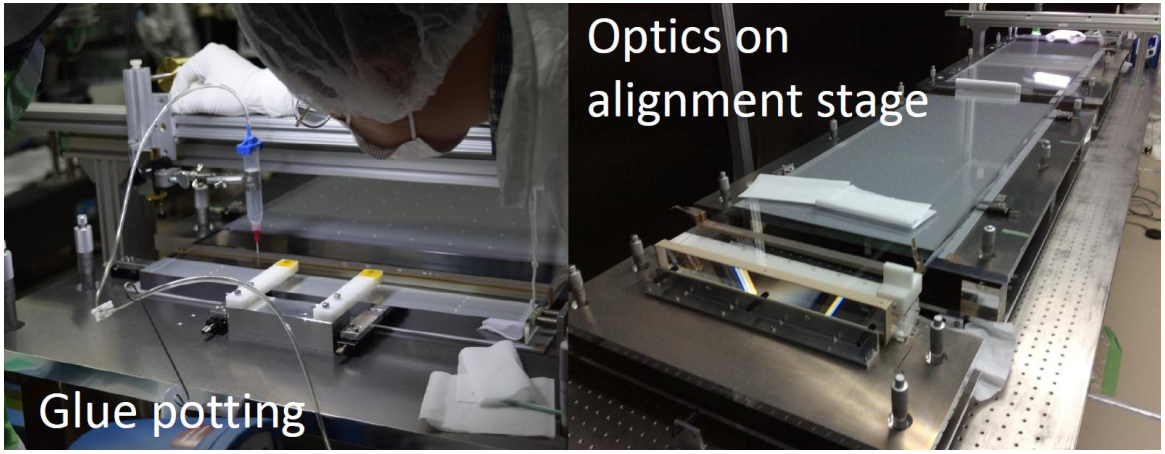
- Belle II experiment
  - Higher luminosity B-factory experiment; x50 integrated luminosity from Belle
- Particle identification; Ring Imaging Cherenkov detectors
  - A fake rate for K/π separation 2-5 times smaller than Belle
- TOP detector measures Cherenkov light arrival time/position precisely, then reconstructs particle velocity.
- 16 TOP modules are located in the barrel region outside of tracking device.

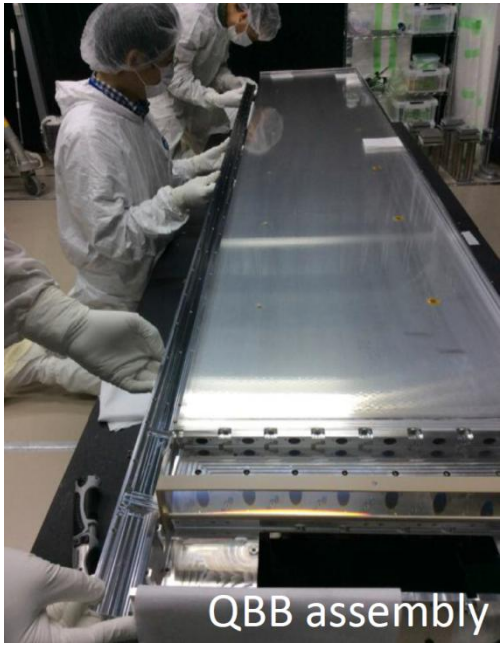


TOP（Time-Of-Propagation）Counter



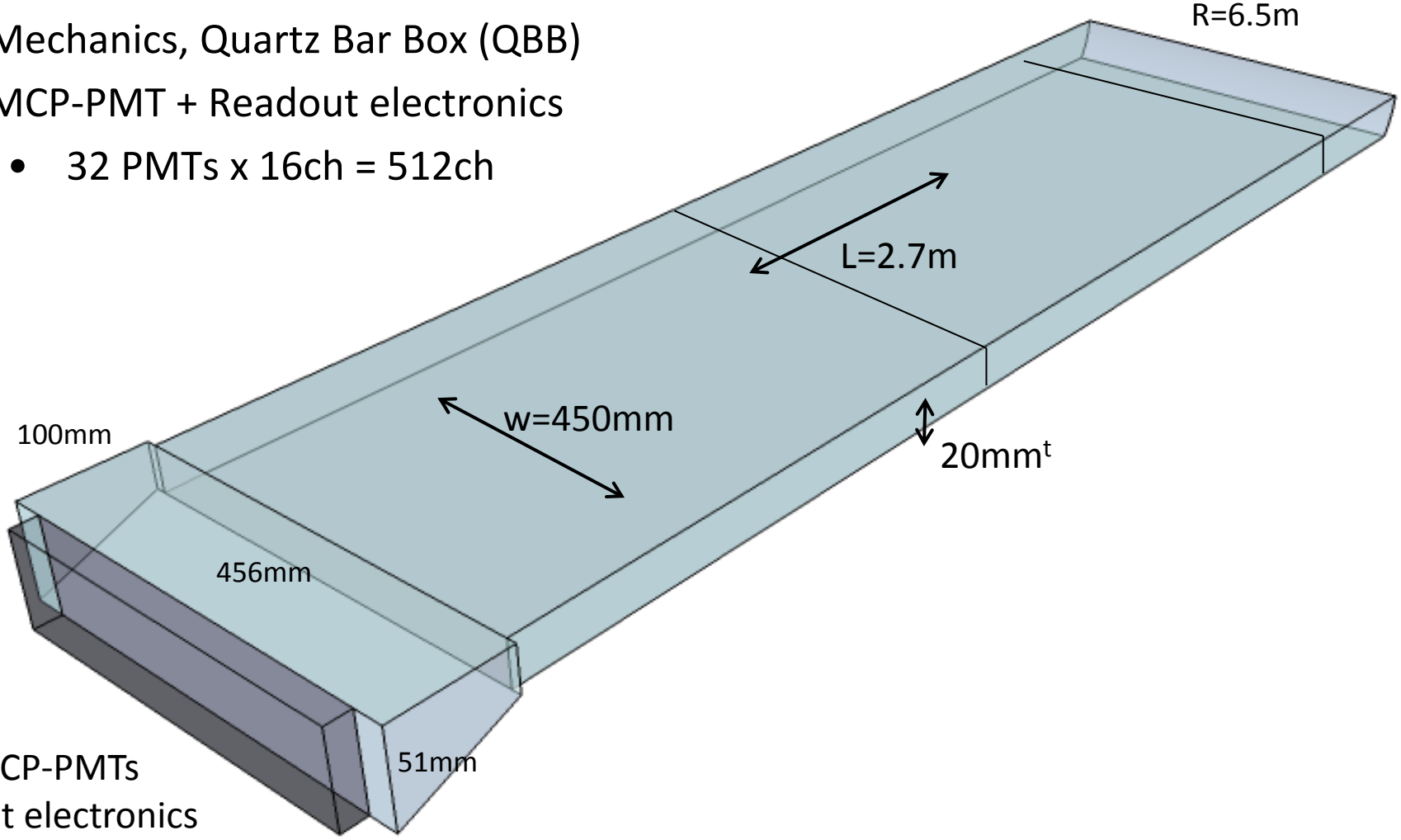
Module construction/installation done



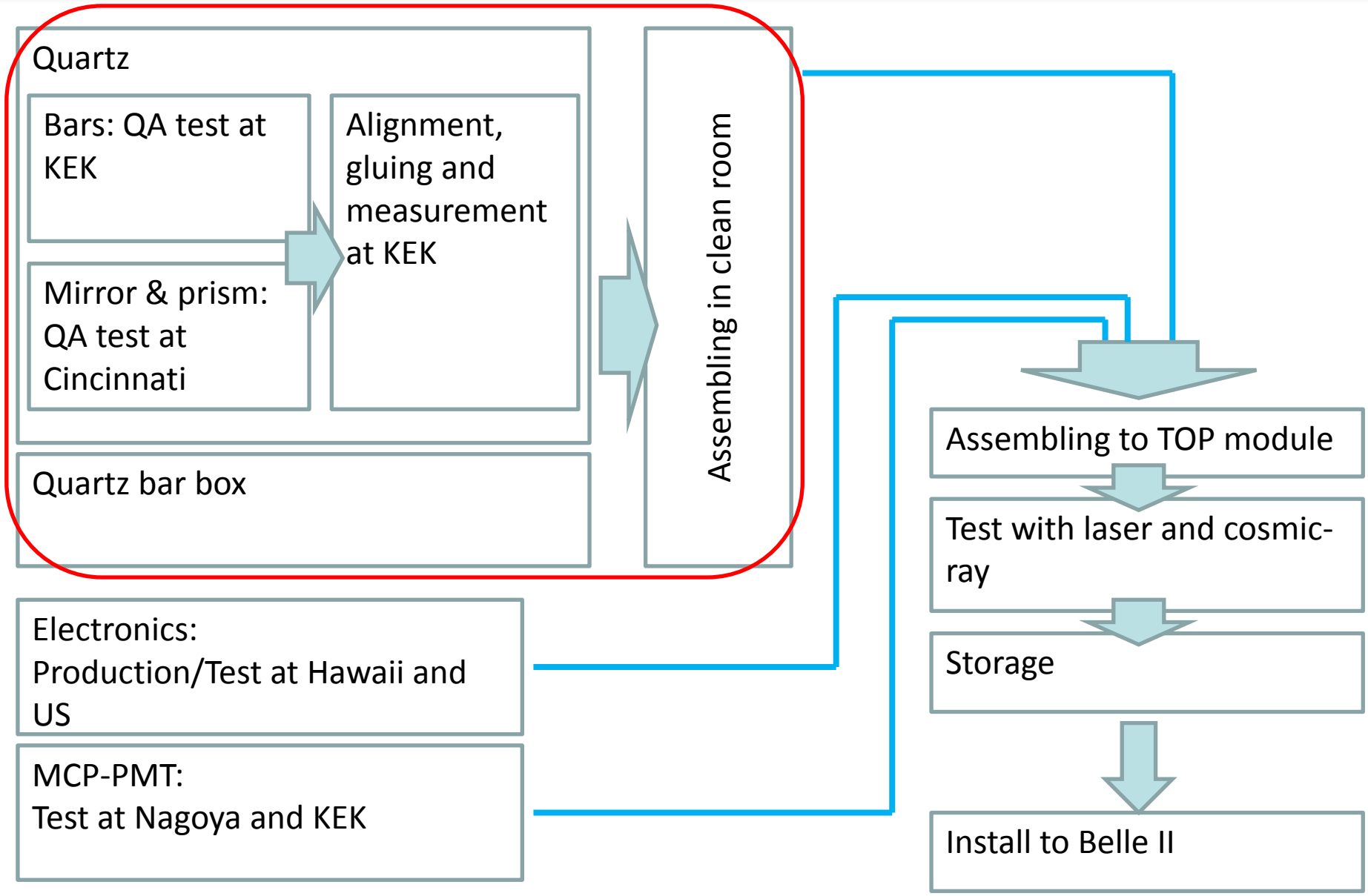


TOP module components

- Quartz radiator; two bars, mirror and expansion prism
  - Glue each other
- Mechanics, Quartz Bar Box (QBB)
- MCP-PMT + Readout electronics
  - 32 PMTs x 16ch = 512ch



Construction flow overview



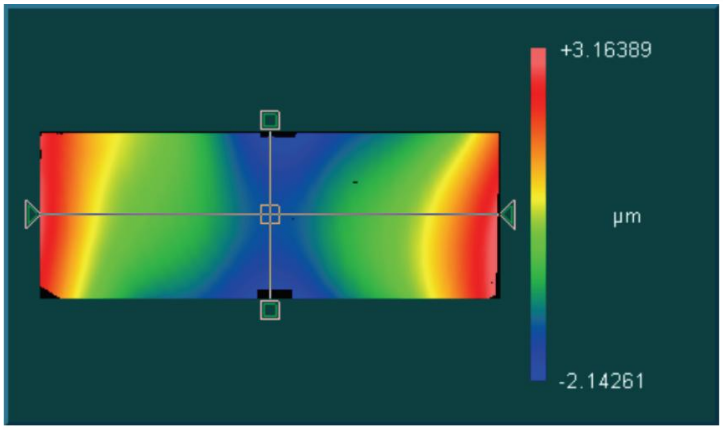
Quartz radiator requirements

- Quartz material; Corning 7980 class 0, grade D or better
  - DIN58927 class 0 material has no inclusions (inclusions ≤0.01 mm diameter are disregarded).
  - Grade D (or superior) material having index homogeneity of ≤3 ppm over the clear aperture of the blank. This is verified at 632.8 nm according to the supplier brochure.

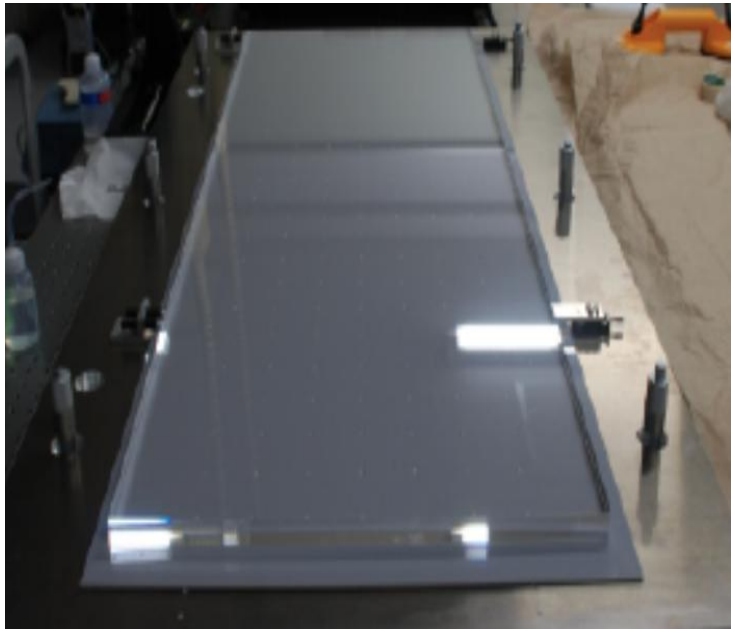
- Need high quality surface
  - Roughness: 0.5nm (to keep total reflectance)
  - Flatness: <10λ(6.3μm) over full aperture (to keep ring image)
  - Edge chamfer: <0.2mm
    - Small tip area

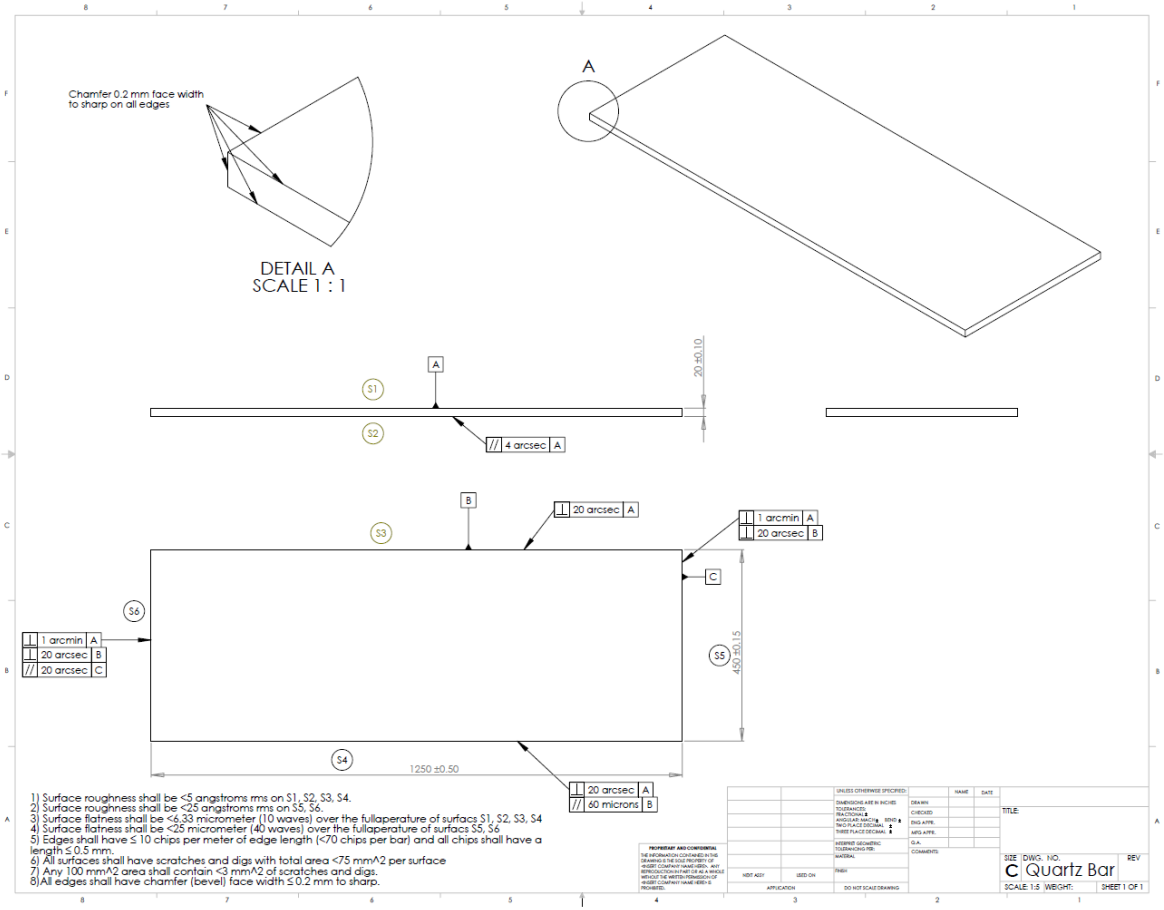
Quartz bar

- Prototype production by Okamoto-optics.
- Most of production bars by Zygo
  - Because of production rate

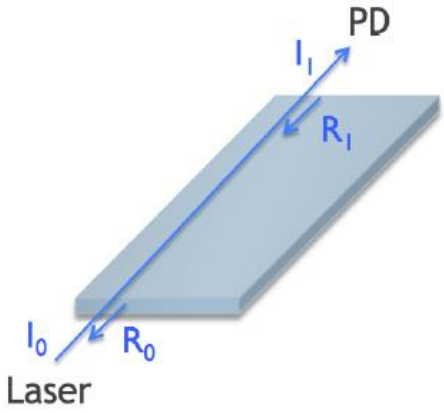


Interferograms of one of the bar surfaces from metrology report



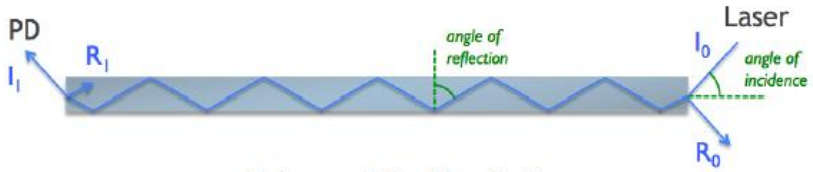


Acceptance test (bar)



Bulk Transmission

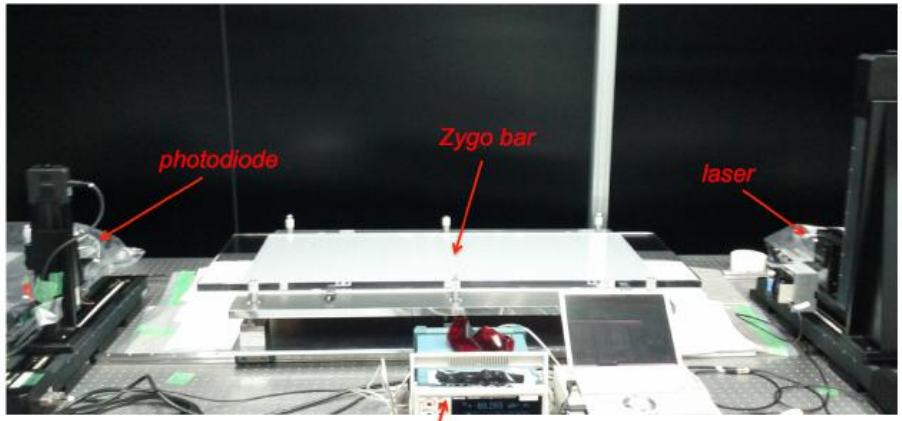
$$I_0 (1 - R_0) \tau (1 - R_1) = I_1$$

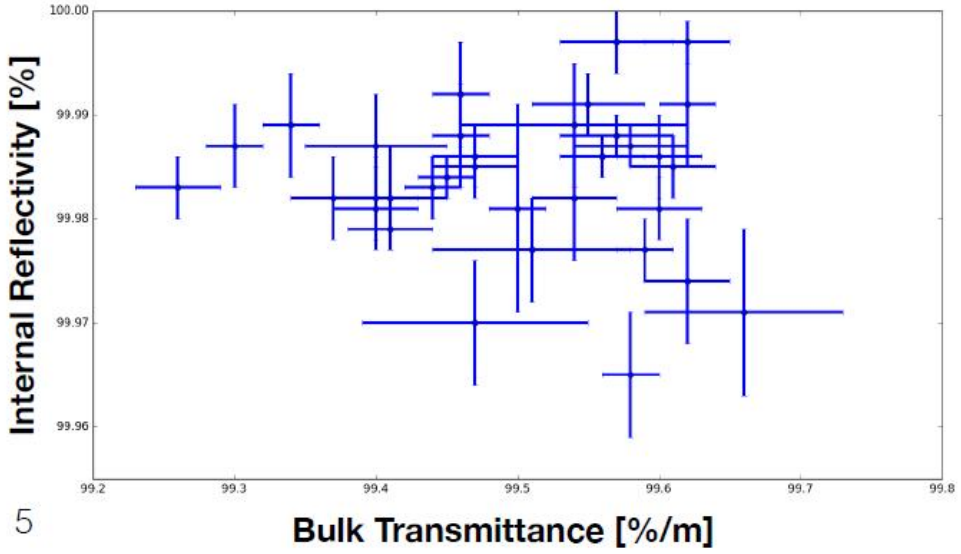


Internal Reflectivity

$$(I_1 - R_1) = (I_0 - R_0) \cdot \alpha^N \cdot \exp\left(-\frac{L}{\Lambda} \cdot \sqrt{1 + (Nh/L)^2}\right)$$

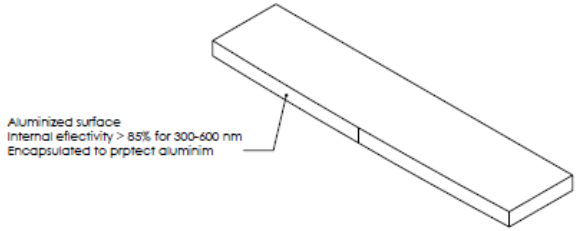
Requirement:
Bulk Transmittance: > 98.5 %/m
Internal Reflectivity: > 99.9 %



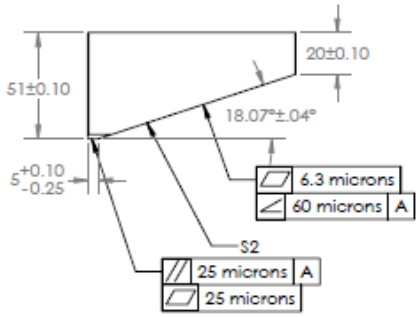


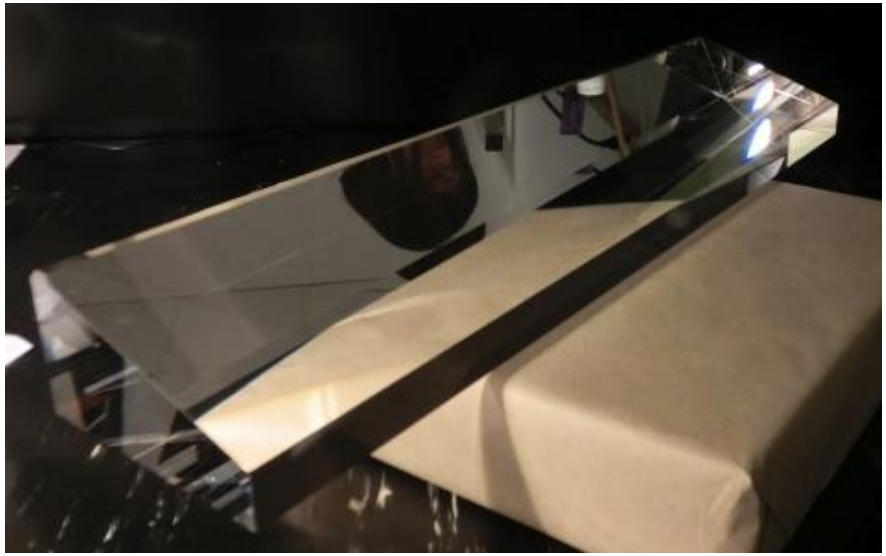
Mirror and expansion prism

- Mirror by Exelis
  - Spherical mirror (R=6.5m)
    - Aluminized
    - Peak at the edge



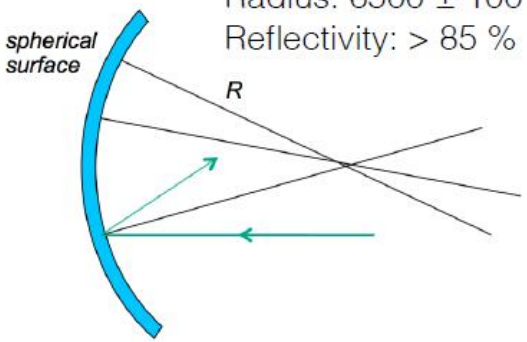
- Prism by Zygo

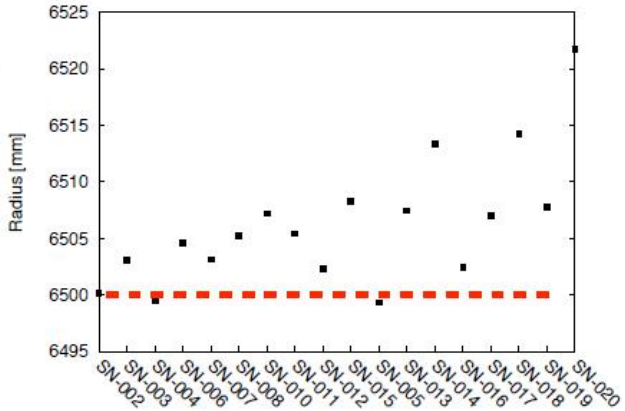


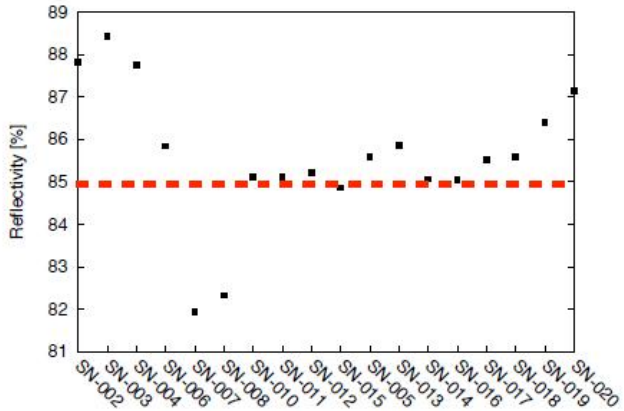


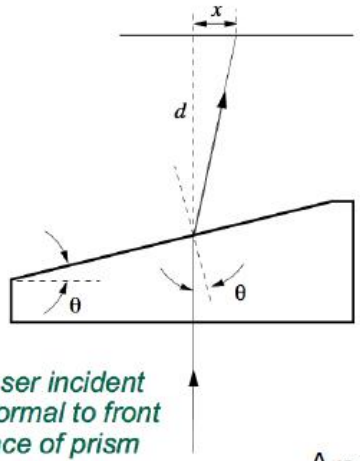
Acceptance test (mirror and bar)

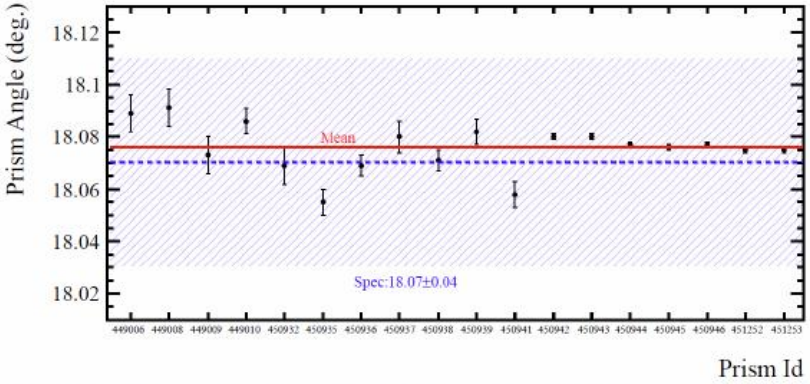
Specification
Radius: 6500 ± 100 mm
Reflectivity: > 85 %

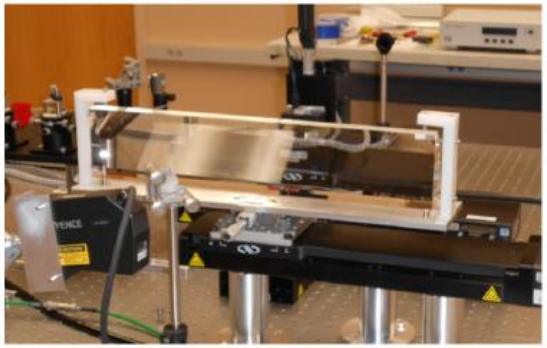












Angle of tilted face: 18.07 ± 0.04 deg (± 144 arcsec)

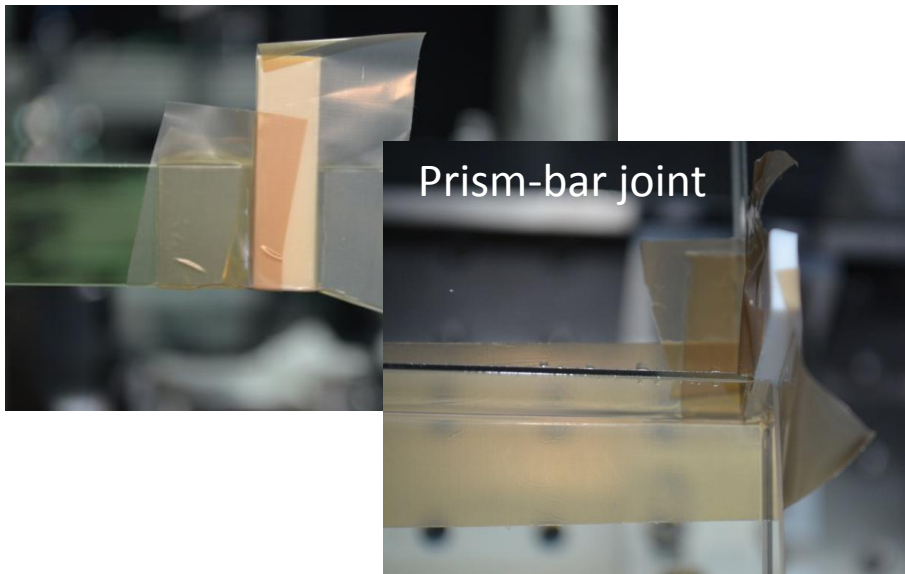
Gluing studies

- Used EPOTEK 301-2 glue
  - Need to keep joint stable by fully cured (~2 days)

- Developed “taping method”
  - Put tapes on bottom and sides of joint and pot glue on joint
  - Need to reduce leak for stable joint (optimization of gap, taping etc.)
- Strength tests
  - Checked glue joint strength for several cases
  - Prepared small quartz pieces (5x5x2cm^3) with polished surface
- Test with large sample
  - Put glue between the dummy mirror glasses and check the situation
  - Two well-polished dummy mirror quartz

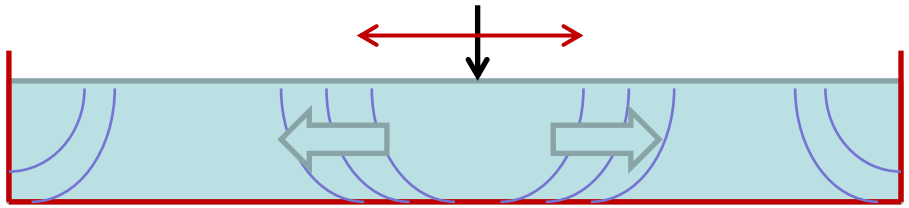
Taping method development

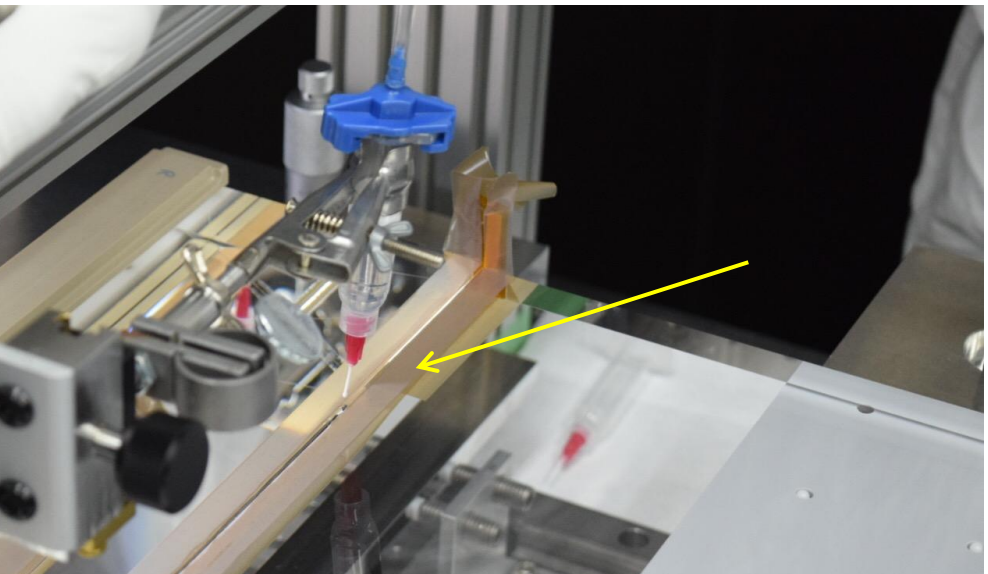
- Put tape under and side of quartz to keep the glue in the gap.
  - Remove tapes and clean up after fully cured (2~3 days after)
- Chose softer Teflon tape
  - Easy to fix the leakage around the edge
- Teflon block and tape for prism part
  - Difficult joint due to the difference of width; Prism (456mm), bar (450mm)
  - After several ways, finally no leakage happened
- Enabled to align/tune after taping by using soft tape

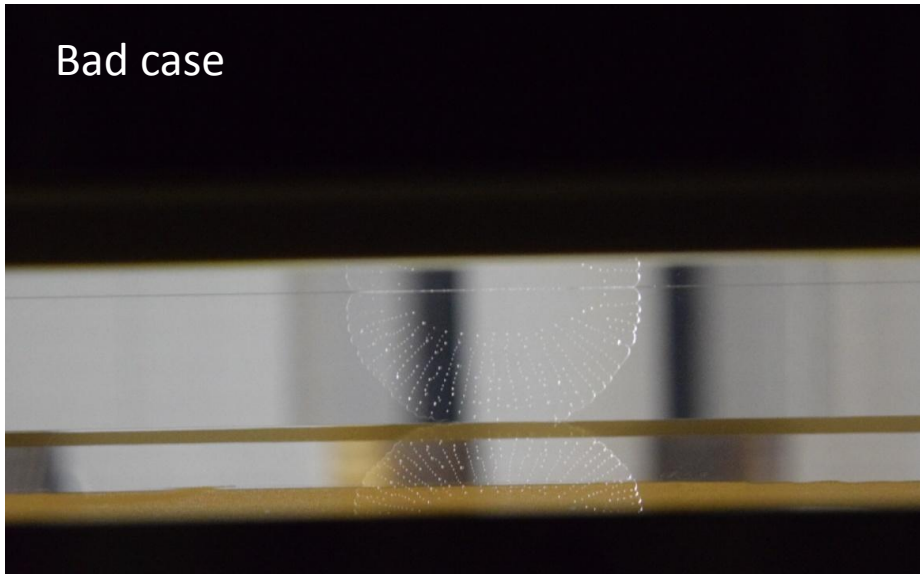


Glue flow

- Pot glue at the center of joint
- Move dispenser head forward following glue front.
  - Not to include air bubble
- Fill up the gap by glue (~one hour)
- If there are many bubbles, remove joint, clean surface carefully and retry again.

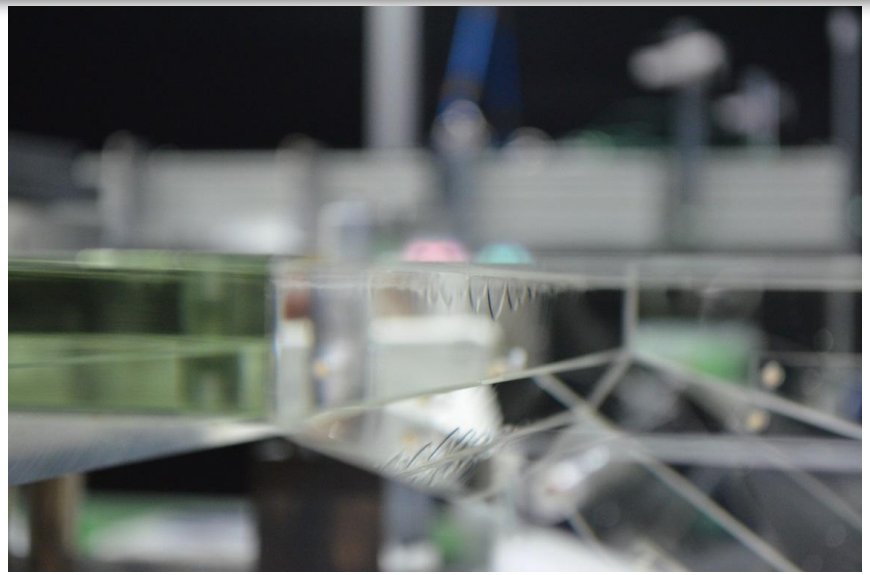


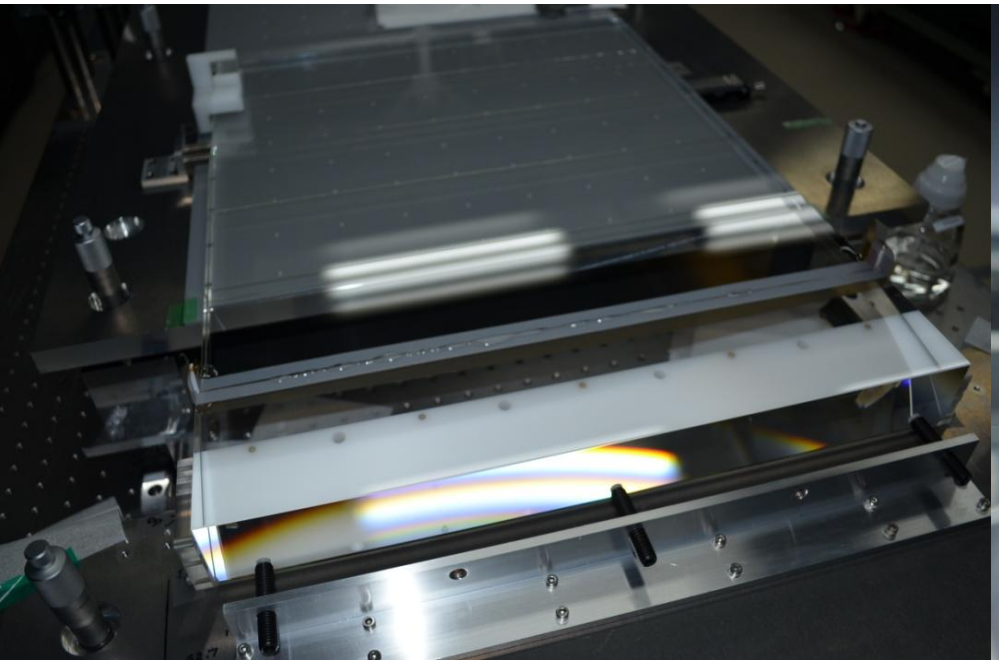


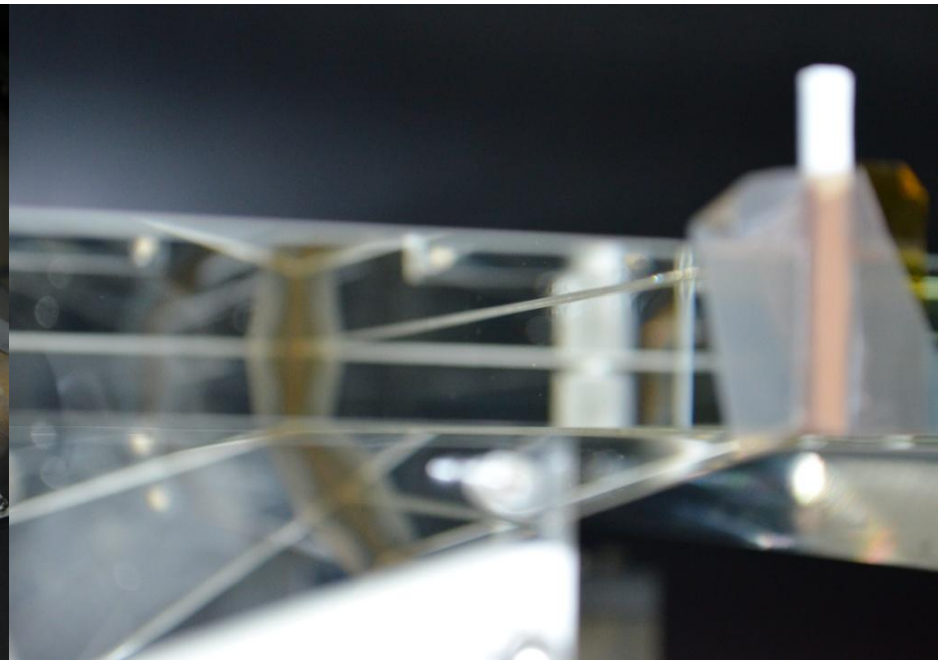


Striae like structure of glue

- Found index change of glue (striae like structure) along cure progress
- Found putting additional glue on top can avoid (or weaken).
  - Put Teflon tape as a dam on the top surface

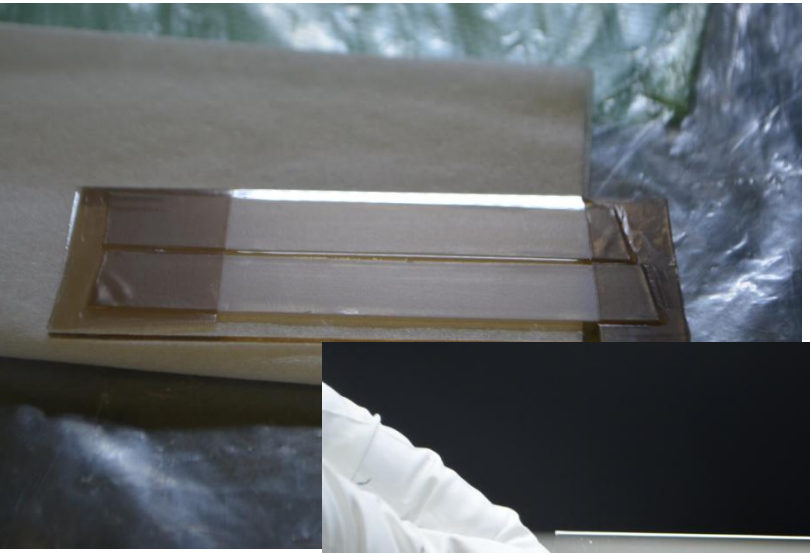


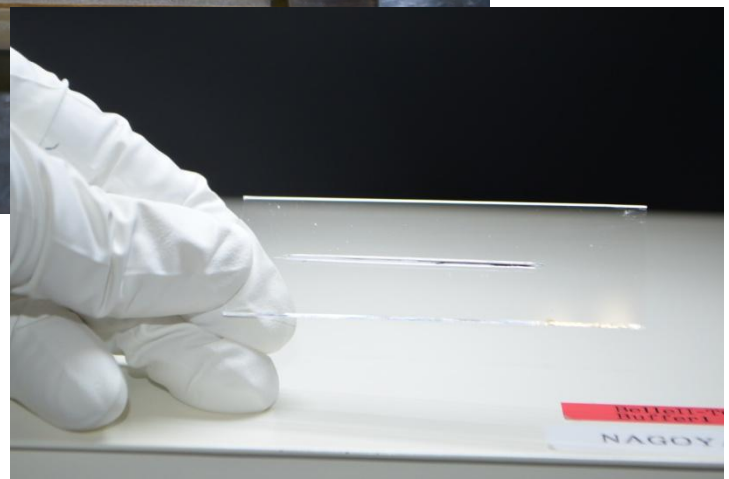


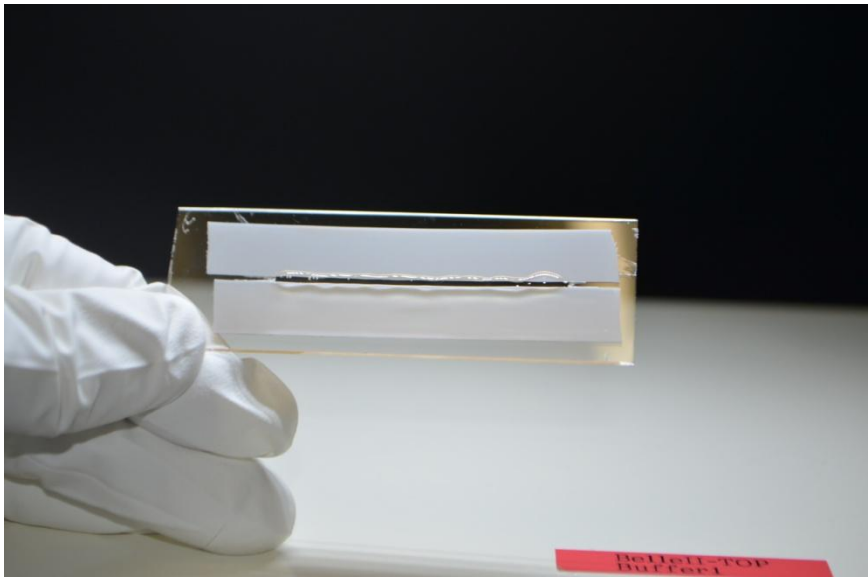


Glue cleaning tests

- Check cleaning of remained glue between dam after half/full cure
  - We could remove, although thicker glue needs much acetone and time.
- Try to use thinner dam and less remained glue
  - Pre-cleaning at half cure state (5~8hours after mixing) makes the process easy.



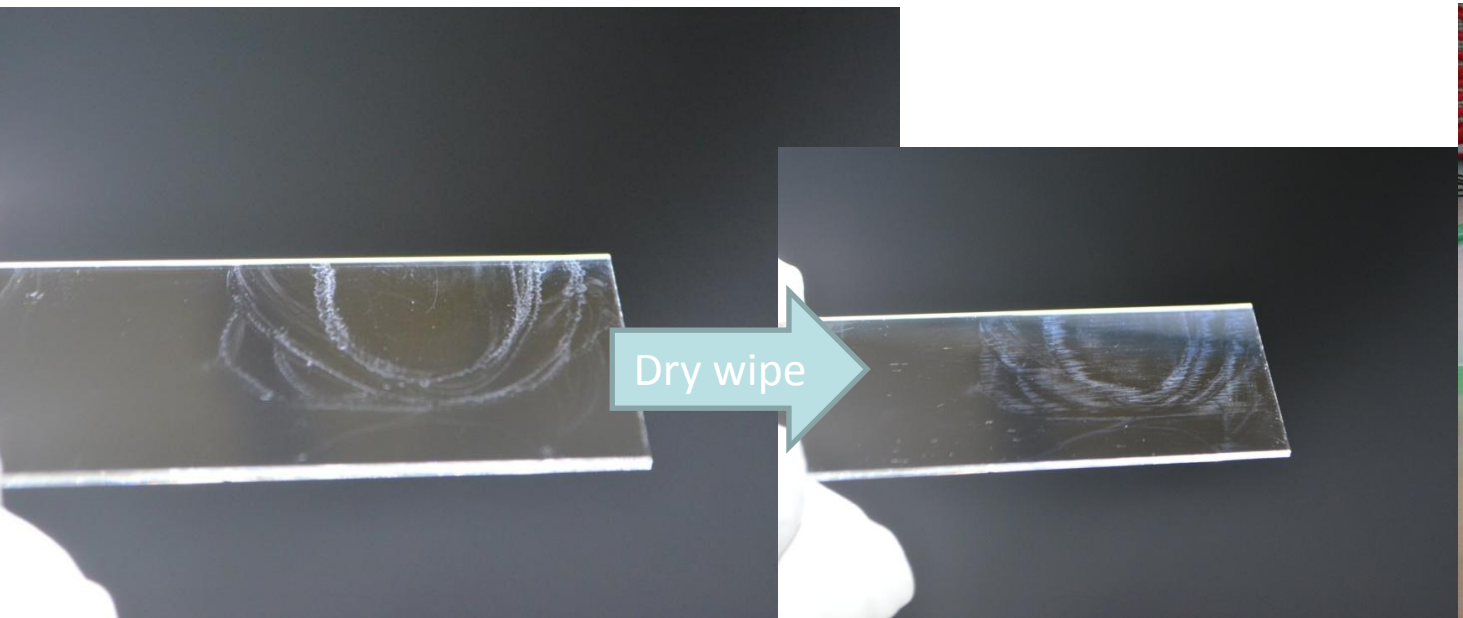




Acetone residue after evaporation

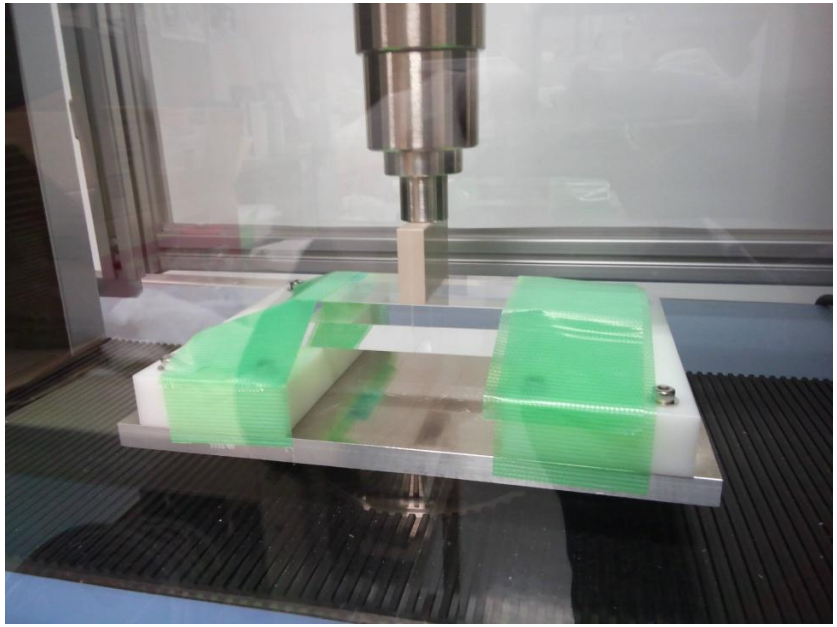
- Found visible acetone residue after the evaporation
  - No clear residue for fresh acetones (just after getting from original bottle)
  - It looks due to leeching/dissolution from washing bottle.
    - Longer storage (>several weeks) shows more visible residue.
    - The bottle was recommended by Zygo.

→ Changed to use small Teflon bottle (to refresh short time cycle)



Bending test with small polished quartz

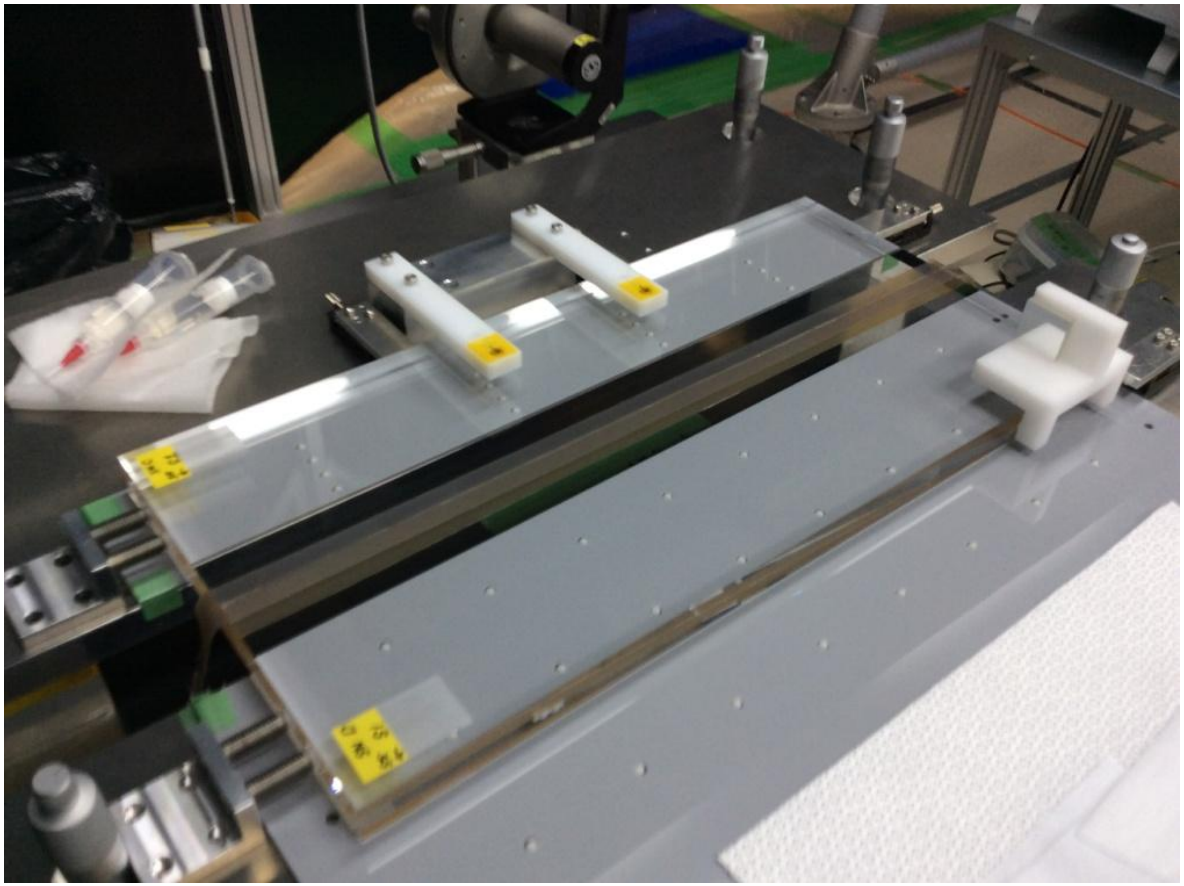
- Check the strength with the “normal” procedure
  - Alignment, taping, putting glue, curing, un-taping, cleaning the excess
- Tested many small samples
  - 841N; corresponds to the maximum stress by the self weight of 2.5m quartz bar supported at the end point without QBB. (extreme case)
- Glue applied by the default procedure shows good strength.
  - No strange delamination was seen during the test.



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

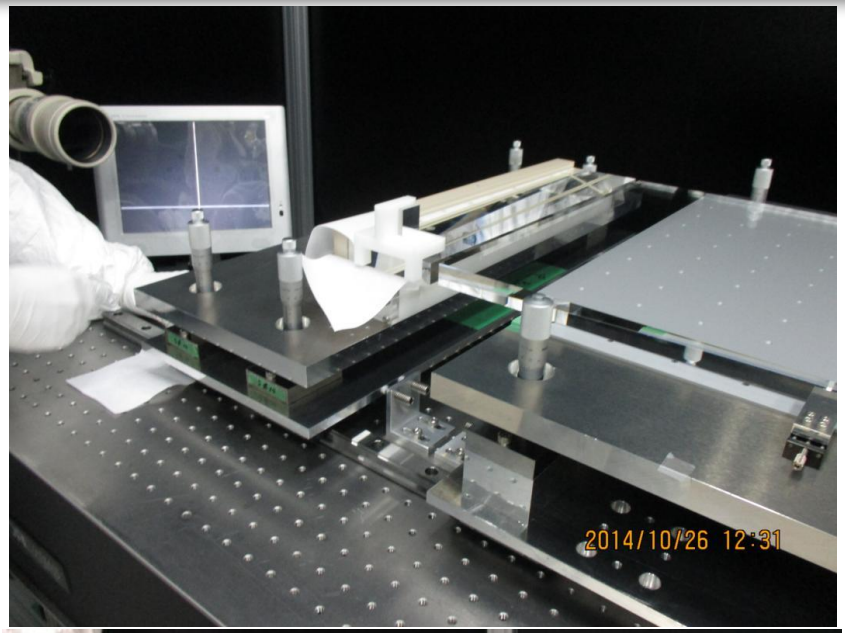
Test with large sample

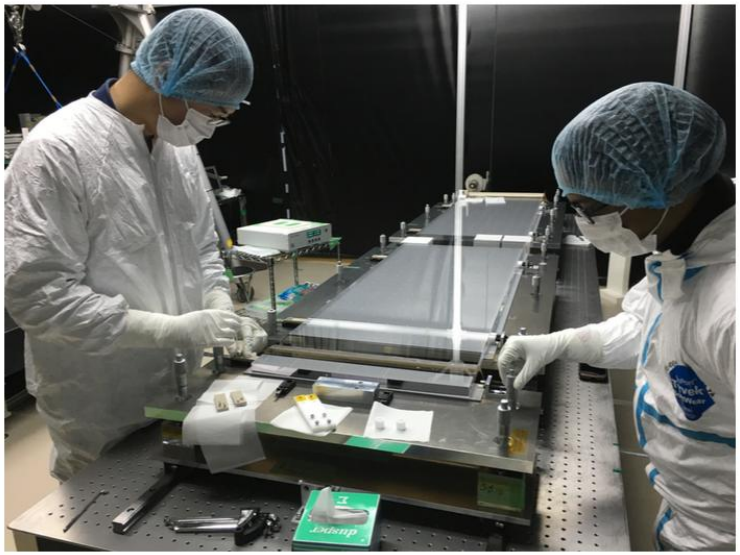
- Glue cured with large quartz sample (same surface quality with mirror)
  - Again, visible stripe-shape index change found at beginning, but become very weak after full cure

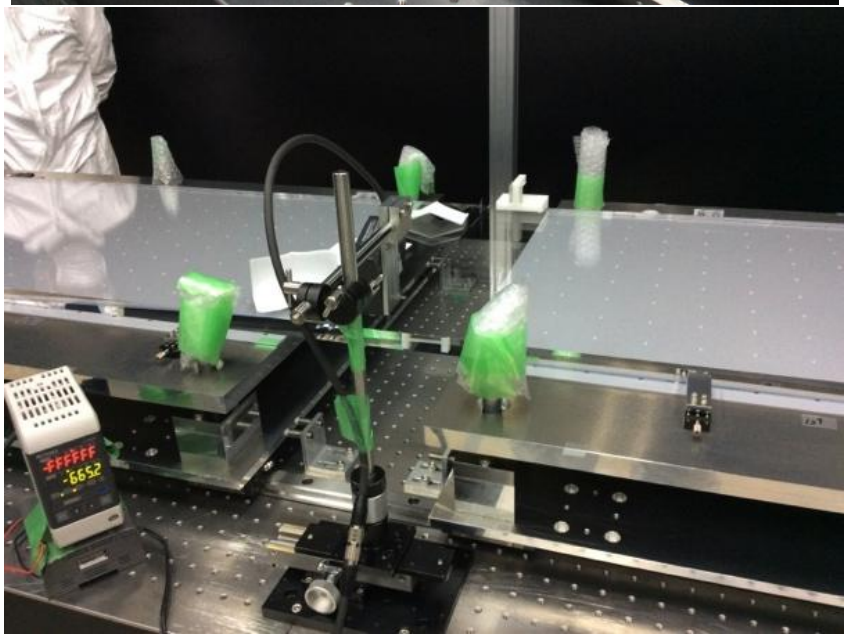


Quartz alignment

- Optics joints are cleaned carefully, then aligned by gluing stage
  - Quartz position is tuned by micrometer heads at stage corners and side.
  - Relative angle and height are measured using autocollimator (~10arc-sec, ~0.05mrad) and laser displacement sensors (~20micron), respectively.
  - Gap between parts tuned using plastic film (t~50μm)

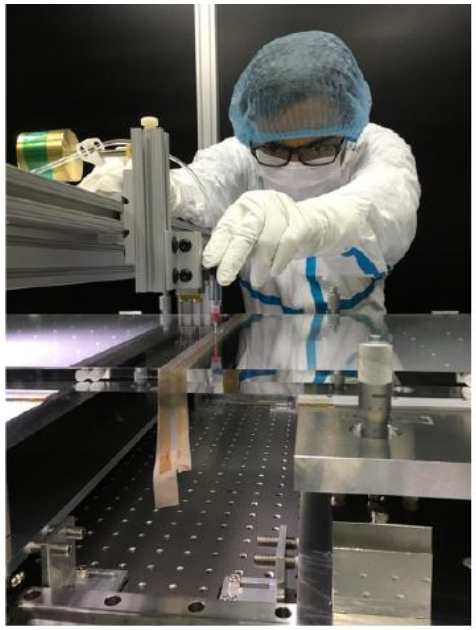


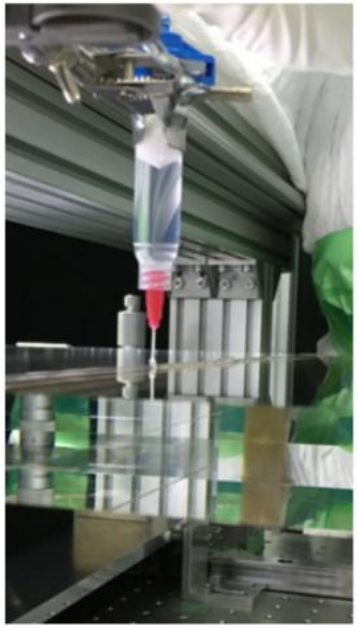


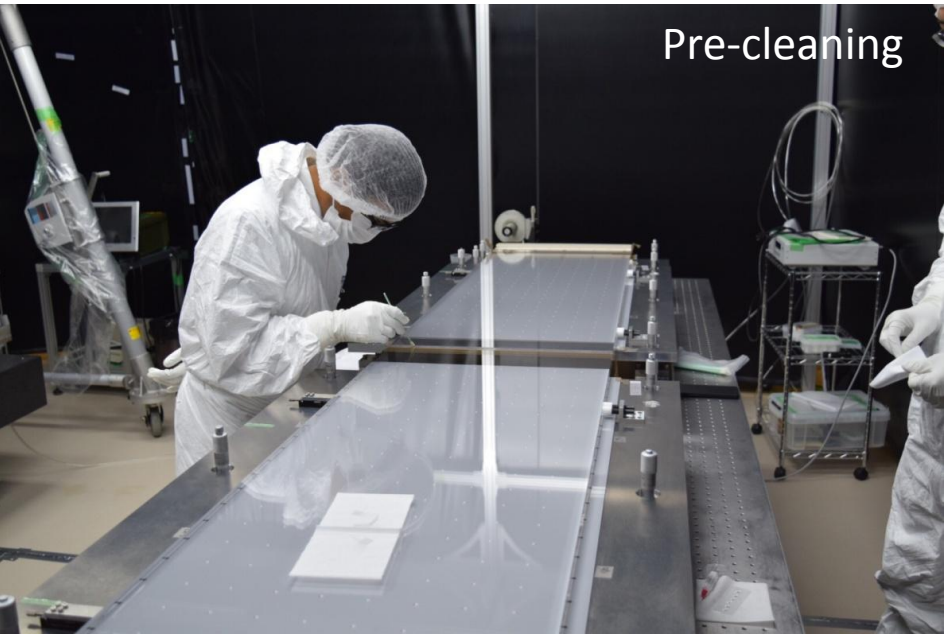


Gluing of modules

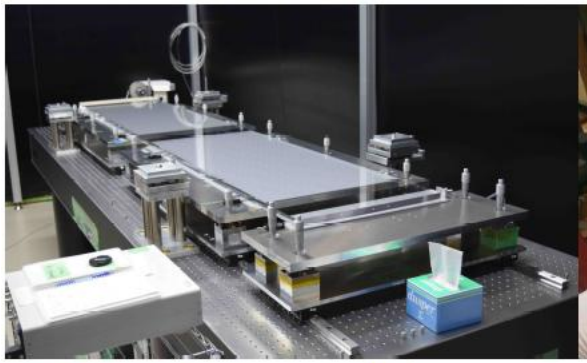
- Put tapes after the alignment
- Pot EPOTEK301-2 glue on the gap
- Pre-cleaning of glue excess
- Clean excess glue after fully cured and final inspection of quartz shape



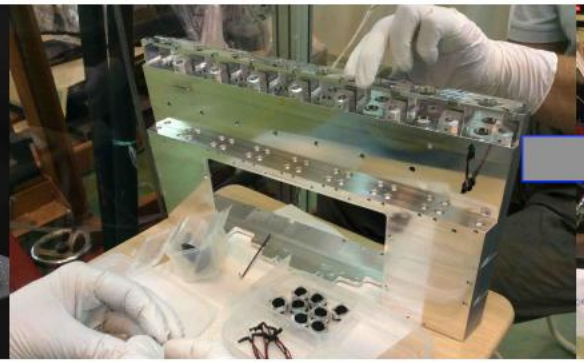




Assembling



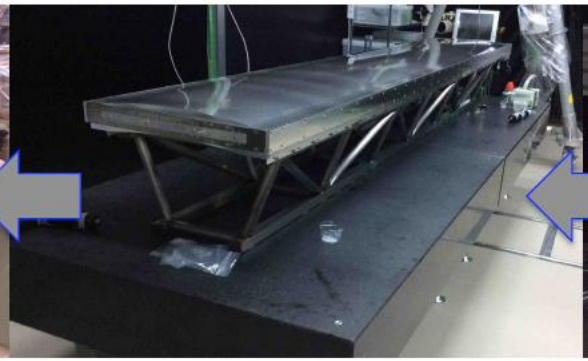
Optics: alignment, gluing, curing and aging (~2 weeks).



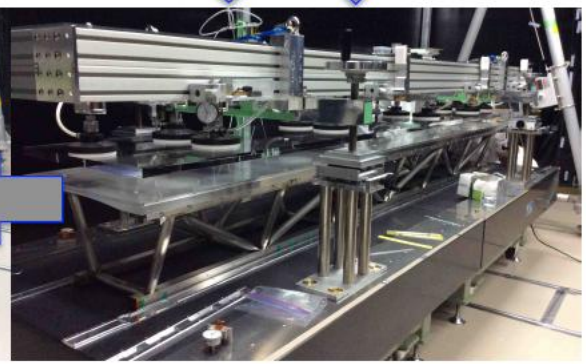
Enclosure: gluing CCDs and LEDs, integrating fiber mounts.

QBB: strong back flattening, button & enclosure gluing.

Put on a cart. PMT and front-end integration, performance check.



QBB assembly and gas sealing.



Move optics to QBB using the "lifting jig".

Summary

- We finished 16+1 TOP module production and installation.
  - Produced 16 modules in one year.
- Quality assurance test shows excellent quality.
- We studied many gluing procedures using slide-glasses, small prisms, small quartz sample and large quartz sample, to fit to large quartz.
  - Developed “taping method”
  - Confirm good glue strength with our procedure
- Quartz gluing with alignment tools worked well.
- Assembly with quartz bar box was done successfully.