Assembly report about Input Faraday Isolator of KAGRA

f2f Meeting at Tokyo
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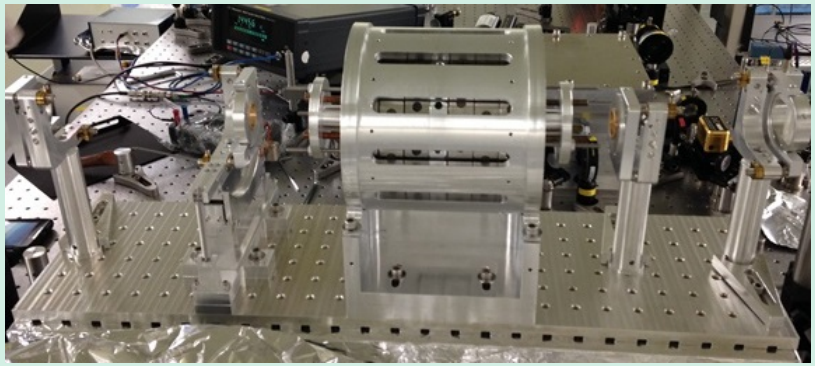
D.Tanner and K.Somiya

IFI of KAGRA

▷ **Design** – KAGRA adopts arranged IFI of aLIGO.

	Commercial Faraday	KAGRA's high-power Faraday isolator
Photo		
Price	3k USD	48k USD
Weight	1kg	45kg
Max power	50W	200W
Work in vacuum	No	Yes
Mode distortion	Yes	No

Commercial one would not work for KAGRA

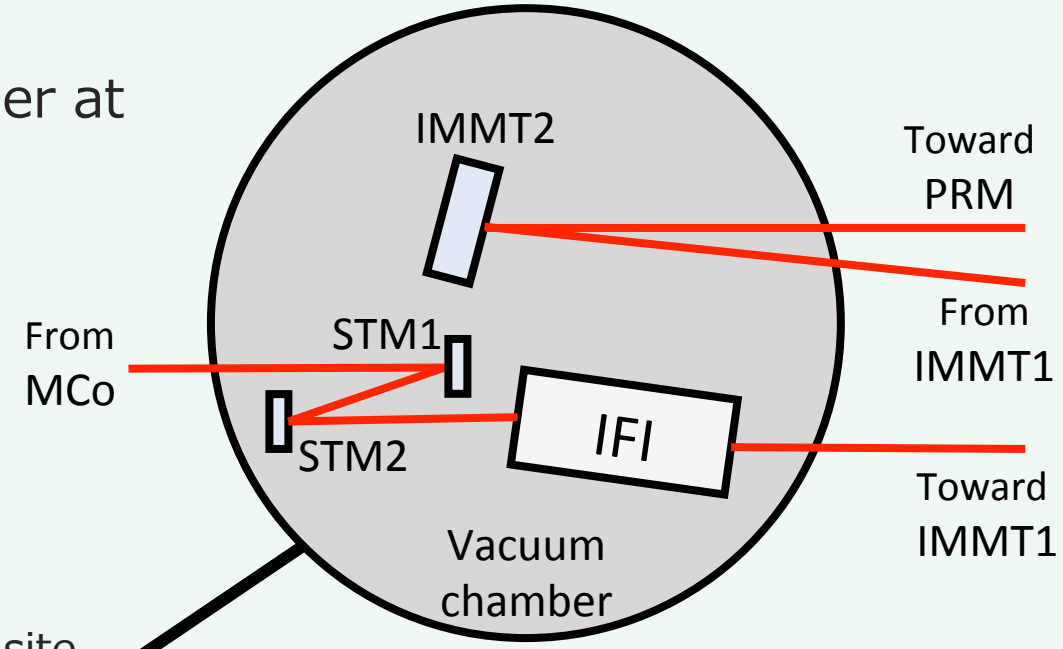
3 IFI of KAGRA

▷ Location

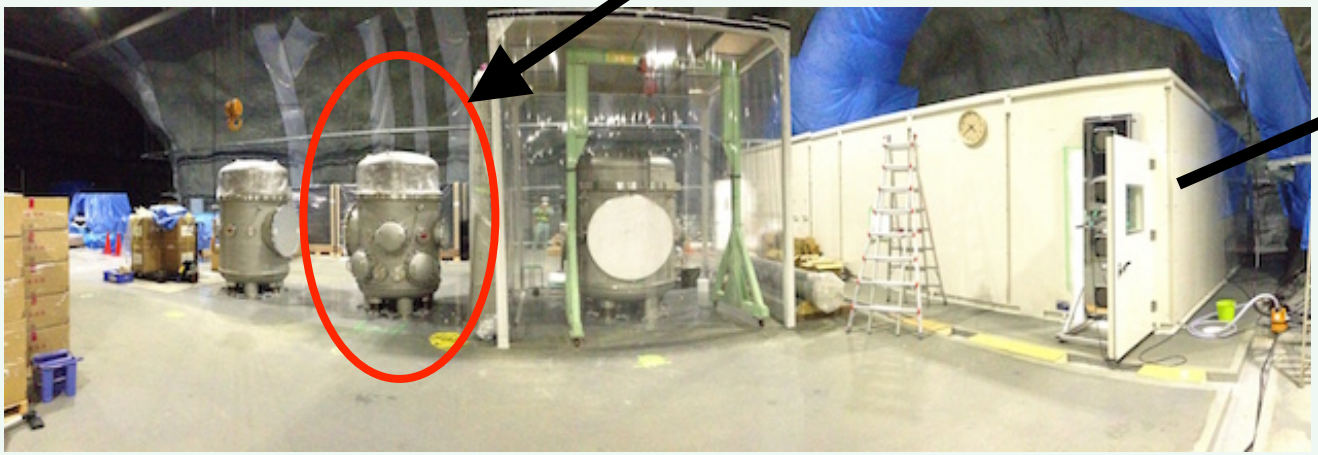
- Put in the vacuum chamber at the between MC & MMT.

▷ Requirement

- Transmittance: 95%
- Isolation ratio: 35dB
- Vacuum correspondence

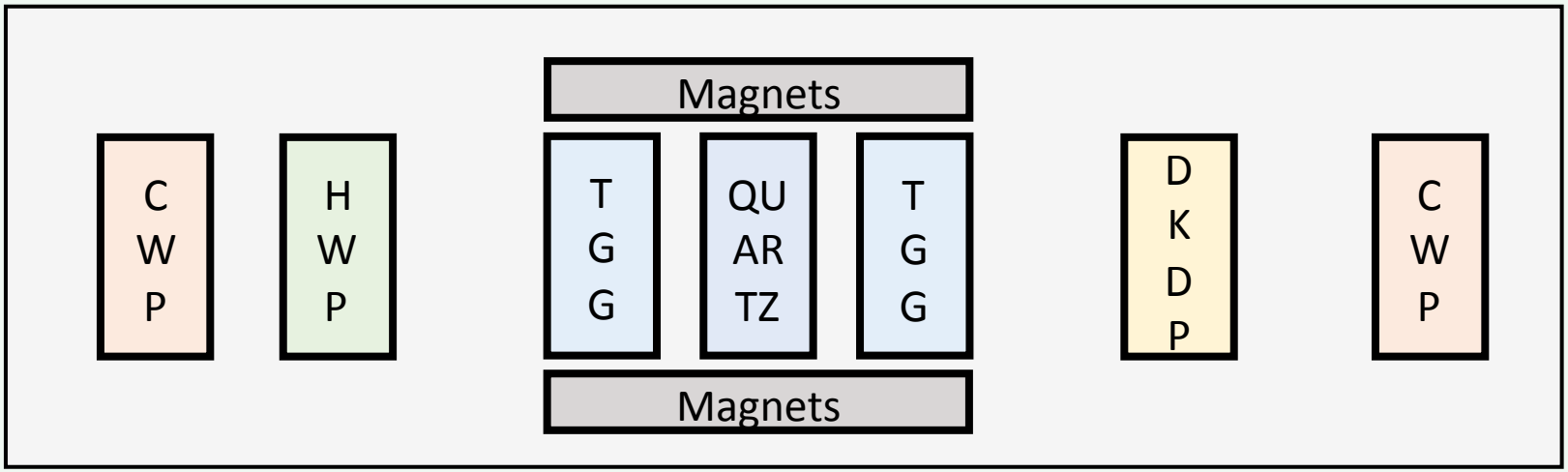


Center room at KAGRA site



4 IFI of KAGRA

▷ **Components** – 6 kinds of optical elements

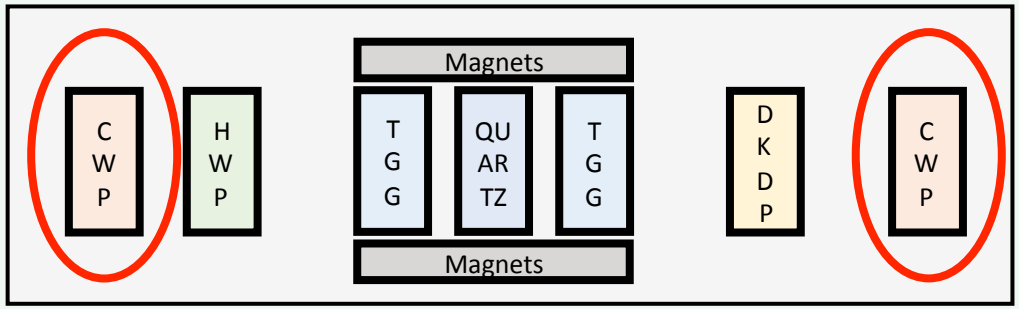


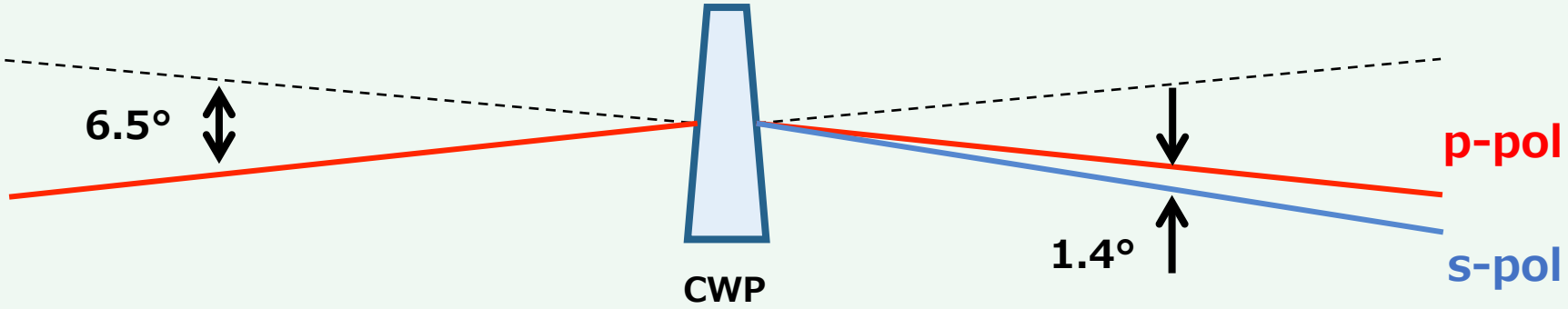
	Diameter [mm]	Thickness [mm]	Reflectance* [ppm]	Refractive index
CWP	25*25 (trapezium)	3 ~ 6.825	1200	S:1.6424 P:1.4797
HWP	25.4	1.8	300	1.5341
TGG	20	10.41	1500	1.9437
QUARTZ	20	10.69	500	1.5340
DKDP	25.4	3	1500	1.4931

IFI of KAGRA

▷ **CWP** (Calcite Wedge Plate)

- Split the p-pol and s-pol.
- Performance is better than PBS or TFP





After beam passed CWP
- p-pol 6.5° refracted
- s-pol 7.9° refracted

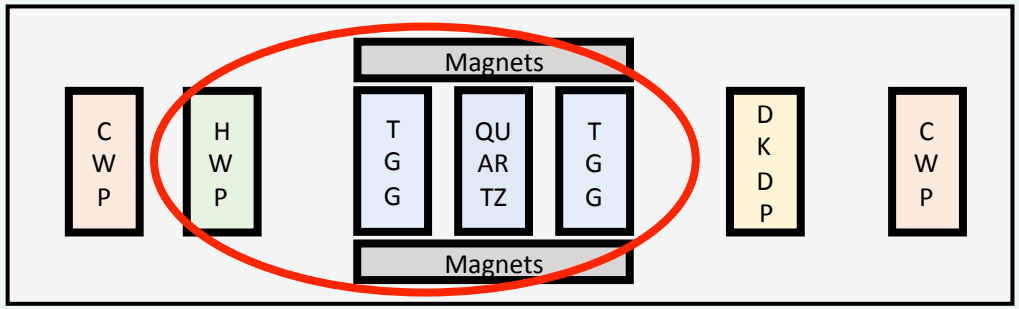
⇨ **p and s-pol are split 1.4°**

IFI of KAGRA

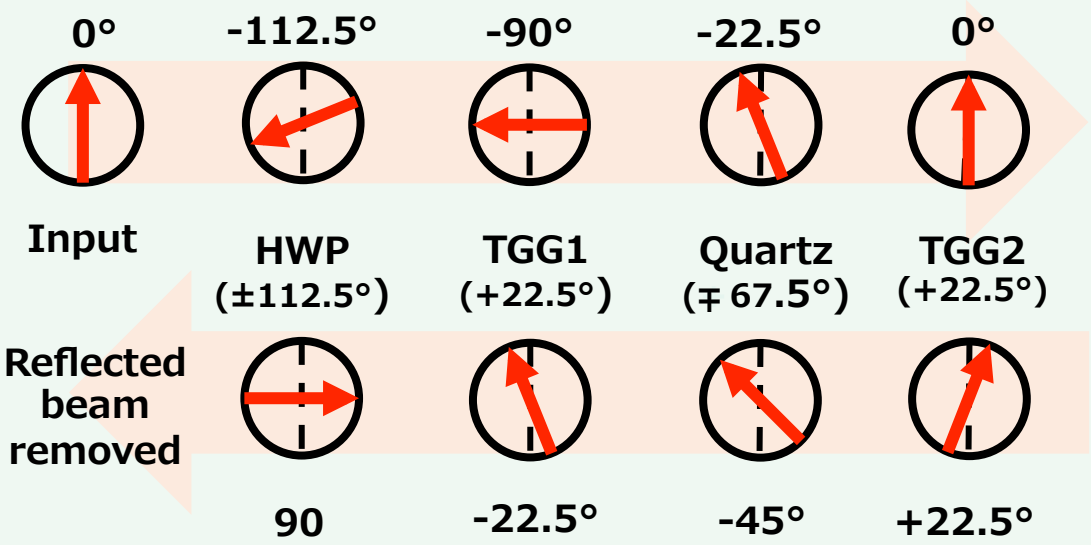
JOSA B. Vol.17. issue 11, pp. 99-102 (2000)

▷ Rotators

- HWP (Half wave plate)
- A pair of TGG crystals
- Quartz rotator
- Strong magnet rings



Steps of rotation



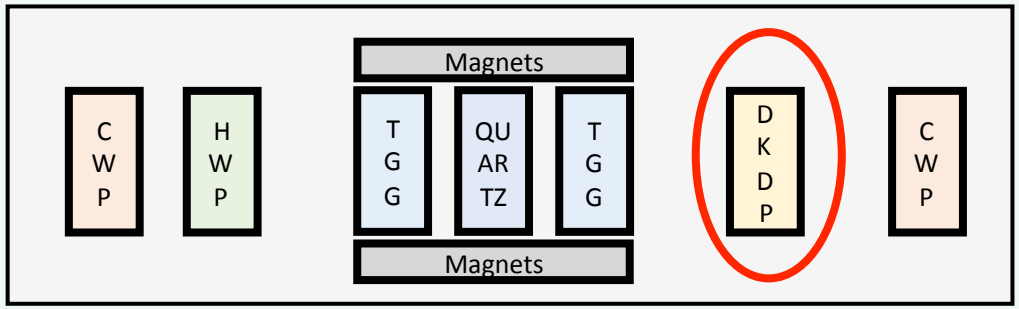
KAGRA IFI's rotators suppress
self-induced depolarization of high-power laser

IFI of KAGRA

2002 Class. Quantum Grav. 19 1793

▷ DKDP

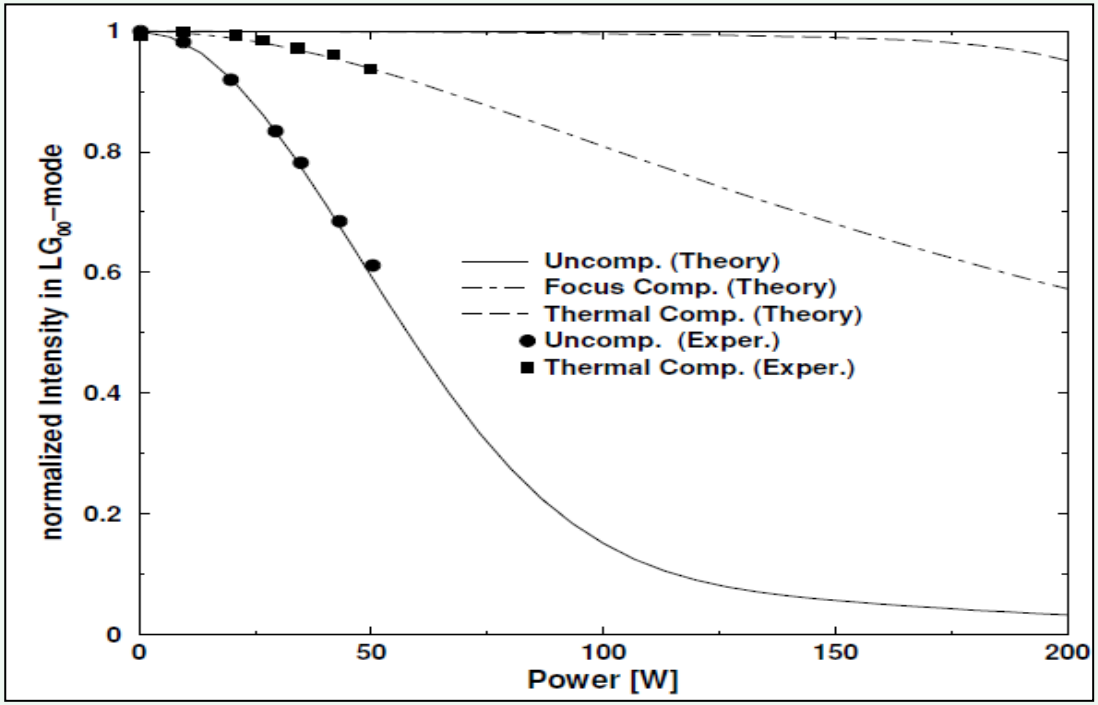
- Compensate the thermal distortion depending on power.
- Sensitive to humidity.



・Laser power changes under lock acquisition.
・KAGRA's IFI is in vacuum.

⇩

KAGRA needs DKDP



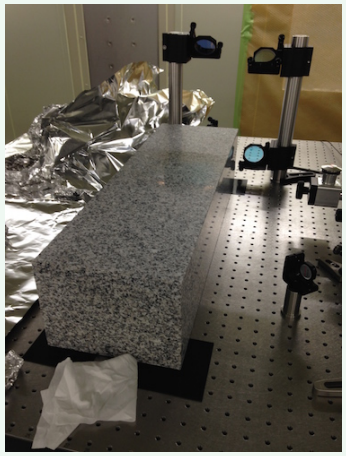
Assembly at KAGRA site ①

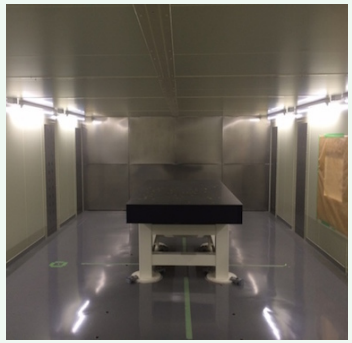
▷ Dec 1-16 2014, @PSL table in Kamioka mine
▷ with 3 people from Tokyo Tech & 3 people from U.Florida
(Yano, Kataoka and Somiya) (Mueller, Goetz and Tanner)

Place
- There is no particle >0.3um.
- Assemble at the cleanest upper side.

Additional table
- Reduce magnetic effect from PSL table.
- Beam passes with periscope.

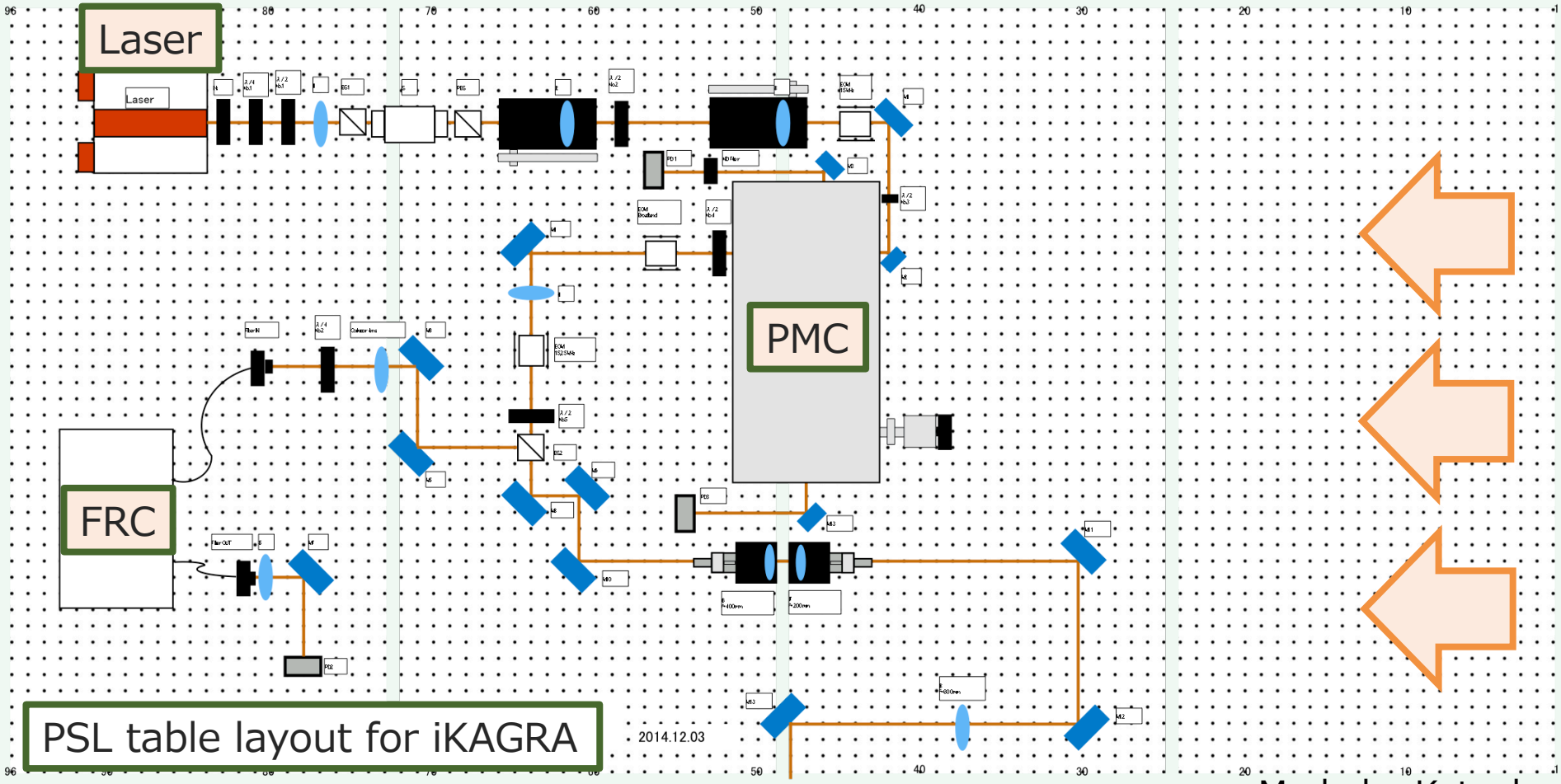
IFI parts & tools
- Cleaned and baked @U.S.
- Used with UHV (Ultra High Vacuum) foil





9 Assembly at KAGRA site ①

▷ Layout of the PSL table
- Cleaned air flows from right side.

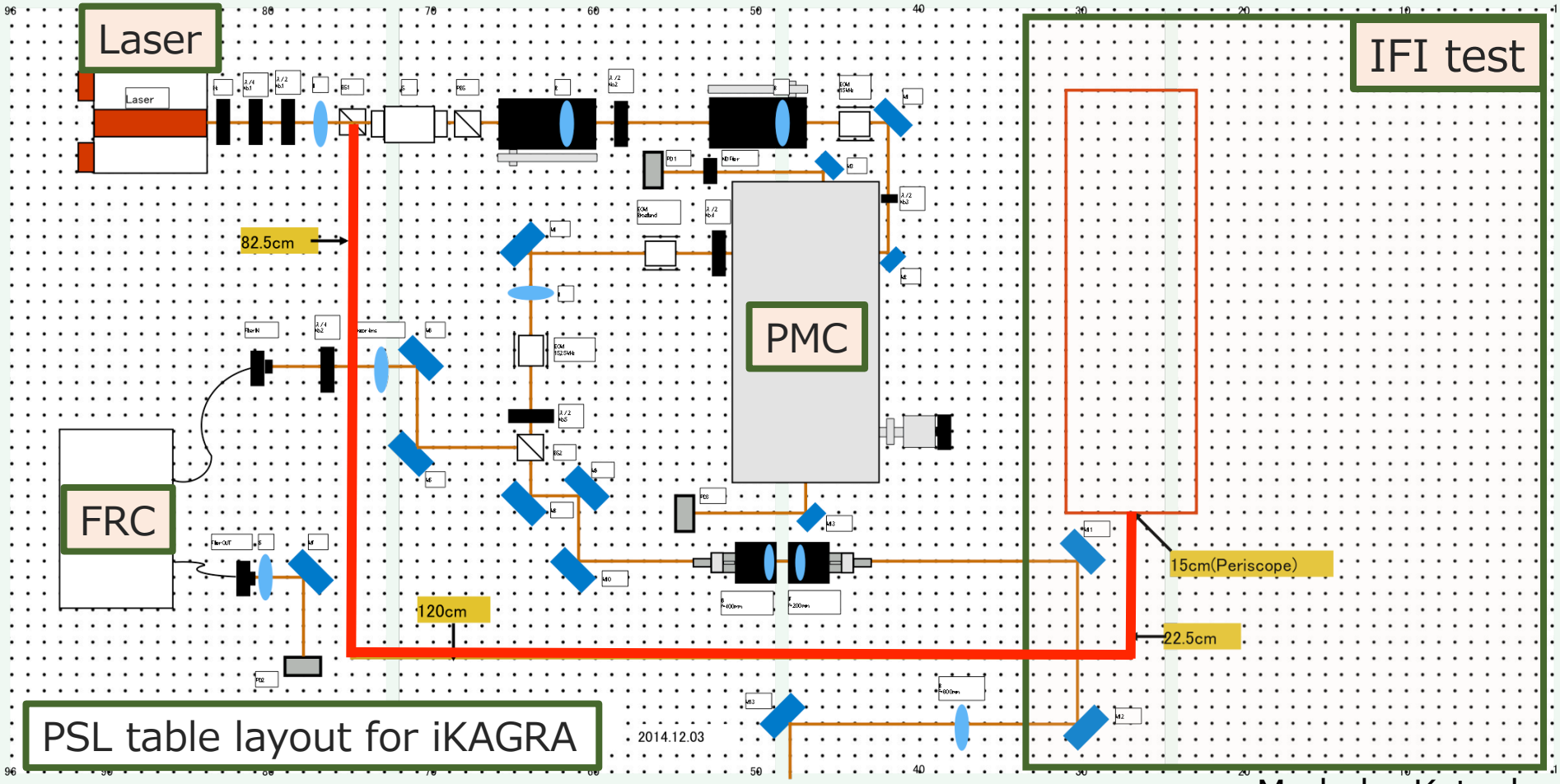


Made by Kataoka

10 Assembly at KAGRA site ①

▷ Layout of the IFI assembling

- We uses beam before PMC because PSL's work was late.



Made by Kataoka

Assembly at KAGRA site ①

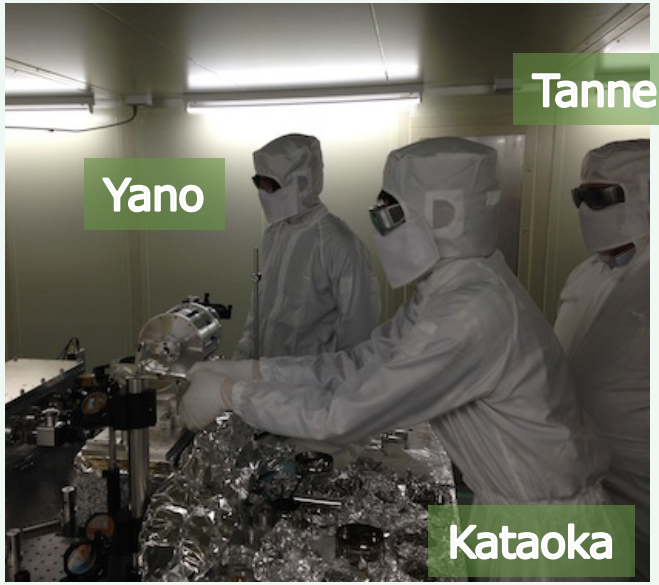
▷ Assembly steps.

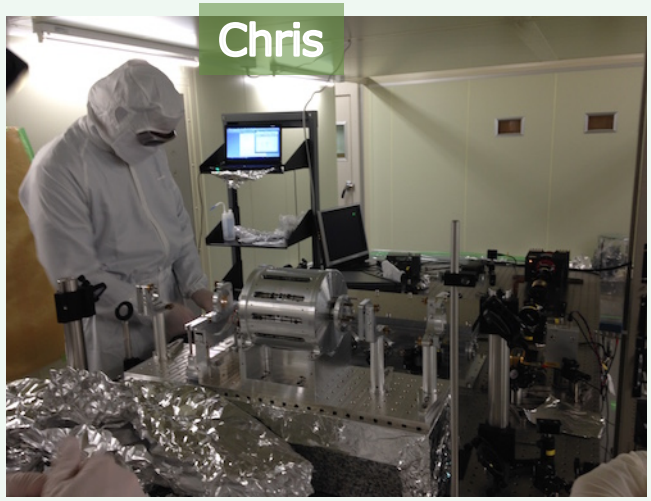
Installation and alignment

1. **HWP**
2. **CWPs**
   – rotate to adjust the height of both pol.
3. **Magnet rings**
4. **Second TGG holder**
   – adjust the angle to adjust the polarization.
5. **First TGG-Quartz holder**
6. **DKDP**

Measuring

7. **Transmittance of s-pol**
8. **Isolation ratio**
9. **Reflected beam's isolation ratio**
   – optimize by adjustment of the sTGG-QR holders.
10. **Reflected one's transmittance of s-pol**





Assembly at KAGRA site ①

▷ Assembly steps.

Installation and alignment

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Measuring

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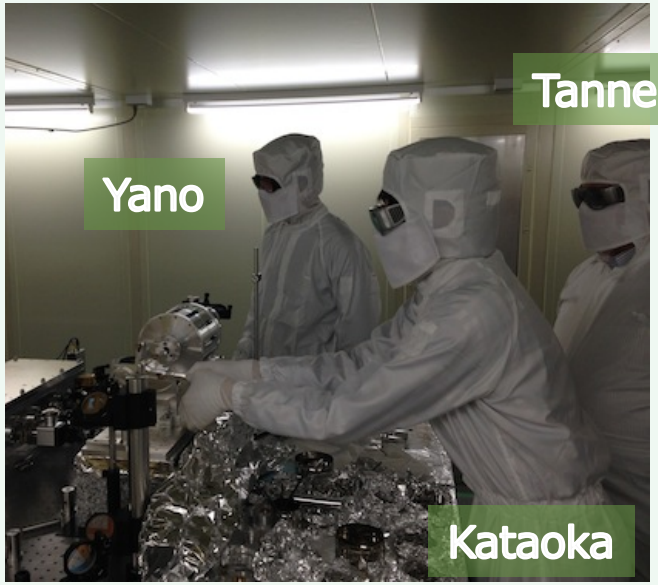
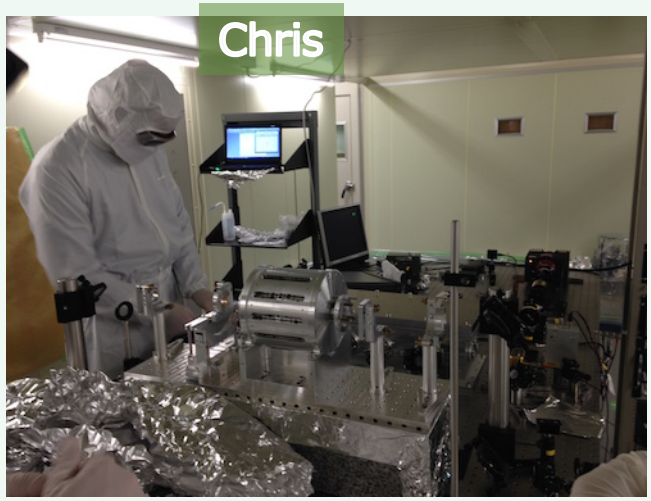
   – optimize by adjustment of the sTGG-QR holders.
10. **Reflected one's transmittance of s-pol**

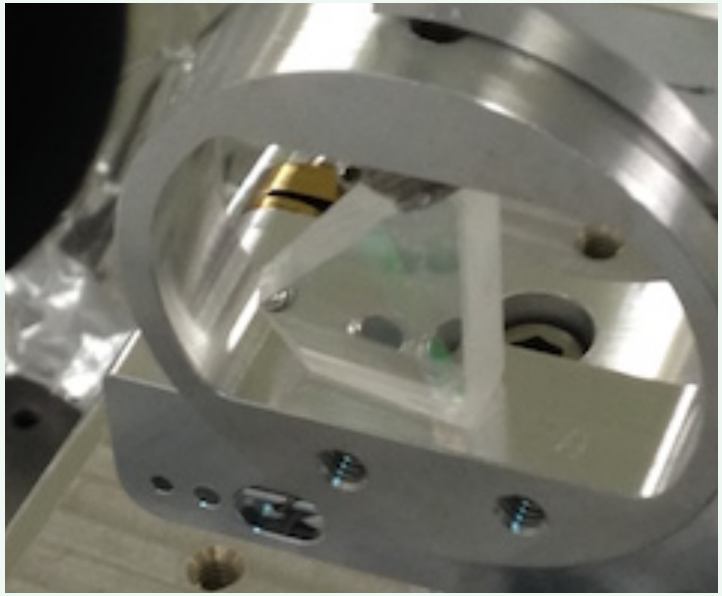
Tokyo Tech students worked under the direction of UF people.

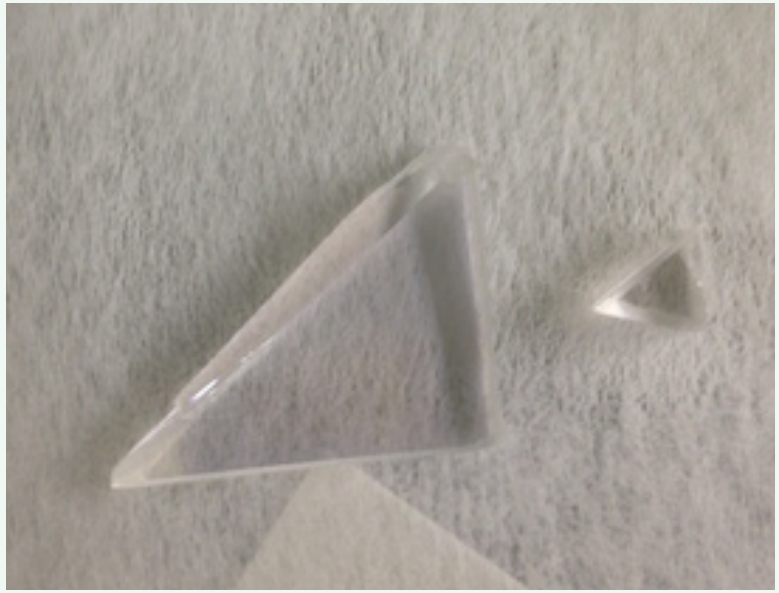




Assembly at KAGRA site ①

- Most of the assembly of the IFI was completed.
- Second CWP was dropped. – We measured with the broken one.





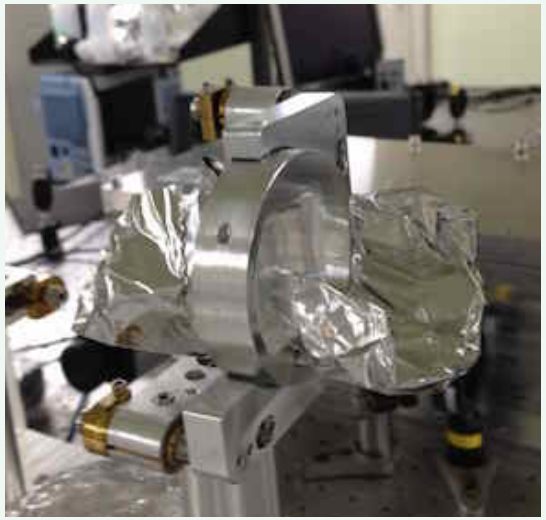
We achieved

Transmittance: 94%
Isolation ratio: 43dB

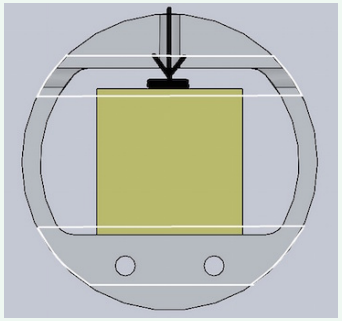
Broken CWP may has invisible cracks. ⇒ **The broken CWP should be replaced.**

Assembly at KAGRA site ②

- ▷ Jan 8-11 2015, @PSL table in Kamioka mine
- ▷ with 3 people from Tokyo Tech



safety stops image



New CWP was dropped again.
The CWP didn't get broken,
but possibly contaminated.

→ Measure the reflected beam.

→ Made safety stops temporarily.
aLIGO may need one too.

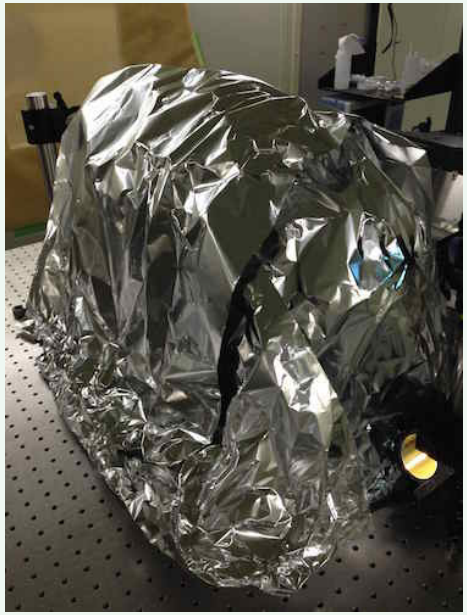
We achieved
(w/o DKDP)

Transmittance: 93%
Isolation ratio: 41dB

Good isolation ratio but insufficient transmittance

Summary

▷ **Assembly**
- Most of the assembly was completed.
- Isolation ratio → optimized
- Transmittance → not enough
  (Caused by uncleaned beam?)



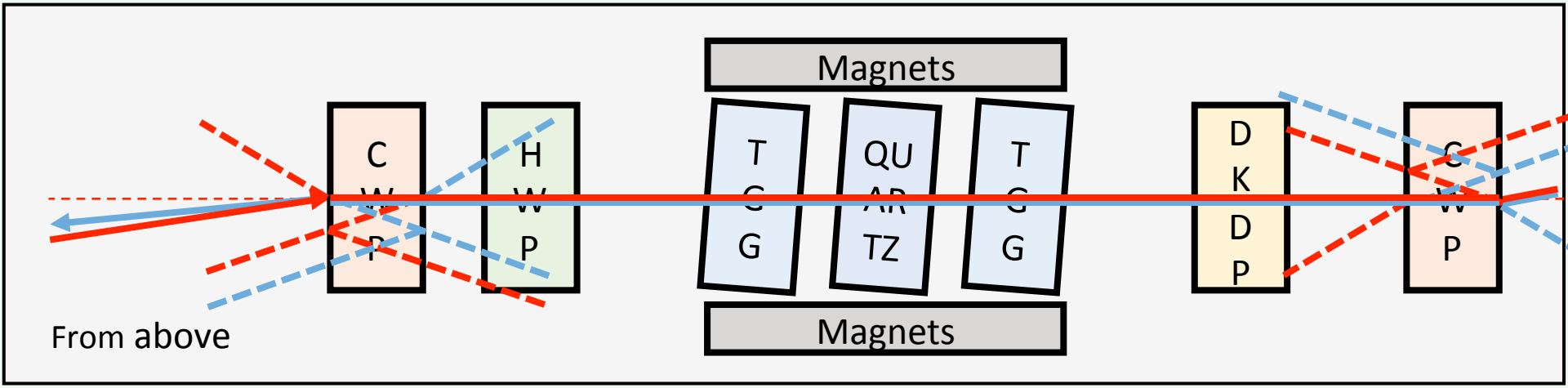
▷ **Now situation**
- IFI is covered with UHV @clean room.
- DKDP is stored @Tokyo Tech.

▷ **Future work**
- Optimize the transmittance.
- Consider ghost beams.
- Install to the vacuum chamber.

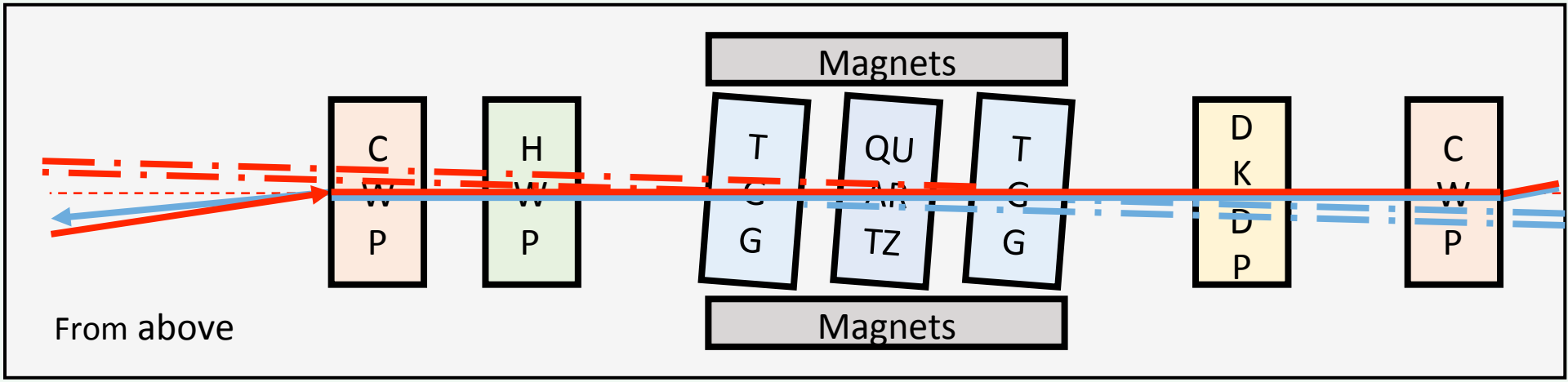
Fin.

16 Ghost beams

Ghost Beam from CWPs (～1.0e-06 power times of input)



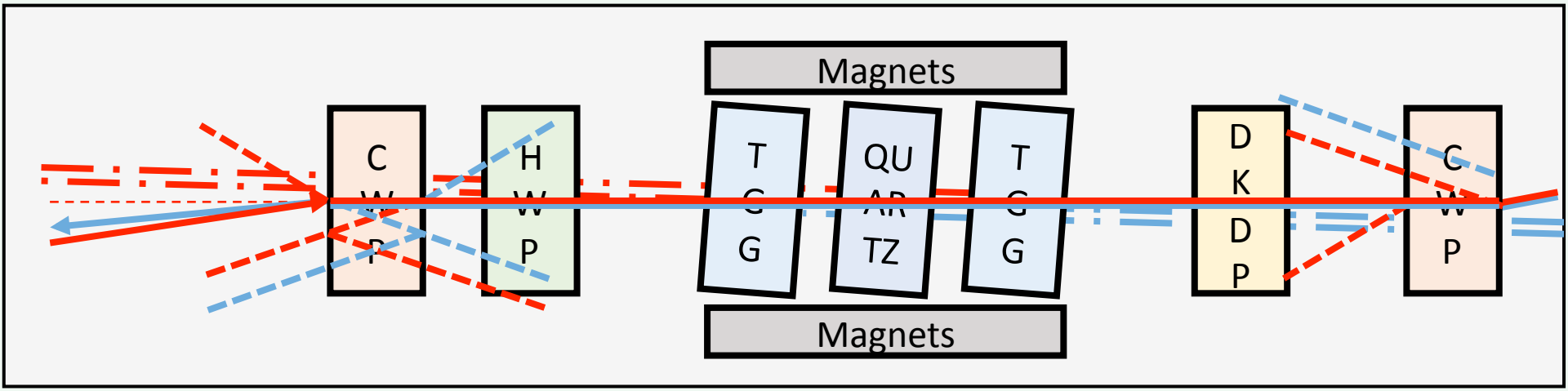
Ghost Beam from TGGs



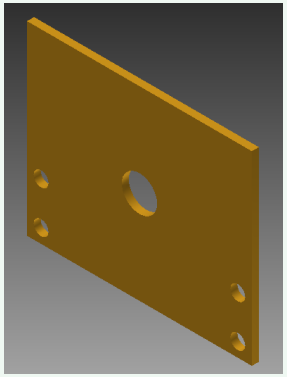
Holders of TGGs and QUARTZ are adjusted by rotating a little.

17 Ghost beams

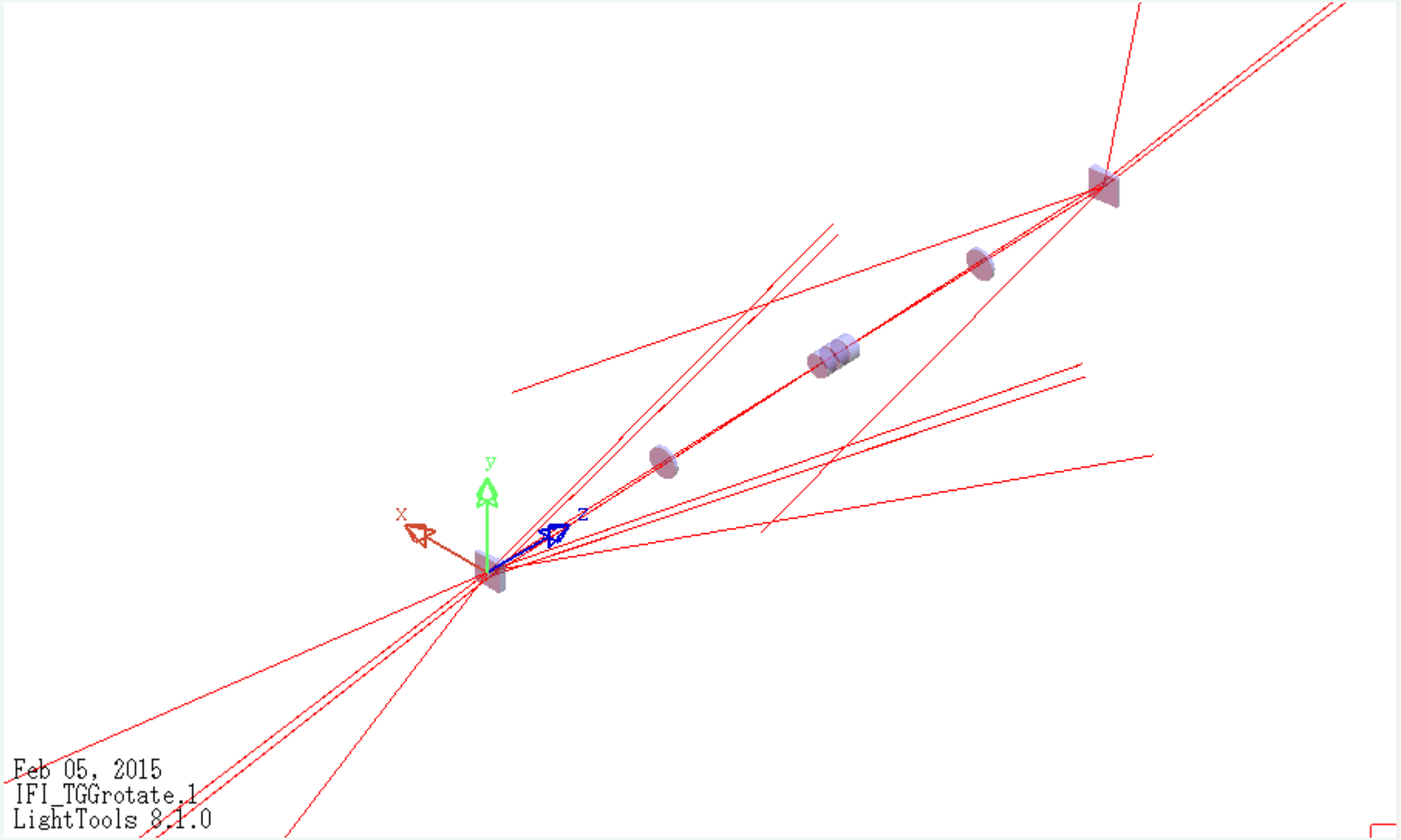
Ghost Beam from CWPs (～1.0e-06 power times of input)



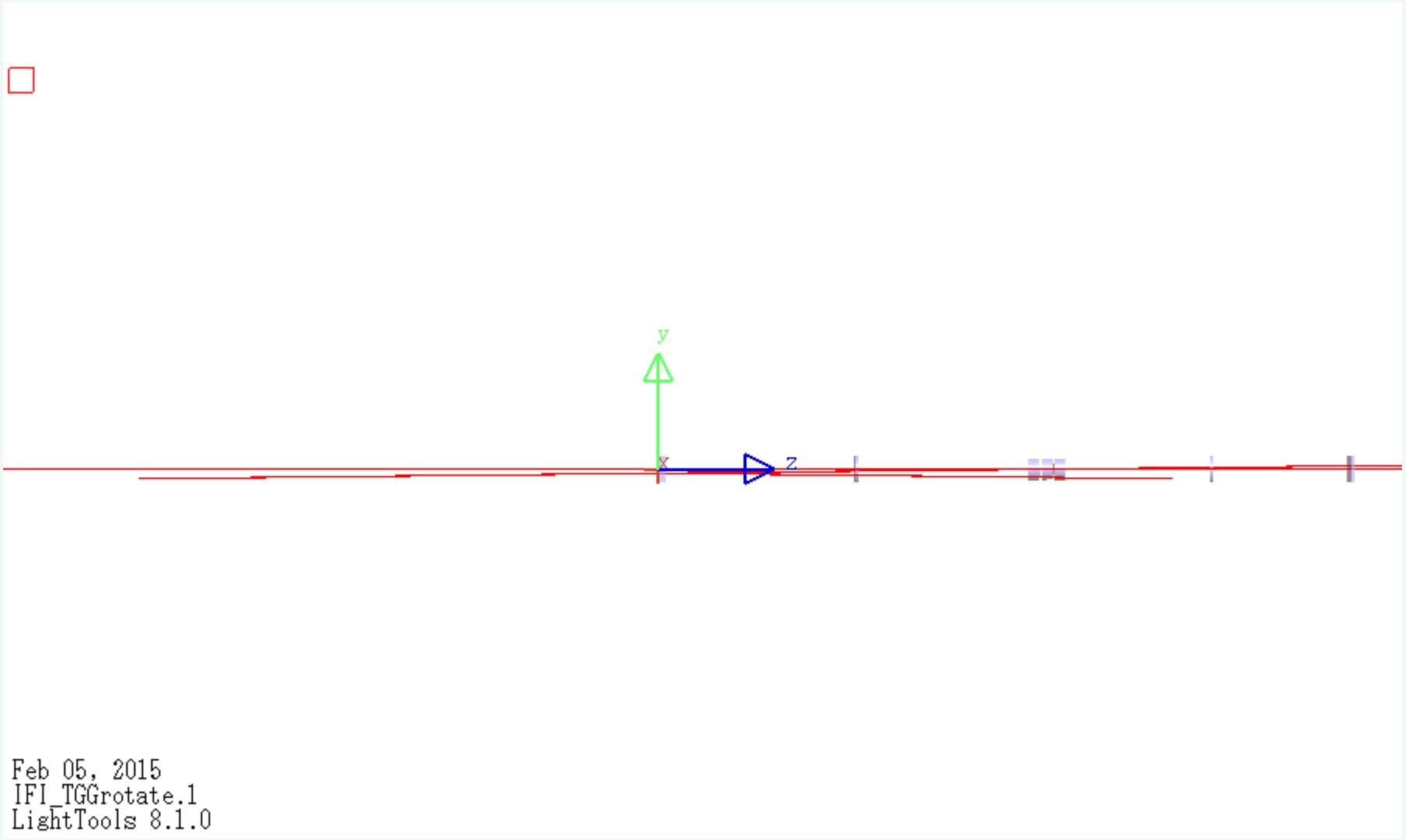
- 6 baffles are necessary at least to cut the ghost beams. 4 are for CWPs, 2 are for TGGs.
- We already have 3 baffles which are designed for aLIGO.



Ghost beams

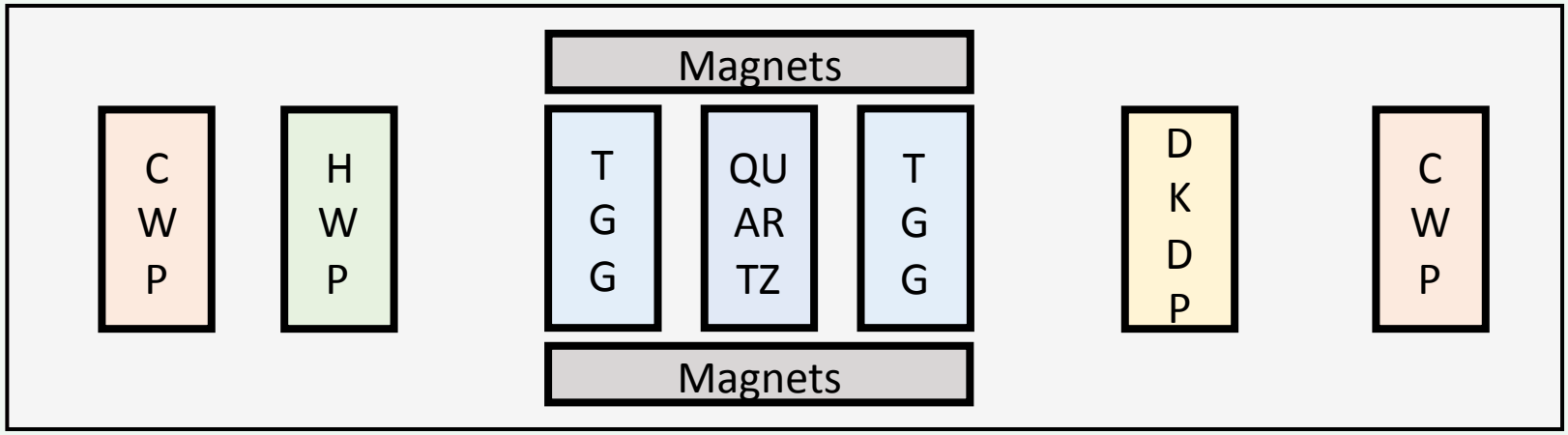


Ghost beams



20 IFI of the KAGRA

▷ Details of the IFI



	Diameter [mm]	Thickness [mm]	Reflectance [ppm]	Ghost beams power (Measured) [ppm]
CWP	25*25 (trapezium)	3 ~ 6.825	1200	1: 124 2: 496
HWP	25.4	1.8	300	
TGG	20	10.41	1500	575
QUARTZ	20	10.69	500	
DKDP	25.4	3	1500	

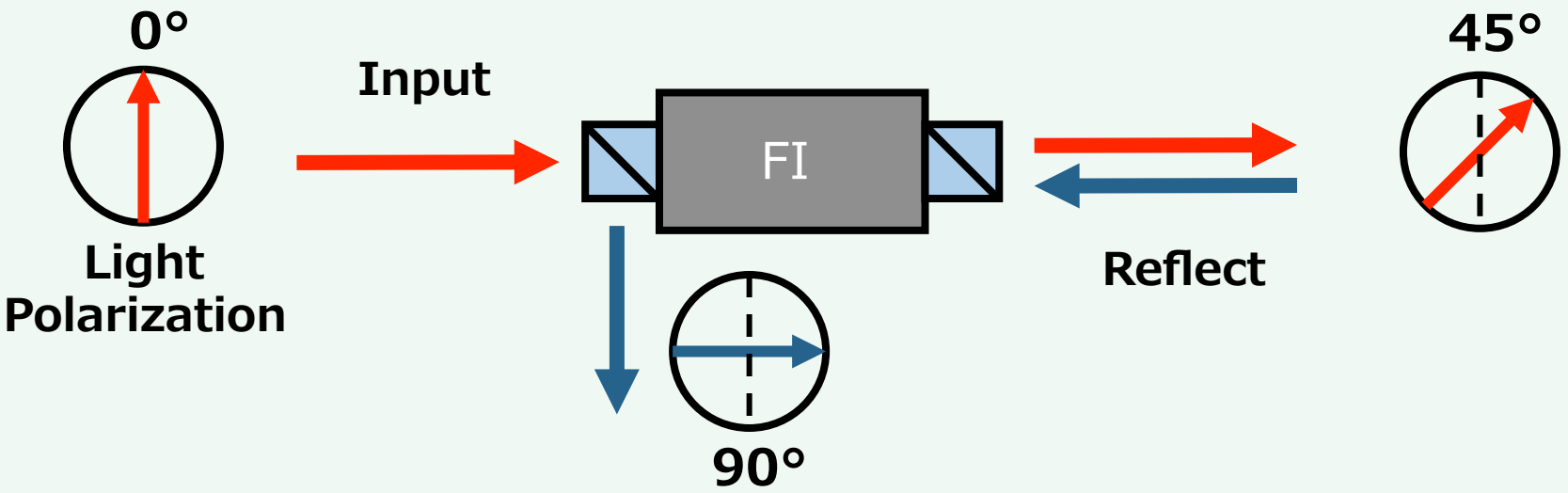
Faraday Isolator

▷ **Roll**

- Isolate the reflected beam from input beam not to break the laser.

▷ **Mechanism**

- Rotate the polarization of the beam by using the magnetic effect.



KAGRA will use 180W laser,
so we adopt the FI which can work in high power .