TAO/SWIMSの分光用スリットマスク交換機構のアップグレード

Upgrade of TAO/SWIMS Multi Object Spectroscopy Unit

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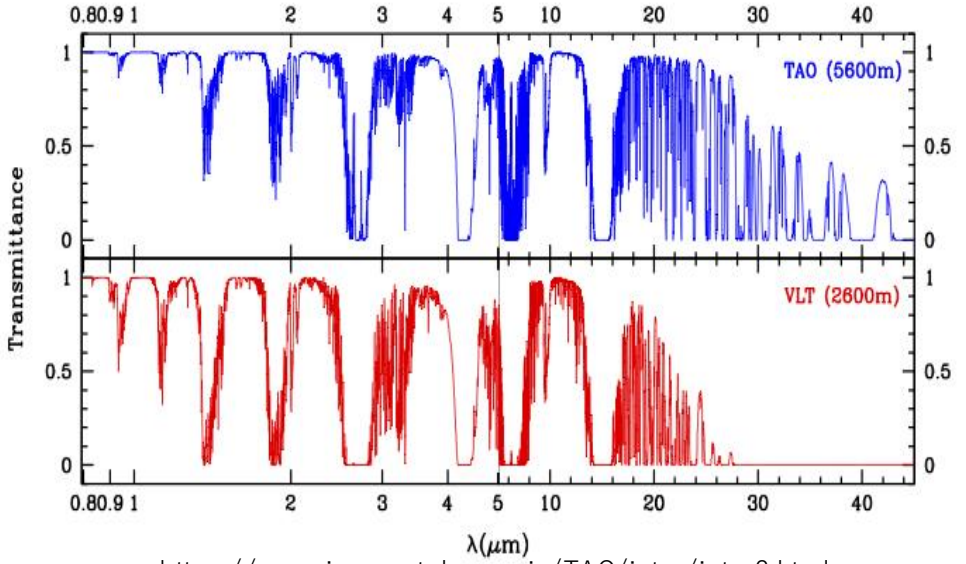
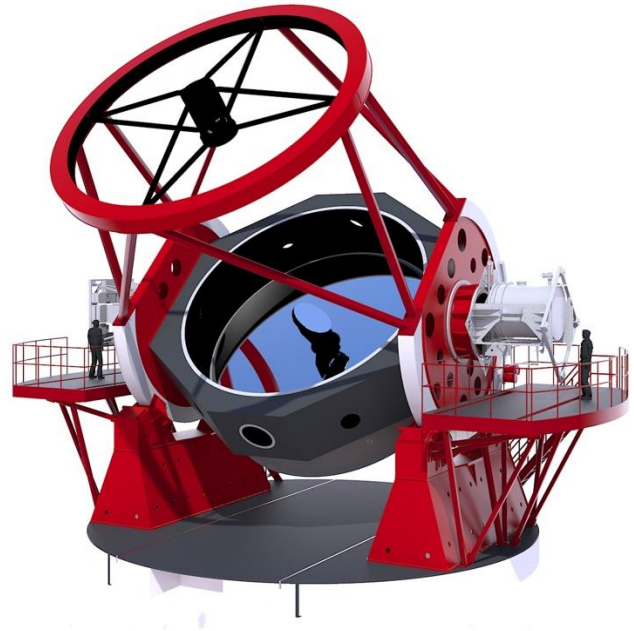
What is TAO



https://www.ioa.s.u-tokyo.ac.jp/TAO/intro/intro2.html

- Infrared wavelengths are absorbed by the atmosphere
  →It is difficult to observe from the ground
  ⇨TAO (The University of Tokyo Atacama Observatory)
    - Diameter: 6.5m
    - Under construction on Mt.Chajnantor in Chile (5640m)
    - The highest and very dry
      →Continuous near-infrared wavelengths ($0.9\sim2.5\mu m$)
        Mid-infrared wavelengths($\sim38\mu m$)



- Science case with TAO
  - Wide and deep survey at NIR→Origins of galaxies and the universe
  - Direct observation of dust at MIR→Origins of planets and materials

What is SWIMS

Simultaneous-color Wide field Infrared Multi-object Spectrograph

Overview

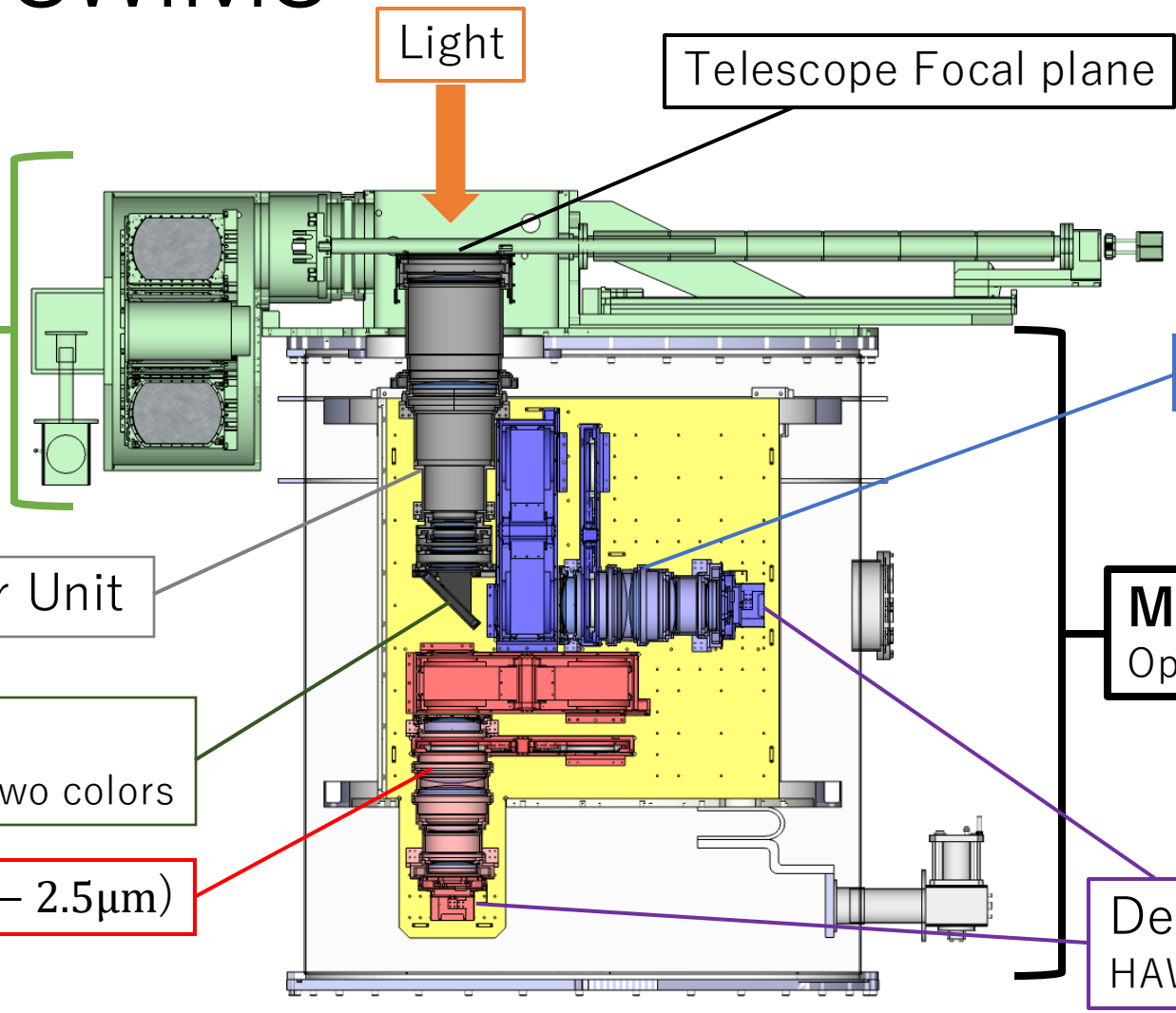
- Simultaneous-color Wide-field Infrared Multi-object Spectrograph
- 1st generation instrument for TAO (Nasmyth focus)
- Science observations on the Subaru Telescope for 2 years from 2021 (Cassegrain focus)

Specification

- Wavelength coverage: $0.9-2.5\mu m(0.9-1.4\mu m/1.4-2.5\mu m)$
- Observation mode(TAO)
  - Imaging with wide FoV : $\phi 9.6'$
  - Multi-object spectroscopy : R~1000, ~30 objects/mask
  - Integral field spectroscopy : FoV~$17.17'' \times 14.0''$

  →Two-color simultaneous observations are available for any mode with a single exposure

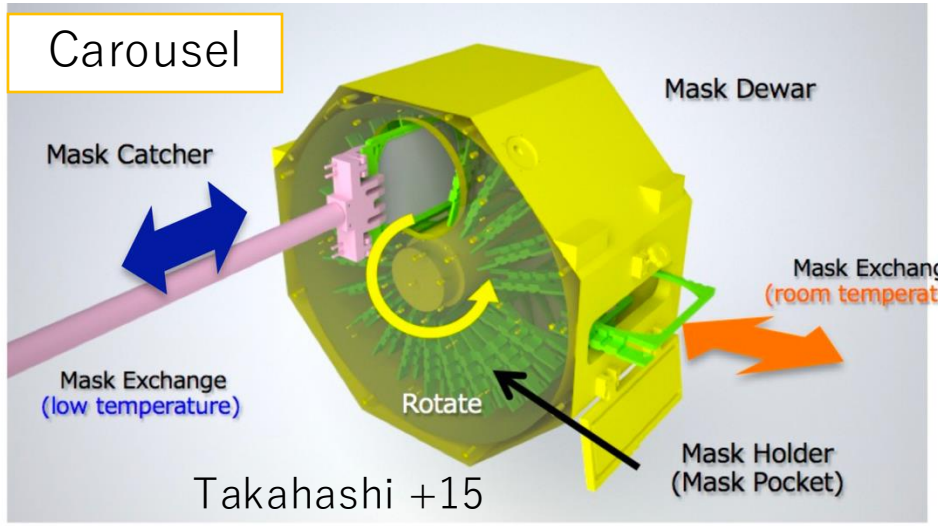
Structure of SWIMS



MOSU
Multi Object Spectroscopy Unit
- Multi-slit mask
  →Multi-object spectroscopy
- IFU(Integral Field Unit)
  →Integral field spectroscopy

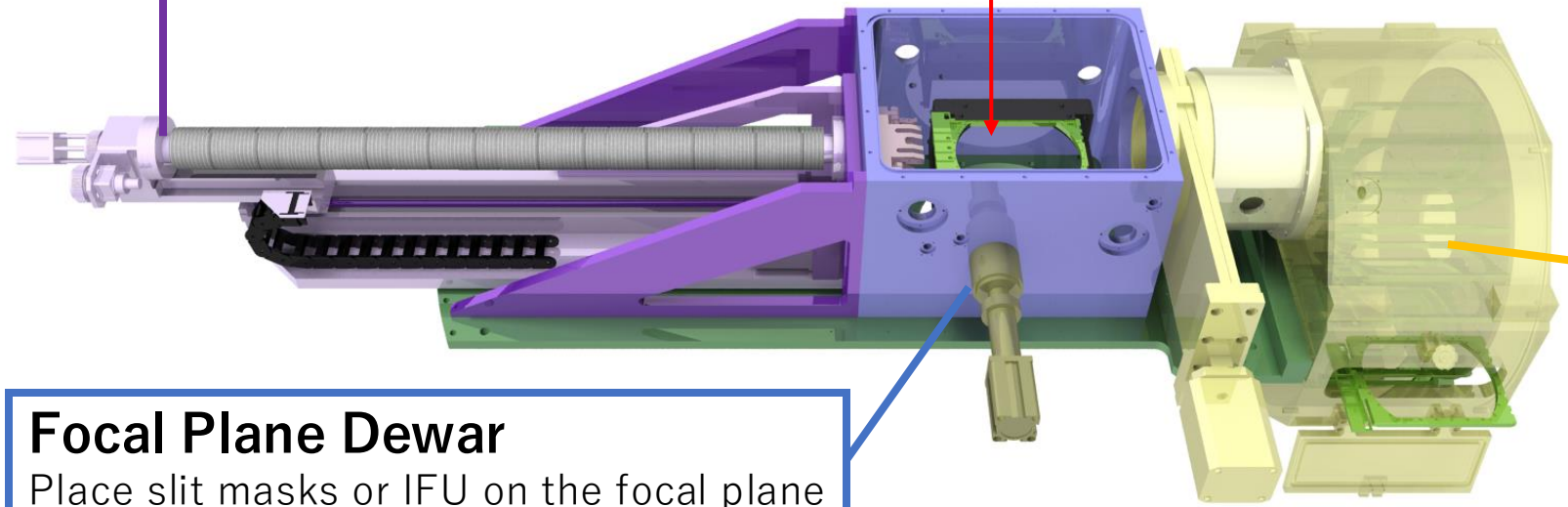
Structure of MOSU

Exchange slit-masks or IFU under vacuum and cryogenic conditions



Mask Catcher
Grab and carry slit masks or IFU

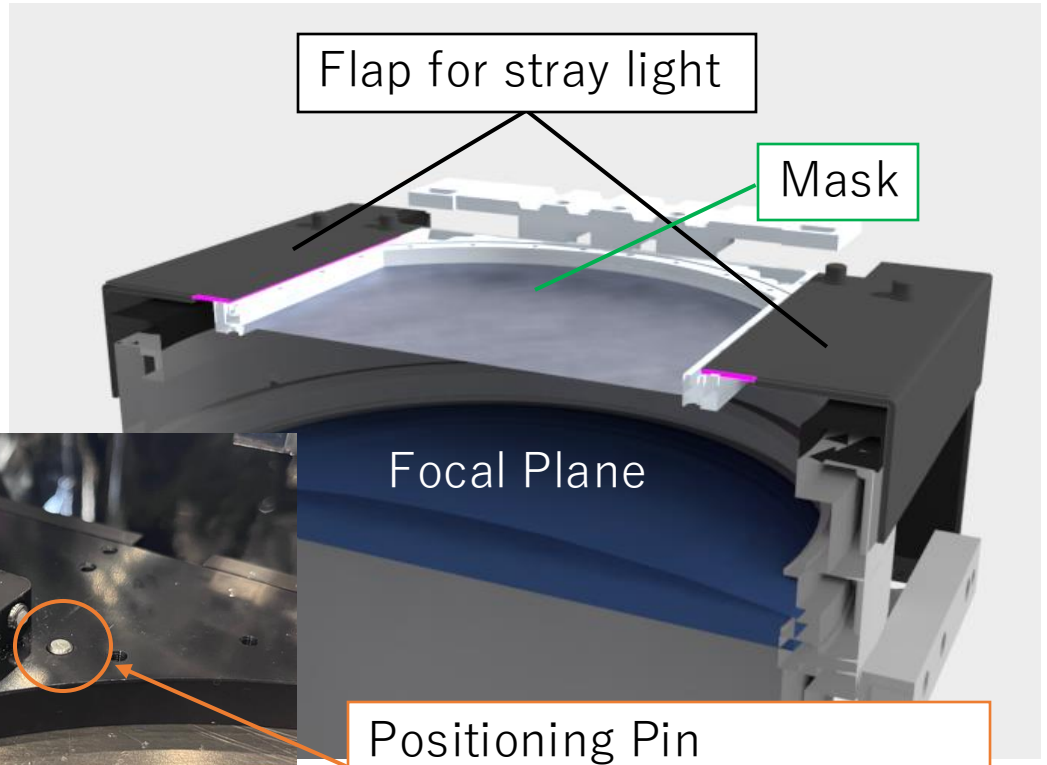
Focal plane

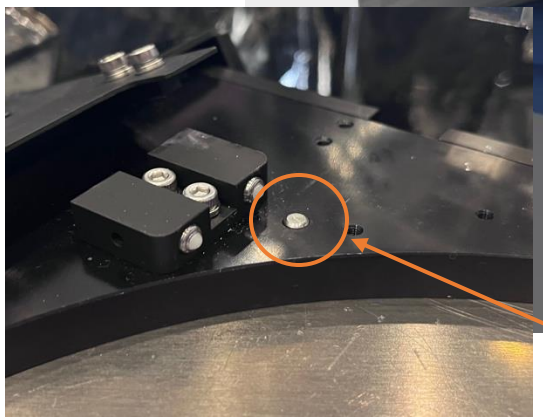


Slit-mask Dewar
Rotate holding slit masks and IFU in carousel

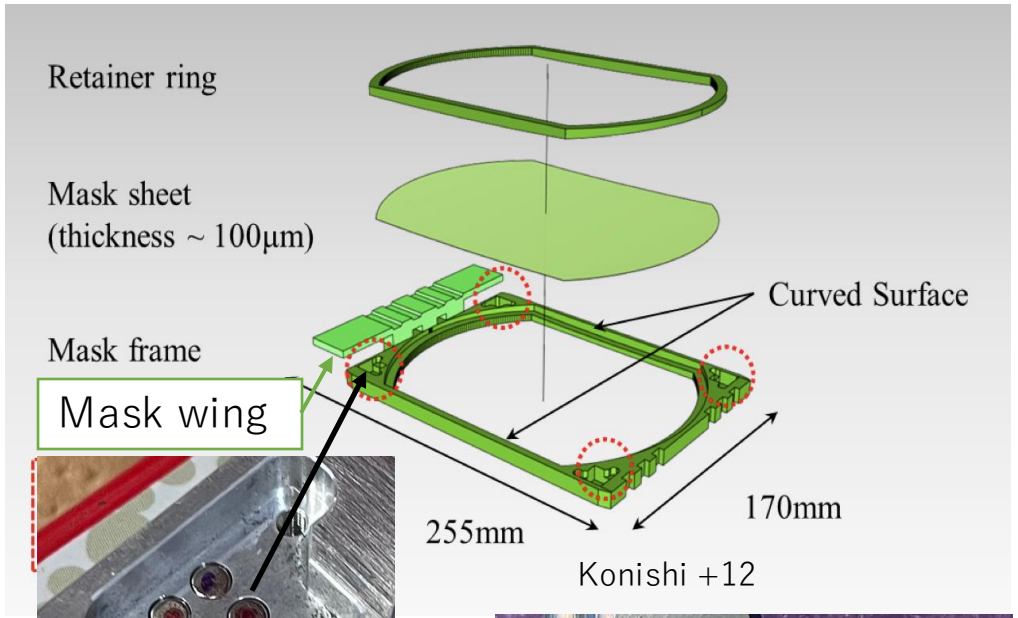
Focal Plane Dewar
Place slit masks or IFU on the focal plane

Focal Plane of MOSU and Slit Mask

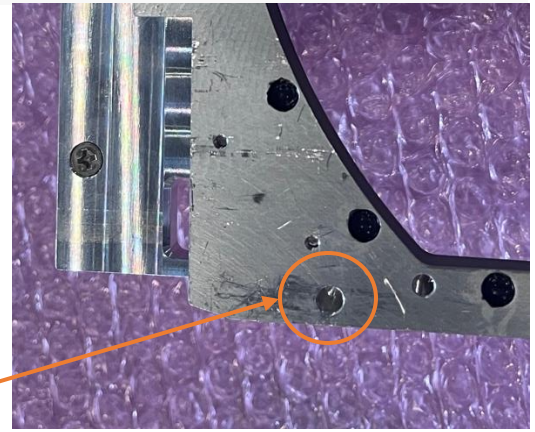




Positioning Pin
2 positions at the catcher side



3×3 Magnet Array
Positioning at 4 corners

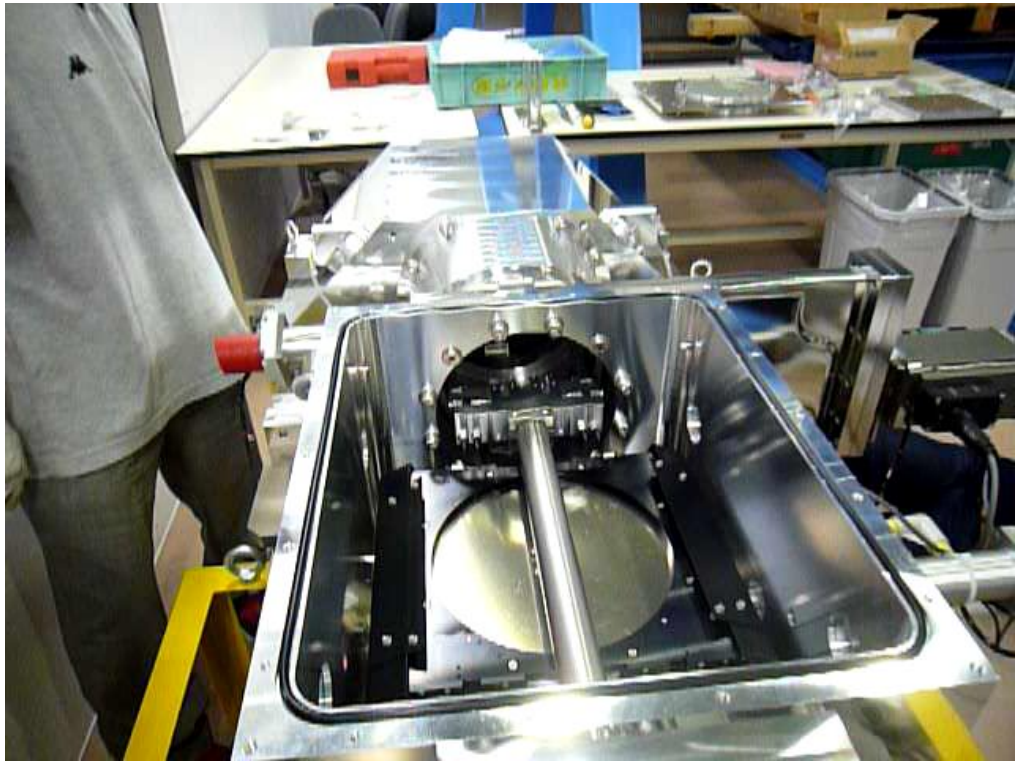


Hole for positioning pin

Magnets Arrays & Positioning Pins
→Position and fix the mask on the focal plane

Process of placing the mask on the Focal Plane

1. Carry the mask to the focal plane by the catcher
2. Open the catcher and place the mask on the focal plane
3. Close the flaps for stray light



Problem of MOSU on TAO

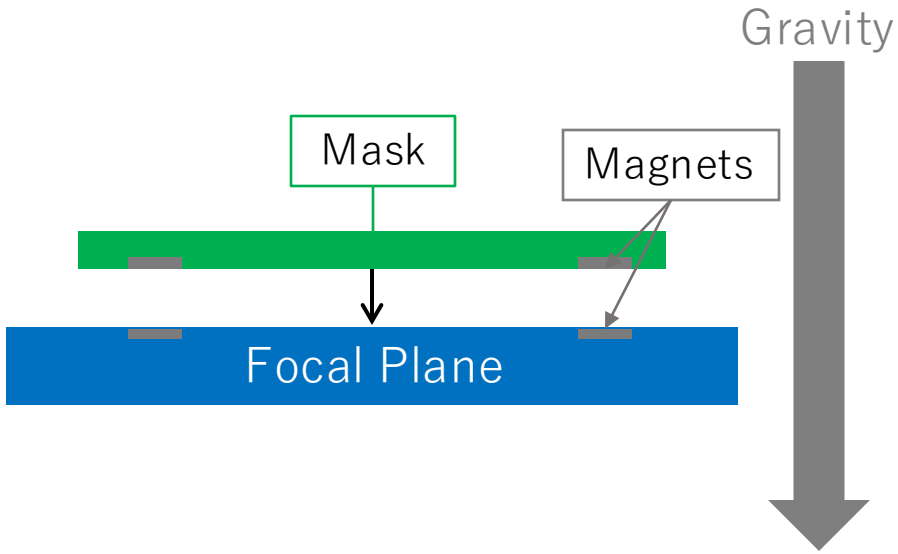
・Installation focal plane on Subaru : Cassegrain focus

→Focal plane of MOSU is perpendicular to gravity direction

→During mask exchange, when the catcher is open, the mask fall to the direction of gravity

→The mask can be installed on the focal plane

Cassegrain focus(Subaru)



Problem of MOSU on TAO

・Installation focal plane on Subaru : Cassegrain focus

→Focal plane of MOSU is perpendicular to gravity direction

→During mask exchange, when the catcher is open, the mask fall to the direction of gravity

→The mask can be installed on the focal plane

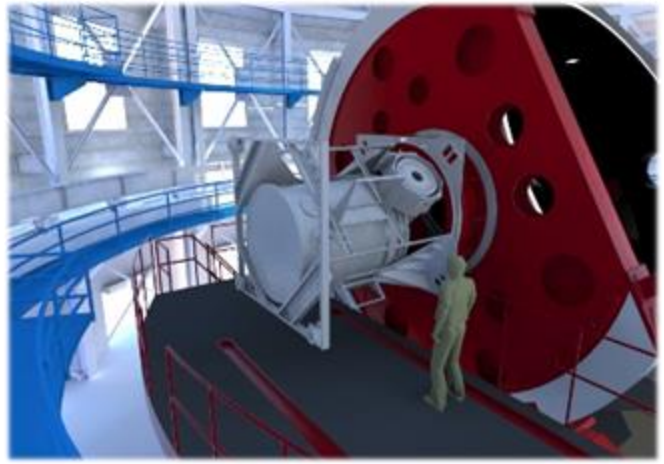
・Installation focal plane on TAO : Nasmyth focus

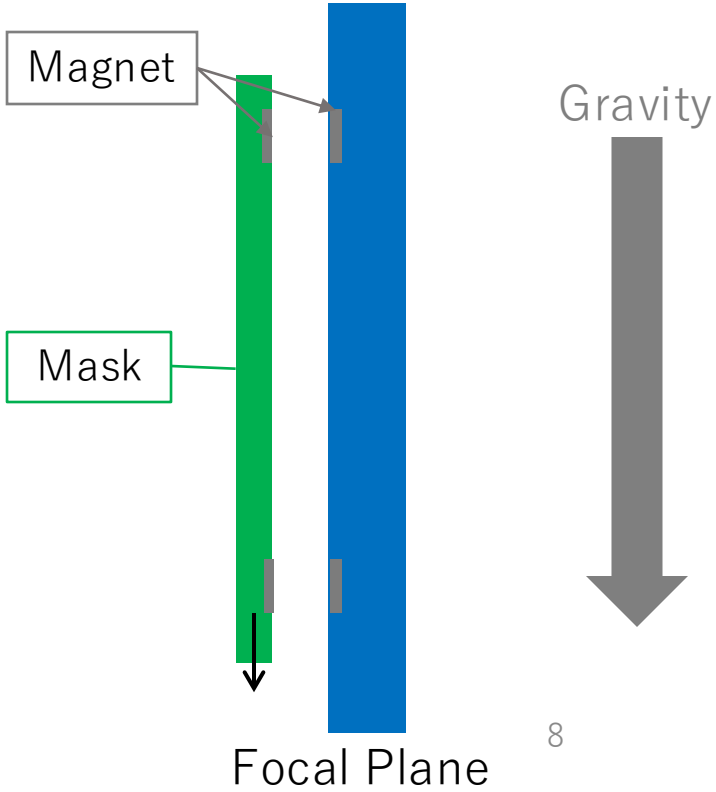
→Focal plane of MOSU is parallel to gravity direction

→The mask can't be installed and be dropped

⇨**Need to upgrade MOSU**

Nasmyth focus(TAO)

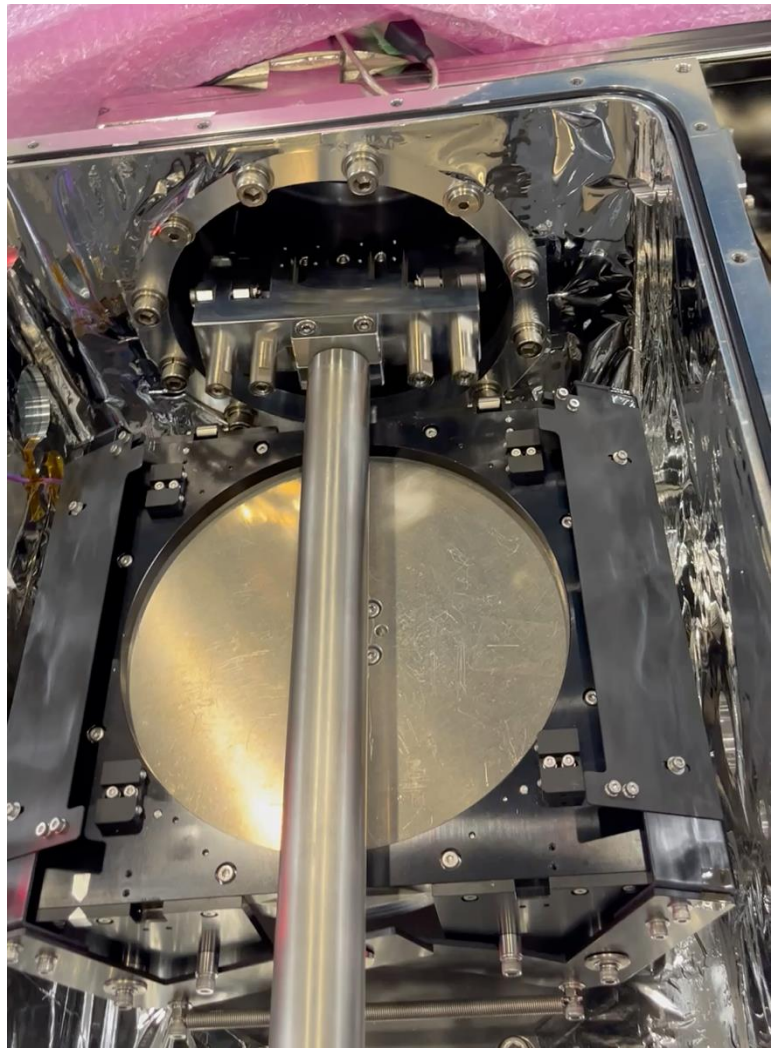




Upgrade 1: Change mask placing process

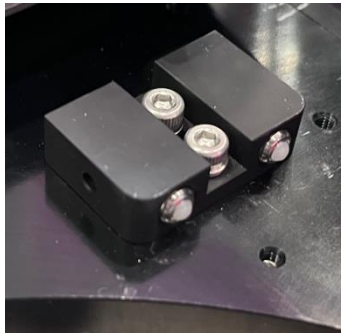
1. Carry the mask to the focal plane by the catcher
2. Close the flaps for stray light, while holding the mask by the catcher, and push the mask to the focal plane
3. Open the catcher and place the mask on the focal plane
   →Mask is fixed by magnets and positioning pins

→The mask can be always mechanically supported

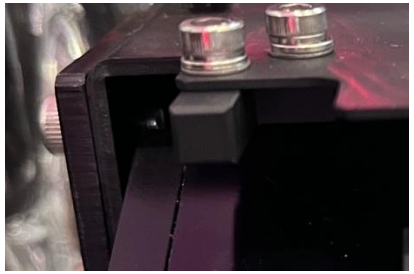


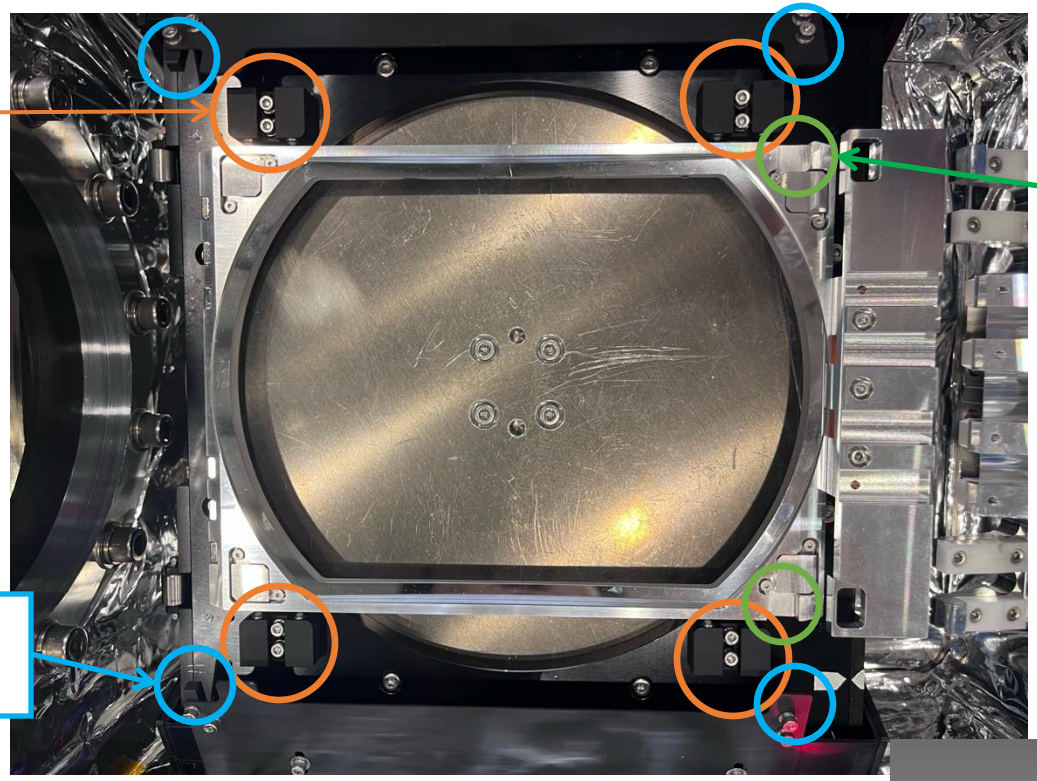
Upgrade 2: Add new components

Plungers(at 4 corners)
Adjust the position of the mask
Stroke: 0.8mm



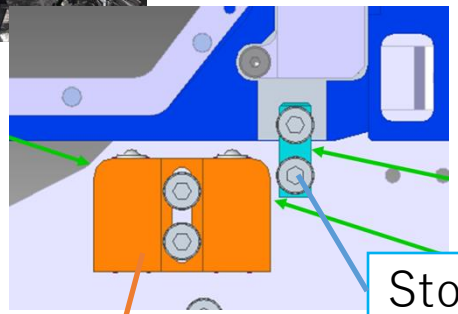
Stoppers(at 4 corners)
Support the position of the mask

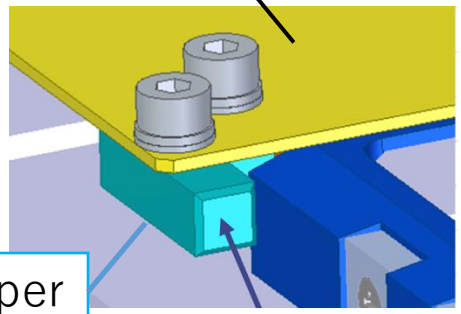




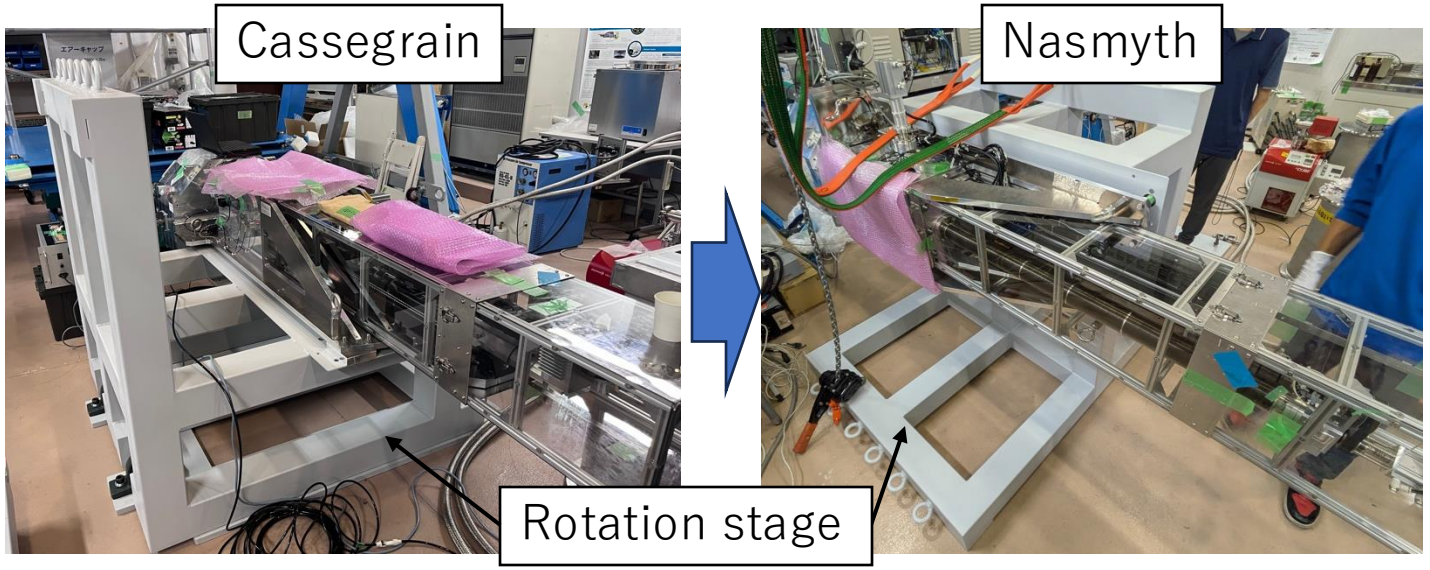
Cutouts of mask frame
For stoppers, when closing the flap

Close the flaps for stray light





Operation test



Condition

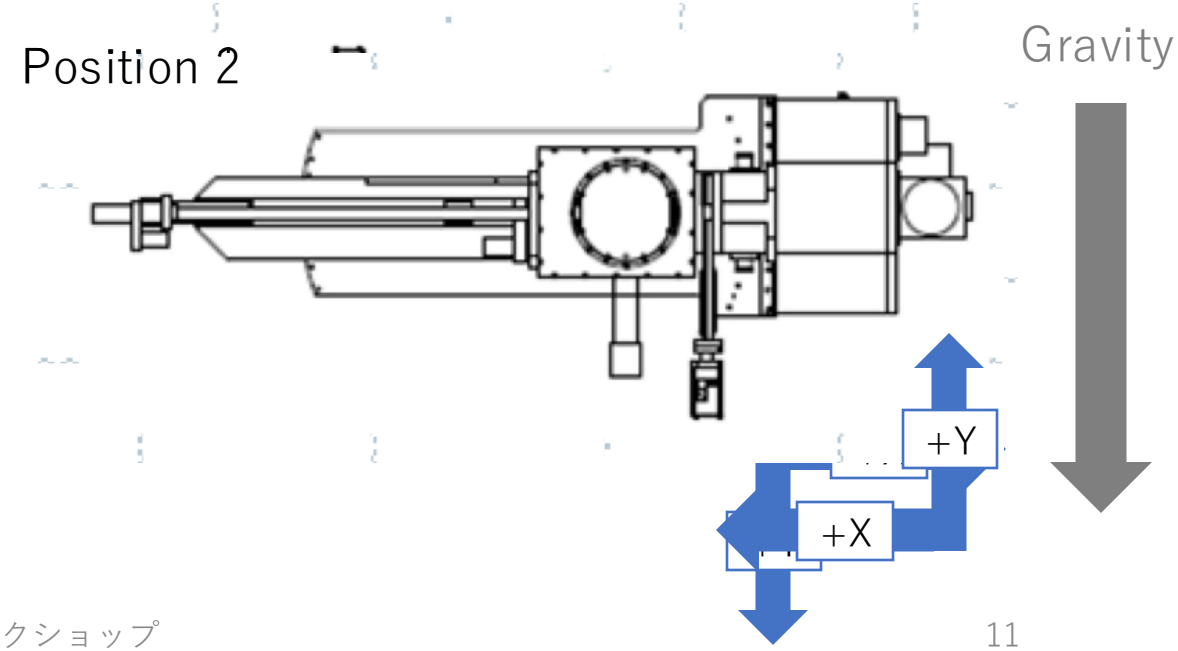
Two orientations reproducing the Nasmyth configuration

- ±90° from the horizontal position

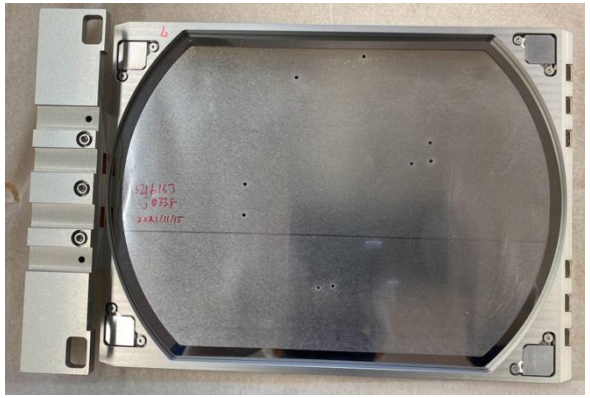
  Position 1: +Y = the direction of gravity

  Position 2: −Y = the direction of gravity

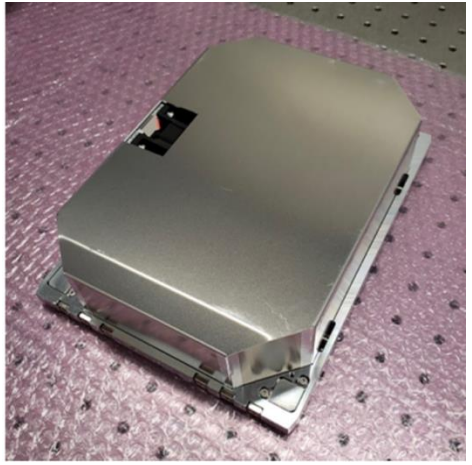
  (Rotated using the rotation stage)



Operation test



Slit-mask
・~330g
・$235 \times 170 \times 10\mathrm{mm}^3$



IFU
・~900g
・$< 235 \times 170 \times$
$55\mathrm{mm}^3$

Procedure

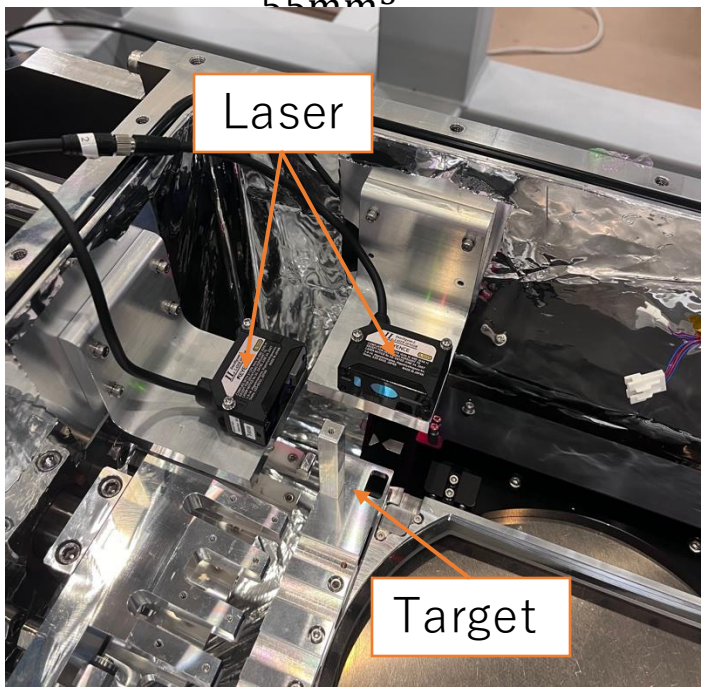
・Operation test with new process

・Test using mask or dummy IFU for testing

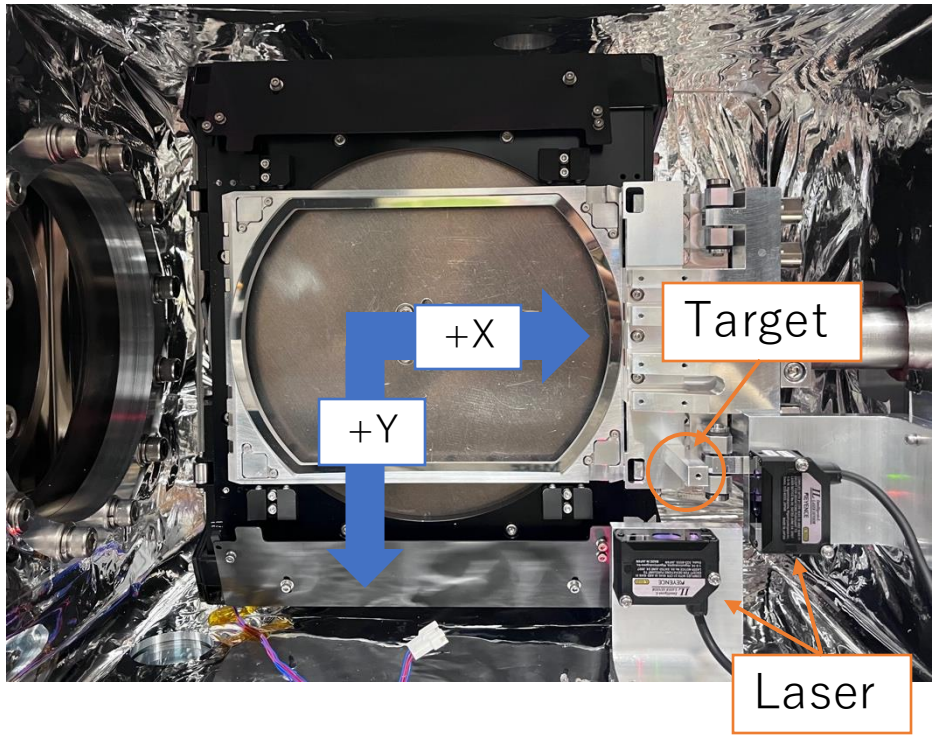
・Measurement of positional repeatability of installation

・If the mask position varies with each installation, the light will be displaced on the detector

・Measure using the laser sensor



Detail of the measurement



Condition of measurement

・Measure X and Y directions

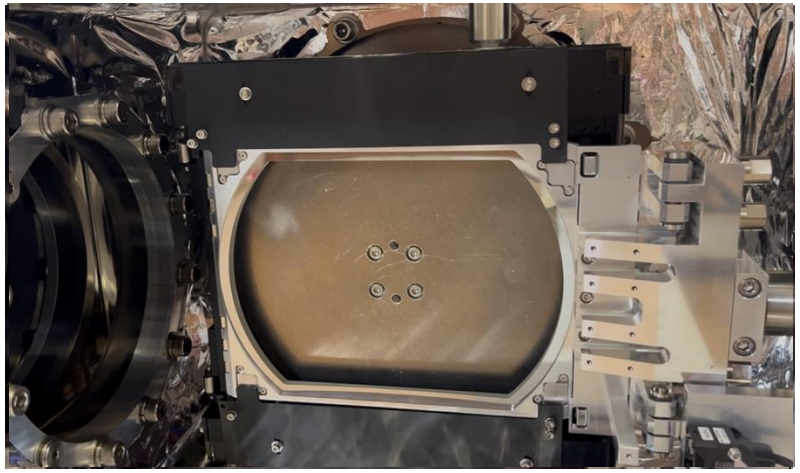
　・The initial position of the mask on the focal plane = (0, 0)

・The values increase as the target approaches the laser

Requirement

・Displacement : $< 1\mathrm{pixel}$ (detector) = $< 46\mu\mathrm{m}$ (focal plane)

Sequence of one trial



Move the mask to the initial position on the focal plane

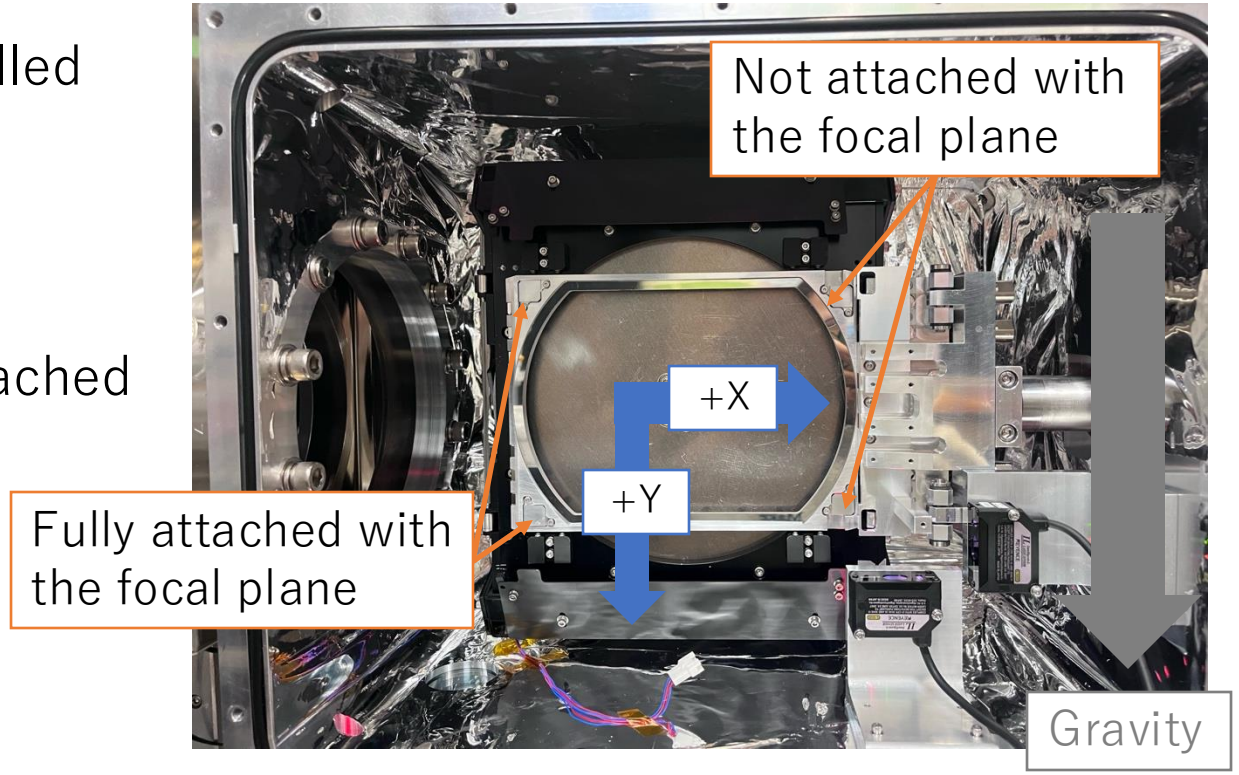
Close the cap and hold the mask

Operation test with new process: Result

・Both of mask and dummy IFU couldn’t be installed correctly

- ・not fall off the focal plane
- ・slipped down to the direction of gravity
- ・Magnets on the catcher side are not fully attached

⇨A measure to prevent slipping down is required

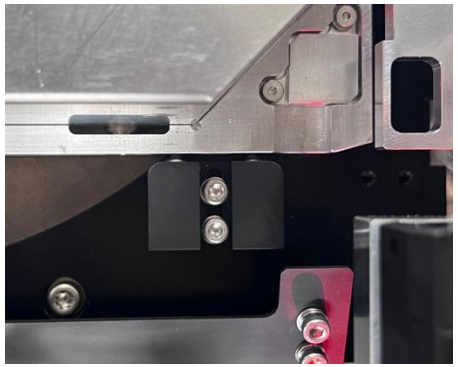


Measure to avoid slipping down

Measure

Optimize the position of the plunger

→Raise the position of the lower-right plunger (~2mm)



Result (dummy IFU, position 1)

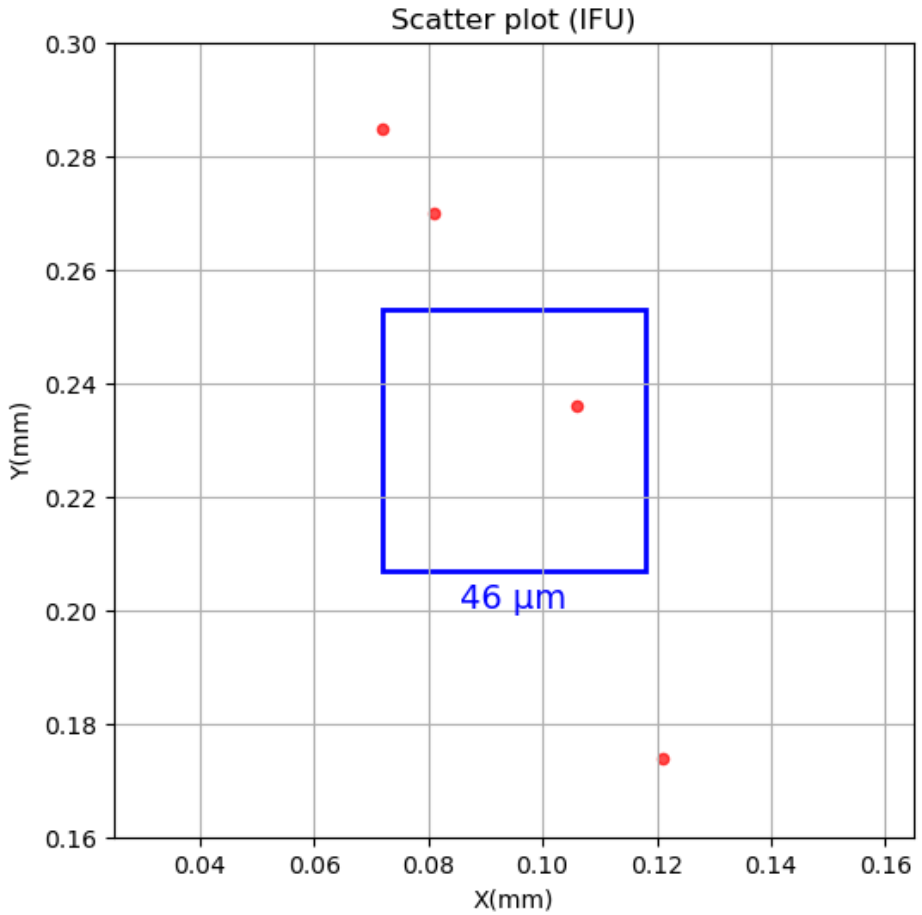
・For all the trials, the mask was installed correctly

⇨effective to put the plunger close to the mask

・no positional repeatability

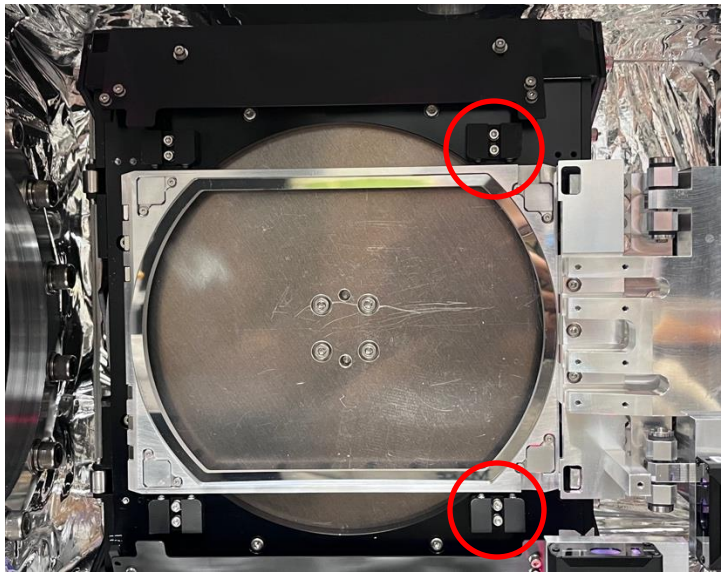
・X: 49μm, Y: 128μm

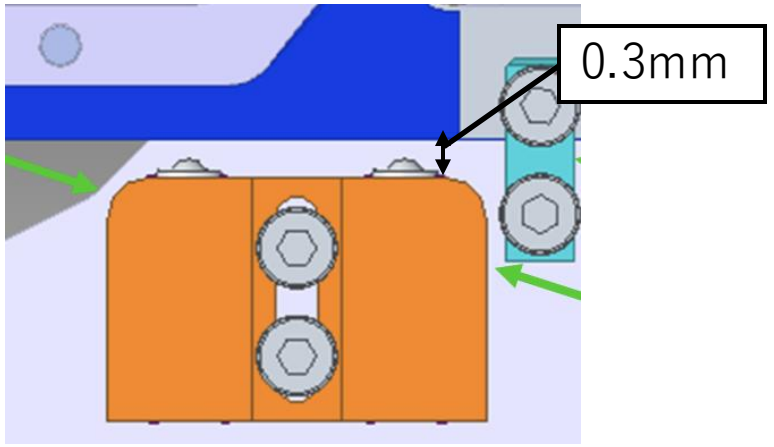
⇨better to put the plunger closer to the mask



Measure to avoid tilting downward

⇨Move the both plunger on the catcher side closer to the mask



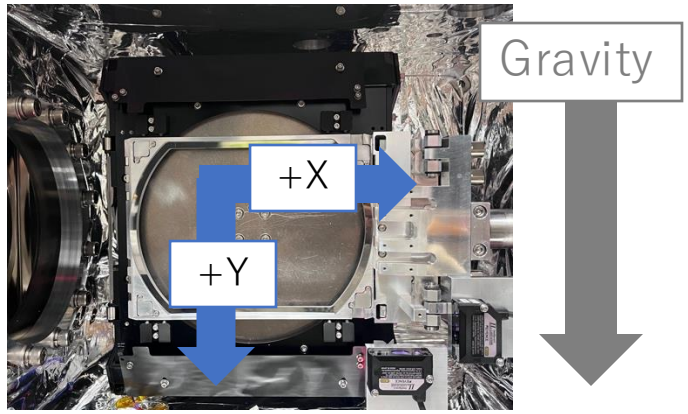


→Mask can be installed with positional repeatability in 2 positions

→Test in 2 positions

Operation test with measure: Result

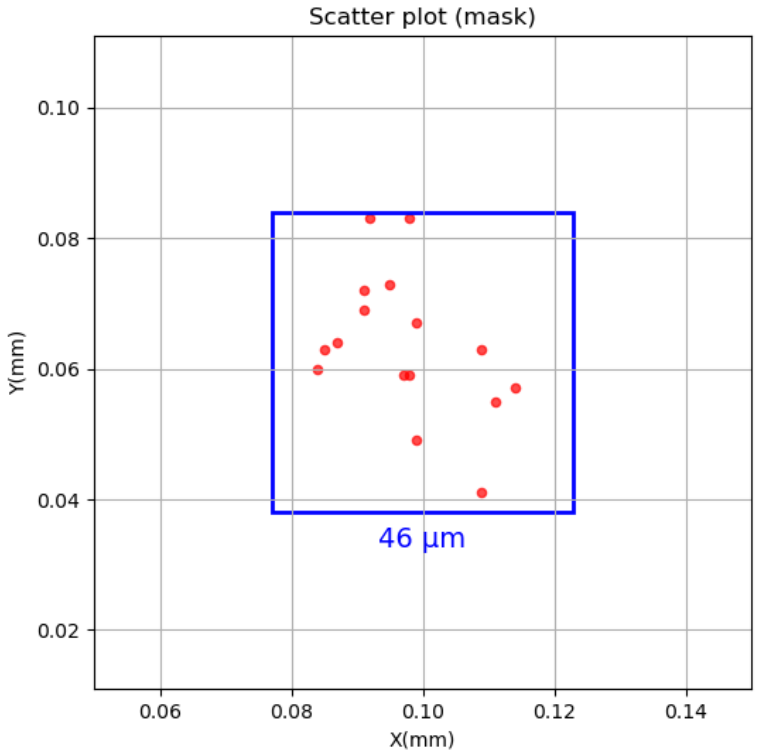
Position 1: +Y = gravity direction



Results of 16 trials(Mask)

- Installed correctly for all trials
- Scatter of the final position
  - X: 30μm, Y: 42μm

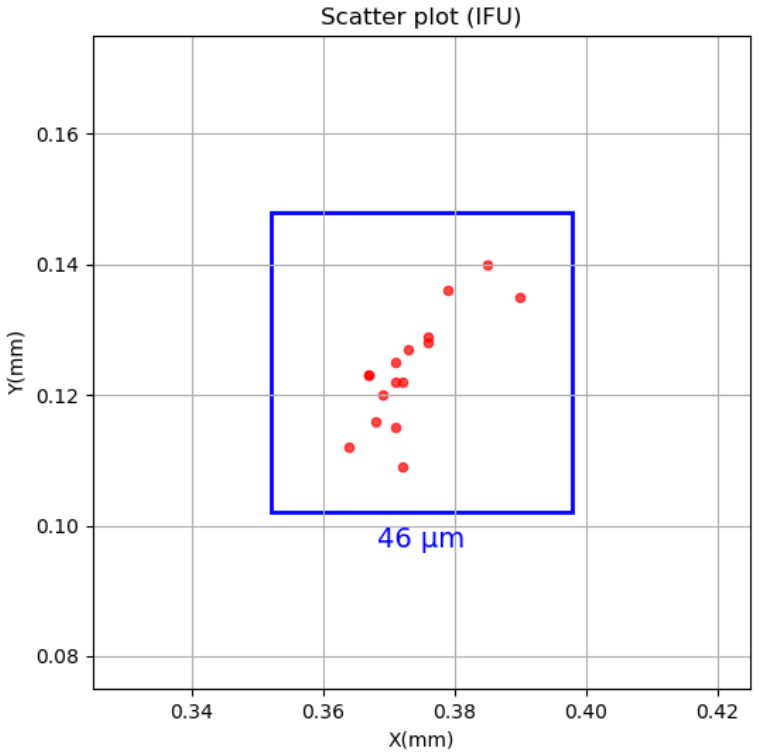
⇨**meet the requirement(<46μm)**



Results of 16 trials(IFU)

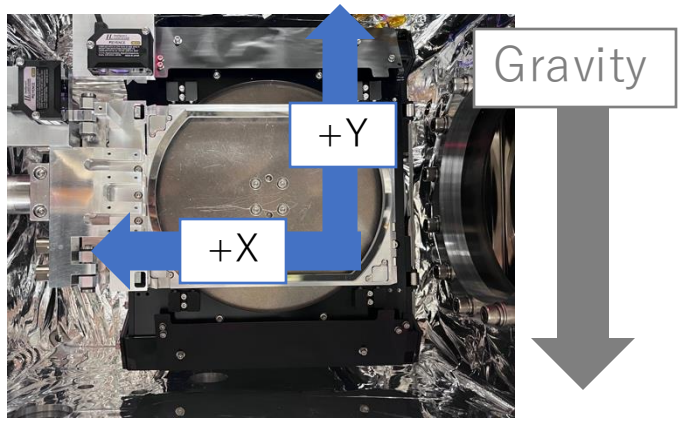
- Installed correctly for all trials
- Scatter of the final position
  - X: 26μm, Y: 31μm

⇨**meet the requirement(<46μm)**



Operation test with measure: Result

Position 2: -Y = gravity direction



Results of 16 trials(Mask)

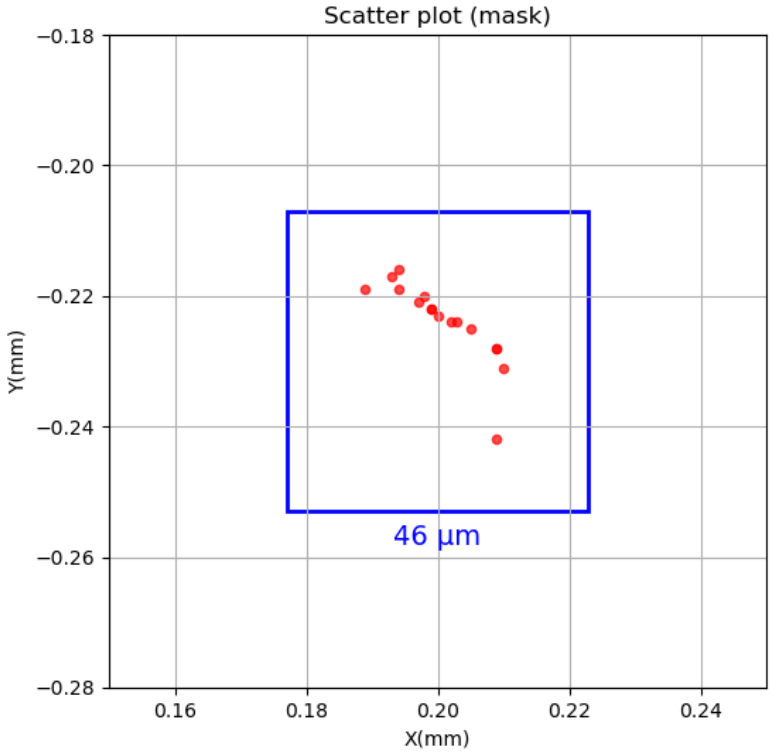
- Installed correctly for all trials
- Scatter of the final position
  - X: 21μm, Y: 26μm

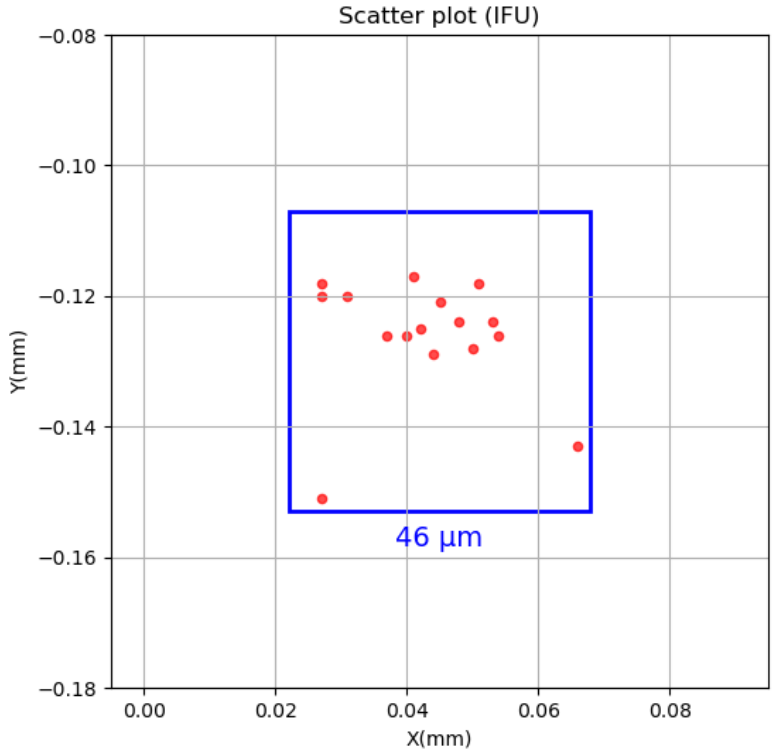
⇨**meet the requirement(<46μm)**

Results of 16 trials(IFU)

- Installed correctly for all trials
- Scatter of the final position
  - X: 39μm, Y: 34μm

⇨**meet the requirement(<46μm)**





Result summary

Configuration	Install correctly	Meet the requirement($< 46\mu m$)	
Flat(Cassegrain)	◯	◯	Mask: $\sim 20\mu m$(X), $< 10\mu m$(Y) IFU: $24\mu m$(X), $13\mu m$(Y)
Position 1(Nasmyth) No measure	×		
Position 1(Nasmyth) With measure	◯	◯	Mask: $30\mu m$(X), $42\mu m$(Y) IFU: $26\mu m$(X), $31\mu m$(Y)
Position 2(Nasmyth) With measure	◯	◯	Mask: $21\mu m$(X), $26\mu m$(Y) IFU: $39\mu m$(X), $34\mu m$(Y)

Future MOSU tests

- Test at different orientations
  - Mount on SWIMS, and rotate the whole instrument
- Adjust the measures
  - Replace appropriate plunger, if available
  - Determine the position of plungers precisely and increase the number of trials

Summary

・SWIMS (Simultaneous-color Wide-field Infrared Multi-object Spectrograph) is 1st generation instrument for TAO

・Upgrading for TAO is in progress

・MOSU can't install masks on the focal plane when mounted on the Nasmyth focus at TAO

→1. Change the process of installing the mask on the focal plane

2. Add new components on the focal plane

→operation test reproducing the Nasmyth configuration

・after applying the measure, **mask and dummy IFU were installed correctly**

・There were **position repeatability of the mask on the focal plane ($< 46\mu m$)**

→Test under different MOSU orientations or with more precise position of plungers

・SWIMS is scheduled to begin operation at TAO in 2027