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Development of a new mid-infrared instrument for the TAO 6.5-m telescope

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Concepts of the instrument

Two advantages of ground-based observations

① High spatial resolution

✓ Spatial resolution is completely limited by diffraction of telescope apertures

→ Larger telescopes on the ground are needed for achieving higher spatial resolution

② Monitoring Capability

✓ Observing time of the space telescopes are competitive
✓ Lifetime of the space telescopes is limited

→ Long-term / systematic monitoring can ONLY be carried out by ground-based telescopes

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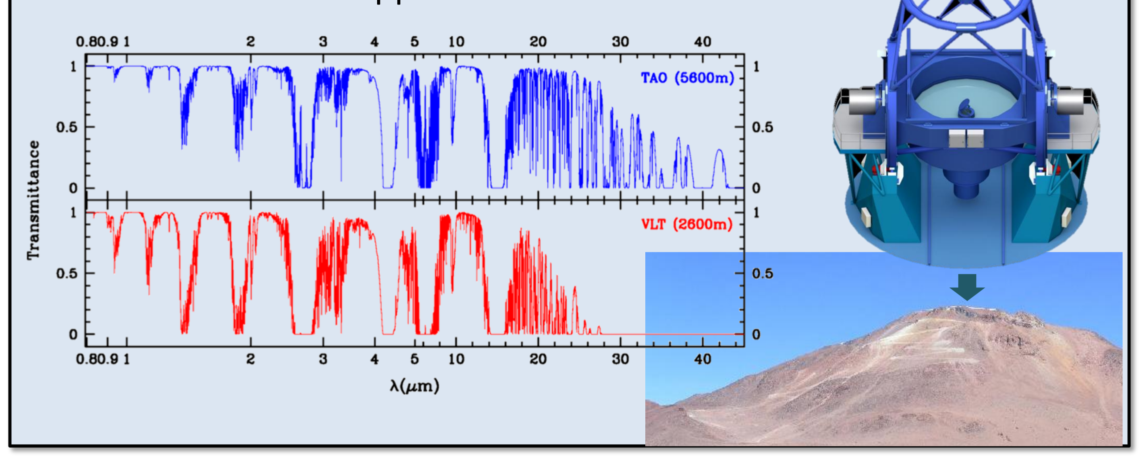
TAO : the best mid-infrared telescope on the Earth

✓ TAO is a new ground-based telescope project (P.I. Prof. Yoshii)
✓ 6.5-m telescope will be built at the summit of Co. Chajnantor in the Atacama desert (altitude : 5,640m = world highest astronomical site!)

High altitude + dry weather condition
→ The N-band and the Q-band windows become clear
New windows appear at 26-38 micron



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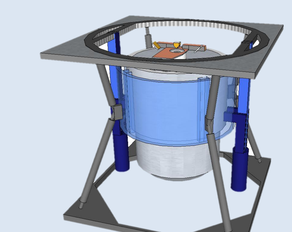
TAO Mid-infrared Camera/Spectrograph

✓ Wide wavelength coverage of 2-38μm
✓ Diffraction limited spatial resolution
✓ A newly invented "Field Stacker" for accurate monitoring
✓ Can be attached to the TAO and the Subaru



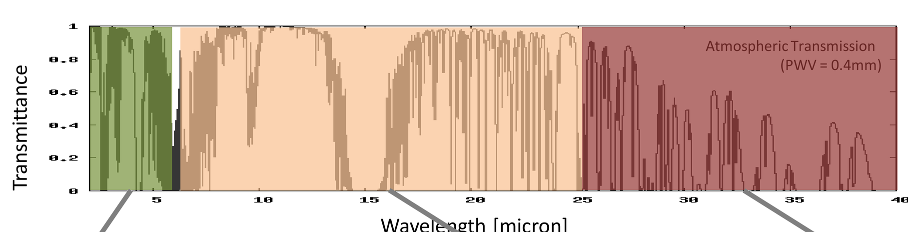
Specifications of the TAO mid-infrared camera/spectrograph

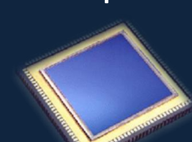
	NIR channel	MIR-S channel	MIR-L channel	Note
Detector	InSb 1kx1k	Si:As 1kx1k	Si:Sb 128x128	
Wavelength	2-5.6μm	6-26μm	25-38μm	
Pixel Scale	0.11"/pix	0.11"/pix	0.46"/pix	@ TAO 6.5m
Field of View	2'x2' or 1'x2' x2	2'x2' or 1'x2' x2	1'x1' or 0.5'x1' x2	w/o field stacker w/ field stacker
Spectroscopy	Slit+grism	Slit+grism	Slit+grism	
Spec. Resolution	R~200 for 2.8-4.2um R~400 for 4.5-5.5um	R~200 for 7.5-13.5um R~150 for 16.5-26.5um	R~50 for 26-38um	

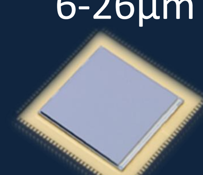
Instrument Design

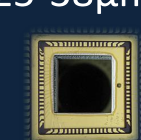
Detectors

Three detectors are employed to cover the wide wavelength range.



Raytheon Aladdin II
2-5μm

InSb
1k x 1k
0.11"/pix

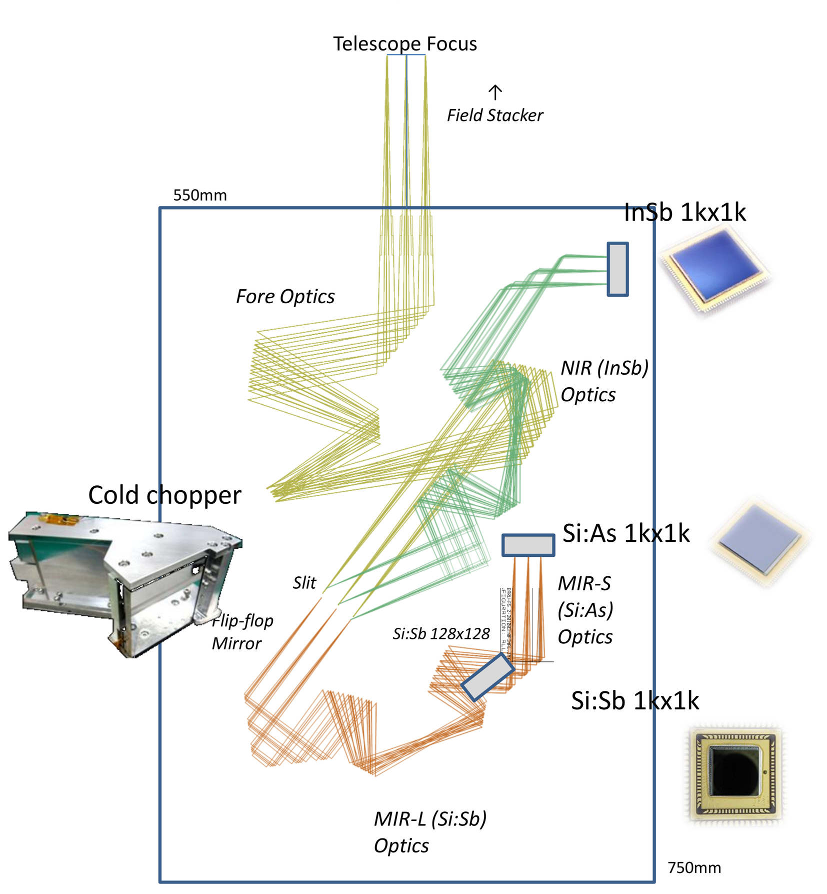
Raytheon Aquarius
6-26μm

Si:As BIB
1k x 1k
0.11 "/pix

DRS Si:Sb-128
25-38μm

Si:Sb BIB
128 x 128
0.46"/pix
※ TBD

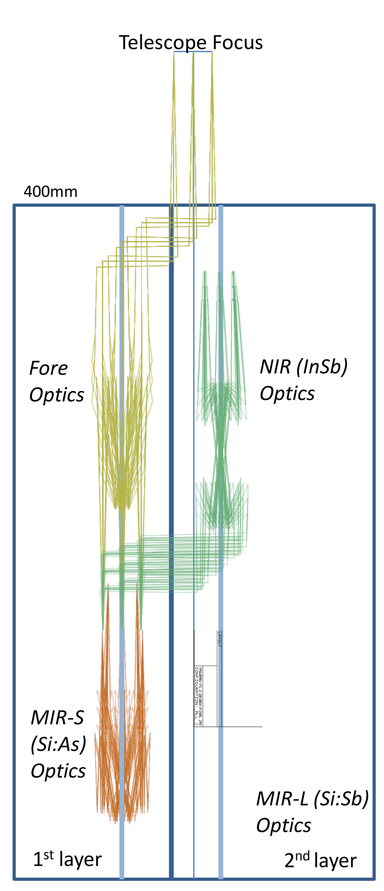
Cold Optics

✓ The cold optics consists of four reflective relay-optics
- fore-optics
- rear-optics 1 : NIR channel
- rear-optics 2 : MIR-S channel
- rear-optics 3 : MIR-L channel

✓ Each of the collimators and the cameras consists of two off-axis confocal mirrors. This design is based on the linear astigmatism theory of Chang et al. 2006
✓ The cold chopper is installed at the pupil of the fore-optics
✓ The filter wheels are placed at the pupil of each rear-optics
✓ Grisms for spectroscopy are installed in the filter wheels



TOP VIEW

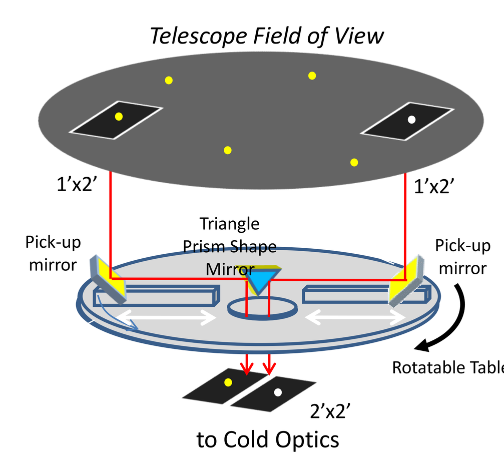


SIDE VIEW

Field Stacker for accurate monitoring observations

Accurate photometry is normally difficult for ground-based observations since the sky is not always stable.
At the optical or the NIR wavelengths, a differential photometric method is widely used for monitoring observations.
← However the differential photometric method cannot be applied for the MIR so far.
✓ The number of stars is very small at MIR wavelengths.
✓ It is not possible to observe more than one stars in the same field in most cases.

Field Stacker : a newly invented optical unit to achieve differential photometry at the MIR
✓ It is a warm optics installed at the telescope focus just before the cold optics.
✓ It consists of two pick-up mirrors and a triangular-prism shape mirror on a rotatable table
✓ The pick-up mirrors can move along the radial direction of the rotatable table, and pick up two separate fields in the telescope field of view.
✓ The picked-up beams are brought to the triangular-prism shape mirror, combined (or stacked) into the single beam, and then led to the cold optics.

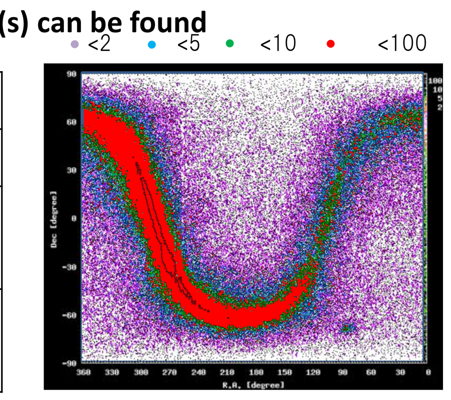


→ The field stacker enables us to observe two arbitrary fields of view, i.e. two or more stars simultaneously

Conceptual studies of the field stacker
"Is the number density of stars at mid-infrared wavelengths enough for the differential photometry"
← We counted the number of stars which is bright enough to be observed by the TAO mid-infrared camera by using AKARI point source catalog.

Fraction of the AKARI 9 micron and the 18 micron sources to which a counterpart star(s) can be found

Telescope	FOV of the telescope	9 micron		18 micron	
		> 50mJy	>300mJy	>130mJy	>1000mJy
TAO 6.5m	25 arcmin	55 %	51%	51 %	15%
Subaru 8.2m	5 arcmin	51%	10%	41%	0.3 %

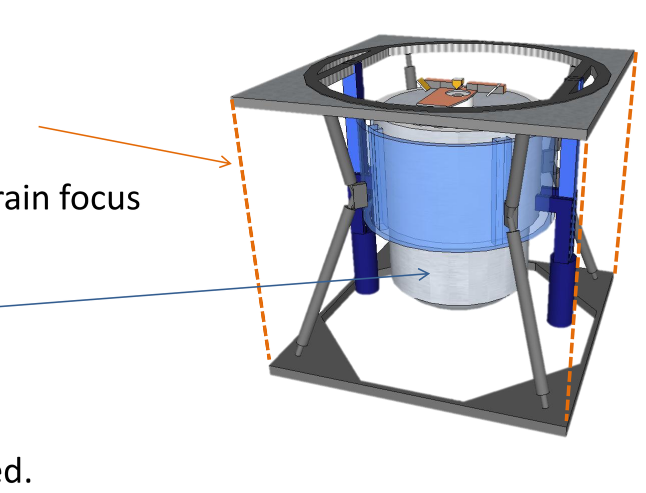


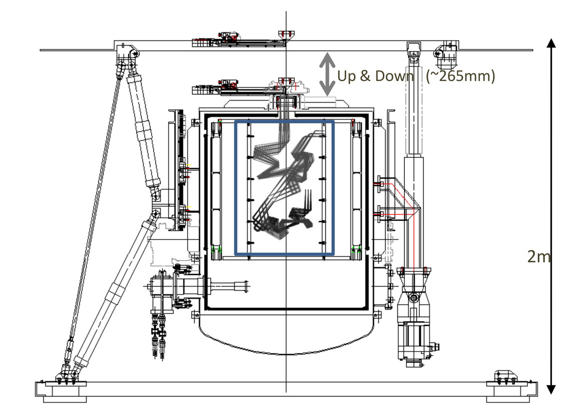
→ The field stacker can be used for about a half of Akari mid-infrared sources (mainly galactic objects).

Cryogenics and Support Mechanics

The whole system
- dimension : 2m x 2m x 2m / weight ~ 2ton can be attached to the Subaru Cassegrain focus

The chamber
- ϕ983mm x height 1390mm
- lifted up & down with a stroke < 265mm to compensate the increased light path when the field stacker is used.
- Two 4K-1W GM coolers
Temperature : Optics ~ 20K
Si:As & Si:Sb detector ~ 5K

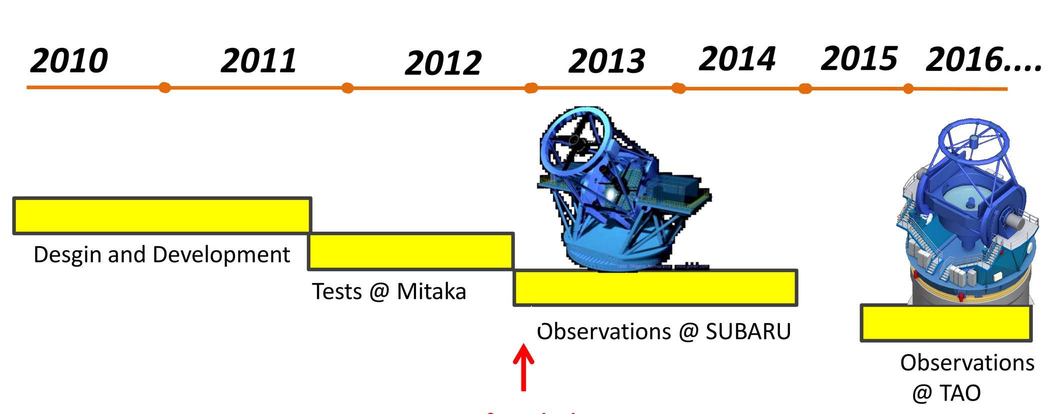




All cryogenic and mechanical support system is manufactured by Sumitomo Heavy Industries, Inc.

Time Schedule

✓ The TAO mid-infrared camera / spectrograph is already funded by the Japanese government.
✓ The commissioning and the early scientific observations will be carried out with the Subaru telescope at the end of 2012
✓ The full operation at the TAO telescope is scheduled in 2016



References & Related papers

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✓ **The prototype instrument MAX38 and related technology**
- Miyata, T, et al. (2008), Proc. SPIE 7012, 701243
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- Nakamura, T. et al. (2008), Proc. SPIE 7018, 70184H
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✓ **Confocal mirror optics**
- Chang, S. et al. (2006), Applied Optics, 45, 484

✓ **Akari point source catalog**
- Ishihara, D. et al. (2010), A&A, 514, A1

Comments & Suggestions are welcome!

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