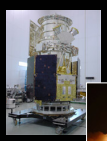
SPICA mission and the MIR-coronagraph for SPICA

Keigo Enya[1*], Shinichro Tanaka[2,1], Lyu Abe[3], Takao Nakagawa[1],
Takashi Miyata[4], Shigeyuki Sako[4], Olivier Guyon[5], Melanie Venet,
Hirokazu Kataza[1], Motohide Tamura[3], Jun Nishikawa[3], Naoshi Murakami[3], Fujita Kenta[6], Yoich Itoh[6],
and SPICA Working Group
(1: ISAS/JAXA, 2: University of Tokyo, 3: NAOJ, 4:IoA/University of Tokyo, 5: SUBARU/NAOJ, 6: Kobe University, *:enya@ir.isas.jaxa.jp)

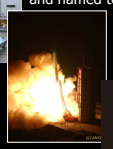
We introduce the Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission and the mid-infrared coronagraph for SPICA. SPICA is the next generation mission of space telescope for infrared astronomy following to AKARI. 3.5 m telescope will be cooled down to 4.5 for observation at 5-200 micron wavelength. The launch of the SPICA is planed to be middle of 2010th. We are developing an mid-infrared coronagraph for the SPICA mission. First, binary pupil masks were studied as a safe solution because of their robustness. Laboratory experiment with the checkerboard-type binary masks were performed using visible light. Achieved contrast averaged in the dark region of the point spread function was 1.1 * 10^-7 without wave front control. Study of Phase induced amplitude apodization (PIAA) and Prolate Apodized Lyot Coronagraph (PALC) are undergoing for challenging solutions. We are developing cryogenic tip-tilt mirror system and deformable mirror for SPICA.

1. From AKARI to SPICA

ASTRO-F was a IR surveyer satellite developed bye ISAS/JAXA and collaborators. ((C) JAXA)



ASTRO-F was launched in Feb. 2006 from Uchinoura Space Center of JAXA and named to be AKARI ((c) JAXA).



All sky survey and pointing observation is now Undergoing successfully ! ((C) JAXA)

Major difference between AKARI and SPICA

	AKARI	SPICA
Type	Surveyer	Observatory
Aperture (D)	70cm	3.5m
cooling	Liquid He Mechanical cooler	Radiation cooling Mechanical cooler (wo Liq.He)
Launch	2006, Feb. launched succesfully	Planed to be Middle of the 2010s
Orbit	Sun syncronous polar orbit	Sun-Earth L2 Halo orbit

=>SPICA is the next generation IR sattelite following to AKARI by ISAS/JAXA and collaborators.

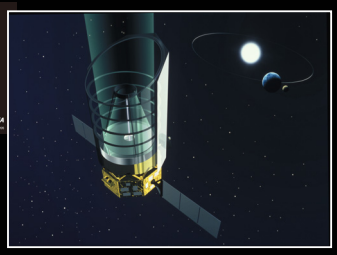


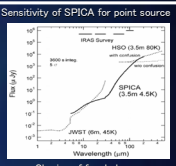
Image of the SPICA In orbit, in middle of the 2010s

2. Outline of the SPICA Mission

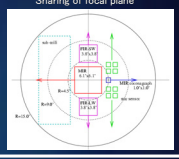
Telescope Aperture: 3.5 m
Temperature: 4.5 K Stirling + J-T closed cycle
Required Optical quality: difraction limited PSF @5mm
Orbit: Solar-Earth L2 Halo
Lifetime: 5 years +
Launch: in middle of the 2010s
Main observing wavelength: 5-200 mm
- Complementary with JWST, Herschel & ALMA
- Next generation IR telescope of ASTRO-F

Main observing wavelength: 5-200 mm

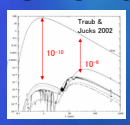
Sensitivity of SPICA for point source



Sharing of focal plane



3. SPICA coronagraph



Schematic view of a SPICA pupil. Obstruction by 2ndary mirror and spiders.

Specification of the SPICA coronagraph

Parameter	Specification
Core wavelength	5-20 μm
Observation mode	Imaging, Spectroscopy
Inner working angle (IWA)	about 5 λ/D*, as small as possible
Outer working angle (OWA)	30 λ/D*
Contrast between	> 10^{-6}
Detector	1k * 1k format Si:As array, 0."1/pixel
Field of View	1′ * 1′
Spatial resolution	Similar to IWA or less
Spectral resolution	200

* λ, D is observing wavelength and telescope aperture diameter.

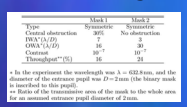
Infrared observation
- only ~10^{-6} contrast required

Free from air turburance
Clean pupil by single dish mirror

=> SPICA is a unique opportunity as a coronagraph platform.
=> We started Development of the SPICA coronagraph

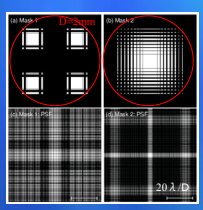
4. Labo. Experiment of checkerboark pupil mask coronagraph (Enya, Tanak, Abe, Nakagawa 2006, A&A accepted, astro-ph/0609646)

● Mask design (see also Tnaka et al. 2006, PASJ, 58, 627)



Type	Mask 1 Symmetric	Mask 2 Symmetric
Central obstruction	30%	No obstruction
IWA* (λ/D)	7	3
OWA* (λ/D)	16	30
Contrast	10^{-7}	10^{-7}
Throughput** (%)	16	21

* Is the experiment the wavelength was λ = 632.8 nm, and the diameter of the entrance pupil was D = 2 mm (the binary mask is inscribed to this pupil).
** Ratio of the transmissive area of the mask to the whole area for an assessed entrance pupil diameter of 2 mm.

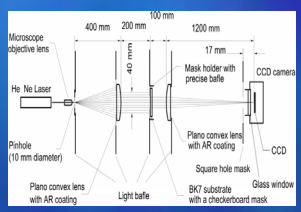


Checkerboard pupil Mask
- robust and achromatic

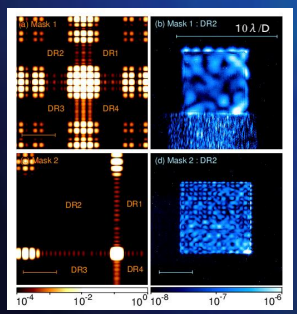
Fabrication
- AIST(National Institute in Japan)
- Al film(100 nm) onBK7 substrate
- Electron beam and lift-off

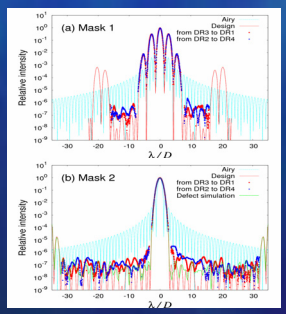
● Measurement

All optics was set on a optical bench in a dark room with air clearning system. ND filter(OD=2, 4, ,6) and various exposure time were used for high dynamic range measurement. A square hole mask was used fro the dark-region measurement.



● Results

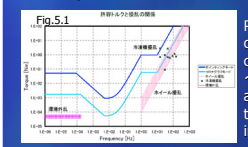




=> Average contrast: 2.7x10^{-7} (Mask 1), 1.1 x10^{-7} (Mask2)
=> SPICA specification is satisfied.

5. Cryogenic Tip-Tilt Mirror System

● Why needed?



Pointing error caused by cooler, compressor or other components vibration can be ~ 3′, while required pointing acuracy is ~ 0′.3. This gap is too large to solve by improvement of pointing system.

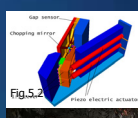
=> Cryo. tip-tilt mirror is indispensable.

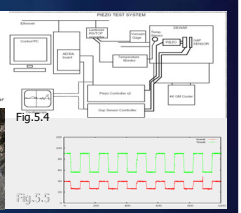
● Specifications

working temperature: 4K
beam size: φ70mm
stroke: ±3"@sky
±1.25'@mirror tilt
frequency: > 100 Hz
Accuracy: 0.03 " @sky
speed: 5 ms for setling
heat generation: ~ 3 mW

● development and experiment

Design of proto-type of the cryogenic tip-tilt mirror is shown in Fig.5.2. Fig.5.3 shows the cryogenic chamber cooled down to 10K with GM cryo-cooler. Fig5.4 shows system for experiment for the proto-type mirror. Motion of a piezo actuator was confirmed in this chamber. The system also comfirmed 5′ chopping in room temperature(Fig.5.5). It turned out that:





=> Proto-type system is nowu under construction and examination.
=> heat generation is critical problem(10 times larger now)

6. Toward the MIR-coronagraph for SPICA

● Other coronagraph
- Phase Induced Amplitude Apodization (PIAA, Guyon 2003)
- Prolate Apodized Lyot Coronagraph (PALC, Aime et al. 2002)

● Labo. demonstration of a MIR coronagraph
- Cryostat, cooler, IR detetor, mirror-optics, etc.

● Comparison and selection of coronagraph considering astronomical observation plan