COMICS: The Cooled Mid-Infrared Camera and Spectrometer for the Subaru Telescope

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ABSTRACT

In this paper, we present the design and test performance of the COMICS, the mid-IR instrument for the 8.2 m Subaru Telescope at Mauna Kea. The instrument has both imaging and long slit grating spectroscopy capabilities in the 8 - 26 μm wavelength range. In the camera section, there are selectable three sets of lens assembly, one for the 10 μm imaging, another for the 20 μm imaging, and the other for the 10 μm pupil imaging. This camera section has an SBRC 320 $\times$ 240 Si:As IBC array and serves as a slit viewer and as a camera pixel scale of 0.130 arcsec. The spectrograph section is designed to have five SBRC 320 $\times$ 240 Si:As IBC arrays. Five arrays will cover 8 - 13 μm wavelength range in two positions of the grating with resolving power around 2500. So far, two arrays are installed for the spectrograph section and full spectral region is covered with tilting the grating. Selectable four sets of gratings provide spectral resolution ranging from 250 to 10000 in the N band and around 2500 in the Q band.

Keywords: Mid-infrared, Instrument, Spectrometer, Camera

1. INTRODUCTION

Seven facility instruments[1] of the Subaru telescope[2] achieved or will achieve their first light from late 1999 to 2000. COMICS (COoled Mid-Infrared Camera and Spectrometer) is one of them and has both imaging and long slit grating spectroscopy capabilities in the mid-infrared.

The COMICS has been planned since 1992. In the early stage of the development, we have developed MICS (Mid-Infrared Camera and Spectrometer)[3] as a prototype instrument that has both imaging and long slit grating spectroscopy capabilities in the 8 - 13 μm. The COMICS has been assembled in 1999 and started test observations from December 1999.

In this paper we describe the specifications of the instrument, characteristic points of the design and some of its first light results.

2. INSTRUMENT SPECIFICATIONS

2.1. Imaging and Slit-viewing mode

The camera section has capabilities to imaging in the N band and the Q band. The focal plane scale for imaging is chosen so as to attain diffraction limited angular resolution at 8 μm. This camera section has an SBRC 320 $\times$ 240 Si:As IBC array.[4] Wider direction of the detector corresponds to the direction of the slit in the slit viewing mode.

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Table 1. Imaging specifications

Detector	320 × 240 element Si:As BIB
Focal plane scale	0.130 arcsec/pix
Field of view	42 arcsec × 31 arcsec
Wavelength coverage	8 – 13 μm 16 – 26 μm
Filter wheel	12 filters including blind

2.2. Spectroscopic mode

The spectrograph section designed to have five 320 × 240 Si:As IBC arrays. Narrower direction of each array corresponds to the direction of slit. Five arrays are placed in the direction of spectral dispersion (each width is 320 pixels) with spacing correspond to about 250 pixels. This alignment covers the 8 – 13 μm wavelength range in two positions of the grating with resolving power around 2500. The narrowest slit width and the focal plane scale of the spectrometer are optimized at 10 μm. In high-resolution mode, order sorting is accomplished via filters within the fore-optics. This function is currently unavailable becasue a lack of appropriate filters.

Table 2. Spectrograph specifications

Detector	5 × 320 × 240 element Si:As BIB
Focal plane scale	0.165 arcsec/pix
Slit width	0.33, 0.50, 0.66 or 1.00 arcsec
Slit length	40 arcsec
Spectral resolution	250 (8–13μm) 2500 (8–13μm) 2500 (16–26μm) 10000 (8–13μm)

3. OPTICAL DESIGN

The optics is mounted on a cooled base plate in the vacuum chamber (Fig1). It consists of three sections, a fore-optics section, a camera section, and a spectrograph section.

3.1. fore-optics

To achieve efficient capability in both 8 – 13 μm and the 16–26μm wavelength regions, the COMICS has selectable two entrance windows. It takes a few hours to alternate the window without break a vacuum of the chamber and keeping the optical system cold.

Optical layout of the fore-optics is shown in Fig2, where the powered mirrors are designated M1 – M4, and the folding flats FM1 – FM4.

A set of powered mirrors M1 – M2 makes a beam from a point source to be parallel and makes an image of the telescope pupil at the cold stop. After the cold stop, two filter wheels are located. Another set of powered mirrors M3 – M4 reimages the image at the telescope focus on a slit. All powered mirrors are aluminum mirrors made by high precision diamond turning.

Each filter wheel has 6 positons. One position of each wheel must be blank to use another wheel and one position must be blind to get dark images, thus 9 positions are available for bandpass filters. A folding flat FM1 has two-axis tilt adjustment capability to put the pupil image in the center of the cold stop.

3.2. camera optics

Optical layout of the camera section is also shown in Fig2, where the three sets of lens assembly are not shown and only a lens wheel is shown. One of the lens assemblies is for the 10 μm imaging, another is for the 20 μm imaging, and the other is for the 10 μm pupil imaging.

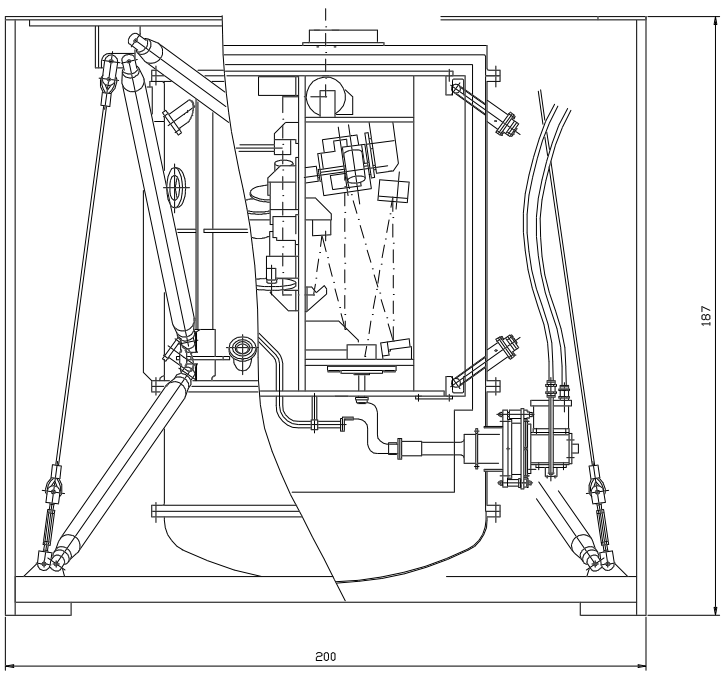

Figure 1. The whole system, including electronics, is housed in the standard container of the Subaru Telescope (2m x 2m x 2m in size and 2000 kg in weight). The vacuum chamber is supported by lods. The optics in the vacuum chamber is cooled to about 35 K and the detector temeprature is cotrolled at any temperature between 6 K and 10K.

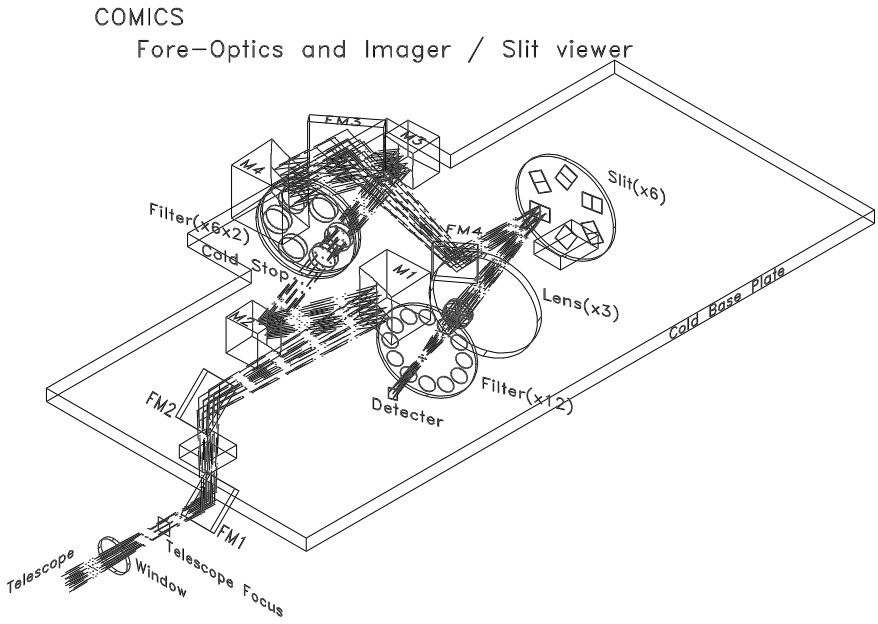

Figure 2. Fore-optics and imager/slit-veiwer are located above the base plate. Fore-optics are reimaging optics equipped with a cold pupil and consisting of four aspheric mirrors (M1 - M4). Imager/slit-veiwer is a lens system. FM1 - FM4 are flat folding mirrors.

3.3. Spectrograph optics

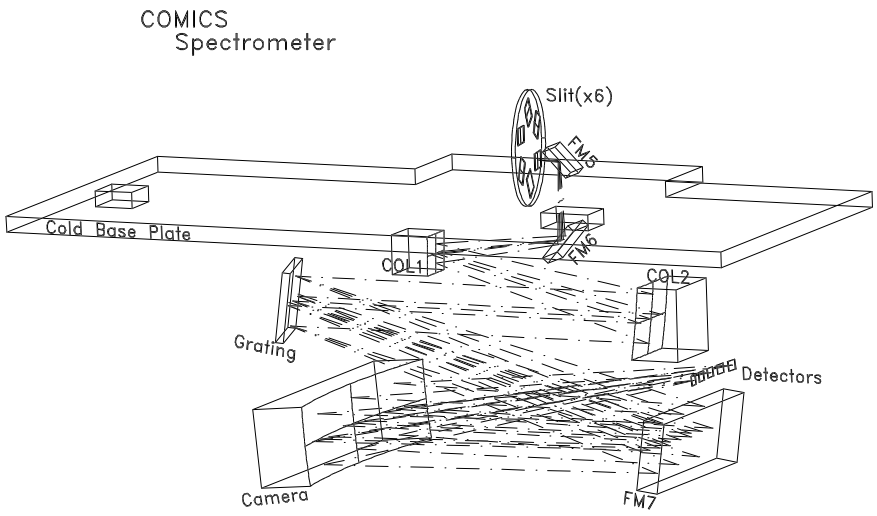

Figure 3. Optical elements for the spectroscopic section are positioned below the base plate of the optical bench. Three gratings are put on a remotely controlled mount. Five 320 by 240 element Si:As BIB detectors are put along the curved focal surface of the spectrometer camera. FM5, 6 and 7 are just flat folding mirrors.

Optical layout of the spectrograph optics is shown in Fig3, where the powered mirrors are designated COL1 – COL2 , Camera and the folding flats FM5 – FM7.

Slit wheel has 6 positions to select slit width, including one flat mirror for imaging. After passing through the slit wheel, the light is collimated by a set of mirror COL1 – COL2 and the parallel beam is directed to the grating. There are four selectable gratings on a wheel. This wheel assembly is mounted in a box that has another axis of rotation to adjust the incident beam angle to the grating. From the grating, the light is dispersed and directed toward the fold mirror FM7. The fold mirror directs the light toward the camera mirror. The camera mirror has spherical surface, the center of curvature is located near the grating. This focuses the dispersed light on a spherical surface. Five detectors are assembled on this spherical focal surface with spacing narrower than the width of each detector. This alignment covers the $8 - 13\ \mu m$ wavelength range in two positions of the grating with resolving power around 2500.

4. PERFORMANCE AND STATUS OF THE INSTRUMENT

The COMICS has been assembled in 1999 and started test observation from December 1999. In this section we describe the performance and the status at that time.

4.1. Cryostat

- Setup time : 1 day to make a vacuum and 5 day for cooling down including 1.5 day liquid nitrogen additional cooling.
- Achieved temperature : $35K$ for the optics, $4K$ for the detectors, and the stable controlled temperature with operating detectors is $6.0K$.

4.2. Detectors

One detector for imaging and two for spectroscopy are installed. At this time, bias settings of the detector were not good and we are tring to optimize them. Some of the parameters described here will be improved.

- Conversion coefficient : 170 electrons / ADU
- Dark current : $4 \times 10^5 electrons/sec$ for imaging detector, $9 \times 10^4 electrons/sec$ for spectrometer detectors
- Read-out noise : 4 ADU
- Full well depth : 1.1×10^4 ADU
- Efficiency (includes optics efficiency) : 1%

4.3. Optics

Table 3. Installed filters

Imaging filter		
Filter-ID	Central Wavelength(μm)	Width (μm)
F04	7.8	0.7
F05	8.7	0.8
F06	9.8	0.9
F07	10.3	1.1
F08	11.6	1.1
F09	12.5	1.2
F12	18.5	1.2
F13	20.8	0.9
Fore-optics filter		
F01	10.5	6.0
F17	19.0	3.8
F18	23.0	4.6

Filter F18 was broken after the test observation at Dec. 1999.

Installed gratins are low-resolution($R \sim 250$) for the N band (8–13μm), medium-resolution($R \sim 2500$) for the N band, and mid-resolution($R \sim 2500$) for the Q band (16–26μm). For low-resolution mode, full spectral region is coverd by one detector. For the mid-resolution modes, full spectral region is coverd by two detectors by adjusting the grating angle.

In case of the medium-resolution mode for the N band, highly monochromatic light falling on a pixel and the change of the wavelength from a pixel to other pixels cause stripe patterns. This fringe patten is seen in Fig4, where absorption lines of NH_3 indicate the direction of the slit.

4.4. First light results

Achieved performances at the test observation in Dec. 1999 are summarized in Table4.

Sensitivities are estimated from the measured data with an assumption that total flux from a point source falls into 9×9 pixels. This assumption was reasnable from the performance of the telescope at the observation time, and this makes the sensitivities worse. For about spatial resolution, we used the best case data (Fig5, Fig6).

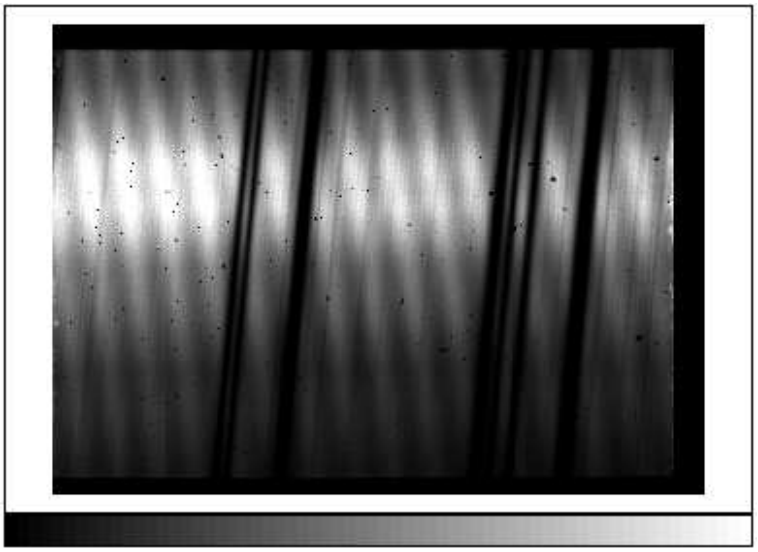

Figure 4. Fringe patten and NH_3 absorption lines in the mid-resolution mode ($R \sim 2500$) . Horizontal direction is the spectral direction. NH_3 absorption lines appear as black lines. Direction of fringe peaks is not the same as the direction of the slit.

Table 4. Achieved performance in Dec. 1999 for point source

Imaging Mode		
Sensitivity ($1\sigma/1sec$)	$1.08Jy$ at $8.7\mu m$	
	$0.47Jy$ at $9.8\mu m$	
	$0.39Jy$ at $11.6\mu m$	
Spatial resolution	FWHM$\sim$ 0.4arcsec at $11.6\mu m$	Best Case
N band low-resolution mode		
Sensitivity ($1\sigma/1sec$)	$1.51Jy$ at $9.0\mu m$	
	$1.85Jy$ at $11.0\mu m$	
	$1.92Jy$ at $13.0\mu m$	
Spatial resolution	FWHM$\sim$ 0.4 arcsec	Best Case
Spectral resolution	$R \sim 230$ at $12.8\mu m$	
N band medium-resolution mode		
Sensitivity ($1\sigma/1sec$)	–	Not yet estimated
Spectral resolution	$R \sim 2500$	

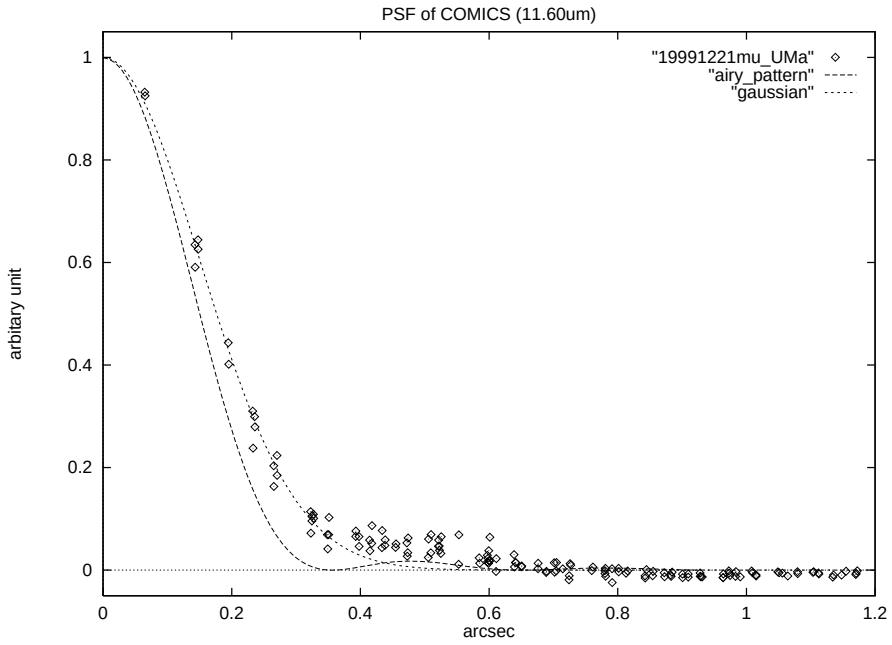

Figure 5. Radial profile plot of the observed point source data. Gaussian profile of FWHM=0.35 arcsec (dotted line) and Airy pattern (dashed line) are also shown.

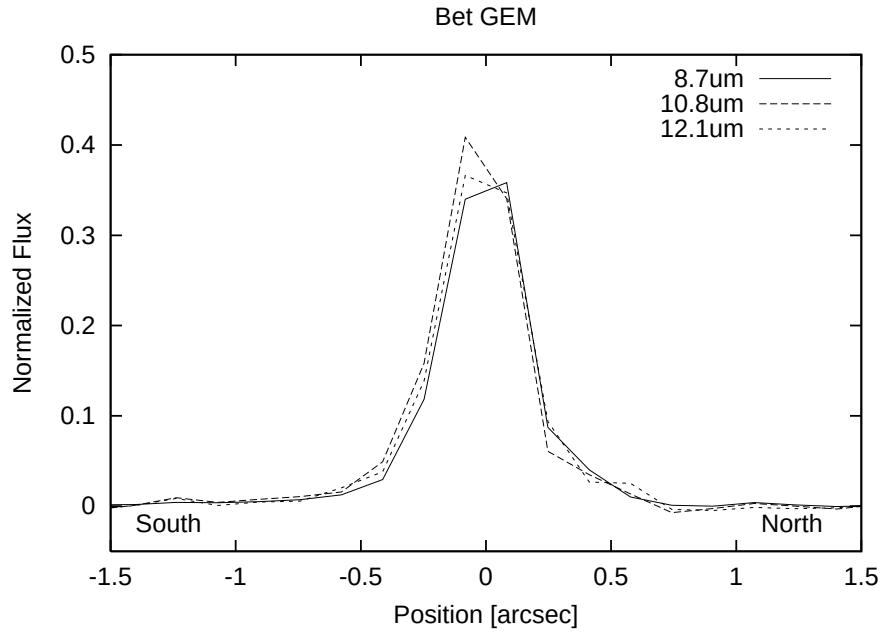

Figure 6. Profile of the observed point source data along the spatial direction.

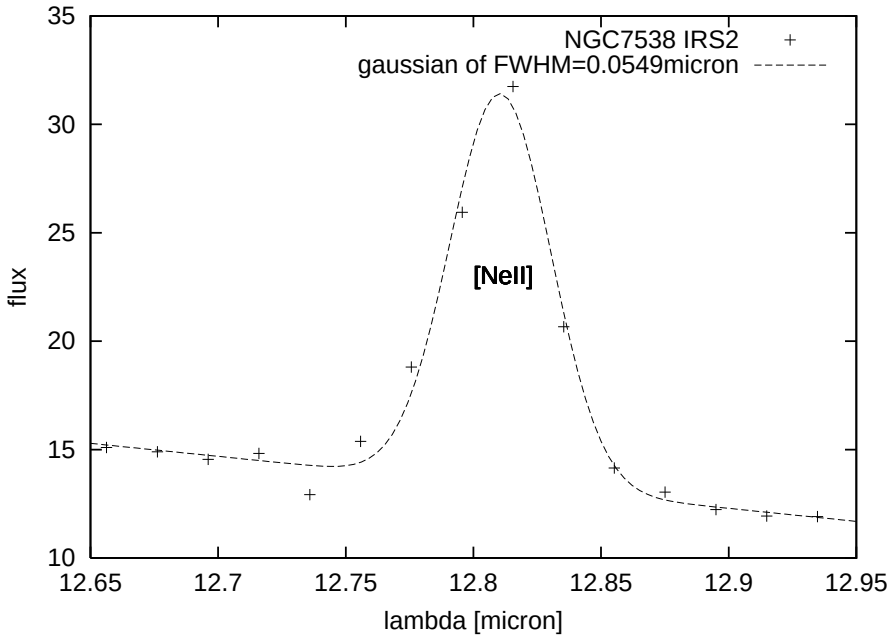

Figure 7. [NeII] line profile of NGC7538 IRS2 is plotted with a Gaussian fit profile.

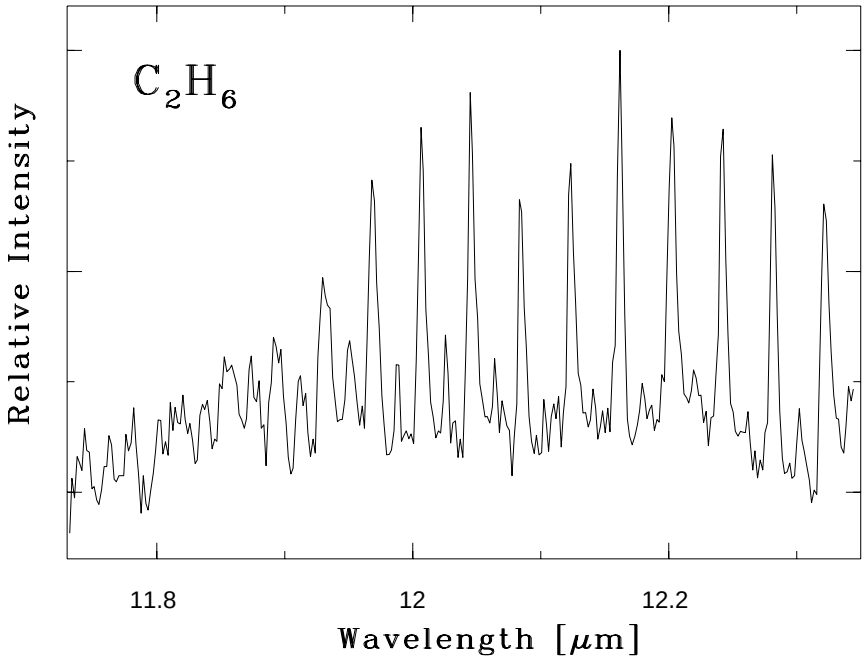

Figure 8. C_2H_6 lines of Jupiter.

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