RIMAS

Optical Design Development of the Imager/Spectrometer for the Discovery Channel Telescope

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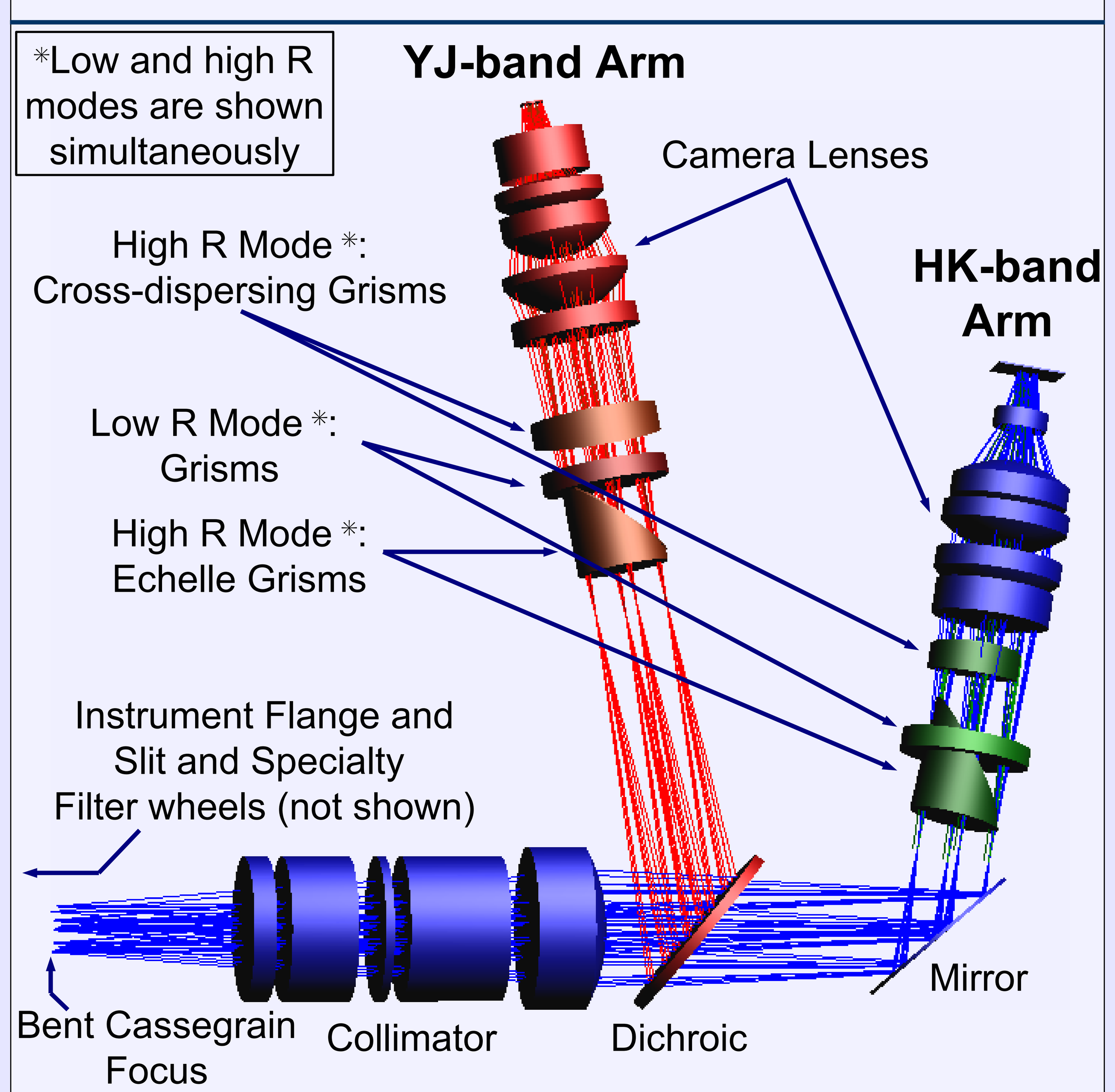
Abstract

The Rapid IMAger – Spectrometer (RIMAS) is a collaborative effort between the University of Maryland at College Park, NASA-GSFC and Lowell Observatory designed for use on the 4.3 meter Discovery Channel Telescope at Lowell. The primary science goal of the instrument is the study of gamma-ray burst (GRB) afterglow appearing in the near-infrared. Continuous operation will allow measurements beginning minutes after the prompt emission. We present the results of the RIMAS optical design development. The instrument consists of two arms separated by a dichroic: the first for the Y and J bands (0.97 – 1.07 and 1.17 – 1.33 μm) and the second for the H and K-bands (1.49 – 1.78 and 2.03 – 2.37 μm) [1]. Each arm will be equipped with two broad band filters for imaging, as well as low resolution and echelle grisms. The imaging modes are designed to be diffraction limited, with one pixel corresponding to ~0.35 arcseconds, while the diffractive modes have resolving powers of approximately 30 and 4,500. With photometric and spectroscopic capabilities, RIMAS will be well positioned to quickly determine redshifts, followed by high resolution spectroscopic studies of GRB afterglow.

Design Overview

RIMAS is divided into two optical arms; one for the Y and J bands and the other for the H and K bands. The layout is shown below.



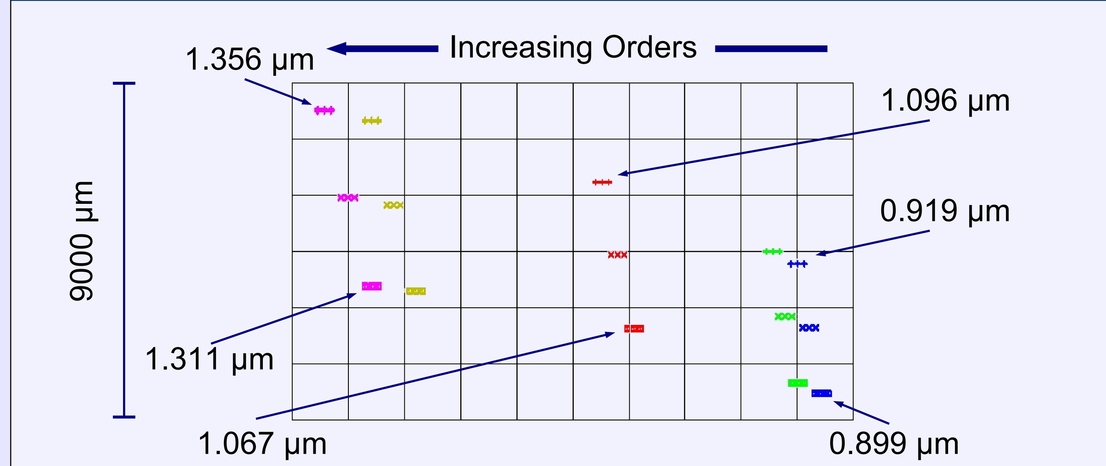
Each arm is equipped with two grisms (grating-prisms), as well as two filters for photometry. These optical elements are located on a wheel near the pupil, which allows the operational mode to be quickly changed.

Science Goals

RIMAS is designed to study high redshift GRBs with afterglows appearing in the NIR. The instrument will quickly determine redshifts of candidate GRBs detected by *Swift* with either photometry or low resolution spectroscopy. Further absorption studies will then utilize the high resolution spectroscopic modes.

High-R Spectroscopic Modes

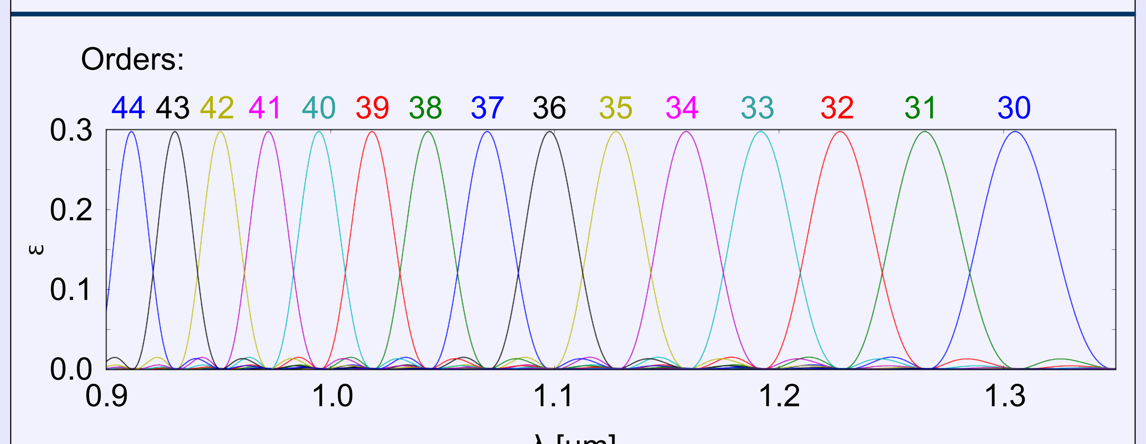
The high resolution spectroscopic modes are designed to have R ~ 4500 with a 7" x 0.6" slit. This requires the use of Echelle grisms followed by cross-dispersing grisms for order separation. These grisms are again located on the filter-wheel of each optical arm. The relative as-designed positions of test wavelengths in the Y and J bands are shown below.



The following table provides R-values at sampled wavelengths.

Wavelength [μm]	R	
0.899	4400	Arm 1
1.081	4100	Arm 1
1.356	3900	Arm 1
1.393	5700	Arm 2
1.774	5500	Arm 2
2.443	5300	Arm 2

The efficiency with which each wavelength is diffracted into a given Echelle order was calculated using a scalar treatment given by Loewen and Popov (1997) [3]. These efficiencies are shown below for the Y and J bands.

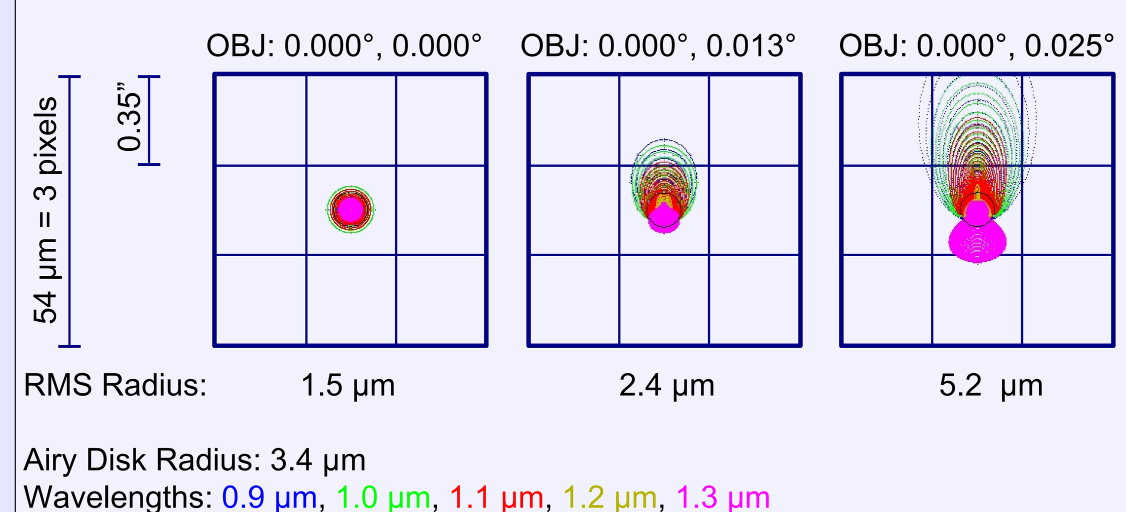


The efficiency of the first order of the cross-disperser is not included in this plot.

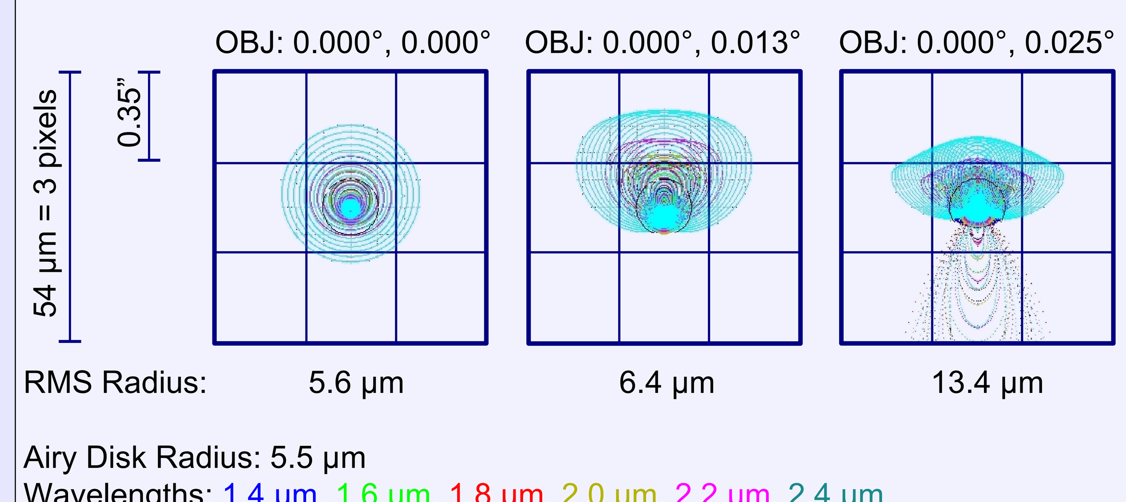
Imaging Modes

The imaging modes are designed to be nearly diffraction limited. The imaging mode is selected by rotating a filter into the beam near each pupil. As-designed performance is indicated by the spot diagrams below (generated using ZEMAX optical design software) [2].

Specifications	
FOV	3 '
Plate Scale	0.35 "/pixel
Pixel Size	18 x 18 μm
50% Encircled Energy Diameter	4.2 – 7.8 μm



YJ-band spot diagrams



HK-band spot diagrams

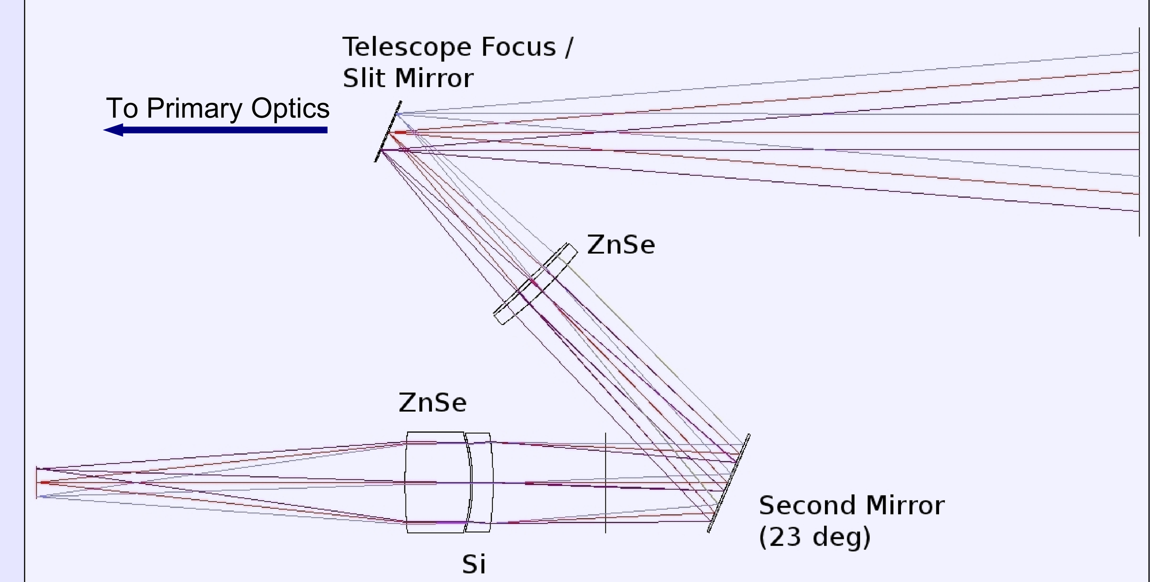
Low-R Spectroscopic Modes

The low resolution spectroscopic modes are designed to have R ~ 30 with a 0.6" wide slit (other slit widths are to be determined). This is achieved with a single grism on the filter-wheel of each optical arm. The following table provides R-values at sampled wavelengths.

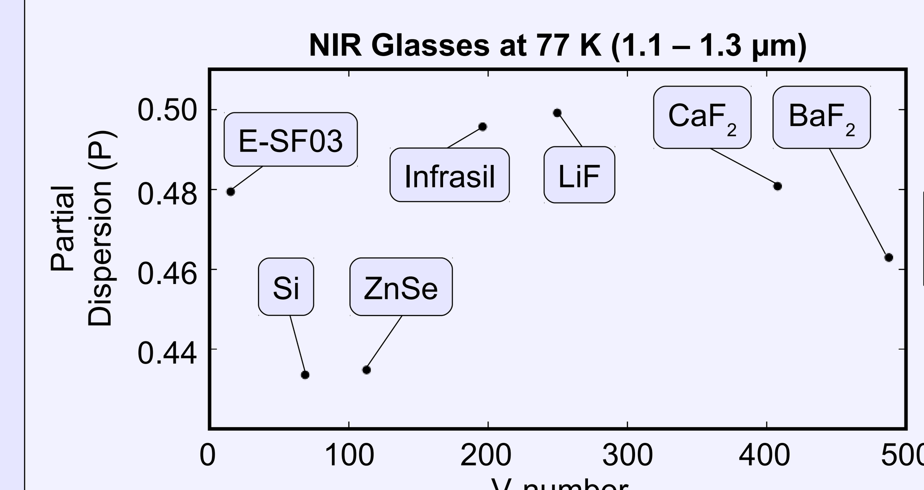
Wavelength [μm]	R	
1.0	28	Arm 1
1.2	34	Arm 1
1.3	37	Arm 1
1.5	26	Arm 2
2.1	37	Arm 2
2.3	41	Arm 2

Reflective Slit Imaging Optics

To assist in guiding light from sources through slits for spectroscopy, fields surrounding the slits are simultaneously imaged. These fields are redirected by making the surface surrounding a slit reflective, and tilting it relative to the optical axis. A single lens is used to image the pupil on a lens doublet, which in turn focuses at a detector. The optical layout is shown below.



The optical axis for this lens system is decentered to allow the beam to pass beneath a system of two wheels. The first wheel holds the slits and the second holds specialty filters. Silicon and ZnSe were chosen to achromatize the system, based on the prescriptions of Ren and Allington-Smith (1999) [4]. Si and ZnSe have relatively high indices and similar partial dispersion values when compared to their relative Abbe numbers. This reduces secondary chromatic aberration ($\nabla \ell$ - see below).



$$\nabla \ell \propto \frac{P_1 - P_2}{V_1 - V_2}$$

References and Resources

[1] PC Hewett, SJ Warren and others. *MNRAS*, 367(2), 2006.
[2] http://www.zemax.com/
[3] EG Loewen and E Popov. *Diraction Gratings and Applications*. CRC Press, 1 edition, 1997.
[4] D Ren and JR Allington-Smith. *Opt. Eng.*, 38(3), 1999.
[5] D Leviton, BJ Frey and others. *Proc. SPIE*, 2005, 2006, 2007.