Gemini Planet Imager 2.0: Upgrades to the IFS including new spectral modes

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Summary:

The Gemini Planet Imager (GPI) is a high-contrast imaging instrument designed to directly image and characterize exoplanets. GPI is currently undergoing several upgrades to improve performance. In this paper, we discuss the upgrades to the GPI IFS. This primarily focuses on the design and performance improvements of new prisms and filters. This includes an improved high-resolution prism which will provide more evenly dispersed spectra across y, J, H and K-bands. Additionally, we discuss the design and implementation of a new low-resolution mode and prism which allow for imaging of all four bands (y, J, H and K-bands) simultaneously at R≈10. We explore the possibility of using a multiband filter which would block the light between the four spectral bands. We discuss possible performance improvements from the multiband filter, if implemented. Finally we explore the possibility of making small changes to the optical design to improve the IFS's performance near the edge of the field of view.

New Spectral Modes for GPI

The GPI integral field spectrograph (IFS) is a near-infrared (0.9–2.4μm) lenslet-based instrument with a 2.7″×2.7″field of view capable of detecting exoplanets within <0.5 arcseconds of their host star.

The GPI IFS is undergoing several upgrades to improve its performance and capabilities – these upgrades are illustrated in the optical layout of GPI shown in Figure 1.

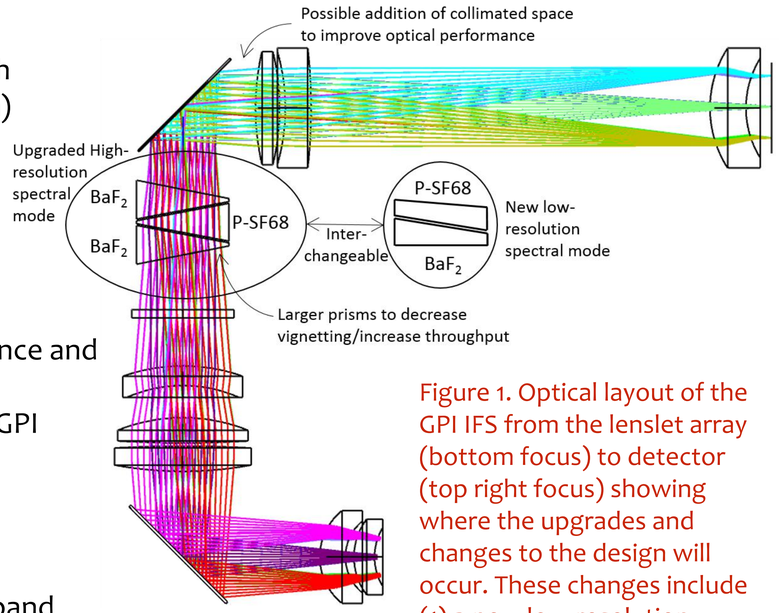

Figure 1. Optical layout of the GPI IFS from the lenslet array (bottom focus) to detector (top right focus) showing where the upgrades and changes to the design will occur. These changes include (1) a new low-resolution spectral mode, (2) an upgraded high-resolution mode, (3) addition of collimated space and (4) larger prisms to decrease vignetting.

Upgraded High-Res Mode

The original GPI IFS contained five bandpasses (Y, J, H, K1 andK2). K band was split to allow the spectra to fit on the detector, but the new upgraded IFS will be capable of imaging all of K-band simultaneously due to a new dispersion element. Further the upgraded spectral resolving power now varies less across the four bands from R=λ/Δλ=~46–77; see Table 1 for list of all High-res mode parameters.

Table 1: GPI High-Res Spectral Mode Parameters

Band	Cut-on/off (μm)	Length (pix)	R = λ/Δλ
Y-band	0.95 – 1.07	18.3	76.9
J-band	1.13 – 1.34	19.4	57.0
H-band	1.498 – 1.796	16.8	46.5
K-band	2.00 – 2.40	20.0	55.1

A New Low-Res Mode

GPI 2.0 will have a new low-resolution mode that will allow for simultaneous imaging across y, J, H and K band (λ= 0.97–2.40μm). The new mode will provide a spectral resolution of R=λ/Δλ≈10 across all bands (roughly 2-4 pixels per band). The total spectral length is 20.0 pixels with a gap between each spectra of 2.5 pixels on the detector. Table 2 lists the number of pixels across each band and the corresponding spectral resolution. Note that there is a 2-3 pixel gap between each band.

Table 2: GPI Low-Res Spectral Mode Parameters

Cut-on/off (μm)	Band	Length (pix)	R = λ/Δλ
0.97 – 1.07	Y-band	2.9	15.0
	GAP	2.3	
1.17 – 1.33	J-band	2.8	11.1
	GAP	2.2	
1.49 – 1.78	H-band	3.3	9.3
	GAP	2.3	
2.00 – 2.40	K-band	4.1	11.2
	Total length:	20.0	

A new prism material for GPI's IFS

The new high resolution prism is three elements:P–SF68 and twoBaF2elements. This material combination was chosen to provide near-uniform spectral lengths of all four infrared bands as well as zero-deviation. This material provides a superior dispersion profile compared with the prism glass used in original GPI IFS (S-FTM16) and is comparable in performance to L-BBH2 used in CHARIS (see Figure 2 for comparison of materials).

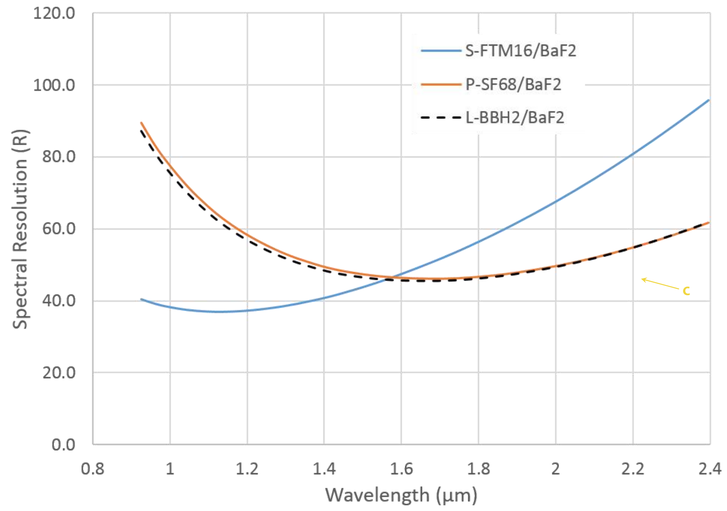

Figure 2. Spectral dispersion (for high resolution prisms) ofP–SF68/BaF2,L–BBH2/BaF2andS–F T M16/BaF2.Higher spectral resolution is desired at shorter wavelengths in order to achieve equal spectral length in y, J, H and K-band. The P–SF68 and L–BBH2 prisms provide near equal spectral lengths across all four spectral bands

Multiband filter for the Low-Res Spectral Mode

We are exploring the possibility of including a multi-band (4-band) filter in low-res mode to improve performance and provide isolated images of each of the 4 bands. Figure 3 shows an illustration of the filter and the resulting GPI spectrum.

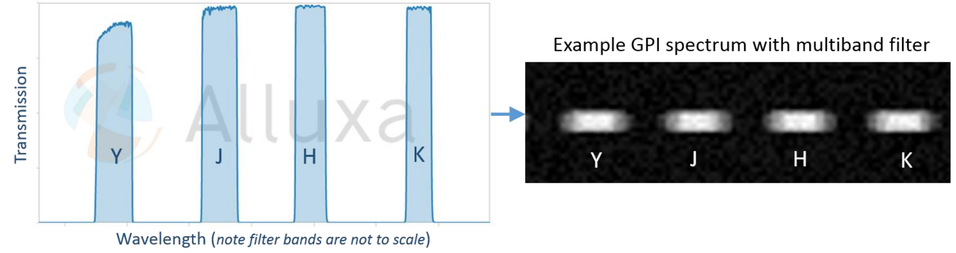

Figure 3: Illustration of a 4-band filter (left) that could be implemented with the low-resolution prism. The resulting spectrum on the GPI detector (right) is four well separated images of the science target in each spectral band. The well separated spots can provide an independent means of wavelength calibration as well as other performance improvements.

Improved Optical Performance

The edge of GPI's field of view suffers from some astigmatism and coma. A slight increase (+20mm) in the amount of collimated space improves performance near the edge of GPI's field of view (see Figure 4).

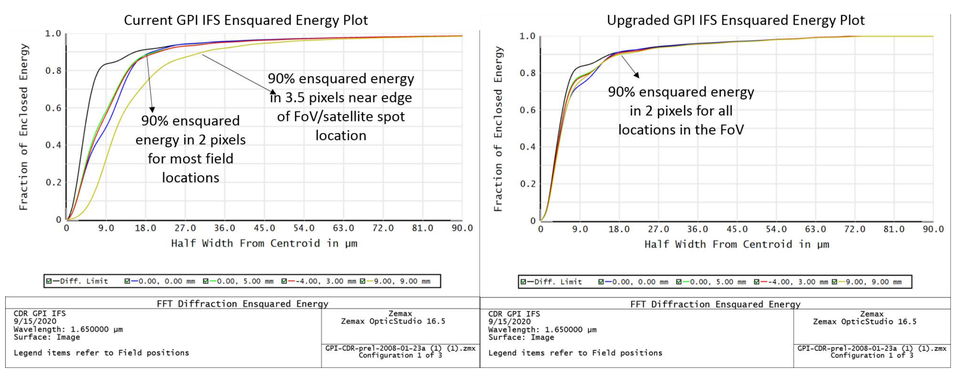

Figure 4. Ensquared energy at various positions on the detector for the current GPI instrument (left) and with proposed upgrades (increased collimated space, right). For reference, one pixel is 18 microns.

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