Optimized Narrowband Visible to Near-Infrared Filters for the Psyche Multispectral Imager

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Abstract

The Psyche Multispectral Imager is a visible to near-infrared camera system that will be flown on the *Psyche* mission to the M-type asteroid (16) Psyche. The Imager is equipped with 8 filters that will be used for color imaging and multispectral observations. We present the results of a spectroscopic study of metallic and metal-silicate meteorites and laboratory minerals that have been used to optimize the Imager filters. Our study indicates that the merging of two previously-proposed filters and the addition of a new near-infrared filter will enhance mission science return.

1. Introduction

The Main Belt asteroid (16) Psyche is the largest of the M-type asteroids (D > 200 km) and the target of NASA's *Psyche* Discovery mission [1]. Measurements of density, radar albedo, thermal inertia, and reflectance are consistent with (16) Psyche being largely composed of metal. The Psyche Multispectral Imager (henceforth the 'Imager') is a visible to short-wave near-infrared (~400 to ~1100 nm) CCD camera designed to characterize topography, geology, and composition of the surface of (16) Psyche [2]. The Imager consists of a pair of redundant, identical 148 mm focal length *f*/1.8 camera assemblies and accompanying digital electronics assemblies. Internal to the camera assemblies are filter wheels containing 8 filters specifically chosen to maximize the Imager's ability to address *Psyche* mission science objectives (Table 1). These objectives include assessing the mixing of silicates and metal on the surface, as well as detecting the presence of sulfide minerals like oldhamite and troilite that are indicative of reducing conditions during (16) Psyche's formation. The *Psyche* mission will be the first close-up encounter with a metallic asteroid, and thus the bandpasses of the Imager's filters must be carefully chosen to best capture reflectance features in the spectrum of (16) Psyche that can address mission science objectives.

Table 1. Psyche Multispectral Imager Filters

	Band[a]	λ (nm)	Purpose
As-proposed filters	Clear	540±140	Unfiltered for OpNav, topography, geology
	B	437±25	Sulfide continuum, blue "true color"
	o	495±12.5	Search for evidence of sulfides
	v	550±12.5	Sulfide continuum, green "true color"
	w[b]	700±25	Peak reflectance continuum, red "true color"
	0.75	750±12.5	Search for low-Ca pyroxene
	p	948±25	Search for high-Ca pyroxene, characterize weak Earth-based feature
	z	1041±45	Search for evidence of olivine
Updated	~w	725±20	Peak reflectance continuum, red "true color"
	x	850±25	Search for evidence of low-Ca pyroxene, other ~1.0 μm features, capture Psyche Earth-based feature

[a]Eight Color Asteroid Survey designation [3]
[b]As-proposed filters highlighted in red have been replaced with new filters highlighted in blue.

2. Methods

We have selected a set of 26 meteorite samples from Arizona State University's Center for Meteorite Studies collection that contain a broad range of materials relevant to potential Psyche surface compositions. These meteorites span a range of classes, including IAB and IVA irons, mesosiderites, pallasites, enstatite chondrites, a group of H and L ordinary chondrites, a lodranite, aubrites, and a diogenite. These classes were sampled to cover a broad range of bulk metal contents, from nearly entirely iron-nickel metal with minor sulfides seen in iron meteorites, to silicate-dominated assemblages with essentially no metal. When available, the samples were analyzed as powders, gravels, or roughened and polished surfaces. We used an Analytical Spectral Devices FieldSpec 4 (FS4) spectrophotometer to capture bidirectional reflectance spectra from 350-2500 nm to cover the Imager's spectral range. Our light source is a quartz-tungsten lamp and all spectra are calibrated to a Spectralon white reference standard, which has near-uniform reflectance in the FS4 measurement range. The phase angle was 30°. The wavelength range measured by the FS4 enables measurement of absorption features near 1000 nm that are attributable to iron in silicates like olivine and pyroxene. Furthermore, the Imager is intended to capture absorption features from some sulfide minerals, such as oldhamite at 495 nm and 948 nm, and a change in slope of the troilite reflectance spectrum at ~650 nm.

3. Results

After convolving each full-resolution spectrum to the as-proposed filter set, it was evident that the 700/750 nm filter pair (bands *w* and *0.75*) were not capturing significant differences in absorptions or spectral slopes. These filters have thus been replaced with a single filter at 725 nm, which enabled consideration of a new filter placed elsewhere in the Imager-relevant wavelength range. Two filters were considered for adoption: a near-UV filter at 380 nm and near-IR filter at 850 nm. The near-UV filter offered potential leverage discriminating FeS from iron meteorite powder, a possibility of characterizing space weathering from UV slope, and higher detector quantum efficiency. The near-IR filter offered better silicate mineral discrimination, better capture of the near-IR absorption seen in CaS, and better capture of the possible minor absorption feature seen in reflectance data of (16) Psyche [*e.g.*, 4]. For these reasons, the near-IR filter was selected as the best option for the available filter slot. Figure 1 shows the reflectance spectra from a variety of endmember compositions from the meteorite set convolved to the final filter bandpass selections, including iron meteorite powder, troilite, oldhamite, low- and high-Ca pyroxene, and olivine.

References

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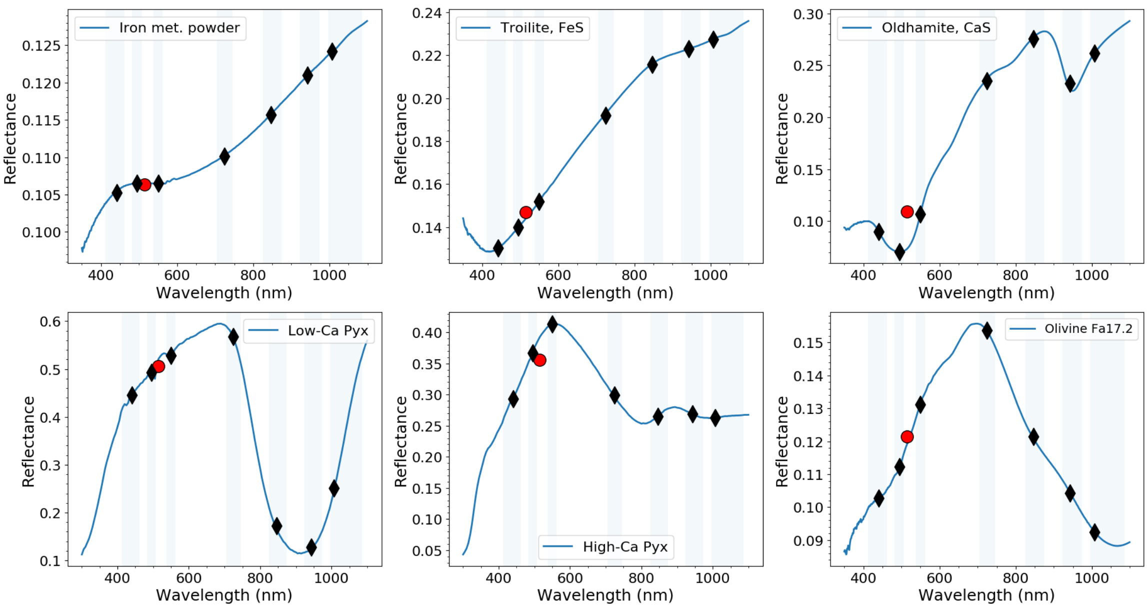

Figure 1: Reflectance spectra of materials relevant to the surface composition of (16) Psyche convolved to updated Imager bandpasses (Table 1). In all plots, the red circle is the convolved broadband clear filter and black diamonds are the convolved narrowband filters. Samples graciously provided by L. Garvie, ASU Center for Meteorite Studies.