

Simultaneous Infrared-Visible Imager/Spectrograph a Multi-Purpose Instrument for the Magdalena Ridge Observatory 2.4-m Telescope



M.B. Vincent*, E.V. Ryan

Magdalena Ridge Observatory,
New Mexico Institute of Mining and Technology,
401 Leroy Place, Socorro, NM, USA, 87801-4681



* mvincent@mro.nmt.edu, phone (505) 835-6758



ABSTRACT



The Simultaneous Infrared-Visible Imager/Spectrograph (SIRVIS) is a planned multi-purpose instrument for the Magdalena Ridge Observatory 2.4-m telescope located west of Socorro, NM. The primary science drivers are asteroid studies, the rapid response to astrophysical transient phenomena and observations of artificial targets such as satellites. For asteroid science, the wavelength range 0.39-2.5 μm gives the most mineralogically diagnostic information on surface compositions using standard filters and low-resolution, $R \sim 200$, spectroscopy. For transients, the telescope's rapid 10° /second slew rate will facilitate acquisition of data on any target within one minute of receipt of notice. For artificial targets, simultaneous two-color imaging will assist in unique determinations and overall condition monitoring. SIRVIS has two channels, a cryogenic NIR channel covering 0.85-2.5 μm at 0.27 arcsec/pixel, and an ambient temperature-pressure visible channel covering 0.39-1.0 μm at 0.15 arcsec/pixel. The beam is split by a cryogenic, red-pass dichroic mirror located between the telescope focal plane and the respective collimators. Both channels use refractive optics. The instrument is being designed to initially phase in the visible channel, then the NIR channel, and readily accommodate upgrades. For sky subtraction, the telescope is nodded between 30-60 second NIR integrations. Long visible integrations are made possible by shifting the CCD charge in sync with the nod.

SIRVIS Serves Three Scientific Functions



1) Photometry to measure the brightness of a target in selected filters.

- * Simultaneous visible and NIR photometry to derive colors.
- * Atmospheric extinction corrections are simplified as both channels observe through the same airmass.
- * 3σ detections of V ($0.55\ \mu\text{m}$) ≈ 22.5 and J ($1.25\ \mu\text{m}$) ≈ 19.0 targets in 10 second long images.
- * 3σ detections of V ≈ 25.0 and J ≈ 21.5 targets in 10 minute long images.
- * 1% photometry on V ≈ 21.5 and J ≈ 18.0 targets in 10 minute long images.

2) Spectroscopy for surface material characterization and temperature measurements.

- * The visible and NIR spectra offer continuous coverage from $0.39\text{-}2.5\ \mu\text{m}$.
- * Overlap in the $\sim 0.85\text{-}1.00\ \mu\text{m}$ range simplifies cross-calibration of the visible and NIR spectra.
- * Low resolution spectra maximizes sensitivity to faint targets, or shortens exposures of brighter targets.
- * $R\sim 200$ (R is $\lambda/\Delta\lambda$) spectroscopy is sufficient to identify the mineral content of small bodies or surface materials of artificial satellites.
- * Can measure the black body temperature of warm and hot targets.

3) Astrometry to measure the position and motion of targets.

- * The low, $<0.1\%$, geometric distortion simplifies the measurement of a target's position with respect to reference objects in the same field.
- * Relative astrometry accurate to <0.1 arcseconds across the full field of either channel.

OPTICS



Our design principle is to combine a conventional ambient-temperature visible channel and a cryogenic NIR channel in a simple way. Each channel is optimized for stand-alone operations. Simultaneous use of the two channels is facilitated by an insertable cold ($T < 120$ K), red-pass dichroic mirror (fig. 1). Dichroic cut-off is near $1.14 \mu\text{m}$, and optional second near $0.88 \mu\text{m}$. The dichroic substrate is wedged to minimize astigmatism in the NIR channel. Both channels use refractive optics to deliver to deliver $\geq 80\%$ encircled energy in 2 pixel diameter spots at all wavelengths across most of the field without the need to refocus, and geometric distortion less than 0.1% in both channels. Spectroscopy is facilitated by a slit at the telescope focal plane and gratings near the pupil plane.

SIRVIS Channel Characteristics

	<i>Visible</i>	<i>NIR</i>
Detector	2K \times 2K CCD	1K \times 1K HgCdTe
Wavelength Coverage (μm)	0.39 - 1.00	0.85 - 2.50
Field of View (arcminutes)	5.0 \times 5.0	4.7 \times 4.7
Pixel Scale (arcseconds pixel ⁻¹)	0.15	0.27
Pixel Size (μm)	15	18
Effective f/#	f/8.8	f/5.7
Pupil Diameter (mm)	21	21
Filter Diameter Range (mm)	25 - 32	25 - 32



OPERATING MODES

SIRVIS has a number of possible operating modes and expansion options: two-color imaging (fig. 1), spectroscopy (fig. 2), an expansion to include an occultation and tracking detector (fig. 3), and an expansion to add a blue channel (fig. 4). The visible channel can be implemented as an in-line design (*i.e.* no fold mirrors) before the NIR channel is finished. This versatility is achieved through a simple, modular design.

SKY SUBTRACTION

One of the complicating factors in simultaneous NIR and visible imaging is the discrepancy in the sky constant times. For adequate NIR sky subtraction, the duration of the integrations is limited to a maximum of about one minute by variations in the JHK_s sky levels. After this time, the telescope or secondary mirror must be nodded five to tens of arcseconds off target to start another integration, or series of integrations. High signal to noise visible integrations, though, may require several tens of minutes. We propose a solution that would minimize CCD read noise without using moving optics within SIRVIS. The bi-directional vertical charge shifting capability of certain CCDs can be utilized to shift the charge to remain beneath the optical image through multiple nods. During a nod, the shutter is closed and the CCD is clocked to shift the charge along a column depending upon the direction and size of the nod. The CCD is oriented such that the columns are parallel to the slit. Further aiding this technique are the optics' low geometric distortion that will eliminate blurring between nodes as the plate scale remains constant across the array.

INSTRUMENT and OBSERVATORY STATUS



SIRVIS is in the design stage. The optics are being designed using Zemax-EE®. The optical bench and Dewar will be designed around the optics.

The Magdalena Ridge Observatory 2.4 m, f/8.8 telescope is on schedule for first light in September 2006. The 40' Observa-Dome (Jackson, MS) passed its factory acceptance test on May 9. The telescope FAT is on track for July 17-21 at EOS Technologies, Inc. (Tucson, AZ), see poster "Magdalena Ridge Observatory 2.4-m Telescope", G. Pentland, *et al.*, #6267-104. The telescope site acceptance test is scheduled for completion on September 26, 2006.

The initial instrumentation will consist of a 4K × 4K CCD mounted at the Nasmyth instrument port derotator. A f/7.5 focal reducer will be added shortly thereafter to provide a square 11.7 arcminute field of view. A filter wheel box holding ten 100 mm square filters is currently being fabricated at New Mexico Tech for our CCD and visiting instruments. The telescope offers a generous 325 mm spacing between the Nasmyth port flange and the telescope focal plane to accommodate a wide range of instruments.

For more details of the Magdalena Ridge Observatory, please see our website at:

<http://www.mro.nmt.edu/>

Webcam at: <http://www.mro.nmt.edu/2.4m/webcam/>

Panoramas at: http://infohost.nmt.edu/~mvincent/MRO_Panoramas/

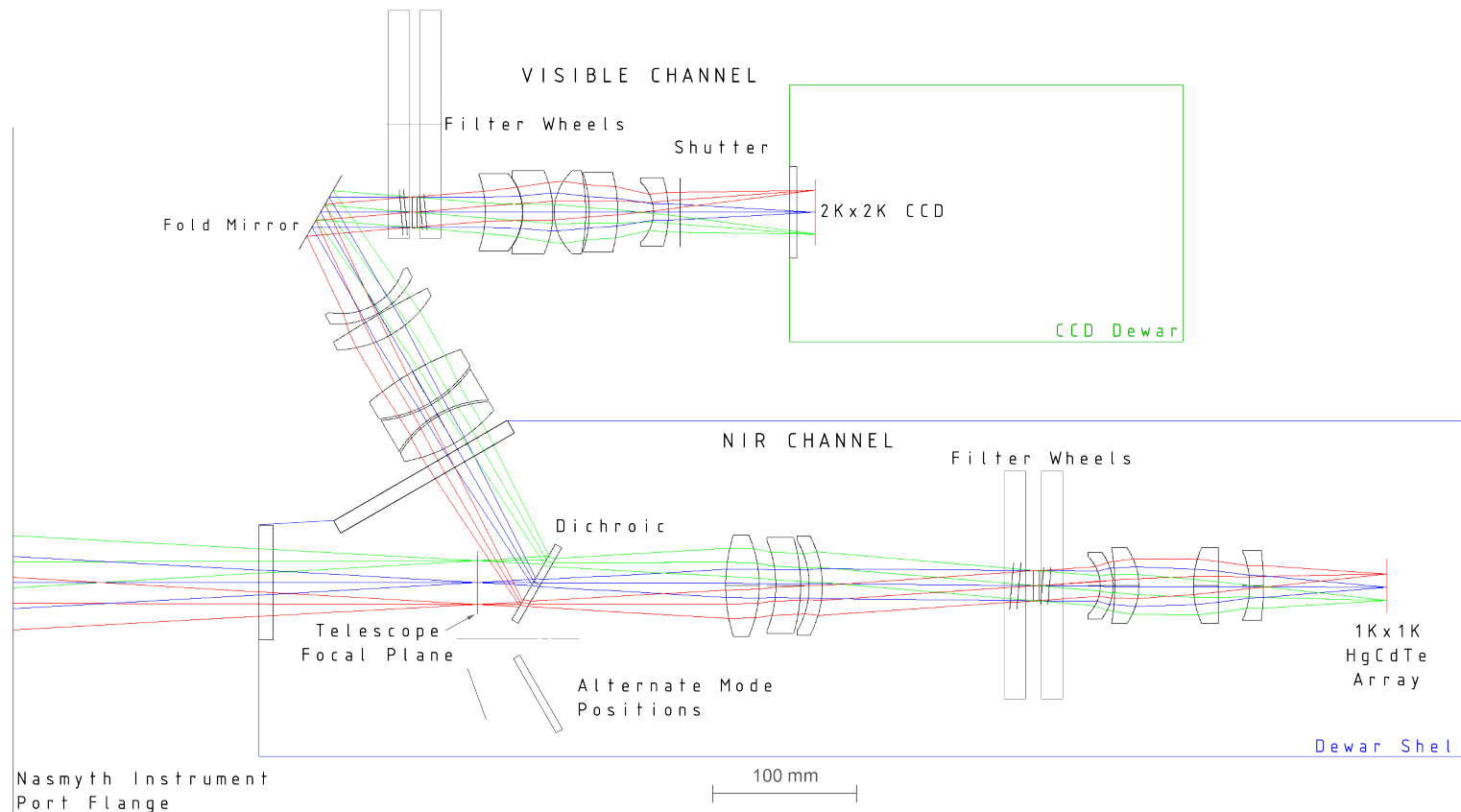


Figure 1. Two-Channel Imaging Mode. The dichroic mirror reflects visible light out of the Dewar, and transmits NIR. A NIR blocking filter inside of the exit window minimizes the stray radiation entering the NIR channel and reduces heat load to the Dewar. The cryogenic slit plates and dichroic mirrors are located on wheels, and are rotated in/out of the optical path. The ambient temperature channel allows the use of standard visible filters – no need for custom, cryogenic filters.

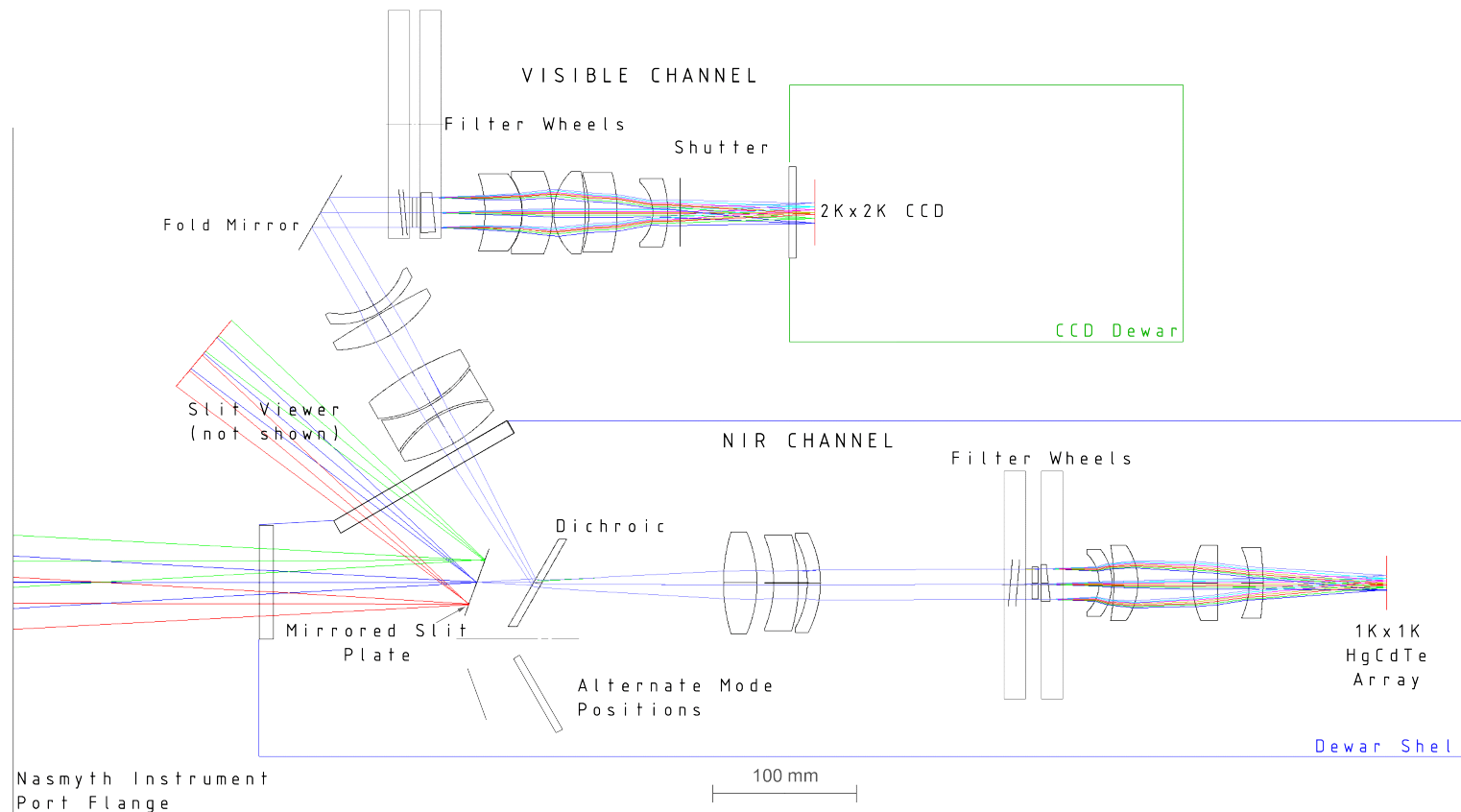


Figure 2. Two-Channel Spectroscopy Mode. A mirrored slit plate is rotated into the telescope focal plane. The slit length is perpendicular to the page. Light not entering the slit is reflected to the slit viewing channel. As shown, the slit viewer light path is an ambient temperature channel, though it may be configured as a cryogenic channel. Grisms are located in the rear filter wheels. Simultaneous slitless visible spectroscopy and NIR imaging is also possible on visible bright, NIR dim targets.

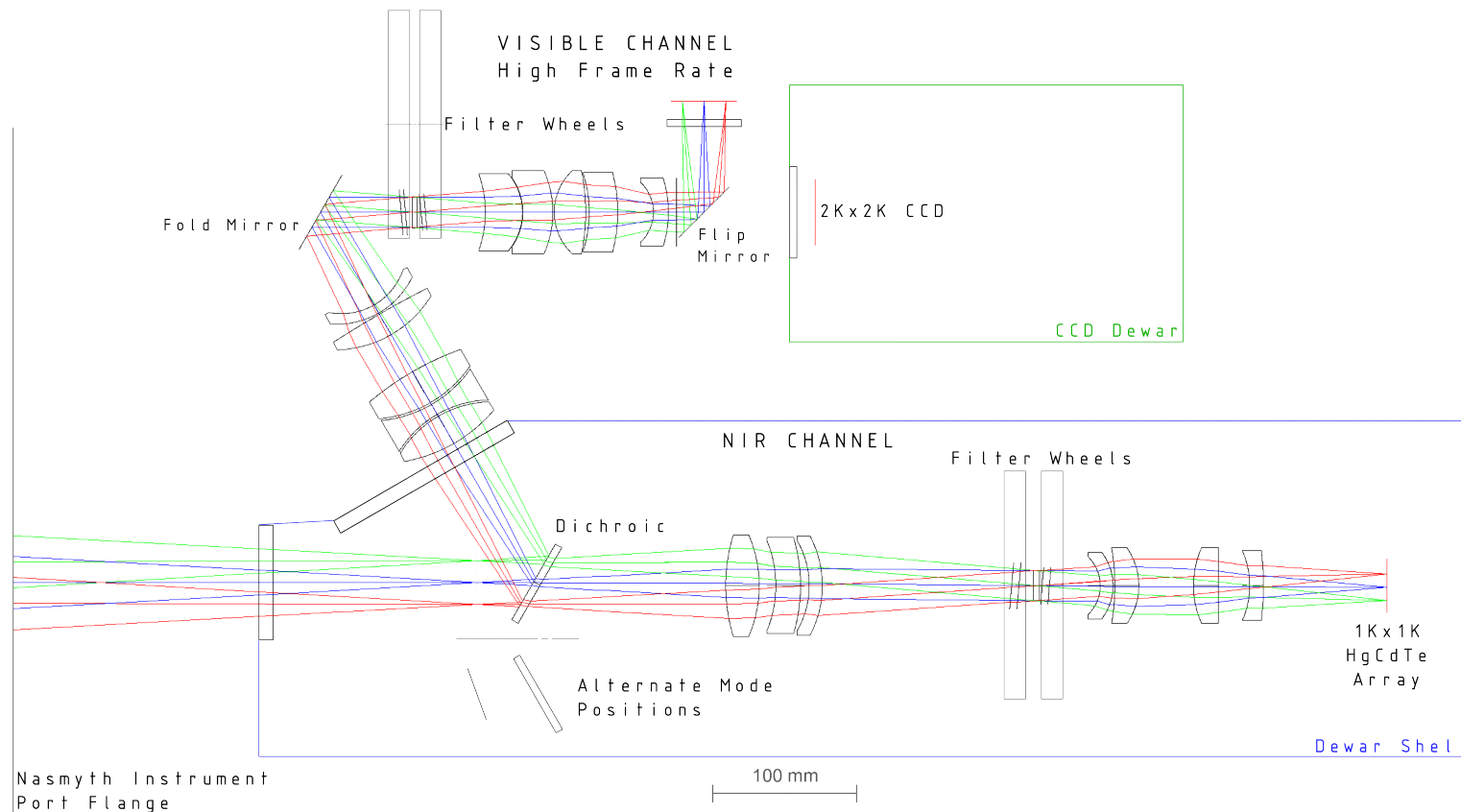


Figure 3. Expansion to Occultation and Tracking Mode. This mode requires frame rates in excess of 100 second^{-1} . To achieve this, a dedicated visible channel detector is required since the $2\text{K} \times 2\text{K}$ CCD cannot reach the necessary rates. A flip mirror is quickly inserted between the visible camera optics and the CCD to redirect light. The NIR array is inherently high frame rate, especially when windowed. Both channels are designed to have ample space between the last element of the camera optics and the detector.

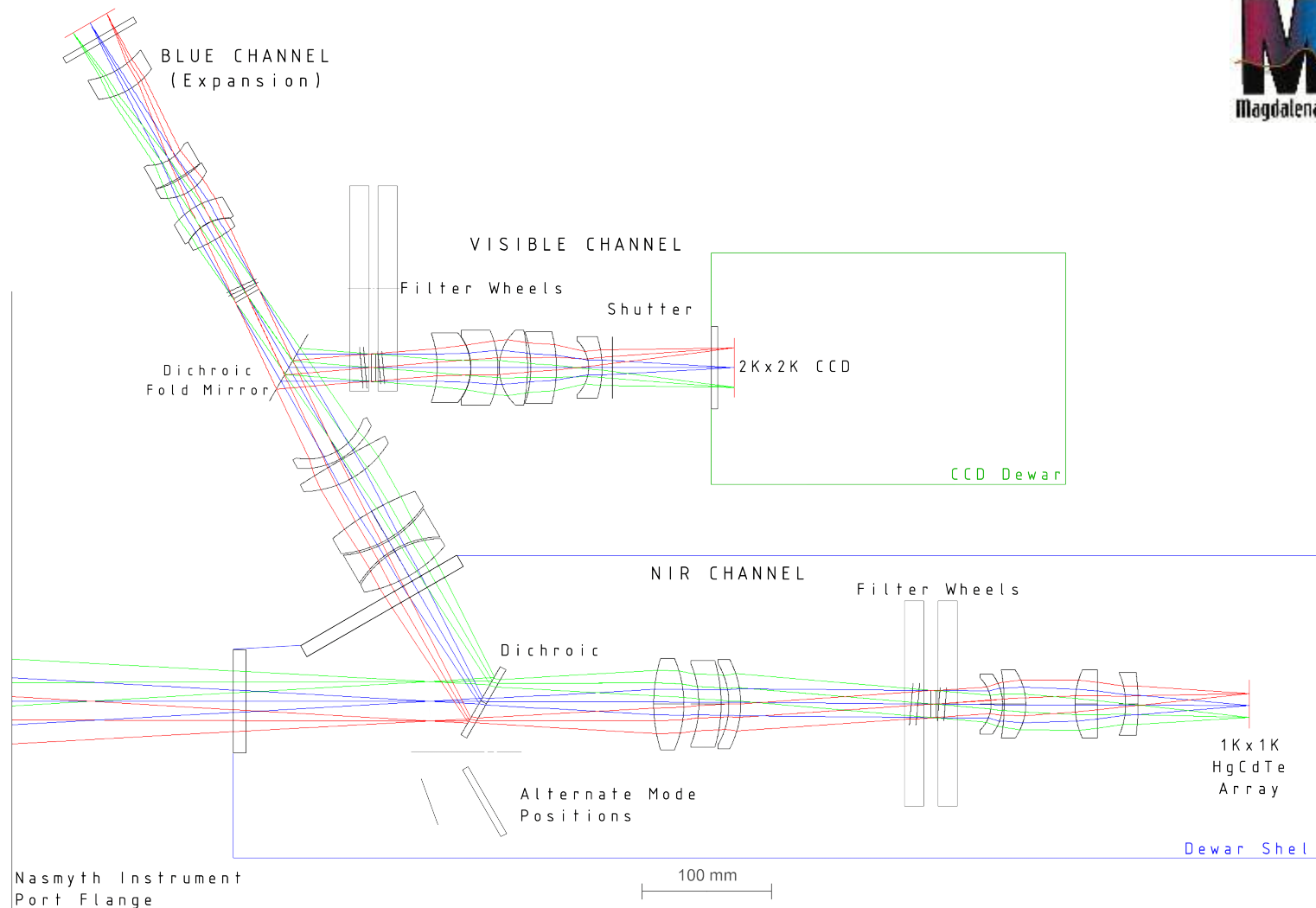


Figure 4. Expansion to Three Channels. The visible channel fold mirror is replaced with a blue-pass dichroic mirror. The blue-channel is optimized for 0.33-0.55 μm . The visible channel collimator is designed to operate over 0.33-1.00 μm . Two different dichroics with cutoffs at 0.43 and 0.55 μm are required to use both the Johnson-Morgan *UB* and SDSS *u'g'* filters. To provide clearance between the blue detector and the NIP flange, a fold mirror may be placed behind the dichroic.