ARC 3.5m | NICFPS

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1. Instrument Description

The Near-Infrared Camera & Fabry-Perot Spectrometer (NIC-FPS), which combines the capabilities of a large format, near-infrared imaging camera with a full-field Fabry-P´erot etalon, was built by the University of Colorado at the Center for Space Astrophysics and Space Astronomy , University of Colorado with support from Rice University, Ball Aerospace and the Astrophysical Research Consortium.

NICFPS reimages the telescope focal plane using cryongenic optics; it has three filter wheels hosting a set of 4 broadband and 12 narrow-band filters, plus a filter mask for dark frames. A Lyot stop is positioned in the telescope pupil plane. The cryongenic etalon can be positioned into the optical path for the Fabry-Perot mode (but has not yet become fully operational). The detector is a Rockwell Hawaii 1-RG 1024x1024 HgCdTe device with a 0.273 arsec/pixel scale and 4.58 arcmin sqaure, unvignetted field, and sensitivity from 0.85 to 2.4 microns. The instrument is designed for high throughput and 2 pixel (at 2 microns) sampling under good seeing conditions (~0.5 arcsec) at Apache Point.

1.1 Imaging mode

Imaing mode capabilities include both broad and narrow band. Standard broadband filters allow deep NIR photometry from ~1.0 to 2.4 microns in the standard wavebands of Mauna Kea J, H, and Ks, plus a Z-band filter that overlaps with optical CCD photometry from ~0.85-1.0 microns. A Y-band filter (10% CWL) is also available for NIR follow-up on candidate z~7 objects as performed, for example, by the UKIDSS survey.

Narrow band imaging is performed with a set extremely narrow (0.4% CWL) filters which were selected to capture several of the most diagnostic emission lines in the NIR, such as molecular hydrogen (V=1-0,S(1)) at 2.1218 microns and Brackett gamma at 2.1661 microns. A redshifted or continuum filter is available for each filter, typically an emission line redshifted to z=0.004 such as molecular hydrogen at 2.1297 microns or Brackett gamma at 2.1742 microns, which will not contain the emission line in local (unredshifted) galactic sources. The redshifted filter can either be used to remove the NIR continuum which is nearly identical to that captured by the emission line filter or it can be used to capture the emission line in external galaxies at approximnately Virgo cluster redshifts (z~0.004). In the latter case, the role of the two filters is reversed as the original emission line filter becomes the continuum filter. The narrow band filter set is used during Fabry-Perot mode for order sorting.

Most NIR imaging is conducted using dither patterns which allow removal of compact (stars and distant galaxies) astronomical objects (as well as bad detector pixels) so that local sky frames can be created for data reduction (and bad pixels and cosmic rays can be removed from science frames). Dither patterns are available as scripts in a TUI pulldown menu.

The full set of narrow band filters are shown in the following table.

Filter Name	CWL at 77 K, 5º AOI	FWHM at 77 K, 5º AOI	Peak Transmission	Summary	Data
Z	990.6 nm	276.15 nm	96.93 %		
Y	1028.75 nm	109.16 nm	94.61 %		
FeII-1.26	1257.05 nm	4.3 nm	79.91 %		
FeII-1.60	1599.24 nm	5.1 nm	79.80 %		
FeII-1.64	1644.16 nm	5.5 nm	79.66 %		
FeII-1.65	1650.35 nm	5.3 nm	81.93 %		
SiVI-1.96	1965.07 nm	6.3 nm	90.38 %		
SiVI-1.97	1972.8 nm	6.64 nm	84.37 %		
H2-2.12	2121.63 nm	6.93 nm	83.20 %		
H2r-2.13	2129.64 nm	7.4 nm	76.61 %		
BrG-2.16	2166.35 nm	6.9 nm	88.64 %		
BrG-2.17	2173.91 nm	7.2 nm	87.56 %		
H2-2.25	2247.4 nm	7.6 nm	81.85 %		
MKO J band	1251.3 nm	152.5 nm	93.40 %	-	-
MKO H band	1638.85 nm	287.9 nm	97.44 %		
MKO Ks band	2147.35 nm	317.9 nm	97.51 %		

Since the filters are in the cryongenic dewar, they cannot be easily interchanged.

1.1.1 Secondary focus offsets for Nicfps filters (based on data taken November, 2008)

The offsets between J, H and Ks	
J	0
H	-20 microns from J
Ks	-30 microns from J
Narrow band offsets from J band	
FeII-1.26	+20 microns
SiVI-1.97	0 microns
SiVI-1.96	-10 microns

Narrow band offsets from H band	
FeII-1.60	+25 microns
FeII-1.64	+25 microns
FeII-1.65	+20 microns
Narrow band offsets from Ks band*	
BrG-2.16	0 microns (-10 - +15)
BrGr-2.17	-5 microns
H2-2.12	+25 microns (+15 - +30)
H2r-2.13	+15 microns (0 - +30)
H2-2.25	+5 microns (0 - +10)
*Note: Best guess of the secondary focus offset with the range based on bracketed Ks measurements. Range in the parentheses are the spread of the Ks measurements	

1.2 Fabry-Perot mode

NIC-FPS has a cryogenic Fabry-Perot (FP) etalon with a 50 mm clear aperture and finesse >30 for spectroscopic observations which is undergoing testing (Summer 2007) after vendor reworks necessitated by component failure during commisioning. The etalon aperture is about 80% filled by the collimated beam and is unvignetted. A Lyot stop (at cryogenic temperature) is positioned where the entrance pupil is reimaged and is under-sized to block stray light from thetelescope structure at the edge of the primary mirror. The stop also contains a central obstruction which is oversized to block stray light from the secondary The FP mode allows full field spectroscopy at R~10,000 (30 km/sec) of a number of diagnostic NIR wavelengths. Narrow-band filters as described in the previous paragraph are used for emission feature waveband selection and order sorting.

Typical observations would include stepping through the free spectral range (a CS-100 controller tunes the etalon via the TUI) of the selected order sorting filter at between one and two times the finesse (nominally 30-60 "slices"). In this way, a data cube can be created which contains two spacial and one velocity dimension for the entire imaged field.

Additional observational details and strategies will be provided after successful testing of the repaired etalon.

1.3 Detector operations

The NICFPS detector is a Hawaii 1-RG HgCdTe 1024x1024 chip. As with other IR detectors, it has the capability to be read out non-destructively, allowing for multiple readouts per exposure. In NICFPS, the number of times the detector is read out for each exposure is determined by the Fowler Sampling (FS or NFS, Number of Fowler Samples) setting.

Appendix D

The NFS=0 mode is somewhat unusual for an IR detector; in this mode, the array is reset, the specified exposure time elapses, and then the detector is read out. In this mode, exposures include not only the readout noise of the detector, but also the "kTC" noise associated with the reset operation. See section 3.3 for measured values of the different types of noise.

The NFS=1 mode corresponds to double correlated sampling, where the array is reset and then read out the first time; subsequently, the specified exposure time elapses, and the array is read out the second (and final) time. Using the difference between the second and first readouts, NFS=1 removes the kTC noise; the readout noise in the difference frame corresponds to sqrt[2] times the readout noise of a single readout.

For NFS=2 and higher, the array is reset, then read out the specified number of times consecutively. A second series of readouts is performed with each exposure in the second series separated by the commanded exposure time from the corresponding readout in the first series. Averaging together the different pairs of exposures or fitting for a slope from the multiple readouts allows one to reduce the effective readout noise.

Each NFS mode has an associated minimum exposure time because of the finite time required for a single readout, about 5.4 seconds before the Summer 2007 upgrades and ~1.0 second post-upgrade. In NFS=1 mode, this sets the minimum exposure time of 2 seconds post-upgrade. (Note that prior to the upgrade, 10.8 seconds will have elapsed before the final read occurs in NFS-1 or 16.2sec in NFS-2. This is relevant for saturation issues in broadband imaging in Ha nd Ks band.) Post-upgrade, the maximum NFS number is 15. In NFS=15 mode, the minimum exposure time is 10.2 seconds; the final read will not occur until 20.4 seconds have elapsed since reset.

Most IR detectors are slightly nonlinear over their usuable range (see section 3.2 for more details). This nonlinearity is correctable, but to do so requires knowledge of the raw number of counts in a frame, and not just on the difference between different readouts. As a result, for the NFS>0 modes, each of the different readouts is stored in the output disk at APO, and a "processed image" representing the mean of the differenced images (plus the final read to allow for saturation checks) is available for real-time downloading during program observations. This pre-processing is required due to the data volume generated during high-number Fowler sampling. File size can be calculated as 2 times NFS# times 2 Mb, plus 4 Mb for the final differenced image. This yields 64 Mb for a NFS=15 image compared to 6Mb for the "processed image" plus the final read.

The following table gives the format of the output images for different NFS settings, including the differenced image. A post-upgrade read-out time of 1.0 second is used in table columns 2 and 3 for illustration. Actual readout time is currently set at 0.68 second -- actual table values can be obtained by scaling tabulated times by this factor.

NFS	Min exp time	Min total elapsed time	primary	ext 1	ext 2	ext 3	file size
0	5.4 pre/1.0 post upgrade	5.4/1.0	1st	-	-	-	2Mb
1	10.8/2.0	16.2/3.0	2nd-1st	2nd	-	-	6Mb
2	16.2/3.0	26.6/5.0	4th-2nd	1st	3rd	4th	10Mb
8	5.4 post	10.9 post	16th-8th	1st	2nd	etc.	20Mb
15	10.2 post	20.4 post	30th-15th	1st	2nd	etc.	64Mb

All of the difference images are stored as floating point numbers; the individual readout are stored as 16-bit integers.

Additional note concerning windowing with the 16 channels with different NFS values:

Full frames use 16-channel readout, which gives the 0.68s readout time. All subframes (windowing) use one-channel readout. So the readout time for a subframe is 16 x [fractional area of chip] x 0.68 in NFS=0 mode. A NFS=1 will double the read time, NFS=2 will be x4, NFS=3 will be x6 etc. Windowing was more useful when we only had a two channel readout but with the added speed of the 16 channels, it may not be very useful any more. Just as a reminder: a window size of 256x256 pixels in single channel window mode will read in 0.7 second. So if your window is smaller than this, it will read faster in one channel than reading the whole window.

1.4 Coronagraph

NICFPS has two warm coronagraphic masks available for use. One mask has the occulting post coming from the top of the image and the other mask has the post coming in from the right side of the image.

Care must be taken when using the coronagraph to observe bright sources (as, presumably, you would like to do). Because the detector has serious latency issues, overexposing while setting up the coronagraph can have very negative consequences for the acquired data.

While positioning the coronagraph, it is recommended that NFS<=1 be used (NFS = 0 is raw, which means the sensitivity function of the chip will be clearly visible, but with a bright enough source that should not be a concern). Exposure times should be limited to a few seconds in any broad band filter; in narrow bands, a longer exposure is acceptable, but it would still be sensible to start with, e.g., a 3-5 second exposure for sources <~ 4 mag. Depending on seeing, the coronagraph may have to be placed deeper into the source such that a wider part of the coronagraph is blocking it.

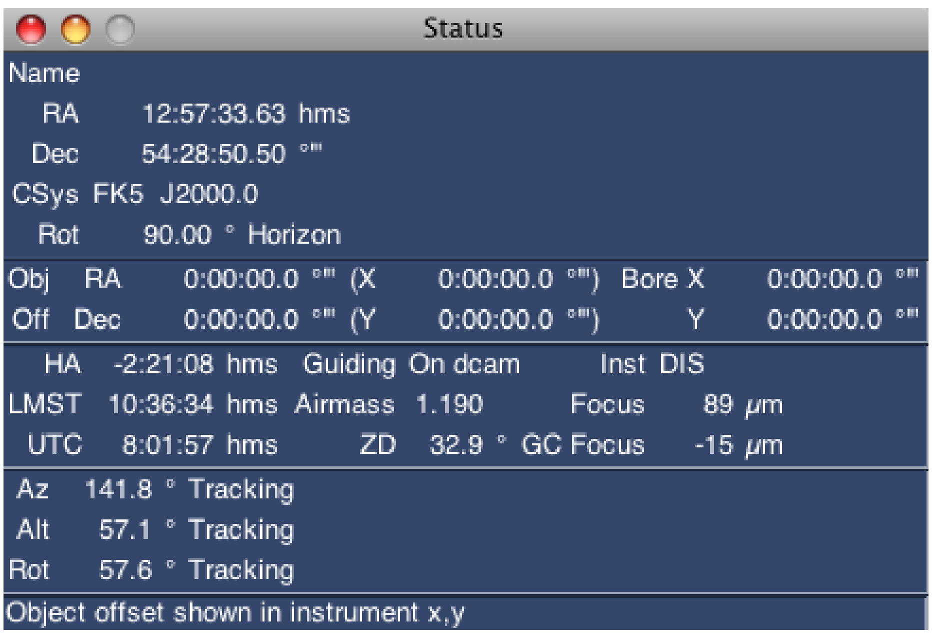
For the data reduction process, at least two orientations must be acquired, but three would be desirable so that no position angle is totally obscured. Once the images have been registered (a process for which the presence of field stars is desirable), a median combine with threshold rejection is a reasonable way to remove the coronagraph from the image.

In order to build an image mask of the coronagraph during the data reduction process, it may be useful to take a (very brief) K band or Open exposure of the coronagraph; its thermal glow can be clearly seen in K band. K-band imaging can also be used to focus the coronagraph using the stepping capability in the NICFPS control panel.

2. Instrument Operation

2.1. Software Control

NIC-FPS is operated within the Telescope User Interface (TUI) software written and maintained by Russell Owen at the University of Washington. A detailed manual is available at http://www.apo.nmsu.edu/35m_operations/TUI/. The main TUI status window looks like this:

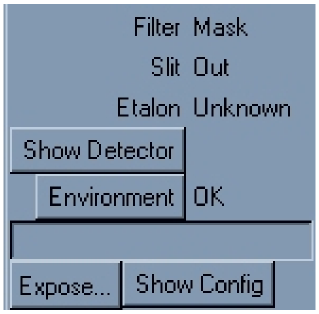


2.2. Configuring the Instrument

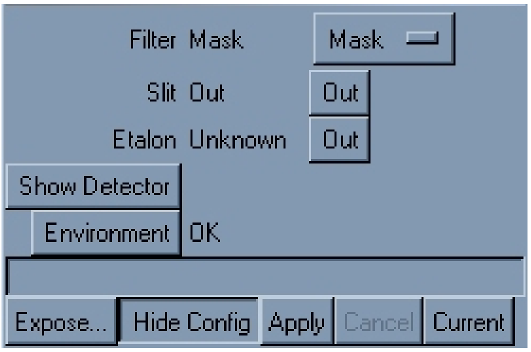
NIC-FPS is operated within the Telescope User Interface (TUI) software written and maintained by Russell Owen at UWashington. More information about the environment is available at http://www.apo.nmsu.edu/35m_operations/TUI/.

For less experienced observers, it is helpful to verify your correct setup request with the Observing Specialist before taking exposures.

In TUI, select NIC-FPS from the Inst menu in the Status (or main TUI) window. If any of the status fields are in pink in the new window, the display needs to be synced with current information; select Refresh Display from the TUI menu in the Status window.



To reveal the configurable aspects, click on the Show Config button.



To change the filter, select a different filter other than the current one then click Apply. Similarly, to cycle the etalon position, click on the small button to the right which says either “In” or “Out” depending on the current etalon position, then click Apply.

> NOTE: When the configuration aspects are left open, it is easy to inadvertently change a number of instrument parameters in harmful ways. To update the displayed values of the different parameters, click the Current button.

To change detector settings, click on the Show Detector button. Either the number of Fowler samples or the size and position of the window (if operating in the window mode) may be specified. Top change these partameters, click on the Show Config button, input the desired values of changes, and click apply. Leach controller configuration changes such as these settings are instantaneously made, so the correct vlues should immediately appear as current settings in the appropriate window.

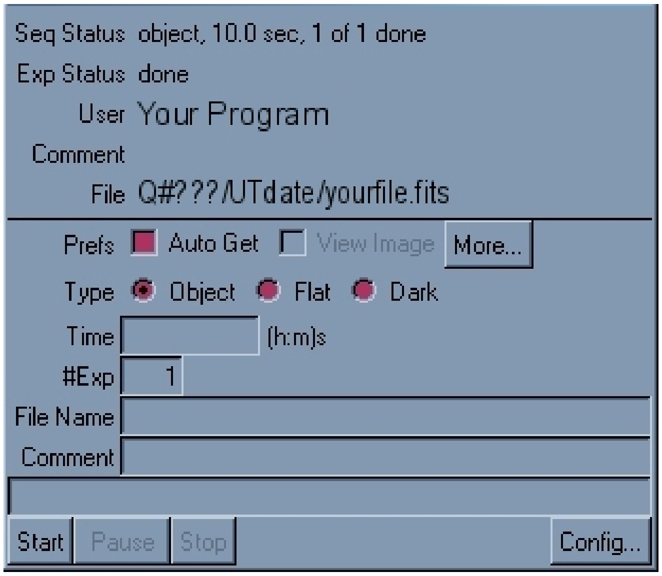
To update the displayed values of the different parameters, click the Current button.

The Environment button provides further information about the physical state of the instrument: temperatures at various locations inside the Dewar and the Dewar pressure read by an ion pump (which also maintains Dewar vacuum) in the front housing.

The FITS header for each image stores the values of all above parameters for future reference.

2.3. Taking Exposures

The Expose button in the status window will bring up another window for setting up and executing exposures.



The expose window is in standard TUI format (for detailed description see here), and, as for other instruments, shows status of the current exposure at the top, and allows you to set the object Type (for the FITS image header), exposure Time, number of Exposures, and root File Name. If you wish to add comments to the file header, place them in the **Comments** field.

All data will automatically be stored on Newton under /export/images/<program ID>/<filename>. However, most users set TUI up to automatically transfer images to their local computer using the Preferences options in the main TUI window menu (see AutoGet and Save To options under Exposures). You can also define a subdirectory (TUI will even create it for you) by entering a name such as <subdir1>/<subdir2>/<filename>.

The FITS header for each image stores the exposure time values (duration, start, stop) plus telescope parameters for future reference.

The Start button begins the exposure or exposure sequence.

- Start - This button starts the exposure or exposure sequence.
- Pause - This button pauses the exposure, you can start it again later.
- Stop - This button stops the exposure AND saves the current data to disk
- Abort - This button aborts an exposure. It DOES NOT save the data.

2.4. Imaging Mode

Running the instrument in imaging mode using the Expose window is straightforward and is commonly used for focusing, checking sky brightness, verifying pointing, and other such "housekeeping" purposes in preparation for science imaging . The user selects a filter and NFS setting in the Config window, enters values in the appropriate fields in the Expose window for exposure time, file name, etc., and then begins an exposure by clicking the Start button. Progress on the exposure can be checked by watching the progress bar as described above. An audio cue in TUI signals the user both when the exposure begins and as it ends, upon the start of readout. See Using Dither Scripts below for normal science imaging.

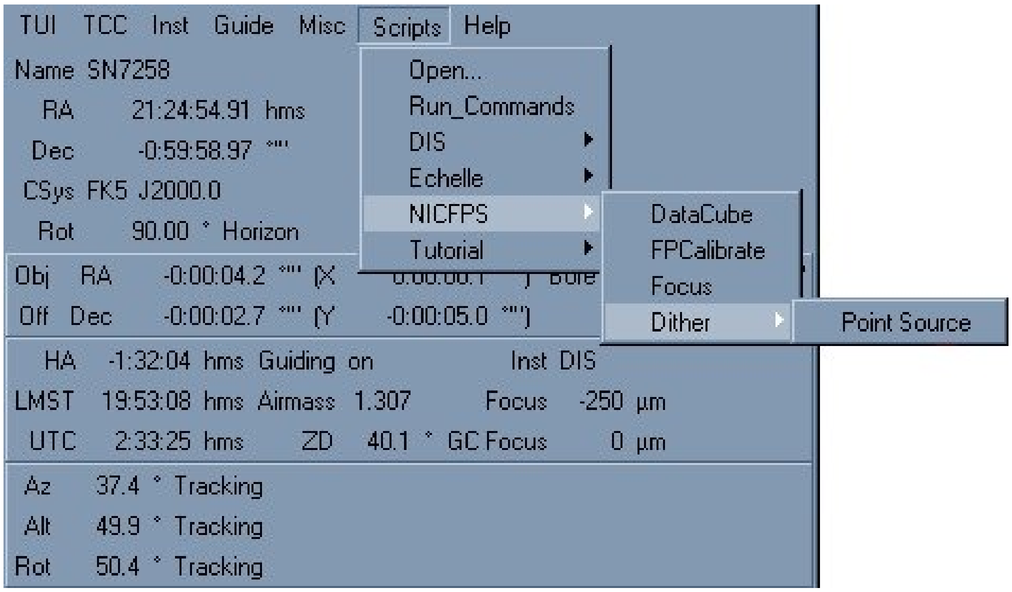
2.5. Using Dither Scripts

For broadband imaging, most observers will want to create and subtract local sky frames to reduce errors that can dominate IR observations because of the bright and variable (temporally and spacially) sky background. Dither scripts are available in TUI for taking multiple images at slighly offset telescope positions. The script can be accessed from the TUI scripts menu, under NICPFS. Choose the appropriate dither script.from the available selection and enter data in fields as described below:

- Point -- Basic five-point dither script with box size (default=20"), exposure duration, and numbewr of exposures at each

position as variables. Used for non-extended sources wheree local sky will be created from target field.
- Point-random -- Variation of above pattern in which each pointing after the first exposure is randomly positioned in a five-by-five arcsec box around the basic dither pattern position before the exposure begins. This pattern option was created to minimize the fixed interval compounding of residuals which results in imperfectly removed features for local sky frames. The first exposure is at the target position for reference purposes during image processing (particularly image co-adding).
- Extended -- Pattern used for extended sources (greater extent than a few acsec) which incorporates a second field, offset a specified distance by observer, to create a sky field that does not contain the extende fetaure(s). When selected, the dither pattern will run between the target and sky fields in an "A-B-B-A" pattern (i.e. Target Ctr - Sky Ctr - Sky UL - Target UL - Target UR - Sky UR - etc.). Offsets are specified in the TUI Offset window when Object XY and absolute are selected.
- Extended-random -- Same as above with five-by-five arcsec random distribution of pointings ater the first exposure.

For narrow band imaging of F-P observations, an abbreviated dither pattern may be desired. For a three-point pattern, for instance, deselect the two corners of the pattern that will not be used and proceed as before. Any of the available dither patterns can be used with fewer that the five dither points of the basic pattern.



The positions are designated in the script interface window according to which corners of a square they define: upper left (UL), upper right (UR), lower right (LR), and lower left (LL). With the central pointing (Ctr), five pointings in all are available. The user can turn the pointings "on" or "off" by clicking in the check boxes by each abbreviation; a box selected with a checkmark will be visited during the dither sequence, while an empty box will not be visited. The user must also enter an exposure time, the number N of exposures to take at each pointing, a filename and optional comment in the appropriate fields. To begin the dither sequence, click Start.

First, the telescope takes N successive exposures, as specified by the #Exp field, at Ctr position (with random offsets as previously discussed). The cycle proceeds as the script nods the telescope and takes images in the following sequence: UL-UR-LR-LL.

> NOTE: There is no field in the script window for the user to indicate how many passes through the cycle are desired, so for each pass the user must again click Start. Any positions not checked by the user will not be visited in the dither cycle, but the progress will otherwise proceed in the direction indicated above.

2.6. Spectroscopic Mode (limited utility)

A grism is installed in the third filter wheel for use with the warm slit assembly in the front housing. The following warm slits are available for the instrument (only one may be installed at a time):0.75 arcsec, 1.0 arcsec, 1.75 arcsec, 2.0 arcsec, 2.25 arcsec. The following bands may be used with the Grism: Z, J, H, Ks, Y (however the warm slit makes Ks measurements difficult). In this operating configuration, low resolution NIR spectroscopy is possible in one filter band (primarily H and J bands only) at a time. Because of the much more sophisticated capability of Triplespec, this limited spectroscopic capability is not normally employed.

2.7. Focusing the Telescope

Manual focusing is best accomplished using GFS=1 either by the Observer or Observing Specialist.

Generally, focusing is most efficiently accomplished by letting the Observing Specialist focus the telescope. They can run the NIC-FPS focus script to expedite the process and provide a current seeing estimate. Then if using the NA2 guider, the image quality can be monitored while guding and the Observing Specialist can recommend re-focsing as needed.

As with all instruments monitoring focus is advisable, as it will change over the course of the night, especially at the beginning of the night before the telescope has reached equilibrium.

3. Instrument Performance

3.1. Detector Characteristics

The CCD in NIC-FPS is a 1024×1024 Hawaii 1-RG manufactured by Rockwell Scientific; it is a thinned, backside-illuminated HgCdTe chip. Post shutdown measurements of gain and read noise taken 8/25/10, region of the chip [462:562,462,562].

Device	Hawaii 1-RG	Linearity	3% up to 54.4k, 5% 56.8K
Serial Number	8341-16-02	Full well	>100k e -
Number of rows	1024	Minimum Exposure:	5.4sec (full chip read, shorter for subframe)
Number of columns	1024	Quantum Effeciency	>65%
Pixel size	18µm	Effective Focal Ratio	at detector f/3.99
Gain	2.94e-/ADU	Field of View: 4.58' x 4.58', 6.42' (corner to corner)	
Readout noise	CDS / NFS 1 = 30 e- NFS 8 = 12.4 e-		
Dark current	<1 e- / second		

3.2. Etalon

Cryogenic Fabry-Perot etalon:

Parameter (As-tested 1995)	1.692 µm	2.192 µm
Finesse (=)	36	37
Transmission	65%	38%
Spectral Resolution	0.152 nm	0.25 nm
Velocity Resolution	26.9 km/s	34.2 km/s
	11100	8770

Wavelength range 1.4 - 2.4 microns. Operational wavelength range set by available order-sorter filters. Etalon has a 50 mm free aperture and 244 micron gap and is be fed with a collimated 40 mm diameter beam.

The F-P etalon used in NIC-FPS was designed and built by Queensgate Instruments, now IC Optical. It is one of only five ever made by Queensgate with both narrow bandpass and environmental tolerance for operation at cryogenic temperatures. It uses a capacitively stabilized, piezoelectrically actuated gap scanning mechanism to maintain the gap spacing and parallelism to roughly ± 1 Angstrom rms. The etalon can be moved in and out of the light beam by means of actuating a linear translation stage to which it is mounted. Motion of the etalon and scans of the free spectral range during operation are controlled in software.

3.3. Detector Linearity/Saturation

As typically set up with bias level ~8,000 cts (ADU), the detector is linear 3% up to 54.4k, 5% 56.8K.

3.4 Instrument Field Distortion

A field distortion map has been prepared by comparing the catalogued positions of field stars to their relative pixel positions on the detector. A sample distortion vector diagram with arrow length multiplied by 10x illustrates the object positions in a single field used to create the distortion solution is provided below. Over 2700 field stars were used to create the final distortion solution.

IDL routines to rectify the field distortion on processed images are available at ???? and the third order polynomial solution is as follows:

$$X_a(x_t, y_t) = ax_t + by_t + cx_t^2 + dy_t^2 + ex_ty_t + fx_t^3 + gy_t^3 + hx_t^2y_t + ix_ty_t^2 + j$$

a	1.0338587	f	2.7399144e-008
b	0.018146029	g	1.1018129e-010
c	-4.3224001e-005	h	-6.1002524e-011
d	-1.4072621e-005	i	2.6863635e-008
e	-3.1596934e-005	j	-10.588495

$$Y_a(x_t, y_t) = kx_t + ly_t + mx_t^2 + ny_t^2 + px_ty_t + qx_t^3 + ry_t^3 + sx_t^2y_t + tx_ty_t^2 + w$$

k	0.014949329	q	-7.7936966e-010
l	1.0362370	r	2.6677639e-008
m	-1.5152848e-005	s	2.8209668e-008
n	-4.5918994e-005	t	-9.5623164e-010
p	-2.8718504e-005	w	-9.7445161

3.5. Detector Gain and Readout Noise

The detector is set at a gain of 2.94e-/ADU for CDS (aka NFS of 1). Higher Fowler sampling modes (NFS < 16) can be used to minimize readout noise as discussed above.

NFS	Readnoise
1	30.0
2	20.9
3	18.3

4	15.3
5	14.4
6	13.5
7	12.6
8	12.4

3.6. Instrument Sesitivity

Limiting magnitudes are given as 5-sigma values achieved in one hour of integration.
NOTE: These values are *calculated using measured values obtained during several 1200 sec integrations.*

Passband	Magnitude
Z	24.2
J	23.3
H	22.5
K	21.9

Integration times to saturate on the sky in various filters were computed from data obtained in November 2004.

Times To Saturate On Sky	
Passband	**Time (s)**
Y	>600
Z	450
MKO J	150
MKO H	20
MKO Ks	20

Photometric Zero Points (measured against 2MASS photometry, July 2005)

Zeropoint	
J	24.807 +/- 0.147
H	25.398 +/- 0.196
Ks	24.949+/- 0.076

3.7. QE/Pixel Operability/Bad Pixel Map

The detector as tested by Rockwell demonstrates a mean quantum efficiency (QE) of 73.0% in J band and 81.9% in Ks band. H-band QE is approximately mid-way between these values on the typical H1RG.) Reference pixels which are not light sensitive make up the outer four rows/columns of pixels, making the active region of the FPA 1016x1016 pixels. Overall pixel operability as reported by the vendor is 98.41%, with 1.56% reference pixels and 0.03% inoperable or "bad" pixels. The small number of bad pixels (275 total, with 33 hot/138 dead) are easily removed by median-processing a dither pattern.

4. Instrument Calibration

Imaging calibration generally consists only of dark frames as discussed below. Sky frames/flats which are obtained in the course of normal program imaging. Dome flats have not been demonstrated to improve the image reduction process over sky flats, but may still be obtained using the quartz lamps.

4.1. Calibration Lamps and Control

The calibration lamps are controlled by the Truss Lamps gui under the Misc item in the command bar in the main TUI window. In contrast with many other TUI controls, these are turned on and off by simply hitting the On/Off buttons; there is no Apply button for these lamps.

4.2. Dark Frames

Even at cryongenic temperatures, there is significant dark current in NIC-FPS exposures of all exposure lengths. As is typical for IR detectors, users should obtain dark frames at all exposure times and NFS settings to match those that will be used during the planned program for the night. Darks can be taken before or after the observing session (the instrument need not be mounted on the telescope) depending on instrument availability. A set of 20-40 darks is typically used for the short duration (<20 sec) exposures typical of broadband Ks and H; fewer are needed as exposure duration increases. Dark frames are usually median combined.

4.3. Dome Flats/Sky Frames

In most infrared observations, the sky brightness is limiting for expoisure duration. As such, the bright (and variable) sky produces sufficient counts for flat fielding without use of dome flats. Normal local sky frames which are used for sky subtraction can also be used for flat fielding ; either a clean median sky or a super sky (created by combining a set of median local sky frames) is normally used for the sky flat. Due to potential variations in pixel-to-pixel response at different wavelengths, sky flats are normally used from the imaged band.

5. Instrument Issues

Rotation Recommendations: At a tracking rate of about 0.1 degree/sec NICFPS is failing exposures spontaneously and intermittently. At normal slewing speed of 1.0 deg/sec, the problem never shows up. If this happens the Obs-Spec needs to initalize NICFPS and you will need to restart your exposure or sequence.

NIC-FPS rotation recommendations depending on sky position of object: Basically, the northeast is the problem quadrant; that's where the instrument will be upside-down at default 0 object rotation.

Sky quadrant	Recommended object rotation
northeast	+/-180 (positive better if observer plans to track for awhile)
southeast to south	-90
southwest	0
northwest	+90

Note: the rotation needs to be changed for every target. For example, when leaving program star and moving to standard star, users must put in new rotation appropriate for standard star's position in the sky. Best way to see where the next target will be is from the TUI window showing the telescope position on the sky (window is labeled "SKY"). If in doubt, ask the Observing Specialist!

Image Persistence: The NICFPS detector has known image persistence issues. Fully saturated pixels will generate a significant number of counts for a short time after saturation. This added generation of counts decays to around the level of dark current (about 2 counts per second) by about 15 minutes after saturation, and it reaches roughly 1 count per second after about 30 minutes. Care should be taken to place science targets in regions of the detector that have not been recently exposed to bright objects.

6. End of your run

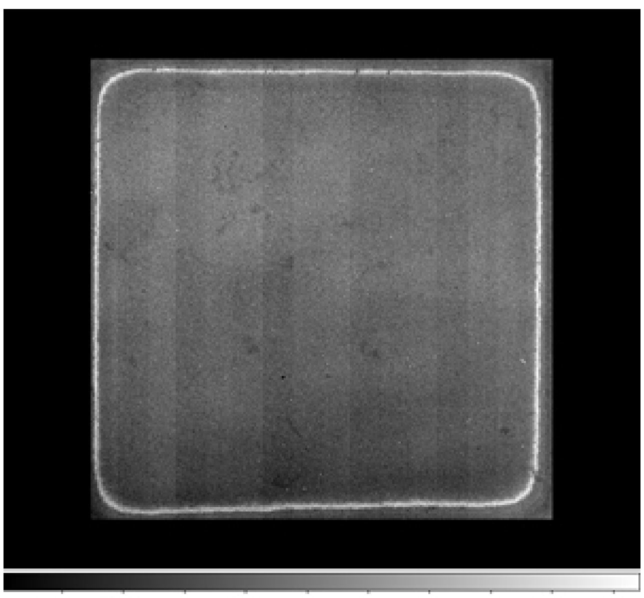
Be sure to turn off any calibration lamps you may have used, **put the filter back in Mask position**, and then hand over the instrument by simply quitting out of the NIC-FPS instrument control window in TUI. In some circumstances, you may continue to use the instrument after your shift, e.g., you are the first half observer and the scheduled second-half observer is not using NIC-FPS. Ask your Observing Specialist for permission to do so if circumstances warrant.

6.1. Data Storage and Retrieval

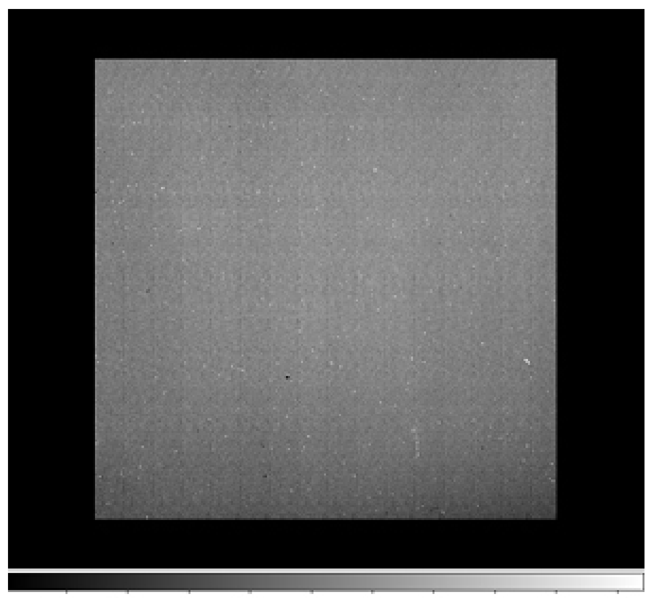
Your normal processed images (after Fowler Sampling processing) will be available on newton.apo.nmsu.edu:/export/images/your program code/UTYYMMDD/ for 9 to 12 months before being automatically deleted. Note: The raw images from which the processed images are made, found in /export/images/forTron/nicfps/*.raw.fits, will be removed after only 90 days. Please insure that you have copied over these raw images soon after your run if you want them. Data can be accessed using your institution's user name and password or ftp-ed via the images account and password on newton call APO (505-437-6822) if you are unsure of the correct login.

7. Data Reduction

Here is a typical NIC-FPS raw NFS=8 dark frame. Bias levels are ordinarily quite stable over many months but can change significantly when the detector setup is modified. Dark frames should be taken for each night of observing to ensure that set-up changes do not affect image processing.



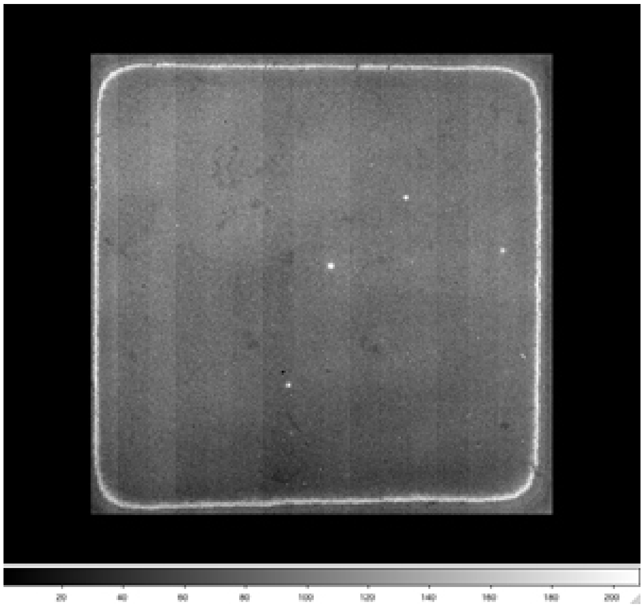
Raw last read



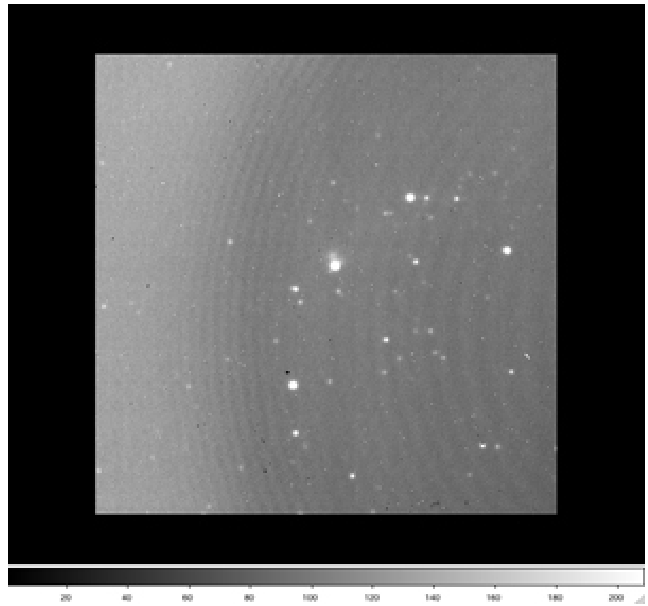
Processed image

Most observers should require only dark frames for calibration purposes. Dome arcs can be obtained from shining the telescope truss lamps off the closed mirror covers. Sky subtraction can be accomplished by either taking images at “sky pointings” off-target, or through the use of Dither scripts described previously. Whichever sky-subtraction approach is used, one will still need a set of dark frames for each exposure time and NFS setting at which object images were taken during the night; furthermore, non-trivial variation of the dark current may occur on a night-to-night basis. The drift in dark current between adjacent nights is usually no more than about 1% but drifts of as much as 5% have been noted; it is thus recommended that, if at all possible, a fresh set of darks be taken once a night. [Note that if the Open position has been selected prior to running darks, detector residuals may be present and may require several minutes with Mask in place before stable dark frame level are achieved.]

Sky levels themselves are also subject to change during a given night, particularly at longer wavelengths where sky levels become more sensitive to changes in the intensity of the airglow and variations in the thermal emission of the sky itself. Observers should monitor the number of sky counts obtained in their object or sky frames to detect drifts during the night that might raise sky level beyond the non-linear threshold. A sample medianed sky frame is provided below:



Raw last read

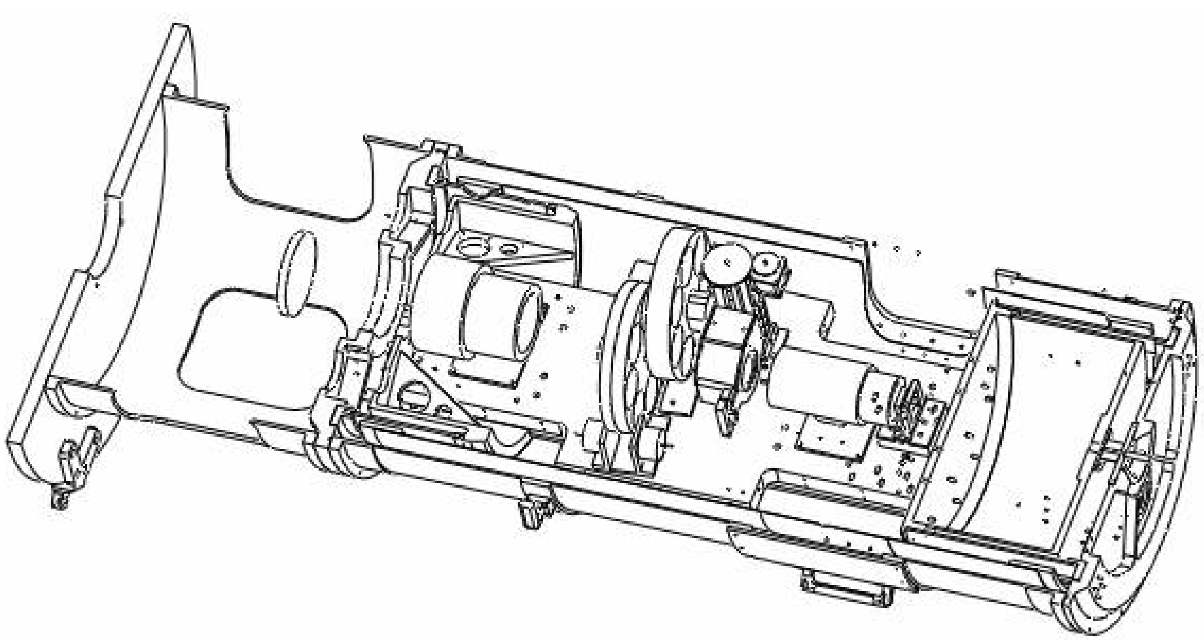


Processed image

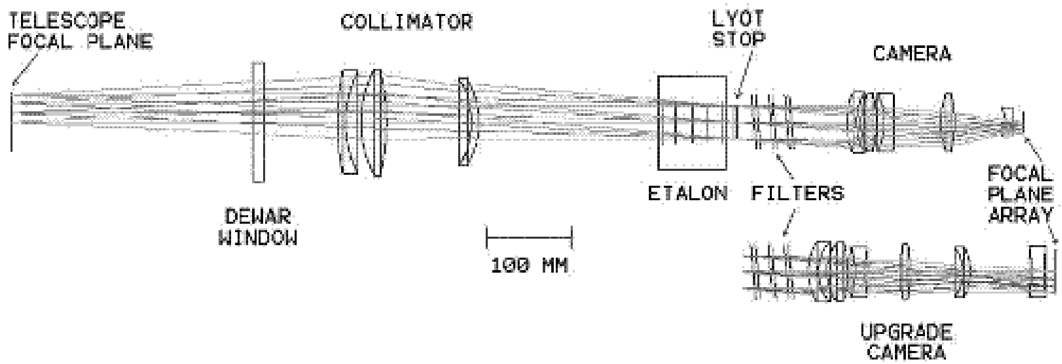
The infrared sky brightness in a given filter band varies both spacially and temporally; on some nights, this variation is rapid and of significant magnitude. Because of this sky variation, a local sky frame usually must be created (and be subtracted) that is temporally and spacially close to target. A set of dither patterns has been provided to allow creation of such sky frames in the course of science observations throughout the observing program.

Appendices

A. Instrument Design



The optical layout of NIC-FPS is shown here:



[CU NICFPS webpage]

[CU NICFPS Instrument Control Software Manual pdf]

All of the optical components, including the etalon, are within the cold vacuum boundary; hence, filters are not easily interchangeable. Users interested in having their own filters installed in NIC-FPS should contact APO.

B. Instrument History

Project Commenced August 2001

Preliminary Design Review

Final Design Review

Engineering Run September 20, 2004 to October 4, 2004

Commissioning November 14, 2004 to January 2005

Upgrade to 16 Channels July 2007 to October 2007

C. Sample NICFPS data

Typical data: bias, flat, arcs, standard stars

D. Intro to Fowler Sampling

Exerpt from *Understanding Fowler Sampling with NIC-FPS* (by J. Davenport)

Infrared detectors have substantially higher read-noise levels than their optical counterparts. The Rockwell Teledyne Hawaii RG1 chip used in NIC-FPS is capable of greatly reducing this read-noise by the use of Fowler Sampling.

Fowler Sampling was developed early in the history of infrared (IR) detector arrays. People quickly realized that the mere act of reading the detector was introducing a large amount of noise. IR detectors (such as NICFPS) can usually be read out non-destructively. This means that while pixel (i, j) is being read,(i+1, j) is not disturbed.

The basic process of Fowler Sampling is to make use of several of these non-destructive reads. The Number of Fowler Samples (NFS), N, is the number of reads desired by the user. By averaging the N reads, one is able to reduce the read-noise by 1/pN. First the array is cleared, then read N times. The first reads are often called pedestal measurements. The detector then integrates for a time T and reads N times again. These secondary reads are known as signal measurements. (The only true exception is for NFS = 0 where the process is simply clear, integrate, read.) Because the detector can read out non-destructively, it can be read while integrating. Actual integration begins as soon as the array is finished clearing. Since there is no shutter on the camera, the system relies on the clearing to begin a new ‘exposure’. Therefore by having these 2N total reads, we are given N images, each with a pedestal and signal read separated by T.

NIC-FPS makes use of FITS extensions to store these multiple reads. For the special case of NFS = 0 the data is simply a single extension for the single read. For NFS > 0 there are 2N FITS extensions.