Near-Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS)

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ABSTRACT

A near-infrared instrument is being built for the ARC 3.5 meter telescope that will operate in both an imaging and a narrow band, full field spectroscopic mode. The 4.5' x 4.5' field-of-view is imaged onto a new-generation, low-noise Rockwell Hawaii-1RG 1024x1024 HgCdTe detector. High resolution (R~10,000) spectroscopy is accomplished by employing a Queensgate (now IC Optical) cryogenic Fabry-Perot etalon. The instrument is housed in a large Dewar of innovative, light-weight design. This report describes the as-built opto-mechanical system for the instrument and the work remaining before deployment at Apache Point Observatory in New Mexico.

1. INTRODUCTION

1.1 Instrument Description

The University of Colorado is building a second generation near-infrared (NIR) instrument for the Astrophysics Research Consortium (ARC) 3.5 meter telescope at Apache Point Observatory in Sunspot, New Mexico. Currently named Near-Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS), the instrument is undergoing integration and test, and is to be delivered to the observatory later this year. Once commissioned as a facility instrument, it will replace the aging GRIM II which provides the community's only NIR imaging and spectroscopy, and will significantly enhance the NIR capabilities of the ARC user community. Figure 1 is a cut-away view of the instrument. The instrument's exterior dimensions are 60 cm in diameter by 180 cm long and it weighs approximately 225 kg.

Low noise imaging and full field spectroscopy will be employed in a wide array of galactic and extragalactic science programs. Two examples of anticipated operations include using the imaging mode to help classify high redshift objects discovered by the Sloan Digital Sky Survey, co-located at Apache Point, and using the spectroscopic mode to explore stellar outflows and shock waves in star forming regions. The NIR is the primary wave band used from the ground for observing atomic and molecular lines that penetrate the high-extinction regions near dust enshrouded objects.

A brief description of the optical design is provided for completeness; a more detailed account can be found in Vincent *et al.* (2003, hereafter Paper 1). The ARC telescope is a 3.5 m, f/10.35 modified Richey-Cretien. A set of interchangeable instruments are available for use at the Nasymth 2 port by the ARC community. The Nasymth 1 port is dedicated to an eschelle spectrograph. NIC-FPS will be mounted at the Nasmyth 2 port when in service.

NIC-FPS optics are designed to provide (at 2 μm) 2 pixel sampling under good seeing conditions of ~0.5" full width at half maximum (FWHM), and 3 pixel sampling at median seeing conditions of ~0.9". These requirements dictated a f/3.99 camera with a 0.27" pixel^{-1} scale. The effective focal length is 13,590 mm. NIC-FPS will be one of the first ground-based instruments to employ the Rockwell Hawaii-1RG 1024x1024 HgCdTe detector with 18 μm pixels

(1016x1016 pixels are active). Cold preamps are to be used for noise reduction since the controller is physically distant (~ 1 meter) from the detector. The field of view is 4.58’ edge-to-edge and 6.42’ corner-to-corner. The geometric distortion is minimized and well characterized at 0.75% at the edges and 1.6% at the corners.

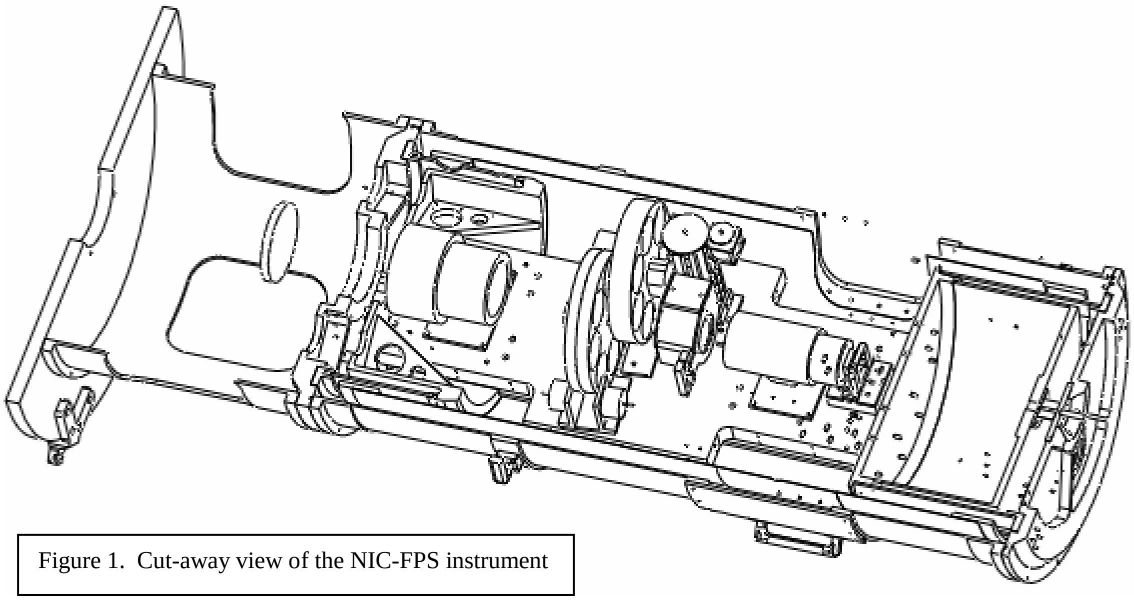

Figure 1. Cut-away view of the NIC-FPS instrument

1.2 Scope of Report

This report provides details of the as-built opto-mechanical system of NIC-FPS and serves as NIC-FPS Paper 2. Paper 1, Vincent *et al* (2003), provided optical design details and instrument specifications. A third and final report will document instrument performance as determined during commissioning and initial science operations. Section 2 below describes the instrument hardware and applied technology for the optical components, the bench support structure, and the Dewar that houses the instrument. Section 3 provides a brief description of remaining work. Section 4 summarizes and concludes the report.

2. INSTRUMENT HARDWARE

2.1 Optical Components

The basic optical layout for NIC-FPS is shown in Figure 2. The instrument’s optical axis coincides with the axis of rotation on the Nasymth 2 port, a design feature that has greatly simplified preparation of the physical systems. An early version of the optical design proposed splitting the optical beam with one path supporting imaging and the other spectroscopy with the Fabry-Perot. By deciding to move the etalon into the optical path when needed, we greatly simplified the geometry of the instrument at the cost of flexing the etalon control cables while cold (near 80 Kelvin). The portion of the cables which is required to flex is removable and is attached to the integral cables that enter the etalon housing (and don’t flex); a spare set of cables is provided in case the repeated flexing degrades the conductors. The etalon mover cables do not flex, so the imaging mode should still be available because even a disabled etalon can still be removed from the optical path.

The entrance window is a 140 mm diameter, 14 mm thick CaF_2 parallel-surface disk that is mounted normal to the axis. It is mounted on an aluminum snout which extends about 12.5 cm back from the vacuum bulkhead. An interior radiation shield in the snout is actively cooled (and coated optically black) to reduce the solid angle of radiation that is incident on the collimator, thus reducing its heat load. The window is sealed by an o-ring and is retained by a simple locking ring. To avoid condensation on the window (all ARC instruments must safely withstand a condensing environment), liquid nitrogen (LN2) boil-off is ported to the vicinity of the window as described in the next section.

The collimator is a three-element optical assembly built by Janos Technology, Inc. The lenses are, in order, optical grade fused silica, CaF_2, and ZnSe contained in a single aluminum housing. Each lens is positioned on a v-block and retained by springs. Differential contraction during cool down aligns each lens with the optical axis. The first element of the collimator is located 384 mm behind the telescope focus. This distance allows the f/10.35 beam to expand to the pupil size of 40 mm. No corrector lens is required in front of the telescope focus. The pupil is located 310 mm behind the collimator. This space allows ample room for three (upgradable to four) filter wheels with additional space for future optical equipment. Angular magnification at the pupil is the ratio of the primary diameter to the pupil diameter or 85x.

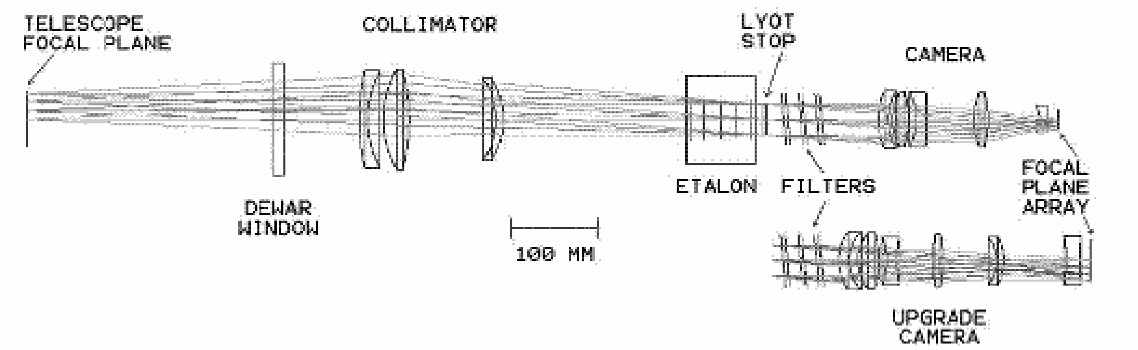

Figure 2. Optical layout of NIC-FPS. Dewar (entrance) window is the boundary of the vacuum volume. Other components are operated near LN2 temperature. Etalon is shown in the full-field spectroscopy position and is retracted for the imaging mode. Note that the as-built system swaps the locations of the etalon and filters on the sides of the Lyot stop due to physical space limitations on the optical bench. The upgrade camera is a potential future enhancement to a 2k x 2k detector.

The 0.39:1 camera, also by Janos, has five elements in a single housing. These are distributed in a triplet (ZnSe, CaF_2, fused silica) followed by a singlet ($CaF_{2)}$ and a field flattener (fused silica). Ghost images are minimized by the design of a convex back surface for the corrector lens in front of the focal plane array (FPA). As in the collimator, v-block lens mounts are used. The optical design was done in Code V and optimized in Zemax.

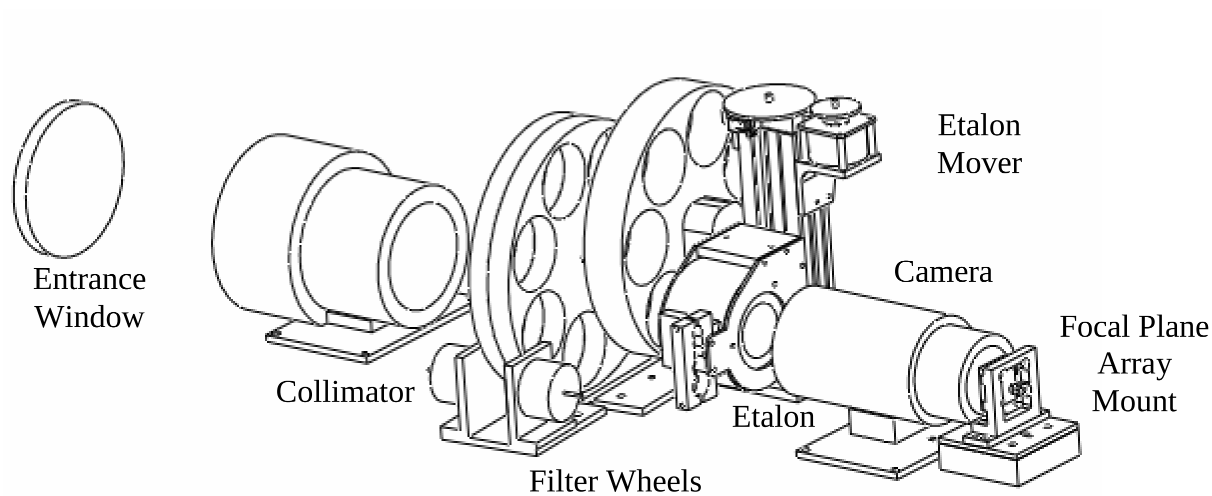

Figure 3. The physical layout of the optical components shows the collimator (3 elements) and camera (5 elements) housings, the double and single filter wheels, and the etalon in the optical path.

Image quality of the baseline design is close to the diffraction limit. RMS spot diameters (including the 3.5-m telescope) are maintained below the pixel size at all wavelengths and positions on the detector. No refocusing is necessary over the operational wavelength range. To simplify manufacturing and reduce cost, all surfaces on both the collimator and camera lenses are spherical and were matched to existing (Janos) test plates. Additionally, assemblies were thermally cycled to LN2 temperatures by the vendor before delivery.

The filter wheels, one single and one double, are based on an Ohio State University, Imaging Sciences Laboratory design. Each wheel is positioned by a cryogenic stepper motor through a pinion gear in contact with a spur gear located around the wheel's circumference. Limit switches continuously monitor the rotational position of each wheel and the final position when the selected filter is aligned to the optical axis.

The wheels have seven slots each with one left empty for a total of eighteen filter slots. Currently, the space is allocated to broadband filters J, H, and K_s (Mauna Kea Filter Set) that were purchased from Barr Associates as part of the Gemini filter consortium and a Z band filter. Central wavelengths are 1.250, 1.635, 2.125, and 1.000 μm respectively. A set of twelve narrow band filters, one blocker, and one as yet unallocated slot complete the inventory. (A low resolution grism may fill the unallocated slot.) Table 1 lists the narrow band filter specifications in terms of the emitting species. The narrow band filters will be used for order sorting during full-field spectroscopy. Central wavelengths were chosen based on key diagnostic lines in the NIR; the filter specifications were chosen to maximize scientific return of the Fabry-Perot etalon.

Species	**Configuration**	**CWL (μm)**	**Δ CWL (μm)**	**FWHM (μm)**	**Δ FWHM (μm)**
H_2	V=1-0 S(1)	2.1218	±0.0004 (5% of FWHM)	0.007 (0.4% of CWL)	±0.0007 (10% of FWHM)
H_2 continuum	V=1-0 S(1)	2.1297	±0.0004 (5% of FWHM)	0.007 (0.4% of CWL)	±0.0007 (10% of FWHM)
H_2	V=2-1 S(1)	2.2471	±0.0004 (5% of FWHM)	0.007 (0.4% of CWL)	±0.0007 (10% of FWHM)
[FeII]	$^6D_{9/2}$ - $^4D_{7/2}$	1.2570	±0.0002 (5% of FWHM)	0.004 (0.4% of CWL)	±0.0004 (10% of FWHM)
[FeII]	$^4F_{7/2}$ - $^4D_{3/2}$	1.5995	±0.0003 (5% of FWHM)	0.005 (0.4% of CWL)	±0.0005 (10% of FWHM)
[FeII]	$^4F_{9/2}$ - $^4D_{7/2}$	1.6440	±0.0003 (5% of FWHM)	0.0055 (0.4% of CWL)	±0.0005 (10% of FWHM)
[FeII] continuum	$^4F_{9/2}$ - $^4D_{7/2}$	1.6501	±0.0003 (10% of FWHM)	0.0055 (0.4% of CWL)	±0.0005 (10% of FWHM)
Br γ	n=7→4	2.1661	±0.0004 (5% of FWHM)	0.007 (0.4% of CWL)	±0.0007 (10% of FWHM)
Br γ	n=7→4	2.1742	±0.0004 (5% of FWHM)	0.007 (0.4% of CWL)	±0.0007 (10% of FWHM)
[Si VI]	$^2P_{3/2}$ – $^2P_{2/2}$	1.9650	±0.0003 (5% of FWHM)	0.0065 (0.4% of CWL)	±0.0006 (10% of FWHM)
[Si VI] continuum	$^2P_{3/2}$ – $^2P_{2/2}$	1.9730	±0.0003 (5% of FWHM)	0.0066 (0.4% of CWL)	±0.0006 (10% of FWHM)
Y-band	--	1.03	±0.01 (10% of FWHM)	0.11	±0.01 (10% of FWHM)

Table 1. Filter specifications for narrow band filters to be used as order sorting filters for full-field spectroscopy. Full width at half maximum (FWHM) and central wavelengths (CWL) are specified to optimize the science return of the Fabry-Perot etalon

The Fabry-Perot etalon (QI EC50WF) was provided by Rice University for use at LN2 temperatures for full-field, R~10,000 spectroscopy. The velocity resolution is ~30 km/sec., finesse is ~40, and the free spectral range is 0.008 μm or 0.4% at 2 μm. It has a 50 mm clear aperture through water-free, fused silica windows that will be filled to over 80% by the beam. The etalon will be moved into the beam by a stepper motor driven, traveling nut design linear stage that is mounted normal to the surface of the optical bench. The stepper motor and limit switch set are identical to those used for the filter wheels, although the limit switches monitor only the ends of travel of the etalon.

The focal plane array is mounted on a molybdenum bracket which is fastened to an aluminum base plate. The bracket material was chosen to CTE match the molybdenum thermal block upon which the detector is hard mounted by the vendor. The large CTE difference between molybdenum and 6061-T6 aluminum are compensated for by a pin and slot arrangement with a pair of tensioners retaining the molybdenum bracket. The arrangement is designed to also mount on a linear stage in case there are positioning adjustments needed during optical testing.

In order to simplify assembly and avoid realignment delays, all optical bench components are positioned on slip-fit pins along the optical axis. All housings and support mechanisms are made of 6061-T6 (or 6062 in the case of the etalon mover) aluminum as is the optical bench. This single material construction minimizes differential thermal contraction during cool down to and operation at temperatures of around 80 Kelvin.

2.2 Optical Bench Support Structure

The optical components are mounted on a fully cantilevered structure at the telescope's Nasymth-2 port. Beginning at the telescope rotator face, the structure consists of a mounting plate, front housing, vacuum bulkhead, cold stand-off assembly, and optical bench assembly (see Figure 4). The entire structure is designed for rigid support of the optical components at all angles as the instrument is required to rotate (about the optical axis) a full 360 degrees in either direction (since the ARC3.5 is an altitude/azimuth system needing an image de-rotator). A description of each of the parts of this structure is provided in the order listed above.

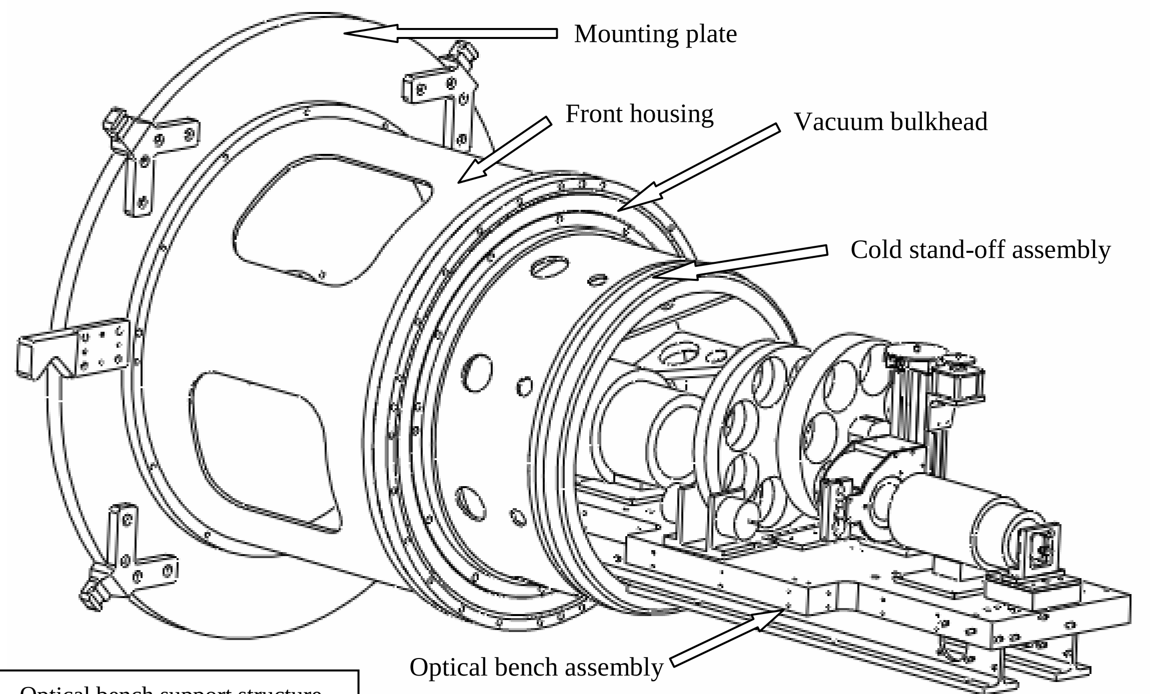

Figure 4. Optical bench support structure.

The mounting plate is a 2.5 cm thick by 80 cm diameter aluminum plate which is attached to the rotator face by a set of four welder's clamps. The plate is positioned by two kinematic bars, one which sets the x-axis or lateral alignment and the second which works with the first to set the y-axis or vertical position. The bars are constructed of tool steel to ensure that operational wear is minimal and aligned positions are maintained. The welder's clamps and rotator face maintain the z-axis positioning of the instrument. The center of the plate has an opening for the optical path. Attached to the mounting plate is a baffle and field stop at the telescope focus (warm focus) which lies ~21 cm beyond the rotator face.

Attached to the mounting plate, and aligned by a pair of slip-fit pins, is the front housing. This 60 cm diameter by 50 cm long cylinder provides a structural standoff for the vacuum chamber as well as a housing for detector and stepper motor controllers, electrical penetrations, cable drop, pressure sensor, nitrogen backfill connection, and vacuum chamber over-pressure relief valve. This warm front housing design allows an approximate 30% reduction in the vacuum chamber volume, while providing access to the warm telescope focus. The housing has a set of service openings for maintenance access, but is closed off during operation by panels that are light (and Miller Moth—a significant operational annoyance at Apache Point every summer) tight. The front housing heat load, which is under 10 watts, is primarily due to the detector controller. Since the instrument is required to operate in a condensing environment, forestalling condensation on the entrance window is essential. The volume is maintained at a low dew point and the heat load is somewhat offset by exhausting LN2 boil-off into the housing. The cable drop is a strain relieved opening on the underside of the housing through which the service cabling exits the instrument. As the instrument rotates, the cable is wrapped around the housing as on a reel.

On the far end of the housing is mounted the front vacuum bulkhead, also positioned and properly clocked by a pair of pins. The pins are both placed 7.5 degrees to the same side of the vertical plane to force a unique orientation of the attached cylindrical component. (Note that alignment pins are used throughout the instrument to ensure correct placement of each component and simplify assembly. The added benefit of using alignment pins has far outweighed the incremental cost that was incurred by adding them to the design.) The bulkhead is a 5 cm thick aluminum plate that is hogged out (light-weighted) to a minimal wall thickness of 1.25 cm and webbed to retain structural rigidity. On the warm side of the bulkhead is a pair of electrical penetration boxes (that allow attaching internal cabling without the need to access the interior side of the bulkhead) and a cylindrical "snout" on which is mounted the entrance window. On the cold side of the bulkhead are attached the cold stand-off assembly with optical bench assembly and the Dewar housing. A radiation shield is also positioned about 1 cm away from the bulkhead by a set of Teflon bolts. This shield serves to protect the multi-layered insulation (MLI) from the nitrogen back-fill flow as well as provide the first radiation barrier for the cold interior components. The shield material is branded Primirror 11, a polished, nickel coated aluminum that was developed for lighting fixtures. It is used for its high reflectivity and light weight.

The cold stand-off assembly consists of a mounting ring, a G-10 fiberglass ring (spare from the FLAMINGOS project) that provides thermal isolation and structural support for the optical bench assembly, and the aluminum cold stand-off. This design was developed to allow for a reasonable length of thermal isolating material (~21 cm long, 45 cm diameter, 0.5 cm thick), while maintaining the rigidity needed for optical alignment. The cold stand-off is a centimeter thick cylinder that folds the structure back about 20 cm and allows for additional mechanical support for the cantilevered bench. A set of internal gussets are bolted to the cold stand-off to prevent the cylinder from deforming (becoming egg-shaped) under asymmetric loading. The cold stand-off allows the reduction of the Dewar volume discussed earlier. Electrical cables that penetrate the vacuum bulkhead also pass through the face of this component and the radiation shield. This component (and essentially all other components in this instrument that are made of aluminum) is made of 6061-T6 aluminum.

The optical bench assembly consists of the optical bench, two structural beams, and a transition piece and cross beam. The beams are bolted to the underside of the optical bench. Raised, precision-machined pads are used on both the bench and beams to ensure a high tolerance fit between these components. One end of the beams is bolted to the base of the cold stand-off, while the transition piece is attached to the inside front of the cylindrical portion. A cross beam connects the transition piece to both of the beams. Machining of the bench and beams was specified to high tolerance—the finished assembly is flat to less than 40 microns. Re-heat treatment of these components was also done to minimize residual stresses and provide uniform thermal contraction without warping. The transition piece and cross beam attach the bench to the inside of the cold stand-off cylinder approximately 20 cm from the base of the stand-off.

For the cold stand-off and optical bench assembly, the machining was done in stages with retreatment after first pass machining (because of the elevated temperatures while machining the aluminum) to restore the T6 pedigree and then final pass (high tolerance) machining. This approach was adopted to ensure that the final assembly of cold components was of uniform heat treatment so that uniform thermal contraction would maintain the warm alignment. Perpendicularity of the bench to the cold stand-off was achieved to within 10 arcsec. using a high precision level and granite blocks. Displacements were measured by a theodolite viewing a pair of reference blocks through the entrance window, one at the cold stand-off and the second at the position of the FPA on the optic bench. Results measured during cool down indicated that this method produced an assembly that was displaced by ~160 microns vertically between room and LN2 temperature, about half of the anticipated displacement of 350 microns. This displacement is far less than the offset that is possible with the tertiary mirror; this and other slight misalignments will be compensated for by testing for alignment on the sky at varying rotational angles (preparing the "instrument block") during commissioning.

In all structural cold components, stainless steel (SS) bolts, over-torqued by 25%, are used to avoid detorquing of the bolts since the coefficient of thermal expansion (CTE) difference between aluminum and the bolting material is large. Stainless bolts have a CTE that is closer to but still less than that of aluminum, yet closer than black oxide bolts; the cold aluminum contraction does not relax the torque on SS as significantly as it would black oxide. Phosphor-bronze helicoils are used whenever SS bolting is employed to avoid galling of SS in vacuum. (Elsewhere in the instrument, black oxide bolts are used with SS helicoils to minimize costs because phosphor-bronze helicoils are expensive.)

2.3 Dewar

All optical components except the entrance window are housed in a Dewar, a large vacuum chamber that is cooled with liquid nitrogen. The Dewar consists of a pair of vacuum bulkheads, a housing with maintenance access doors, radiation shielding, and a liquid nitrogen tank as shown in Figure 5.

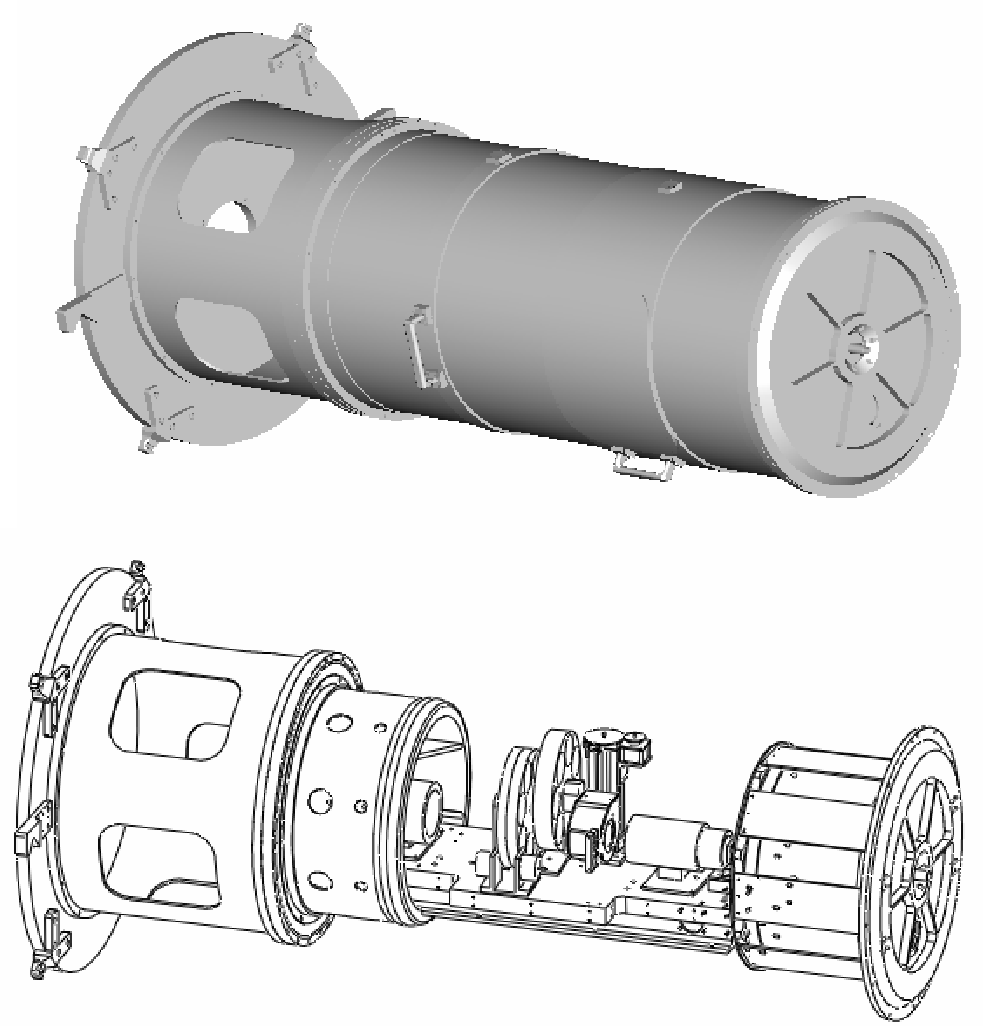

Figure 5. Above is an exterior view of the Dewar with attached warm housing and mounting plate. Below is view of Dewar contents with the housing removed. Note the liquid nitrogen tank is adjacent to but not supported by, the optical bench assembly.

Overall external dimensions of the vacuum volume are 136 cm long by 60 cm diameter which yields an internal volume of about 325 liters (including the internal LN2 tank which is at atmospheric pressure). The entire Dewar (plus LN2 tank) weighs about 100 kg. This high volume-to-weight ratio was required to remain within the ARC 3.5 meter rotator load limits of ~225 kg total (500 pounds) while housing a long optical path instrument.

Light weight construction required a thin-walled chamber housing (0.32 cm) and light-weighted vacuum bulkheads. The chamber housing was machined from a single piece of aluminum by a local shop with integral flanges and openings for access doors. A thicker ring (~ 1 cm) was provided so that curved doors could be bolted directly to the housing. Bulkheads were hogged out to the maximum extent possible with ribs left in place to provide structural strength. Although the housing is light for its size, it is still bulky, so handles were incorporated to ease installation.

On the inside of the housing is suspended a cylinder of radiation shielding which is integral with the housing during installation and removal. The shield consists of a Primirror 11 cylinder with aluminum end rings for structural support and attachment hardware. Multi-layer insulation (MLI) is wrapped around the outside of the shield cylinder and is attached by Velcro pads that are epoxied to the metal. The entire assembly is suspended by a set of SS tension springs which attach to the inside of the vacuum housing. The springs are used to nearly eliminate thermal conduction from the warm shell to the cold shield.

The liquid nitrogen tank is a welded volume that holds 18.2 liters of LN2 when filled (half of the tank volume) to the centerline fill tube. The large tank volume was designed to provide long hold times (48-72 hours) between charges. Since the instrument is mounted horizontally and must rotate 360 degrees on its long axis, the fill line is always above the liquid level. The varying amounts of LN2 in the tank do not contribute either to the optical bench loading because the tank is supported on the housing or to the rotational balance of the instrument because the LN2 does not rotate. This decoupled arrangement should improve the pointing stability of the instrument during operations.

Thermal isolation of the tank is accomplished by mounting the tank on a set of eight G-10 plates that are 0.6 cm thick, 10 cm wide, and 30 cm long. The fill line includes a section of knife-edged bellows that is made of a number of very thin walled SS folds. The tortuous thermal path through this bellows is equivalent to over a half meter of thin-walled (~25 micron thick) SS tubing, yet is compressed into a 3 cm connection. There is also a layer of Primirror 11 shielding plus MLI between the tank and the warm rear bulkhead.

An innovative seal design was incorporated between the LN2 tank and the bellows assembly. A metal core, expanded PTFE (Teflon) o-ring (manufactured by Gore-tex) was seated between two flat surfaces, one which is made of aluminum and the other of SS as shown in the right hand view of Figure 6.

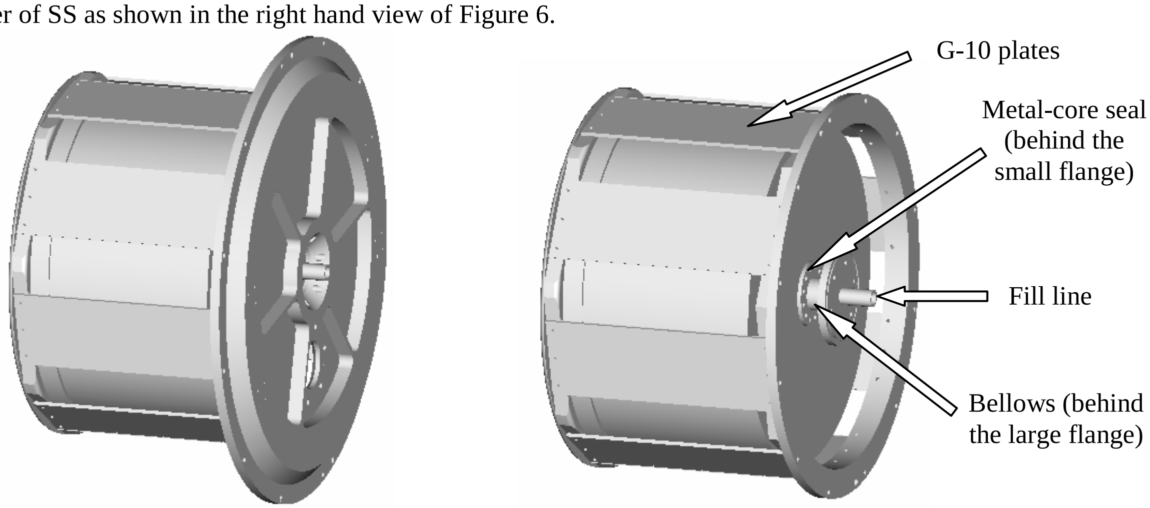

Figure 6. The liquid nitrogen tank with vacuum bulkhead attached (left) and removed. The G-10 plates structurally support the tank while allowing minimal thermal conduction. The bellows and seal assembly with fill line is shown on the right.

This design was chosen over the commonly used bi-metallic transition piece because of space limitations and for ease of assembly. No leakage has been detected (helium leak detection using a residual gas analyzer) after numerous installation and removal cycles with thermal cycles in between. This performance has proven the reliability of these seals; at less than $3.00 apiece, the seals are a great value.

The final two components which maintain the cold vacuum conditions throughout the shielded interior of the Dewar are the thermal straps and the adsorbers. Figure 7 is a photo of two thermal straps connected between the LN2 tank to the left and the optical bench. The straps are made of oxygen-free, high conductivity (OFHC) copper, with 40 layers of thin (0.125 mm) foil making up the flexible portion of the strap. The straps are used to thermally connect the optical bench to the LN2 heat sink while keeping the bench mechanically isolated from the (varying) LN2 tank load. A wrap-around end clamp design was employed for the ends of the straps to avoid the loss of thermal conductivity to the distal layers of foil due to oxidation and less-than-perfect contact between the layers. Operational tests have shown the straps to be highly efficient, with conductivity approaching the theoretical level of a solid copper bar. A few degree differential temperature has been measured with the heat load more than double that expected in normal operations; this differential will drop in direct proportion to the bench heat load. Differential temperatures across the full optical bench and cold stand-off have been demonstrated to be near their design levels.

Figure 7. Thermal straps are shown mounted to the optical bench and the LN2 tank (to the right). OFHC copper was used for the wrap-around end clamps and the 40 layers of flexible foil.

Since the Dewar is intended to operate in the cold condition for up to a year at a time, some method of continually pumping the in-leaking gas must be provided. O-ring permeability is the leading source of inleakage; it was measured at 3.4×10^{-5} standard cc $second^{-1}$, or ~1 liter per year. Based in part on recommendations of the Imaging Sciences Laboratory (in Ref.2), NIC-FPS is being supplied with both charcoal and zeolite adsorption pumping. The charcoal is epoxied (using thermal epoxy Lord 3135A/B) in a single layer to a large surface area (>400 cm^2) of copper plate directly mounted on the LN2 tank face. The Type 3A/4A bead zeolite is contained in a pair of cylinders that are removable for moisture bake-out; the cylinders are mounted to the beams near the LN2 tank. Locations of adsorber materials were chosen to achieve the lowest possible temperatures to improve the adsorption pumping efficiency. Bead zeolite was chosen over the pellet shape to minimize dust generation

3. Remaining Work

3.1 Integration and Testing

The Dewar and support structure have been tested and are acceptable for service. Interior components such as the stepper motor controlled filter wheels and etalon mover are currently undergoing component testing and appear to be acceptable in their current configurations. Detector and controller testing is continuing with an engineering grade detector and two alternate controllers (Rockwell and Leach). The best performing (especially lowest noise performance) controller will be delivered with the instrument. Optical testing with the engineering grade chip awaits completion of detector testing. Characterization of the science grade chip will follow when controller issues are resolved. Etalon testing has been delayed by needed rework on the CS-100 controller. In-band testing of the etalon will be performed after the science grade chip and controller tests are acceptable.

System integration and testing has begun including such activities as cable harness building, component fit-up, and software development. Full system testing which includes cold functional and optical system performance tests is anticipated to occur in July/August 2004.

3.2 Instrument Commissioning

The first engineering run is scheduled for late August or September. Software and system interfaces will be checked and instrument control via the ARC 3.5 user interface will be demonstrated. First light on the instrument is planned for this first engineering run, though system optimization is expected to extend for a minimum of 1-2 months. Actual commissioning tests and initial science observations are planned for 4th quarter 2004. A period of about 3 months of shared-risk operations will follow, allowing ARC community observers to use the instrument while emergent issues are resolved. Final turn-over of the instrument to ARC will occur in early 2005.

5. CONCLUSIONS

The near-infrared imaging and full field spectrographic capabilities of NIC-FPS are soon to be added to the Astrophysics Research Consortium's instrument set for the 3.5 meter telescope at Apache Point Observatory. The instrument will deploy one of the first low-noise Rockwell Hawaii-1RG (1024 x 1024 pixel) detectors for science operations. A unique, high resolution (R~10,000) NIR Fabry-Perot etalon promises to deliver quality science results. The physical system for this instrument is nearing completion and appears to be an optically, mechanically, and thermally stable platform. Although based on proven Dewar technology, this design incorporates a number of significant variations and innovative solutions.

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REFERENCES

1. M. Vincent *et al*, "Near-infrared camera and Fabry-Perot spectrometer – NIC-FPS", Proc. SPIE, **4841**, 367-375
2. B. Atwood, T. O'Brien, "Practical Considerations for LN2 Cooled, O-Ring Sealed, Vacuum Insulated Dewars for Optical and IR Detectors" (2002)