NEWFIRM

SYSTEM DESIGN NOTE

Title: SDN 7101 Flexure Rig Fixtures					
Prepared by	**Date**	**Approved by**	**Date**	**Rev.**	**Rev Date**
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Related documents:					

1. Introduction

This SDN describes optomechanical performance tests of the NEWFIRM camera that are to be performed on the Flexure Test Rig prior to putting the instrument on the telescope, and states requirements for the optomechanical fixtures necessary to carry out these tests.

In brief, the tests relate to instrument flexure, detector mosaic alignment, point source image quality, scattered light, and ghost images. The fixturing must hold the instrument on the Flex Rig with little flexure. An infrared point source must be provided that simulates the input from the telescope in f-number, exit pupil, and image quality, and is variable in brightness. This source must be capable of exploring the NEWFIRM input focal plane from center to corners with little flexure.

In what follows, X and Y directions are in the telescope focal plane, while Z is along the optical axis. The NEWFIRM filter bandpasses are J (1.1-1.4 microns), H (1.5-1.8 microns) and K-short (2.0-2.3 microns).

2. Optomechanical performance tests

These tests are to be conducted during Cold Cycle 2 and subsequent cycles, with the instrument mounted on the Flexure Test Rig. They are also summarized in SDN 7505 Integration and Test Plan. The tests will define internal instrument flexure, detector mosaic alignment, point source image quality, scattered light, and ghost images.

2.1 Instrument flexure

The mechanical design of the instrument is intended to compensate for translation, rotation, and tilt of the internal cryogenic optics assembly, such that a fixed point in the input telescope focal plane is imaged to a fixed point on the detector array, and is held fixed with respect to the guider input, regardless of instrument orientation. To quantify actual system performance, a point source input image must be provided that has low flexure at the telescope focal plane as the instrument orientation is changed. This point source must be movable in the telescope focal plane to several positions to define the residual image motion on the array.

2.2 Detector mosaic alignment

The individual detector arrays will be brought to a common plane by optical bench tests prior to insertion of the detector assembly into the instrument. The concern at this stage is to bring this plane centered on and normal to the instrument optical axis. The test is to translate the input point source in the Z direction in a repeatable fashion, and compare the resulting Z axis values for best focus vs. X-Y position in the focal plane. The point source must have adequate range of Z axis motion, and be movable in the input focal plane to several positions covering field center to field corner in each of the four arrays comprising the detector mosaic. The input point source image quality must permit determination of a well defined best Z axis focus position for all locations in the field of view.

2.3 Image quality across the field of view

NEWFIRM's cryogenic optical system must provide high quality images for a single input Z axis focus value across the array mosaic field of view. Performance will be quantified by taking focus sequences at locations from field center to field corner in each mosaic quadrant, and determining the FWHM variation around the field of view for the optimal focus. The requirements for source positioning and input image quality are the same as for Sec. 2.2. In addition, the input point source must replicate the 4-m telescope input f-number, must follow the input focal surface, and must provide flux from 1 to 2.3 microns to test image quality in all filters.

2.4 Scattered light performance

NEWFIRM is provided with internal cold baffling to suppress scattered light from sources outside the science optical beam, and from residual scatter of in-beam radiation due to optical surface irregularities, dust, etc. Performance will be quantified by looking at light levels across the array mosaic as a function of input source focal plane position and brightness, in all filters. Position and brightness must be adjustable over appropriate ranges, with adequate flux over the spectral range.

2.5 Ghosts

Also of concern are low level, quasi-focussed images of the telescope or instrument pupils (pupil plane qhosts), the warm field stop at the telescope focal plane (focal plane ghost), and ghosts created by multiple internal reflections of light from bright point sources (image ghosts). The input light source must be capable of exploring various positions in the telescope focal plane; replicate the telescope input f-number; mimic the telescope exit pupil; and be variable in brightness. This is to produce the same input illumination conditions as will be found on the telescope.

3. Optical Test Fixture Performance Requirements

It will be noted that while the performance tests described above have distinct purposes, they have strongly overlapping requirements on the test apparatus. Conceptually, this apparatus will be some kind of adapter box or plate that allows the NEWFIRM instrument truss to be coupled to the Flexure Test Rig; a telescope simulator that provides a point source with the telescope f-number and mimics the telescope exit pupil; a means of varying source brightness; and a means of positioning this source to explore the input focal plane. Below I state system requirements. Budgeting of tolerances among components is not attempted here. Flexure, for example, will have to be budgeted between the adapter box, the light source, and its positioning mechanism.

3.1 Flexure

Passive compensation of instrument flexure is a fundamental element of NEWFIRM's design. This compensation has been carefully tuned, using the mechanical structure, to minimize relative motion between the telescope and detector focal planes. The performance of the flexure compensating design is expected to be such that the motion of the detector focal plane projected back onto the input telescope focal plane, with respect to the guide probes that provide closed-loop tracking, will be

a) < 70 microns for an instrument orientation change from zenith to horizon in any direction, using the North guide probe;

b) < 90 microns for the same orientation change, using the South guide probe;

c) < 6 microns for orientation change corresponding to 15 minutes of tracking (Δgravity about 0.06 g) anywhere within 60 degrees of the zenith.

Cases (a) and (b) are extreme, useful for characterizing performance but not to be encountered during science observations. Case (c) represents the orientation change during a background-limited exposure through a narrowband filter on a field at airmass < 2. It is a "real world" science driven situation.

Flexure in the test setup itself must be small enough that the action of the flexure compensating design of the instrument can be verified, or any corrective action adequately quantified, prior to taking the instrument to the telescope.

3.1.1 The point source image provided by the test fixture at the telescope focal plane shall translate by ≤ 1/3 of the predicted compensated detector focal plane value, for any orientation change of the instrument within 90 degrees of vertical.

This corresponds to 23 microns for case (a), 30 microns for case (b), and 2 microns for case (c).

3.2 Source positioning in the focal plane

The source must be movable to several positions around the field of view, from center to corner. While arbitrary X-Y positioning is desirable, this may prove excessively complex or prone to flexure. Hence I specify a minimum number of fixed positions, covering array near-center, halfway to edge, edge, and near-corner on a radius from center. Covering the entire focal plane arbitrarily remains a goal.

3.2.1 The point source image in the telescope focal plane shall be positionable to the following discrete positions in each quadrant of the focal plane: on a line from center to outside corner, at 2.0, 60, 125, and 170 millimeters from field center.

3.2.2 Continuous positioning along the center-to-corner line in each image quadrant, or more generally in X and Y within a 250 x 250 mm square, is a goal.

3.3 Replication of telescope input beam vector

The instrument optics must see an input beam that mimics the telescope, in order to properly evaluate their performance. The NEWFIRM optical design assumes as an input surface a plane surface normal to the optical axis. Away from field center, the input f-cone must be at the same angle as that coming from the actual telescope. These requirements are grouped together since they both relate to placement of the telescope simulator.

3.3.1 The point source image, as it moves from position to position per Sec. 3.2, shall remain in a plane normal to the optical axis without refocus of the input light source.

3.3.2 At each position, the axis of the input f-cone shall have the same unit vector as the input beam from the 4-m telescope.

The f-cone unit vector is at an angle with respect to normal varying from 0 degrees at field center to 0.7 degrees at field corner, always tilted toward the optical axis.

3.4 Replication of telescope f-number and exit pupil

These are also requirements for ensuring that the instrument optics are tested with an input beam that mimics the telescope. They are grouped together since the size and placement of a single mechanical stop in the simulator optical train usually determines both of them simultaneously.

3.4.1 The beam forming the input point source image shall have the same f-number as the 4-m Mayall telescope as used for NEWFIRM, nominally f/7.9.

3.4.2 The source optical design shall provide an exit pupil that is equivalent to the 4-m telescope pupil's size and placement.

The telescope exit pupil is at the 4-m primary. Since the primary is seen by the instrument via the secondary, this is equivalent to a 4-m sized stop about 12 m in front of the telescope focus. This maps onto the instrument's internal cold stop. This requirement, together with the f-ratio requirement, provides the same internal illumination as the telescope for quantifying scattered light and ghosting performance.

3.5 Source Z axis motion

The point source imaged in the telescope (input) focal plane must be adjustable in Z, to explore changes in the output image as a function of input focus. Image growth (increase in diameter) equivalent to five times the design best focus (~2 pixels FWHM) requires ±2 mm of adjustment. I add a further 8 mm to bring the image produced by the telescope simulator to initial best focus. Depending on the simulator design, this image motion may be produced by displacement of the input light source or by mechanical displacement of the entire unit.

3.5.1 The point source image in the telescope focal plane shall be adjustable in position along the Z axis (instrument optical axis) by ± 10 millimeters.

3.6 Input point source image quality

The point source image quality produced at the telescope focal surface by the simulator must be equal or better than that produced by the telescope. While the ability of the simulator to produce the *same* off-axis image characteristics as the telescope is desirable for evaluating instrument performance on the Flex Rig, this is not likely to be possible with a simple system.

3.6.1 Point source image quality produced by the telescope simulator shall be described by the RMS spot radius at the input focal plane.

3.6.2 Simulator image RMS spot radius shall be ≤ 65 microns for any location within the NEWFIRM focal plane and in each of the NEWFIRM bandpasses.

The second requirement above is approximately equivalent to an image FWHM < 2 pixels anywhere in the focal plane. For comparison, the telescope RMS spot radius is 0.2 microns at field center, 108 microns at field edge, and 245 microns at field corner for a plane through the best focus at field center.

3.7 Point source brightness and spectral range

The simulator point source image must be variable over about a 10 stellar magnitude range (a factor of 10000 in brightness) to mimic the range of stellar brightnesses above background level that NEWFIRM will encounter. While the bright end of this range will produce totally saturated images on the NEWFIRM detector, this is of value for exploring scattered light and ghosting behavior. The source spectral energy distribution must provide adequate flux in each of NEWFIRM's broadband filters, i.e. over the range of 1.1 to 2.3 microns. I expect that the brightness range and adjustment can be provided by an incandescent source operated with variable voltage. Empirical adjustment to desired brightness during an experiment is acceptable; the source need not be calibrated. Spectral coverage will dictate choice of source envelope (e.g. a quartz lamp) and of any transmissive optical materials used in the simulator optics.

3.7.1 Simulator point source image brightness shall be variable over a range of 10000 in flux at the detector. External control shall be provided. This need not be linear or calibrated.

The simulator point source shall produce this flux range for all of the NEWFIRM filter bandpasses.