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NIRSPEC Optics Design Note 13.00
Back-end Collimator Bid Package

1. Introduction

The back-end collimator bid package is reproduced in its entirety on the following pages. It was sent to the vendors listed below. The responses are summarized at the end of this document.

Applied Physics Specialties Limited
Martin High
President

Janos Technology, Inc.
Mr. Jim Waters
Sales Manager

OFC Corporation
Mr. Bob Clark
Director Advanced Systems Development

SORL
Fred Kingsley
Sales Manager

SSG, Inc.
Joe Robichaud

Speedring Systems, Inc.
Dale Sabo
Director of Sales and Marketing

NIRSPEC

UCLA Astrophysics Program **U.C. Berkeley** **W.M. Keck Observatory**

Request for Formal Quote

Collimating mirror for NIRSPEC
December 5, 1995

1.0 Introduction

This document is a solicitation for formal quote to produce an off-axis parabola collimating mirror (OAPC). This mirror will be used in the post-slit optics of the NIRSPEC instrument, a high resolution spectrometer being built for the Keck II telescope. We have provided the design specifications, manufacturing tolerances, a clear aperture ray trace, and a sketch of the mirror and nearby optical elements. We welcome vendor input on various aspects of the opto-mechanical design.

2.0 Summary of Design

Figure 1 shows two views of the back-end optics in NIRSPEC. The OAPC design produces an aberration-free collimated beam for the central field point. The object field subtends 0.69° in diameter and sits at the apparent focus of the mirror. The slit orientation will sometimes be vertical (low resolution mode) and sometimes be horizontal (high resolution mode). The object field bundles are telecentric and expanding at f/10.

The mirror will be nominally operated in a vacuum-cryogenic environment (77 K), although the chamber will be periodically warmed to room temperature for maintenance. The mirror will be mounted to structures made of aluminum, so we require an aluminum substrate to assure athermality. The mirror must be coated for maximum reflectivity at near-infrared wavelengths, 1 to 5 μm.

3.0 Statement of Work

This statement defines the responsibilities of both the vendor and UCLA for the proposed contract. The vendor will be responsible for all non-recurring engineering, fabrication, and testing to deliver a finished mirror assembly which meets the specifications in this document. At the time of granting the contract, UCLA and the vendor will finalize a formal verification and acceptance procedure to be performed before final payment. We expect that a successful job would include the following tasks, although an acceptable part need only meet the specifications listed elsewhere in this document:

1. Opto-mechanical design of mirror substrates and support structure
2. FEA modeling of stress and thermal changes for cryogenic use at 77 K
3. Design and procurement of all fixturing and test equipment
4. Substrate preparation
5. Initial figuring
6. Electroless nickel plating
7. Final finishing and post-polishing
8. Gold coating
9. Final testing and qualification at 77 K

4.0 Specifications

4.1 Optical Prescription

Figure 2 shows a top view of the slit-plane and OAPC along with specifications. The rays have been traced from three field points lying in the slit focal plane. The field points lie in the center of the field, and at the slit edges. In the high resolution mode (shown), the slit aperture will be horizontal, or in the plane of the page in Figure 2. In the low resolution mode (not shown), the echelle grating will be replaced by a mirror, and the slit will be out of the plane of the page in the figure.

The optical prescription is provided in Table 1. “Distance” refers to the distance between the surface and the next element. It does not refer to the distance to the parent vertex in the case of the OAPC.

Table 1:
Optical Prescription

Surface	Radius	Distance	Clear Aperture diameter		Rotation[1]
	mm	mm	mm	mm	
Slit	-	1203.296	14.544[2]		-
OAPC	-2400	-1203.296	139.2		6°
Pupil	-	-	120.8		-

[1]rotation is shown in the figures
[2]length of slit

4.2 Opto-mechanical Tolerances

The tolerances were generated by assuming that we can accept a total system wavefront error (WFE) of - 0.66 $\lambda_{0.6328\mu m}$ RMS. After considering others sources of wavefront error in the system, we believe that we can accept - 0.15 $\lambda_{0.6328\ \mu m}$ RMS WFE due to the OAPC design alone.

This condition ensures that the system gives 80% ensquared energy (ESE) within a 27 μm square field at the final array focal plane for field points within the slit; the slit is rectangular and spans ±15O X ±0.2O on the sky. These performance criteria have been measured when the image rotator K-mirror is in the ideal configuration, i.e. $\theta_{IROT} = 0°$. Different image rotator angles will introduce very large wavefront errors from the front-end optics, so the final tolerances on the OAPC will only be important for the case where the front-end is essentially diffraction limited, i.e. $\theta_{IROT} = 0°$. The weight ratios are 2:1:1 for the central:side slit edges:top and bottom slit edges field points.

In some cases, requirements other than those due to image performance provided tighter constraints. These other requirements are listed below. The tolerance table contains symbols following each tolerance value. These symbols are described below and at the bottom of each table. They indicate which requirement was used to calculate the tolerance value.

- **Beam displacement (b)**. Requires a maximum lateral offset of 1.0 mm on any part from the beam's point of view.
- **Scattering (s)**. Requires negligible scattering between 1 and 5 μm.

All values are with respect to the center of the OAPC clear aperture, not the parent vertex. Some of these tolerances refer to the positioning of the reference flat.

Table 2:
Opto-mechanical Tolerances for OAPC

Tolerance	units	OAPC
Surface		
Radius	mm	-1.4p +0.4p
Irregularity	$\lambda_{632.8nm}$ (P-V)	1/4p
RMS surface roughness	Å (RMS)	<75s
Orientation		
x-tilt	mrad asec	0.4b 83
y-tilt	mrad asec	0.4b 83
z-tilt (clocking)	mrad asec	0.4b 83
Vertex Position		
x-decenter	mm	0.4b
y-decenter	mm	0.4b
z-decenter	mm	-

Tolerances are measured with respect to local OAPC coordinate axes. The z-axis is normal to the clear aperture tangent plane. The x-axis is out of the page in the top of Figure 1. The y-axis is orthogonal to the x- and z- axes.

p - image performance gives 80% ESE for the 27 μm pixels on the array
b - 1.0 mm offset of beam footprint
s - negligible scattering

4.3 Qualified Clear Apertures

Figure 3 shows a clear aperture diagram. Rays from 5 field points were traced: center, left and right edges of the slit (high-res mode), and top and bottom of the slit (low-res mode). The final dimensions were calculated to give 2 mm of extra space around the beam footprint.

4.4 Coatings

The mirror surface should be coated for maximum reflectivity from 1 to 5 μm, comparable to either a FSS-99 or FSG-98 coating from Denton Vacuum (Morrestown, NJ). The best choice of coating for performance, adhesion, and durability should be jointly determined during the initial portion of the contract.

4.5 Thermal Requirements

We require that the delivered part perform to the specifications in this document at the operating temperature of 77 K, and that this performance be maintained after many thermal cycles. The procedure for thermal cycling and stress relieving of the mirror substrates is to be determined by the vendor, who will also provide documentation.

4.6 Mechanical Requirements

The vendor will be responsible for the mechanical design of mirror substrates, support structure, tooling, fixturing, machine mounts, and optical reference surfaces. Figure 1 shows the position of the mirror relative to surrounding opto-mechanical structures.

5.0 Acceptance Testing and Documentation

Although tests and procedures need to be agreed upon between the vendor and UCLA, we expect the following issues to be addressed in the response to this solicitation:

1. Qualification of mirror surface
2. Measurement of critical dimensions
3. Cryogenic performance
4. Any fixturing or null optics needed during the testing process
5. Qualification of null optics and test equipment
6. Measured values for all parameters in Table 1

see collbp.pre for figures 1, 2, and 3.

Vendor Responses

The vendor responses are summarized below. The actual responses are included as attachments.

Applied Physics Specialties Limited

no response

Janos Technology, Inc.

They bid $8,150 for one piece, taking exception to the surface roughness spec and the requirement to verify performance.

OFC Corporation

No bid (on file). They would rather have SSG, Inc. take on the responsibility.

SORL

Just like for the front-end optics, SORL gave a very complete response including preliminary sketches of the opto-mechanical assembly. Once again, their thorough approach drives up the cost, and it actually works against them. They bid $26,875 without cryo-verification. They did suggest that the piece could be verified on-site in our chamber, but this is not appropriate.

SSG, Inc.

no response

Speedring Systems, Inc.

We chose Speedring because of their package-deal approach, and their technical expertise exhibited in their bid for the front-end optics. All of these issues are discussed in documentation from them, including the formal statement of work.