Report of the Proof of Concept Review Committee for the HROS Immersed Echelle

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Background

The High Resolution Optical Spectrograph being designed as part of Gemini's Phase I instrumentation program can take two basic forms in order to meet its scientific goals. One form is based upon a relatively high blaze angle echelle mosaic, which is comparable to the KECK HIRES design. The other immerses a moderate blaze angle echelle grating in a UV transparent medium, the net effect being an increase in the angular dispersion by an amount roughly equal to the refractive index of the immersing medium. These two approaches give similar (resolution)×(slit-width) products but offer different levels of throughput and engineering complexity in Gemini's instrumentation environment. Specifically, all instruments are mounted at Cassegrain and are therefore subject to a wide range of gravity loads while being confined to a relatively small volume compared to Nasmyth mounted instruments. Under these conditions a more compact design is preferable, and given the emphasis Gemini has placed on telescope throughput, including in the UV, an immersed echelle becomes attractive compared to a less efficient albeit more conventional mosaic grating spectrograph. In November 1995 a panel composed of the HROS instrument team, IGPO representatives, and experts in the field of high resolution optical astronomy met to assess the trades associated with an HROS based upon the aforementioned design options. This panel recommended proceeding forward with the immersed echelle concept but to not formally eliminate the mosaic grating option until the immersed echelle grating concept could be proven to work. Accordingly, in the spring of 1996 tests were conducted at UCL to demonstrate the viability of coupling a large grating to a prism through an oil couplant, from the perspective of mechanical stability and scattered light. We report here the results of an independent review of this work, to give the HROS team guidance on what design (immersed or mosaic echelle) should be taken into the instrument's conceptual design review, later in 1996.

Final Conclusions and Recommendations

The Proof of Concept review consisted of documentation distributed before the meeting, a lab tour including examination of the test assembly, presentations made by the HROS team, several question and answer sessions, and finally a closed committee session to compile comments and reach closure on formal recommendations. The top level conclusion of the committee is that the immersed echelle concept has been demonstrated to be viable enough to be considered *exclusively* in future design efforts for HROS. The HROS team is to be congratulated for successfully demonstrating the basic mechanical rigidity (in terms of ≤1 μm motion between the echelle and immersion prism) and scattering performance of an immersed echelle. To be clear, HROS has a number of challenges ahead which must be met in order to achieve the desired scientific performance, but the level of risk associated with HROS' immersed echelle opto-mechanical design is acceptably low to support proceeding forward with the next design phase of the instrument. Specific recommendations include:

- The committee felt the potential gains associated with light-weighting the echelle substrate, either in terms of the overall mass budget for the instrument or the support system used with the echelle/prism bracing assembly, does not offset the risk associated with producing either a ribbed or thin echelle substrate. Spectronic Instruments recommends a 75 mm thick substrate and the committee concurs with this advice.

- Spectronic Instruments is currently projecting 1.5 years of work in the production queue for custom gratings and this will likely increase to ~2.5 years in the near future, with the expectation of orders from other large telescope projects arising soon. The committee therefore recommends that HROS establish a firm position in Spectronic Instrument's production queue as soon as possible.

- The committee expressed concern about possible throughput losses associated with an oil/aluminum optical interface. The theoretical reflectivity of this interface has been estimated theoretically by the HROS team but, given the large emphasis on system throughput for HROS, we recommend making a simple test of measuring the reflectivity of an immersed and non-immersed aluminum coated flat mirror. This measure of reflectivity should ideally be done at several wavelengths, including the UV. Furthermore, the HROS team should investigate in more detail the recently completed theoretical work (PhD thesis) of a student at Durham on immersed echelle gratings to further understand the physical nature of the various optical interfaces associated with such systems.

- The HROS team is exploring the use of optical contacting to establish near-perfect optical interfaces between the large fused silica segments that comprise the cross dispersion and immersion prisms. The use of this bonding technique across such large surfaces is an area of risk. Specifically, the long term mechanical integrity of such contacted prisms, in an oil environment (for the immersion prism), is uncertain. To date there is evidence that capillary action can, over prolonged periods of time, allow oil to leach into the optical joint, permitting air to infiltrate the system and decouple the prism segments. Furthermore, the contacting technique is susceptible to even a single speck of dust between the contacted surfaces creating a bubble, which would scatter light and lead to slightly decreased system performance. Given the uncertainties and risks associated with optically contacting large fused silica surfaces, we recommend continuing to consider the use of couplants such as index matching oils and gels as alternatives to optical contacting in future design iterations of HROS.

- In accord with the above recommendations, the HROS team is urged to closely assess the theoretical end-to-end throughput of the instrument as various designs are considered to make sure that one of the unique scientific advantages HROS will have over competing spectrographs is not lost.

Other issues of somewhat lesser importance include:

- Consideration should be given to the use of optically blackened fused silica bonded to the sides of the prisms to trap scattered radiation. Alternate blackened glasses bonded with a pliant glue might also be used instead of simply painting the sides of the prisms flat black.

- Careful consideration should be given to the beveled edges between segments in the immersion prism, so these edges do not become low-level scattering sources in the beam.

- The mechanical integrity and stability of optically contacted surfaces is difficult to predict. In addition, the mechanical integrity of these joints may exhibit undesirable properties which would not normally be acceptable in a support structure such as sensitivity to the ingress of oil or water, low strength, and brittleness. Consideration should therefore be given in the coupling of the fused silica prism segments to the use of a support structure which provides adequate strength and rigidity to insure that the prism segments do not de-couple over time. A start point for the design of this structure would be to consider the individual components as mechanically de-coupled from each other. It should be noted that the mechanically coupled and oiled interface used on the test set-up demonstrated excellent mechanical stability.

- When the final oil for use between the echelle and immersion prism is selected it should be scanned with a lab spectrophotometer down to the nominal expected operating temperature of HROS (e.g., 0 °C) to assure that the transmissive performance of the couplant is preserved across the entire 0.3 - 1.0 μm operating range of HROS. There are at least some indications to date that the oil under serious consideration now may turn slightly opaque when it is chilled.

Appendix A - Charge to the Design Review Committee

1) Is the documentation adequate to assess the technical viability of the proposed immersed echelle design for HROS?

2) Are the tests adequate to evaluate the risks with the proposed design?

3) Can the required grating be constructed or purchased?

4) Have the tolerances to which the system must be fabricated and supported been assessed properly?

5) Is the calculated performance of the immersed echelle viable and realistic?

6) Are there areas of unacceptably high risk in the design due either to choice of technology or inadequate analysis?

7) Is there anything the design team has overlooked?