High Resolution Optical Spectroscopy at Gemini

Lessons Learned

Trades to Consider
High resolution optical spectroscopy was defined as one of the first-generation capabilities for Gemini, with roots dating back to the early ‘90’s.

At the time, HIRES on Keck was producing remarkable results and high-res facilities were being planned across the “8 m club”
Early design trades, driven primarily by cost constraints, eliminated Nasmyth focal stations on Gemini.

This reduced the cost and complexity of the telescope, but effectively transferred cost/complexity to some instruments that are difficult to deploy at a Cass focus.

High-resolution spectrometers are such instruments.
The Early Days of HROS

* Studies were conducted in the mid '90s, principally at UCL, to find a solution to the problem of locating what is normally a Coude’ or Nasmyth mounted instrument at a Cass-focus

* Space and mass constraints of Gemini's instrument environment essentially precluded the use of a large mosaic of gratings and led to the need for an immersed echelle...

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**HROS Technical Note #4**

**Definition of Immersed-Echelle Proof-of Concept**

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**Abstract.** This Note discusses the primary dispersing element of HROS according to the baseline design. That is, we consider a custom echelle coupled to (immersed in) a compound prism. This Note defines a work programme specifically targeted to quantifying and minimizing the risk in this novel approach to an echelle spectograph. The key risk areas are (i) manufacturability, (ii) stability, and (iii) stray light.

1. **Introduction**

The immersed echelle, if proved to be feasible, has significant potential benefit to the scientific productivity of HROS. In particular, the immersed echelle has a higher resolution & throughput product than an alternative design concept utilizing a longer mosaicized echelle in air. The importance of this is recognised by the GSC¹, which stated the requirement that:

"Throughput is the highest scientific priority, particularly in the UV"

The space envelope for HROS has proved to be a challenge. The immersed echelle also results in a more compact spectograph, which is therefore another significant advantage. Indeed, it might prove difficult or impossible to meet both the scientific requirements and the space envelope simultaneously any other way. However, no large echelle spectograph has used this technique to date. Therefore, there is an element of risk as well as benefit, which this document addresses. Interestingly, there is a close analogue with the UCL echelle spectograph. There, we proposed a novel design using large prism cross-dispersers, again on throughput grounds. No UV-transparent prisms of the required dimensions and quality had been produced previously. The approach was consequently considered a risk, and it prompted the AAO to fund a proof-of-concept programme to demonstrate feasibility. The results of the programme were positive, and led to a highly successful commissioned instrument. This Note builds on that experience.

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¹F. Gillett, Gemini Newsletter No 10, June 1995, page 5
HROS Immersed Echelle Concept

HROS Echelle Grating

Fused Silica Cross Dispersion Prisms

Oil interface layer

SILICA PLATE

RULING

CROSS DISPERSER PRISM
- Deployable long camera (R~100K) was removed from the design
- Led to the “high stability” mode of HROS
  - Fiber fed redeployment of instrument in pier lab
  - This too was eventually dropped from the design
GSC Approved HROS Design Requirements

- Built by University College London
- Detector: 2 EEV CCDs with 2048x4608 13.5 μm pixels
- Throughput is highest Priority, particularly in UV
  - Requirement: >10% at R=50,000 and 500nm; goal 20%
- Resolution: ~50,000
- Sampling: 3 Pixels per Resolution Element
- Wavelength Coverage: ~0.3 - 1.0 μm total with essentially all of this range covered in a single exposure
- Stability: <0.05 resolution element in one hour integration
What Happened to HROS?

In 2000 the HROS project was canceled

- Conceptual Design Review → Failed
- Preliminary Design Review → Passed
- Critical Design Review → Failed

Many factors led to this including –

- Constantly changing leadership in the HROS team
  - ~5 project managers and ~3 project scientists over lifetime of project
- Instrument was never competed, just allocated like most other Phase 1 Gemini instruments
- Relatively weak engineering team combined with a complex opto-mechanical system that was constrained by Gemini’s instrument environment
From the ashes of HROS...
Bench High Resolution Optical Spectrograph (bHROS)
**Bench High Resolution Optical Spectrograph (bHROS)**

**bHROS Vitals**
- Fiber fed bench spectrograph built at UCL
  - NOAO integrated detector system
- $\sim 0.5$-0.9 $\mu$m sensitivity
- Uses GMOS-S for acquisition & guiding
- $R \sim 120,000$
- 4x4k CCD mosaic used to sample echellogram
- High stability facility in telescope pier lab
- Due early 2003 - Gemini-South
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Fiber emerges through central hole in azimuth platform.

~35 m fiber

Telescope Pier
bHROS was eventually delivered and commissioned at Gemini-S but saw very little demand –

- Throughput challenged
- Single-shot spectral coverage was inadequate for many science applications
- Spectral resolution (R~120K) was too high for most of the community

bHROS is now destined to be shipped to Argentina, where key components will be used in another spectrometer...
What is more important in providing high-res optical spectroscopy to Gemini’s community – “speed” or “capability”?

- Increasing delivery speed points toward -
  - Fiber-fed instrument if built for Gemini
  - Use of existing instruments (time swaps)
- Increasing capability of instrument points toward -
  - Cass mounted → higher performance but at greater cost and slower delivery time
Deployment Speed

- Use Existing Instruments
- New Fiber Fed
- New Cass Fed

Time to Deploy

~2X

~2X
**ESPaDOnS**

- **Echelle SpectroPolarimetric Device for the Observation of Stars at CFHT**
  - Cross-dispersed echelle spectropolarimeter
  - 40 orders, 369-1048nm, in one single exposure
  - ~15% throughput
  - Data reduction software provided
  - R=81,000 (star only)
  - R=68,000 (star+sky)

- 2004 deployment at CFHT, used regularly ever since
Fiber Deployment

Concept we might explore is to run a fiber connecting Gemini to CFHT.
**ESPaDOnS Option**

**Pros**
- Reduced cost, probably letting us jump start 2 instruments in parallel
- Faster to complete than building/commissioning a new spectrometer
- Reduced performance risk (bench mounted - spectrometer performance known now)
- No loss of optical ports at Gemini (assumes PRVS fiber-feed concept is applied)

**Cons**
- Reduced performance (mainly throughput) compared to Cass mounted instrument at Gemini
- Single object only
- TBD limitations on access - not clear how much time we could get from CFHT for ESPaDOnS
- Inhomogeneous data set (headers, distribution, etc.) compared to Gemini's standard data products if we relied upon CFHT's data systems
Science applications for this instrument will drive its design particularly hard –
- Cass or bench mounted?
- Optimal resolution?
- Throughput a premium?
- UV important?
- Single or multi-object?
- Single-shot λ coverage?
- Extreme wavelength stability & calibration important (exoplanets)?

What will the new “HROS” science case contain?

Who will write it?

When will it be ready?