

# NEXT GENERATION OPTICAL SPECTROGRAPH FOR NOAO

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# Design Goals for a New Spectrograph

- 20 to 40 arc-minute field of view.
- 45% peak system efficiency (includes telescope, spectrograph, grating, and detector).
- Resolving powers of 2000 to 10000 and possibly as high as 30000.
- Spectral coverage of ~1 octave at  $R=5000$ .
- Multi-slit, long-slit, and lenslet IFU capability.
- Operational range from 365 to 1700 nm with CCD and IR detectors.

## Science with NGOS

- Surveys of the Galactic Halo using K giants:
  - sample derived from Mosaic imaging.
  - spectroscopic analysis of radial velocities and abundance with NGOS at  $R=5000$ .
  - Search for clustering or smooth distributions in the velocity and spatial domains.
- Radial velocity studies of large samples in Galactic dwarf spheroidal companions.
- Search for cool white dwarfs.

## Science with NGOS (continued)

- Search for low-metallicity galaxies.
- Large-scale structure evolution at  $Z < 1$ .
- Spectroscopic follow-up and optical identification of targets uncovered by NASA space missions and ground-based optical and near-IR imaging surveys.

# Why a New Spectrograph?

Multi-fiber instruments revolutionized astronomy in the mid-80's by significantly increasing the number of targets that could be realistically observed for a given astronomical study from a few to a few hundred. This increased the validity of the results by an order of magnitude, moving the science out of the regime of small number statistics.

Technological advances in the past decade (optics, optical coatings, CCD mosaics, and grating technology) now allow the fabrication of large format, wide-field, imaging spectrometers which can fully utilize the image field delivered by a telescope (e.g., DEIMOS and IMACS) without the need for fiber optics. With such an instrument, one can further increase the number of observed targets by another order of magnitude, up to the thousands and hundreds of thousands.

## Advantages of NGOS at NOAO

- NGOS will outperform RC spectrograph by factor of **3** in efficiency and factors of **16** to **64** in field coverage.
- NGOS will outperform Hydra by factor of **10** in efficiency.
- NGOS serves as technical stepping stone to the Spectroscopic Wide Field Telescope (>8 meter aperture, >1.5 degree field spectrograph).

# VPH Grating Technology

Instrument concept is based upon volume-phase holographic gratings (*see related poster by Arns, Colburn, Barden, and Williams*).

- VPH gratings work in transmission.
- VPH gratings have high efficiencies.
- VPH gratings can be tuned to peak up efficiency at desired wavelength.
- VPH gratings can be designed to always work in Littrow configuration, simplifying camera optics by minimizing anamorphic factors.

## VPH Gratings (continued)

Additional benefits to VPH gratings are:

- Encapsulated nature protects grating and allows element to be handled and cleaned.
- Anti-reflection coatings can be applied to grating element surfaces.
- Large sized gratings are possible (up to and possibly larger than 300 mm).
- Complex grating structures are possible (e.g. two gratings in one assembly).



# Beam Diameter

There are several issues that push the spectrograph towards a larger beam diameter:

- Resolving power is increased for a given grating line density.
- Angular bandwidth is increased for a given resolving power.
- Field angles are reduced for a given field of view.

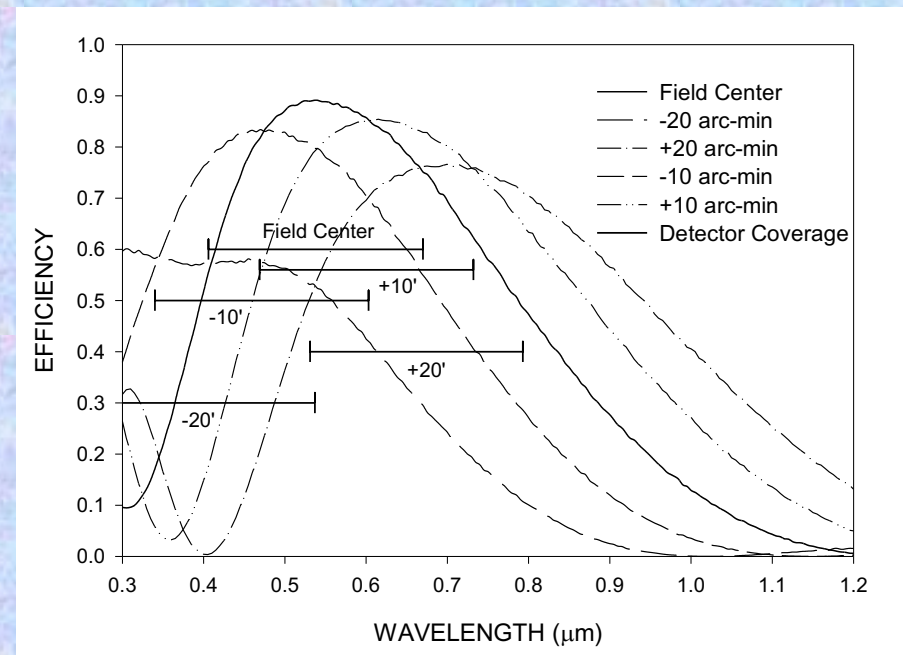
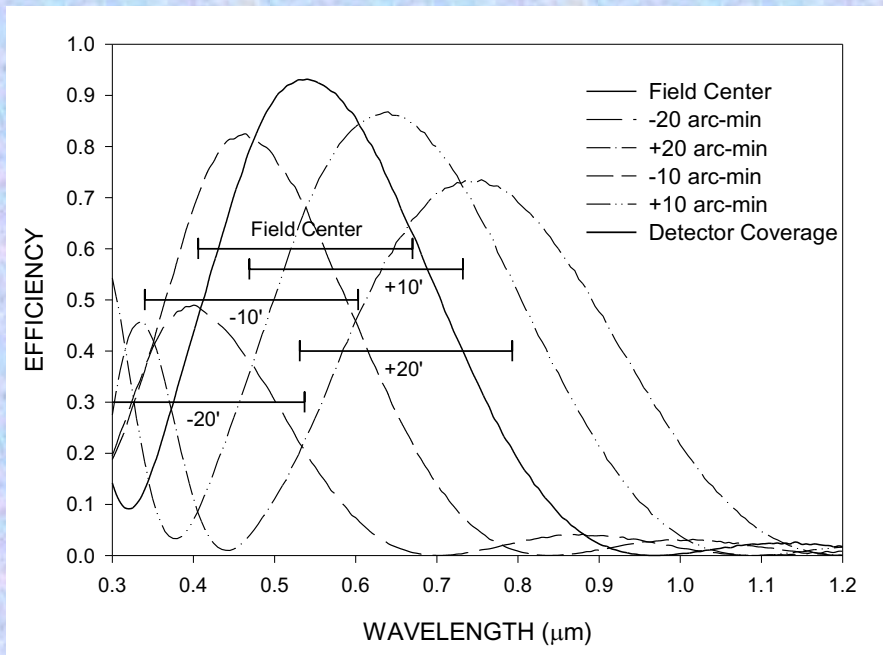
A minimum beam diameter of 200 mm is required to optimally achieve many of the design goals for NGOS.

A 300 mm beam diameter would further improve the performance of the instrument.

# VPH Grating Angular Bandwidth

High line density VPH gratings have narrow bandwidths which might limit the usable field. Large beam diameters reduce this effect for a given resolving power.

Left figure shows effect with a 150 mm beam at R=5000, right figure shows increased bandwidth performance from a lower line density grating providing the same resolving power in a 200 mm diameter beam.



# Tunable Spectrograph Concept

Title:

Creator:

CreationDate:

- Schematic of a tunable spectrograph which takes advantage of VPH gratings by implementing a camera that can be articulated with respect to the collimator and grating.
- Tunable for peak efficiency at the desired wavelength.
- Tunable for diffraction order.
- Adjustable prisms may minimize the level of camera articulation required.

# Design Challenges

- **Space constraints** - How to fit a coude-sized spectrograph at the Cassegrain focus.
- **Articulated camera** - Minimize flexure while allowing adjustability.
- **Maximizing efficiency** - Minimal optics, workable glass choices, and robust anti-reflection coatings.
- **Slit masks** - Mechanical stability with rapid production, minimal setup overhead, and minimal recurring cost.

# F/6 vs F/8 Implementation

## F/6

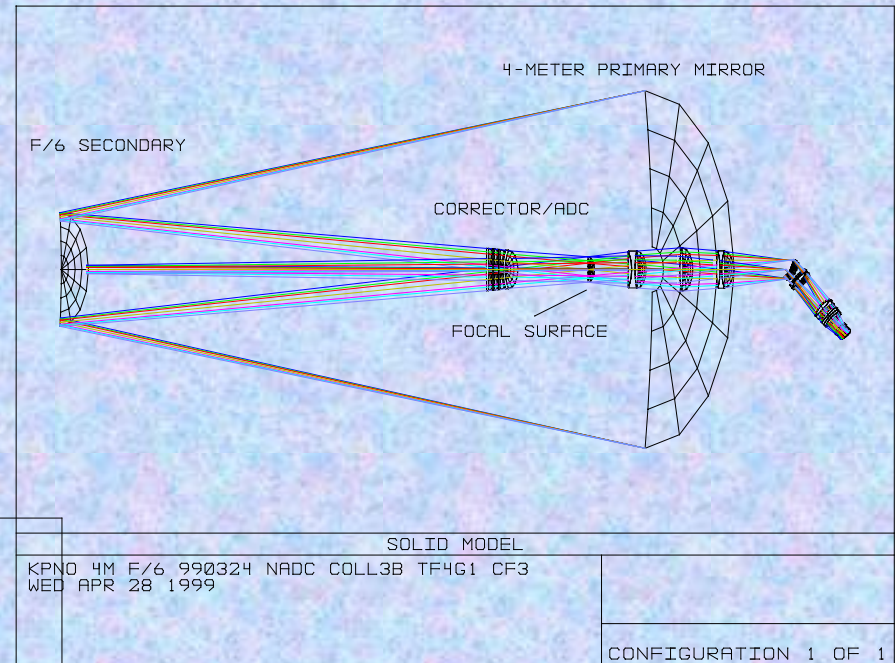
- Requires new secondary.
- Focal surface above primary mirror.
- + Provides sufficient space for beam sizes of 200 and 300 mm with an all transmissive system.
- + Wide field corrector and ADC design give excellent image quality.

## F/8

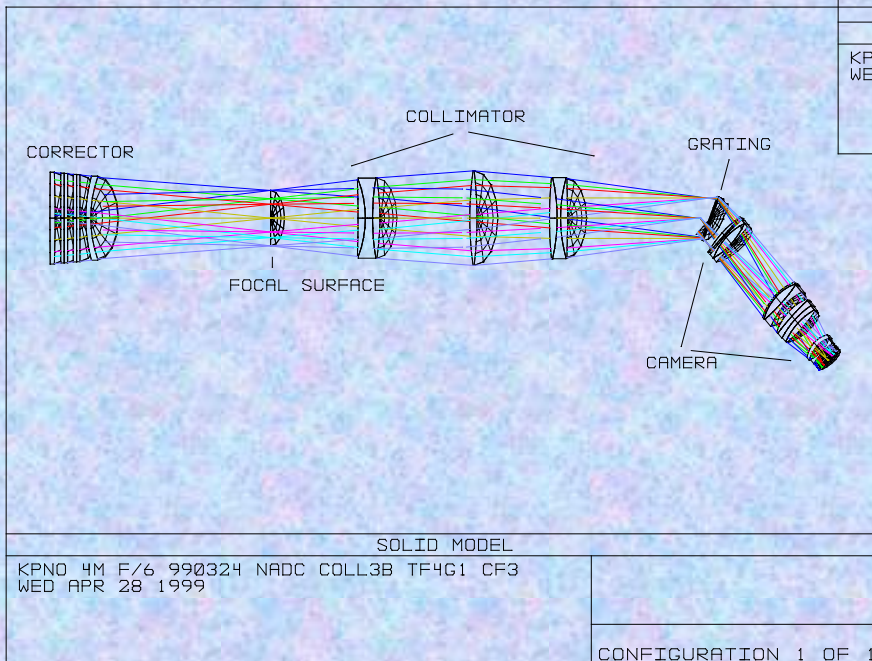
- Unlikely to fit >150 mm beam instrument.
- Likely to require optical folding with mirrors.
- Unlikely to achieve full 40 arc-minute field of view.
- + Retains current secondary and correctors with excellent image quality.
- + More compatible with other Cassegrain instruments.

# F/6 Optical Layout Concept

Conceptual layout of a monolithic spectrograph with a 200 mm beam diameter fed by an f/6 secondary. The focal surface is displaced to a position above the primary in order to provide adequate space in the Cassegrain cage.



Details of the wide-field corrector, ADC, focal surface, collimator, grating, and camera.



# Monolithic vs Quadrant Spectrographs

## Monolithic Spectrograph

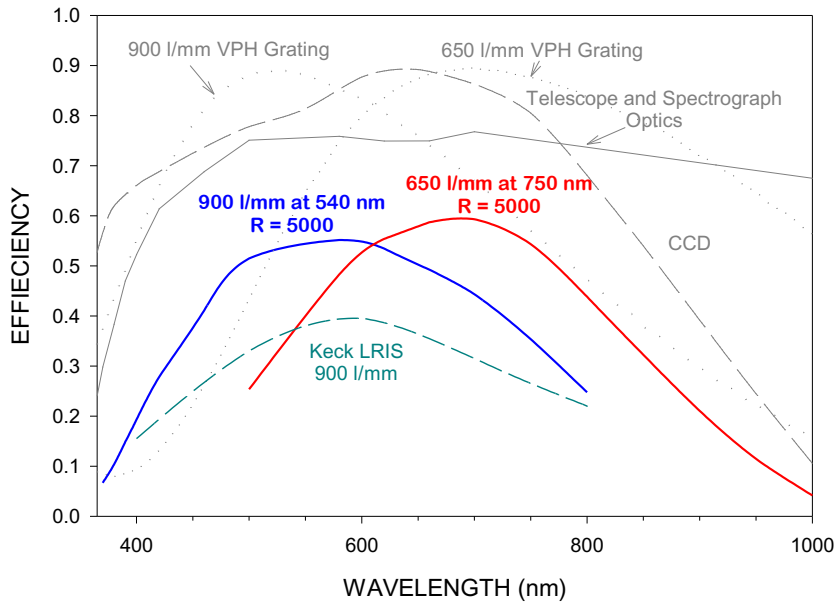
- Single beam, full field.
  - Large optics.
  - May be difficult to fabricate.
  - Requires large detector mosaic.
- + Minimal number of fabricated elements and moving components.
- + Complete field coverage.

## Quadrant Spectrograph

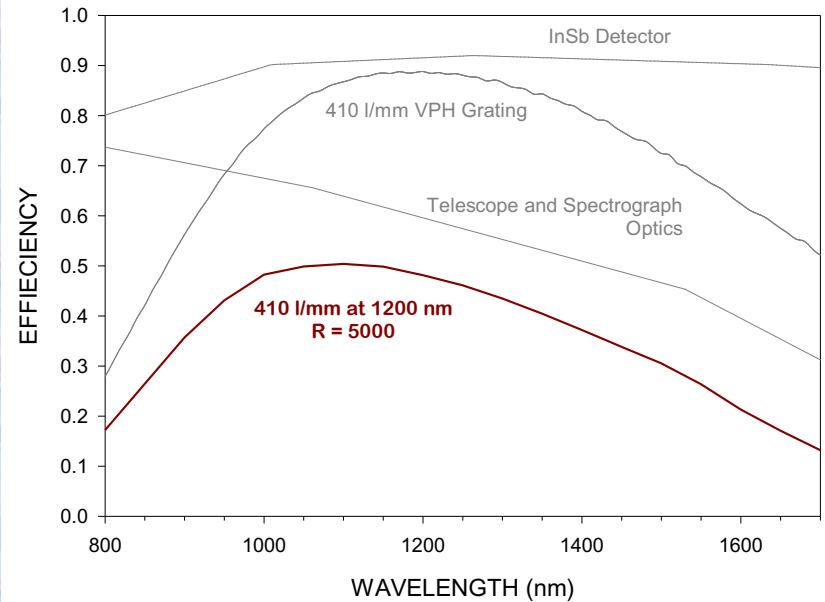
- Four spectrographs, divided field.
  - Lots of fabricated elements and moving components.
  - Incomplete field coverage or gaps due to field division.
- + Smaller, more realizable optics.
- + Smaller mosaic array per spectrograph.

# Estimated Efficiency\*

Total System Predicted Efficiency  
Telescope, Optics, Grating, Detector  
Optical Region



Total System Predicted Efficiency  
Telescope, Optics, Grating, Detector  
IR Region



\*These curves were generated for SWIFT concept in which silver coated telescope mirrors were assumed. NGOS would be about 5 to 10% lower due to aluminum mirror coatings. Resolving powers would also be higher with NGOS (R=8000 for 300 mm beam and 1" slits).



# Development Timeline

- Initial concept study FY99 to mid-FY00.
- Final design and fabrication FY-00 to FY03.
- Science commissioning in FY04.

This is an ambitious instrument which stresses the available resources at NOAO. The development timeline will likely inflate by nearly a factor of 1.5 to 2 without any enhancement in resource availability.

Progress is also dependent on the spectroscopic wide field telescope (SWIFT) project. If SWIFT moves forward, NGOS may be scaled down to a prototype or proof of concept for the more ambitious SWIFT spectrograph.

## Community Feedback Requested

Please feel free to comment on and give us your thoughts about this project. We would also greatly appreciate any design requirements which might enhance the science you would be interested in doing with this instrument.