

Goals: minimize complexity
minimize size, weight (~2m, 1200lbs)
minimize cost (\$1.1M)
complete wavelength coverage (3200A-1 μ m)
high resolution, high efficiency

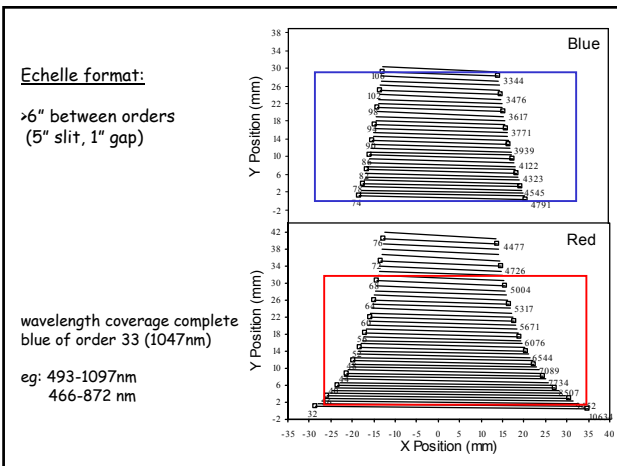
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- double beam (red/blue optimization)
- prism cross-dispersion
- double pass (including prisms)
- standard replicated gratings, in Littrow

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<u>Blue</u>	<u>Red</u>
$\lambda = 3200-4800\text{A}$	$\lambda = 4400\text{A}-1\mu\text{m}$
$R \approx 25,000$ (1" slit)	$R \approx 19,000$ (1" slit)
2 fused silica prisms (apex 38°) R2.6 (6x16in, 52.7 l/mm, 69°) 2k x 4k x 15 μ m CCD	PBM2 prism (apex 47°) R2 (6x12in, 52.6 l/mm, 63.5°) 2k x 4k x 15 μ m CCD



MIKE: Red side (4400A - 1 μ m)

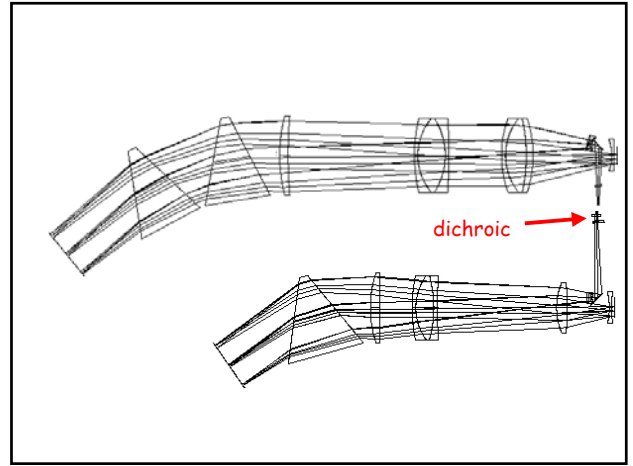
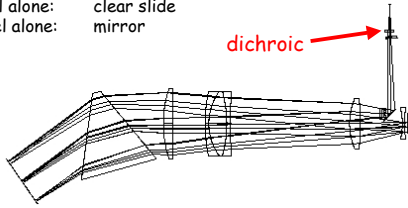
Camera: F/3.3 (1" = 105 μ m = 7 pixels)
150mm pupil, 70mm diameter field
2.8 μ m rms image radius

CaF2 (in triplets), Ohara glasses
AR coatings: avg reflectance 0.5% (0.7% peak)
60-70% transmission through optics

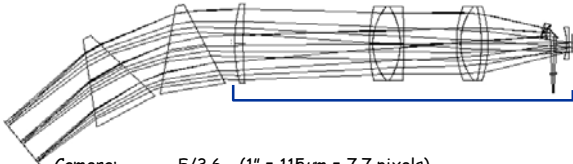
Dichroic:

4mm thick window
back side AR coated
crossover at 4550A (4400 - 4800A)

Red channel alone: clear slide
Blue channel alone: mirror



MIKE: Blue side (3200-4800A)



Camera:

F/3.6 (1" = 115µm = 7.7 pixels)
150mm pupil, 70mm diameter field
2.9µm rms image radius

CaF2, Ohara i-line, fused silica
>70% transmission at λ ≥ 3400A (5% by 3200A)
AR coatings: avg reflectance 0.75% (1% peak)

Bonded elements: Sylgard 184 (Dow Corning optical RTV)

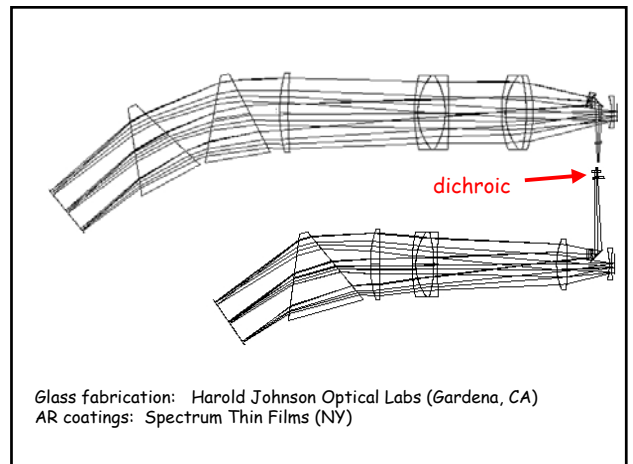
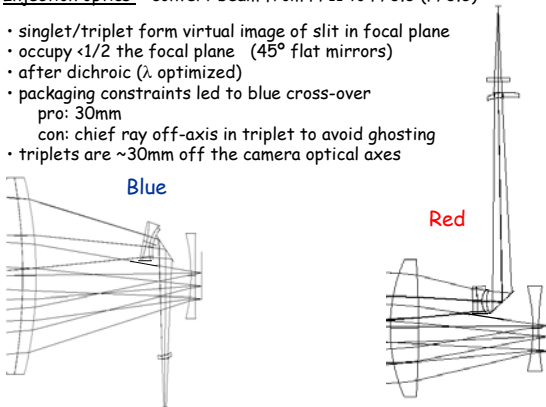
large triplets: 0.25 mm thick (compliance for thermal expansion)
prisms, small triplets: 0.1 mm thick
total path: 2.5mm (97% transmission at 3100 A)
curing time: 1 week at 15° C (operating temp 0-20 ° C)

Simple fixtures held elements while RTV cured.
Manually aligned.



Injection optics: convert beam from F/11 to F/3.3 (F/3.6)

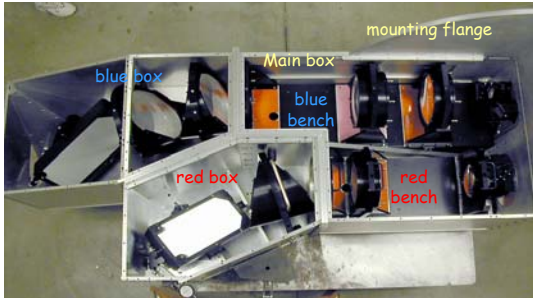
- singlet/triplet form virtual image of slit in focal plane
- occupy <1/2 the focal plane (45° flat mirrors)
- after dichroic (λ optimized)
- packaging constraints led to blue cross-over
pro: 30mm
con: chief ray off-axis in triplet to avoid ghosting
- triplets are ~30mm off the camera optical axes



Glass fabrication: Harold Johnson Optical Labs (Gardena, CA)
AR coatings: Spectrum Thin Films (NY)

Structure: Steve Gunnels

- modular - easy to modify (e.g. cart fixtures)
- easy access (e.g. injection optics)
- aluminum tooling plate ($\frac{3}{8}$ and $\frac{1}{2}$ -inch)
- all joints keyed (light tight)



Rettig Machine (Redlands,CA), Martinez & Turek (Rialto,CA), R. Storts (OCIW)

Structure (cont'd):

Blue plate:

- slit plate
- slit viewing optics
- flipper mirror
- dichroic
- field lenses
- shutters
- blue injection optics
- blue dewar
- diffusing window (flats)



Detectors (Red and Blue):

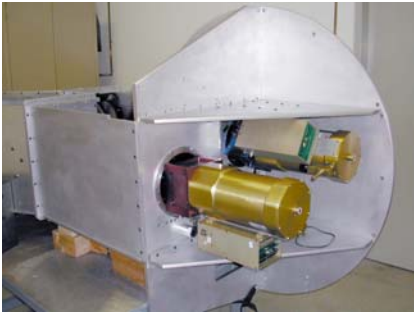
- 2k x 4k x 15 μ back-illuminated CCDs
- SITe ST-002A (Blue: Lincoln Labs CCID-20, when delivered)
- standard, broadband AR coatings

Dewars & CCD electronics: Thompson & Burley (Waimea Detectors Conference, 2002)

- IR-Labs ND-5 cryostat
- liquid nitrogen cooled, ~15 hour hold time (horizontal)
- custom controllers
- field flattener windows

Red/Blue are independent operation, shutter-controlled exposure times.

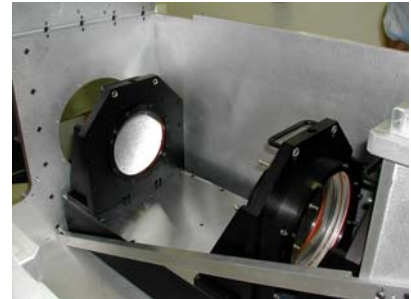
SITe CCDs: read noise ~4 e-/pixel readout 80s (unbinned)



Optical mounts:

Cameras on independent optical benches

- mounted on flexures - focus adjustment (± 1 mm travel)
- remotely adjusted by a worm gear driven eccentric cam
- thermal sensitivity (dn/dT) compensated passively ($\pm 5^\circ\text{C}$)

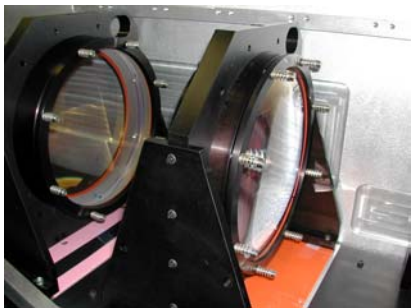


Optical mounts:

- all contact to glass through silicone pads, no contact to CaF2
- kinematic mounts
 - Radially: 2 defining pads, 1 spring-preloaded floating pad
 - Axially: fixed ring, spring-preloaded ring
 - vertical gusset plates, reinforced laterally.
- Adjustments:
 - push/pull screws
 - shims for height

- Prisms: radially
- Gratings: nylon pads, spring preloads

** nothing fixed to glass



Controls:

1. focus control

- flexure-mounted benches
- positioned by motor driven cam
- invar plate: passive thermal focus compensation ($\pm 5^\circ\text{C}$)

2. slit plate

- linear slide, fixed blocking plate
- motorized lead screw
- slit viewing optics for slit selection



Controls (continued):

- 3. comparison source
motorized flipper mirror
hollow cathode lamp.
- 4. manual grating adjustment (altitude, azimuth)
manual screw + spring preload
position from dial indicators
- (5.) diffusing slide for flats
(manual slide)
- (6.) dichroic/mirror/window
(mounted on a removable block)

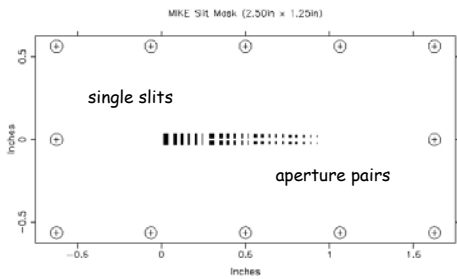


Standard observing modes:

- mounted on Nasmyth platform
fixed position optimized for atmospheric dispersion
(0-0.2" across slit at 0-40 deg zenith angle)
gravity invariant
- mounted on Nasmyth instrument rotator
fixed position angle on sky
not gravity invariant
astatic support for flexure control
- mounted at auxiliary port
atmospheric dispersion always along slit
not gravity invariant
astatic support for flexure control

Observing modes:

•standard: slit selected from mask (5" long max, 0.35-2" wide)



- fiber-fed (Mario Mateo, Alex Athey at U. Michigan)
•128 blue, 128 red fibers, 1.4" aperture reimaging lenses
•plug-plate system w/ telecentrator, 30' field

Optical performance: theory

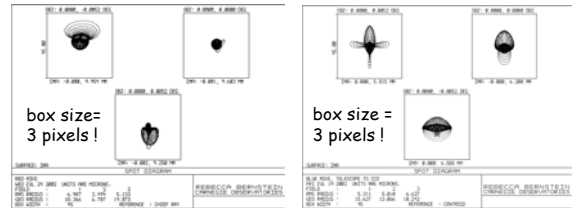


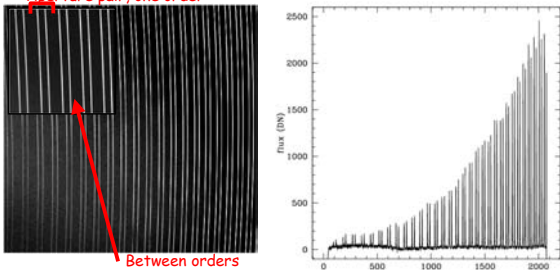
image size
10.4μ rms diameter **11.8μ rms diameter**

Max Resolution (0.35" slit):
R~ 54,000 **R~71,000**

(image variation over field due to off-axis injection optics)

Optical performance: practice

Aperture pair, one order



Between orders

Image tests: **continuum source**
apertures: 0.37" diameter (2.5" gap)
2.6 pixels, 2.8 pixels

→ FWHM of lines = **2.8 pixels** **3.0 pixels**
Note: very low scattered light, clean order separation

Optical performance: practice

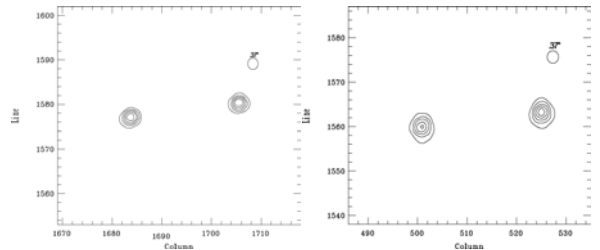
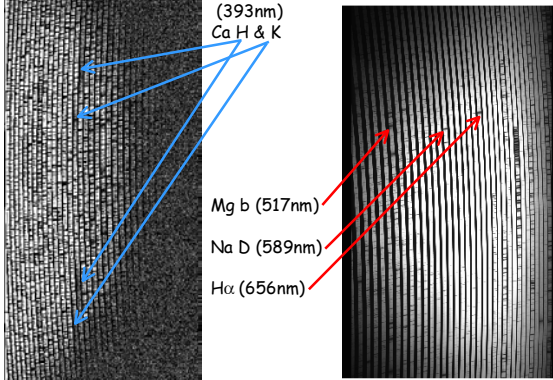


Image tests: **comparison source**
apertures: 0.37" diameter (2.5" gap)
2.6 pixels, 2.8 pixels

→ FWHM of lines = **2.8 pixels** **3.0 pixels**

Optical performance: practice, a solar spectra (daytime)



(through a 5mm thick glass diffuser)

Optical performance: practice, a solar spectra (daytime)

cross-cut, illustrating order separation, scattered light

