

Update on new spectrometer for SOL and divertor measurements on NSTX*

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NSTX Review, 27 August 2009, Princeton, NJ

New spectrometer is part of ARRA funded effort in support of LLD studies on NSTX

- Divertor source characterization
 - Atomic D, Li, C influx **profile measurements in divertor**
 - Molecular sources (D₂, LiD, BD, CD₄, ...)
- Divertor ion sink characterization
 - Electron-ion recombination patterns in divertor (D, He, Li)
 - High- n Balmer (and Paschen) series lines for n_e , T_e estimates
- **Ion temperature** measurements in divertor (based on Doppler broadening) for ion heat transport analysis
- Various applications
 - Divertor and edge measurements in HHFW-heated plasmas
 - Near-infrared spectroscopy for ITER
 - Possibly, SOL flow measurements and helium line ratios
 - Possibly, LTX impurity profile measurements

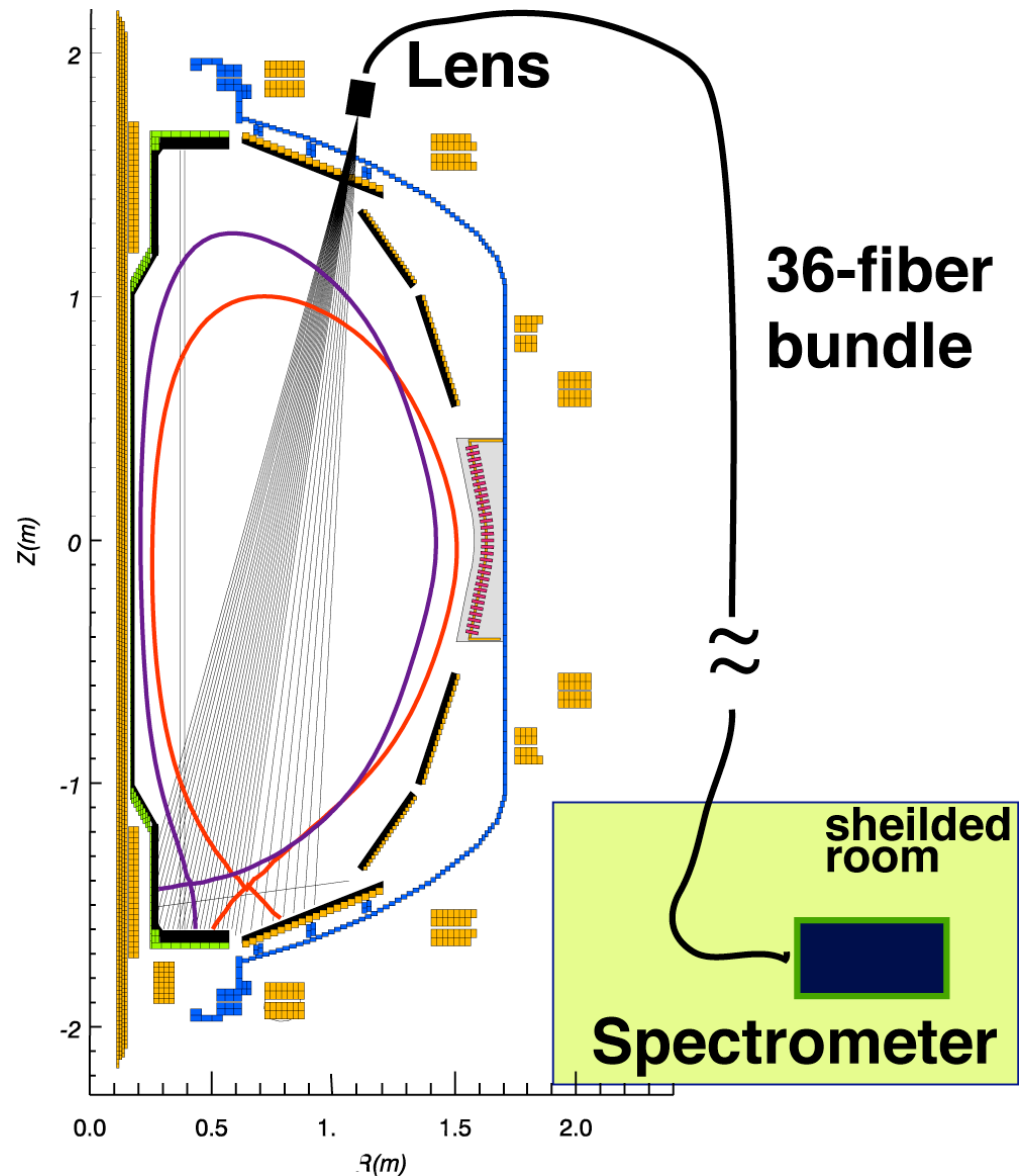
Conceptual requirements to new spectrometer

Diagnostic requirement	Input optics, including fibers	Spectrograph	CCD camera detector
Full divertor coverage with 1 cm resolution	Long FL imaging lens; Small diameter fibers	Stigmatic, aberration-free imaging of input slit of < 1 cm height	CCD chip height
Broadband spectral coverage 350-1200 (1900) nm	Low attenuation in range	Several gratings	Broadband sensitivity
Temporal resolution 1- 50 ms	Optimized throughput	Largest f/# for given size	Fast readout
High spectral resolution > 0.01 nm	Optimized throughput, imaging of divertor on entrance slit	Large size; 2400-3600 gr/mm gratings	Small pixel size (10-15 um)
High imaging quality	Stigmatic, aberration-free imaging	Stigmatic, aberration-free imaging	Square chip

System layout and Components

- Imaging lens
- 30 m fiber bundle
- Spectrometer input optics
- Spectrograph and gratings McPherson Model 207
- CCD detector Princeton Instruments ProEM 512B

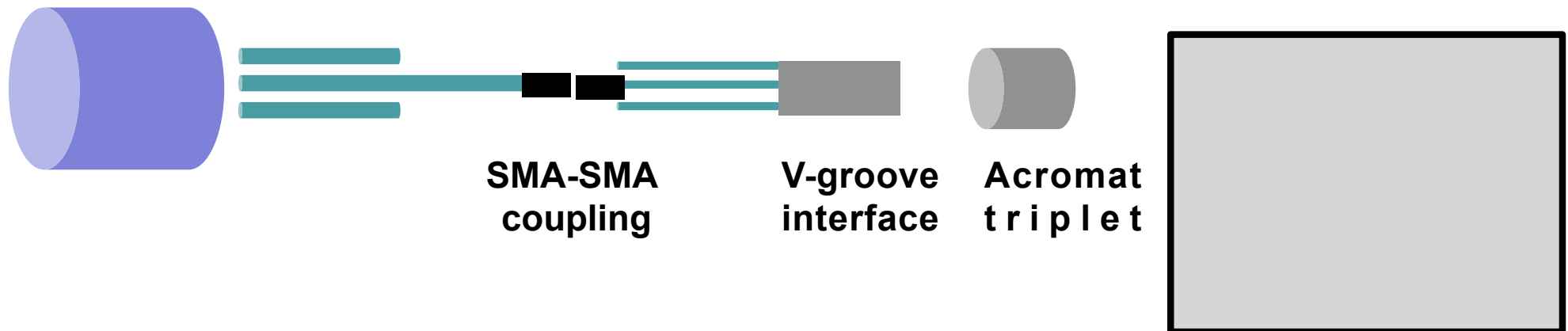
* Reviewed 05/22/2009



Conjugation of optical components

- Matching F numbers:

Lens: 4.5 - Fiber: 2.3 - Matching optics: 4.0 - Spectrograph: 4.7



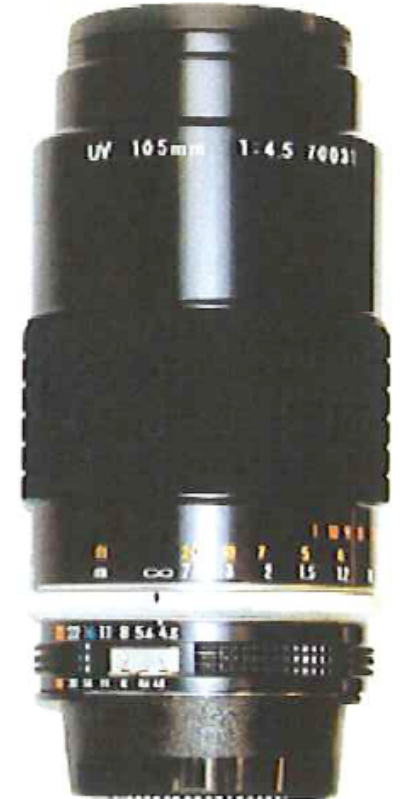
- Magnifications:

Lens: 1./16.7 - Fiber: 1 - Matching optics: 1. - Spectrograph: 1

Imaging lens

- Present lens –
Nikon model Nikkor NIK18028DAF, $f=180$ mm, $f/\#$ 2.8
- New lens: Tochigi Nikon 105mm, $f/\#$ 4.5

Focus Distance	105mm
Maximum Diameter Ratio	1:4.5
Lens Construction	6-set 6-piece
Color Correction Range	220nm ~ 900nm
Angle Of View	23°20'
Distance Range	∞ ~ 0.48m 1.57ft
Magnification Ratio Range	1:10 ~ 1:2
Aperture Range	4.5 ~ 32
Mount	Nikon F mount
Attachment Size	M52 (P=0.75)
External Dimension	Φ 68.5
Length	116.5mm (108mm from the mount base surface) = 4.6"
Weight	515g = 1.14lbs



Daitron Inc.
<http://www.daitron.com>



Imaging lens

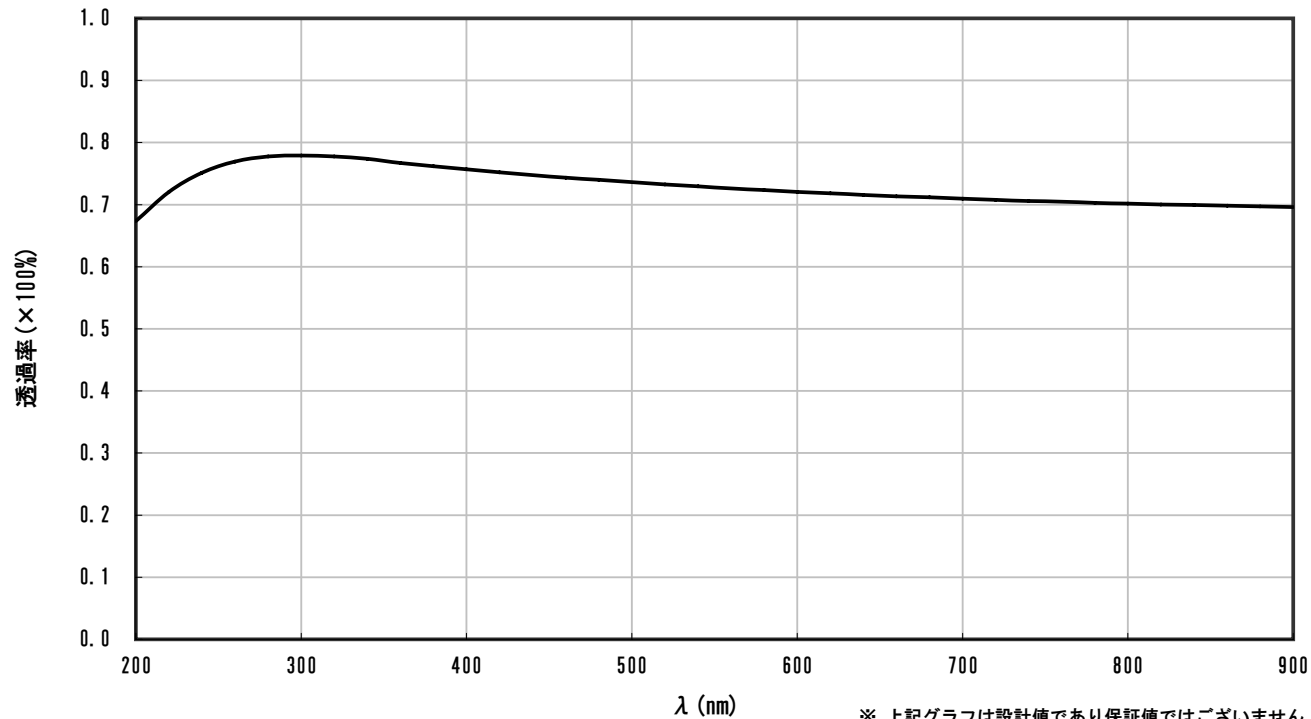
- Tochigi Nikon UV 105mm, f/# 4.5

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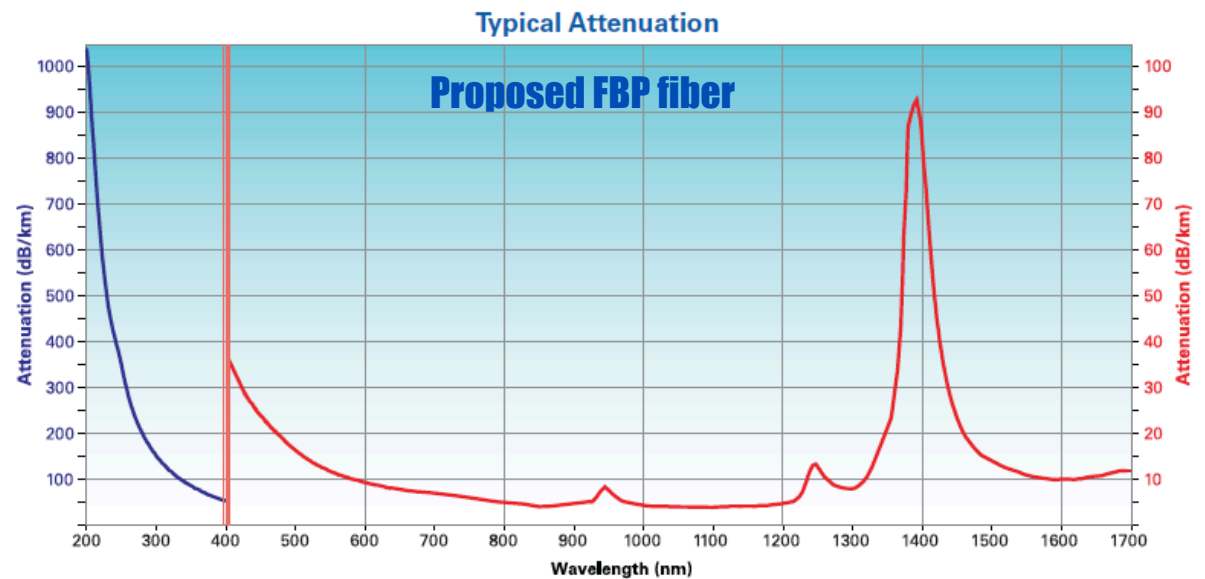
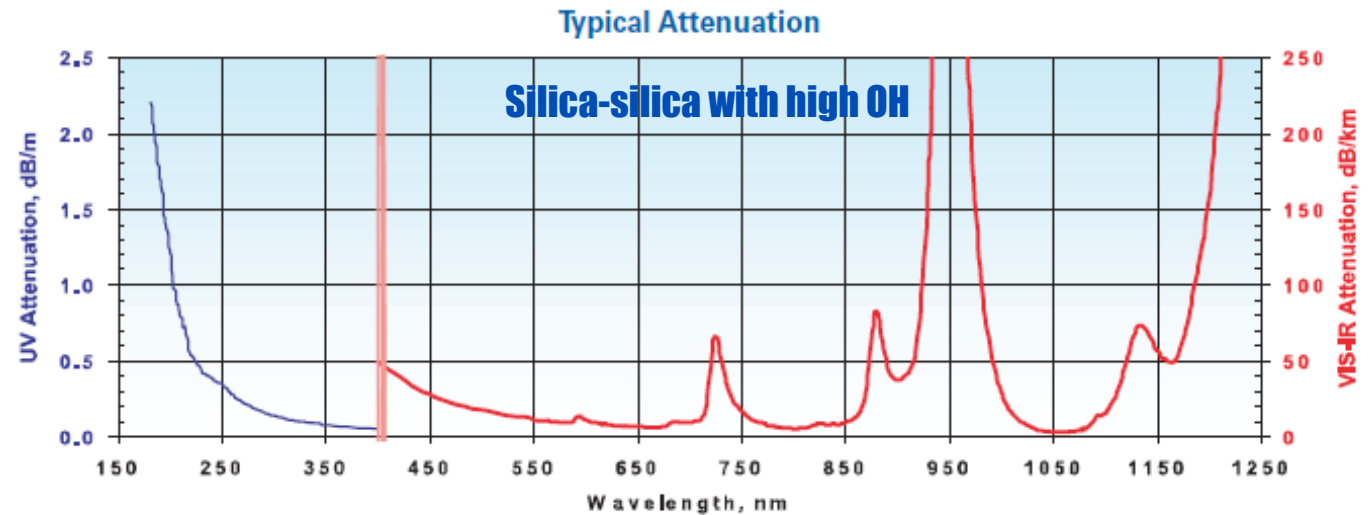
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紫外線撮影用レンズ UV-105mm F4.5 [PF10545MF-UV] 分光透過率特性



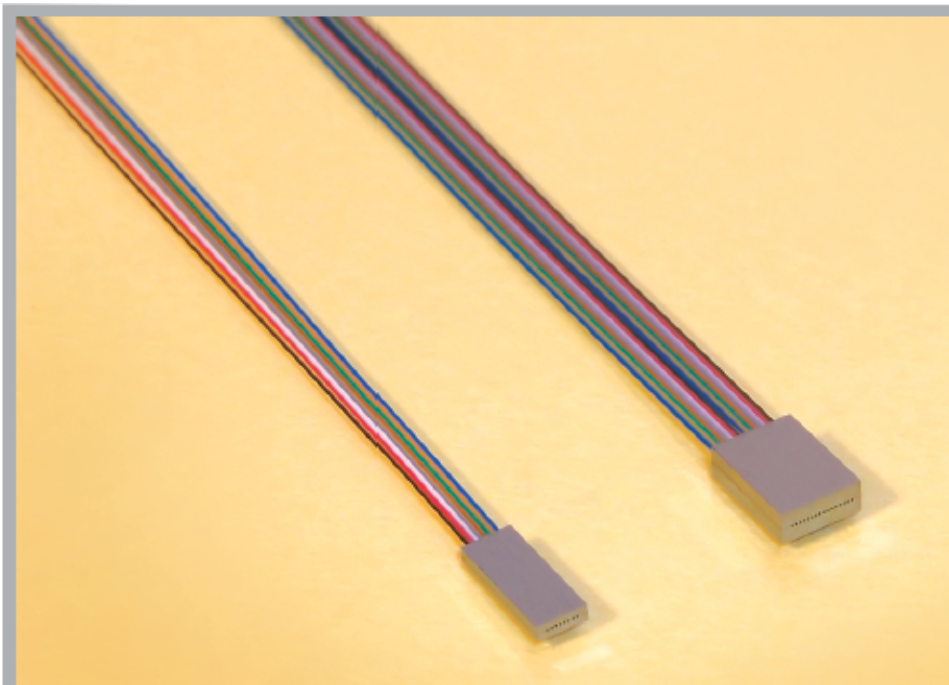
Fibers

- Typical choice – silica-silica with high OH
- Propose new Polymicro FBP broadband fiber
- NA=0.22
(f/#=2.27)
- Type FBP400440480,
- Diameter : 400 um core
- With Nikon imaging lens, estimated spots on divertor - 1 cm diameter

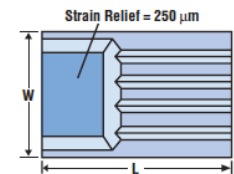
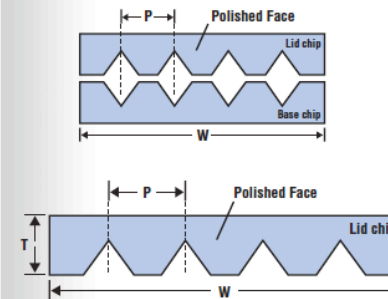


Spectrometer fiber V-groove interface

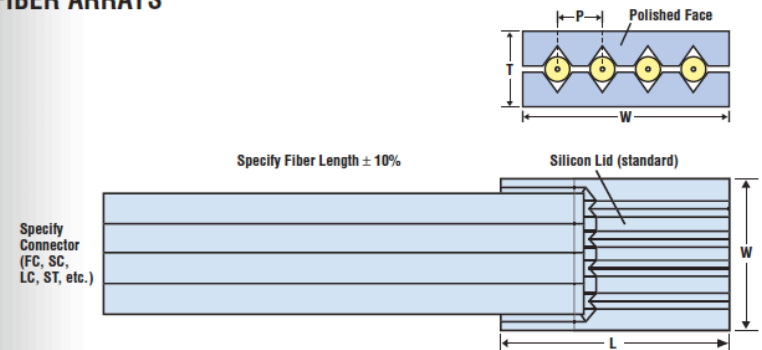
- Interface for 20 input fibers, same type FBP400 as delivery fibers
- Same diameter 400 μm



V-GROOVE CHIPS

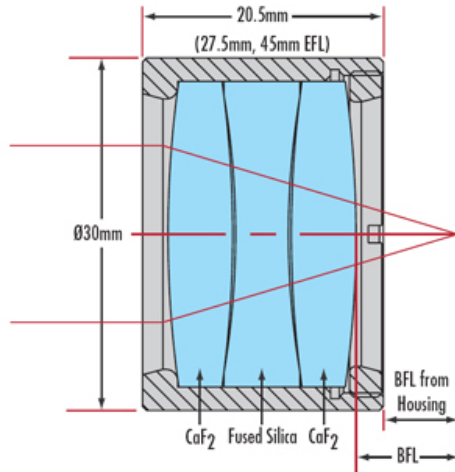


FIBER ARRAYS



Spectrometer front-end focusing optics

- Acromatic lens, 90mm EFL UV-to-NIR Corrected Triplet, Uncoated, Edmunds Optics, Model NT47-311
- Infinity-conjugated (i.e., need 2 to image fibers on slit)



Effective Focal Length EFL	193 - 400nm		400 - 1000nm		193 - 1000nm	
	Chromatic Shift	RMS Spot Size	Chromatic Shift	RMS Spot Size	Chromatic Shift	RMS Spot Size
45mm	1.1mm	88.1 μm	0.26mm	68.5 μm	1.3mm	96.6 μm
90mm	2.0mm	64.3 μm	0.55mm	37.9 μm	2.48mm	69.17 μm
135mm	1.6mm	48.7 μm	0.59mm	30.8 μm	2.14mm	50.71 μm
180mm	1.4mm	45.6 μm	0.61mm	28.3 μm	1.89mm	45.17 μm

Current shopping list

Item	Qty	Company	Price & delivery time
Front imaging lens on NSTX – Tochigi Nikon UV-105mm F4.5	1	Daitron Inc.	\$ 4200.00 4-6 weeks ARO
400-um fibers, type FBP400440480, polished and SMA connector terminated	30	Polymicro Technologies	\$ 10740.00 2-4 weeks ARO
McPherson Model 207 - 0.67m focal length f/4.7 spectrograph with accessories and gratings		McPherson Inc.	60-90 days ARO
• Spectrograph	1		\$ 20, 720.00
• 3600 g/mm grating	1		\$ 9,970.00
• 2400 g/mm grating	1		\$ 9,150.00
• 1800 g/mm grating	1		\$ 8,290.00
• Exit port mirror	1		\$ 1,840.00
• Imaging optic	1		\$ 1,810.00
• Alignment adapter	1		\$ 760.00
• CCD adapter	1		\$ 550.00
• Stepper drive system	1		\$ 3,550.00
CCD camera detector, Model ProEM:512B w/ unichrome UV coating	1	Princeton Instruments	\$ 37,750.00 45 days ARO or sooner
Acromatic lens, 90mm EFL UV- to-NIR Corrected Triplet, Uncoated, Model NT47-311	2	Edmunds Optics, Inc.	Available 11/11/2009 \$ 1,895.00

- No quote for V-groove fiber interface yet