DESIGN, FABRICATION, AND TEST OF WFIRST/AFTA GRISM ASSEMBLY

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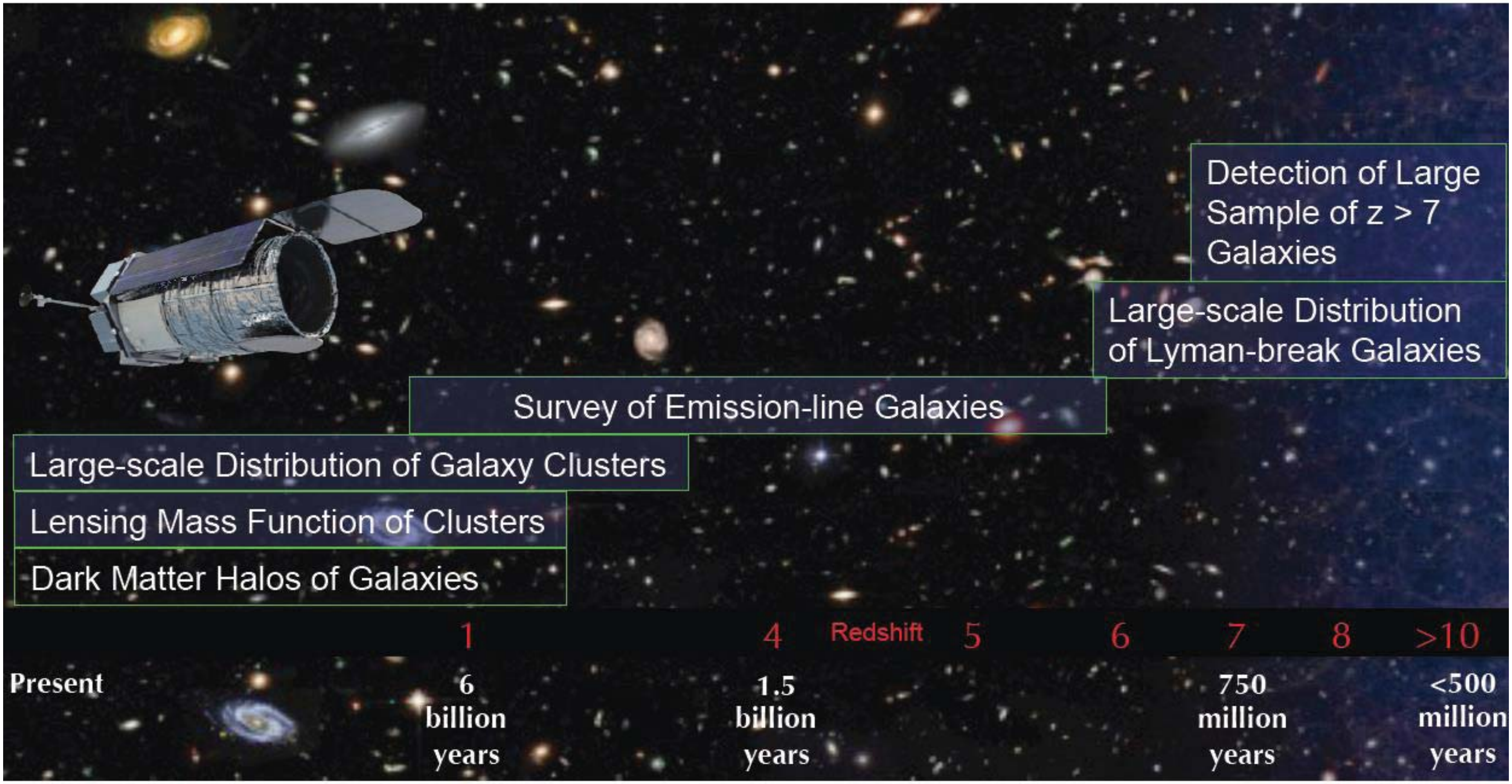
WFIRST-AFTA: A Unique Probe of Cosmic Structure Formation History

Using Observations from the High Latitude Survey and GO Programs



WFIST/AFTA & GRISM ASSEMBLY

- Wide-Field Infra-Red Survey Telescope (WFIRST) is designed to perform wide-field imaging and slitless spectroscopic survey of the sky.
- A compound grism assembly is selected as its slitless dispersing element.
- The challenge of this grism is the wider Field Of View (FOV), larger dispersion, and smaller f/#.
- The challenge is overcome by the innovative design of using two diffractive surfaces.

GRISM Comparison: WFIRST versus HST

- Grisms have been used in a number of Hubble Space Telescope (HST) instruments: Wide Field Camera 3 (WFC3), Near Infrared Camera and Multi-Object Spectrometer (NICMOS), Advanced Camera for Surveys (ACS), etc.
- There are 3 differences that makes WFIRST grism much more challenge than HST's:

	WFIRST	**HST WFC3**
FOV	0.28 degree^2	0.0012 degree^2
Spectral resolution	R = 700	R = 130
f/#	8	11

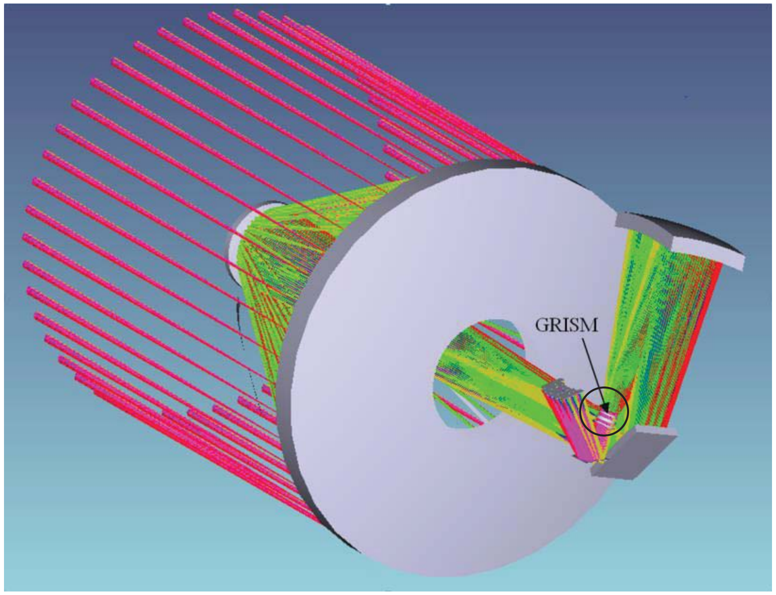
WFIRST GRISM SPECIFICATION

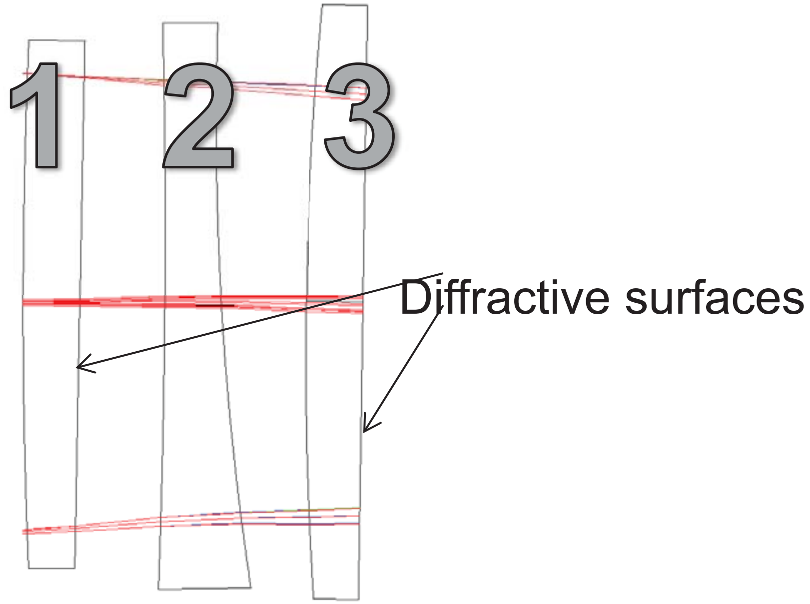
Wavelength range (μm)	1.35 – 1.95
FOV (°)	0.788 x 0.516
Beam diameter at grism (mm)	120
Beam f/-ratio at grism (mm)	~f/8
Wavefront error	Diffraction limited at 1.65μm
Spectral resolving power (per 2 pixels)	645 – 900 (461×λ)
Compactness	70mm total thickness for a fixed diameter ~120mm

DESIGN CONSIDERATION

- The main challenge of the grism design is how to correct the grating introduced aberration in non-collimated space? Besides, it needs to be compact enough to fit into a filter wheel slot. It also needs to be designed parforcal to other filters.
- The aberration is huge at large incident angles (±12.5°) and the amount of aberration is proportional to wavelength.
- The wavelength dependent aberration is very difficult to correct using non-diffractive lenses, even with many freeform surfaces.
- The key is to find a right compensator: another diffractive surface "diffractive lens"

GRISM OPTICAL DESIGN

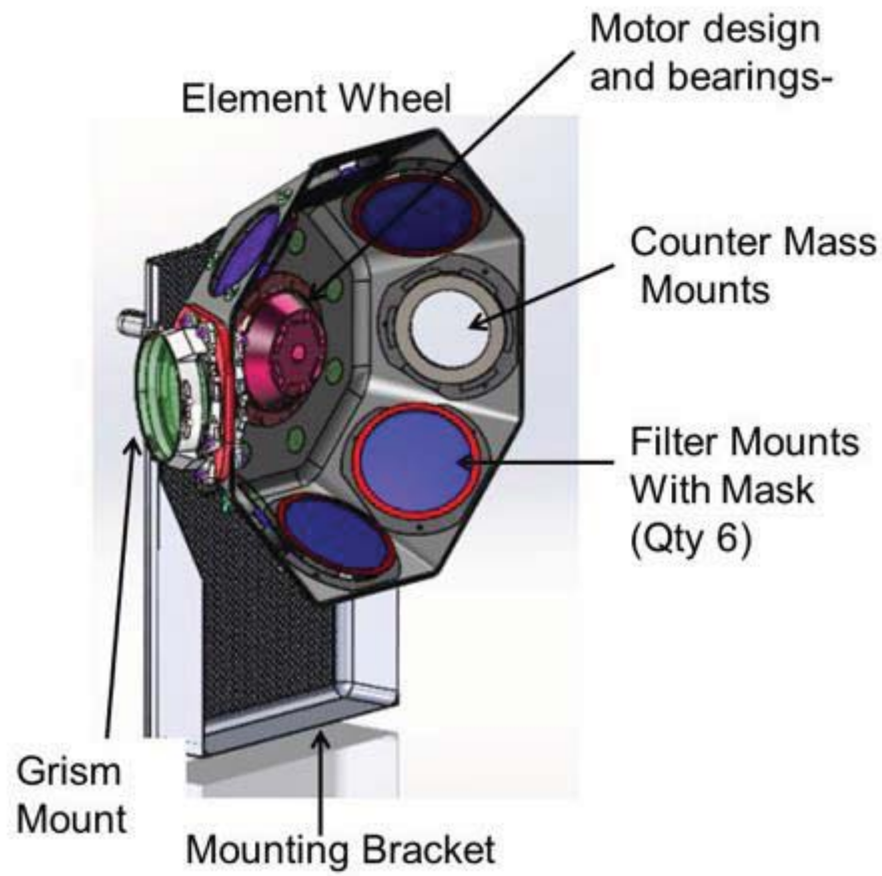




Element 1:	Element 2:	Element 3:
Substrate: fused silica	Substrate: fused silica	Substrate: fused silica
Function: bandpass filter and aberration corrector	Function: prism to make grism zero deviation	Function: grating to provide required dispersion
S1 is sphere, and S2 is diffractive lens on flat	Both S1 and S2 are spheres	S1 is sphere, and S2 is grating on flat

GRISM IN WFIRST ELEMENT WHEEL

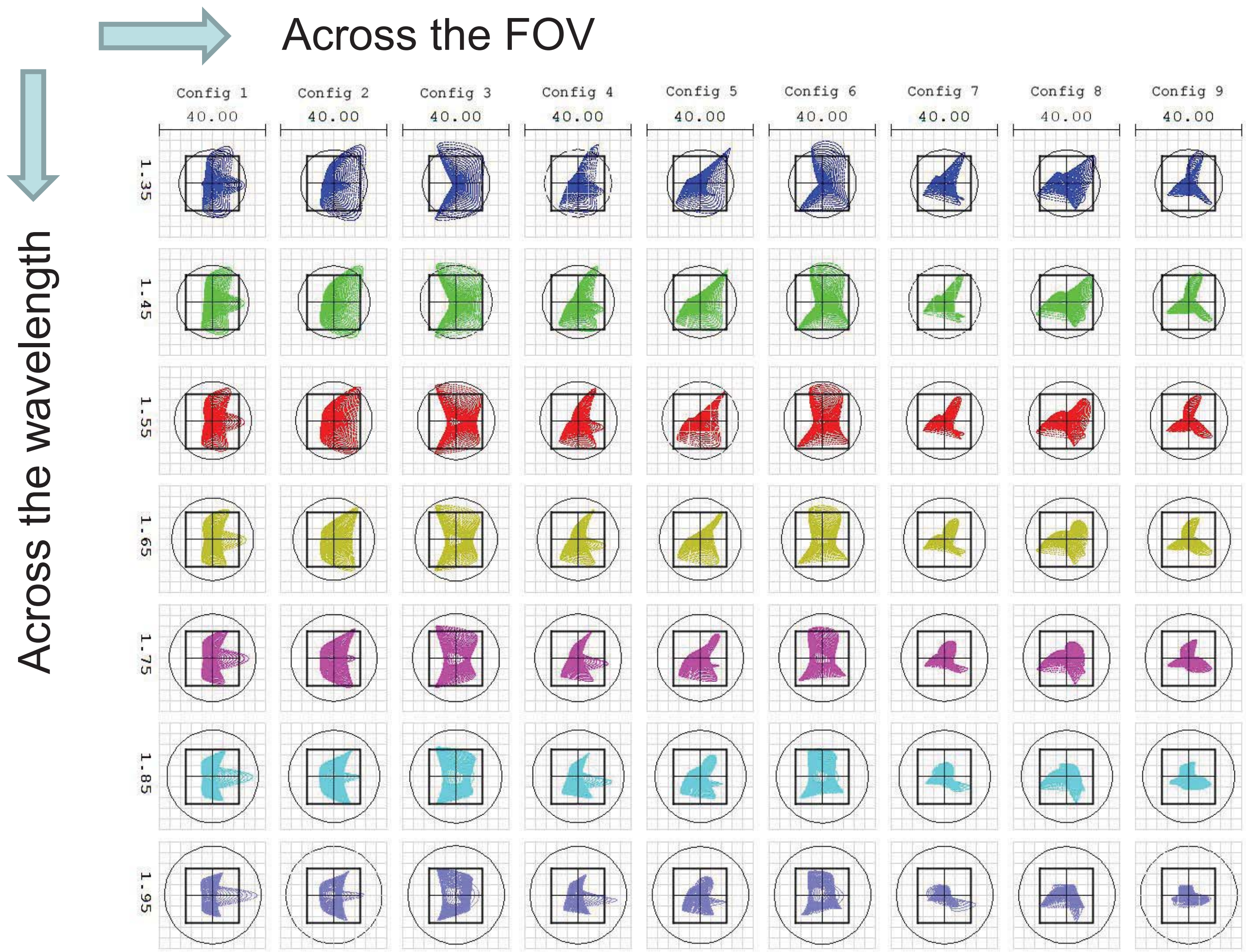
- WFIRST/AFTA has a number of subassemblies, the element wheel is one of the major assemblies.
- Grism assembly is one element in the element wheel.
- Grism has to be compact enough in thickness to avoid conflict with the beams and other subassemblies.



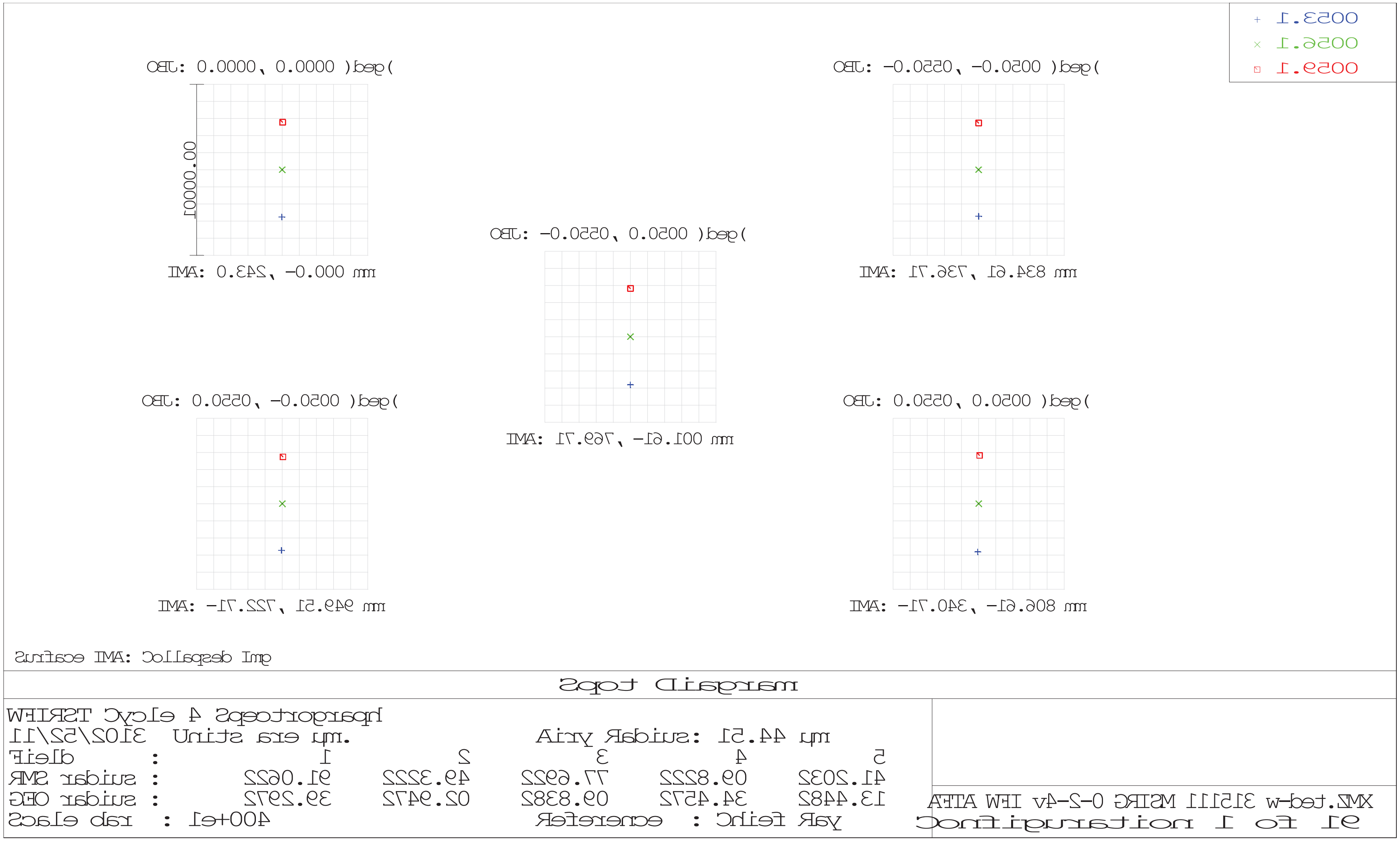
GRISM MATERIAL SELECTION

- Fused silica is selected for all grism elements. Its property is well know and well characterized.
- The diffractive patterns will be ion etched into the lens substrate. The fused silica is one of the best choices for reactive ion etching.
- Because of the more reproducible and small temperature derivative of refractive index of the fused silica, the fabrication and alignment tolerance are greatly relaxed.
- Fused silica has been well characterized at WFIRST operation temperature 170°K.

DIFFRACTION LIMITED PERFORMANCE

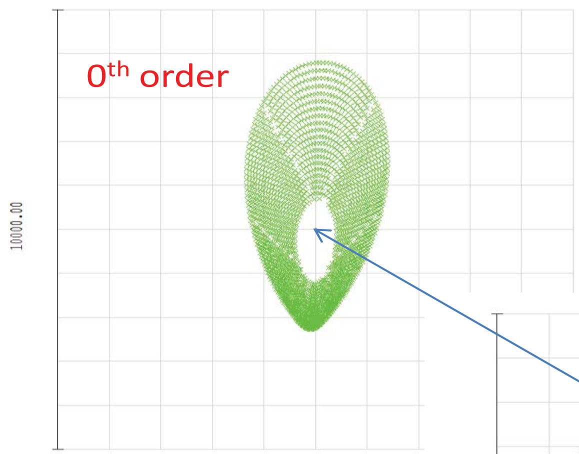


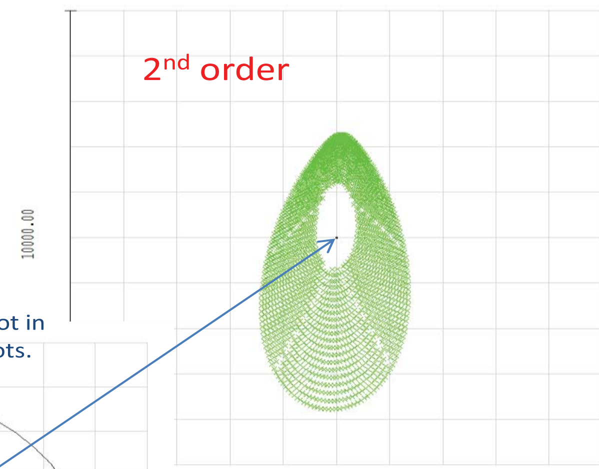
SPECTRAL RESOLVING POWER MEETS SPECS.

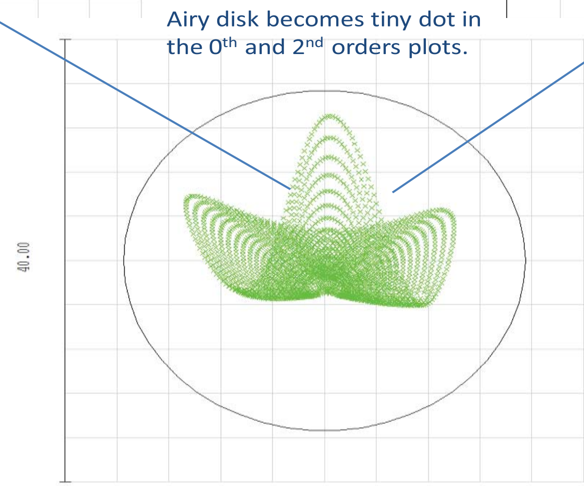


REMOVE UNWANTED GRATING ORDERS TO BACKGROUND

Spot diagram for different diffractive lens orders





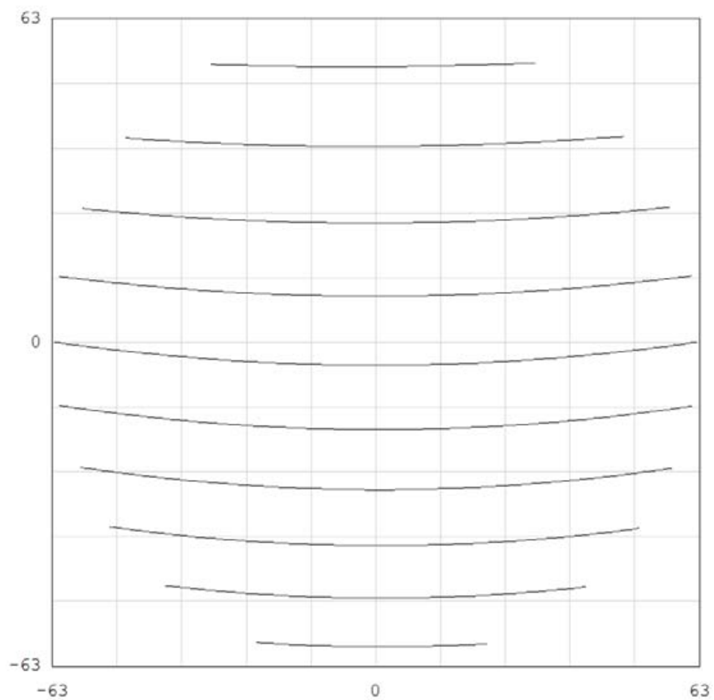


Grating order is +1.

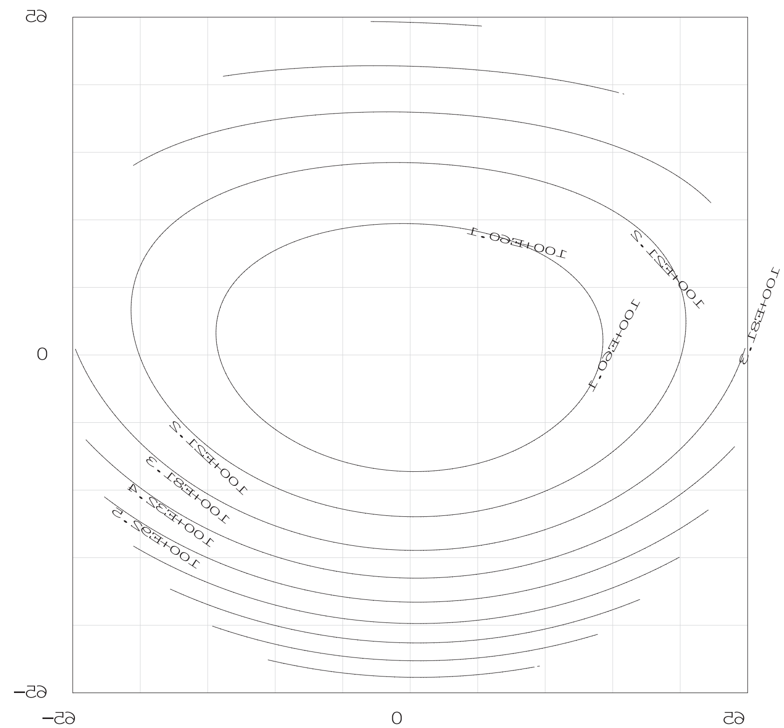
Please notice the scale difference: the 0th and 2nd orders scale bars are 10mm, the 1st orders is only 0.04mm. The rough calculation shows that the intensity of combined 0th and 2nd orders in each pixel is only about 5×10^{-5} of 1st order's, assuming 1st order efficiency is 80%, 0th and 2nd orders have same efficiency.

1st order: fabricated to include >90% energy

PATTERNS OF TWO DIFFRACTIVE SURFACES

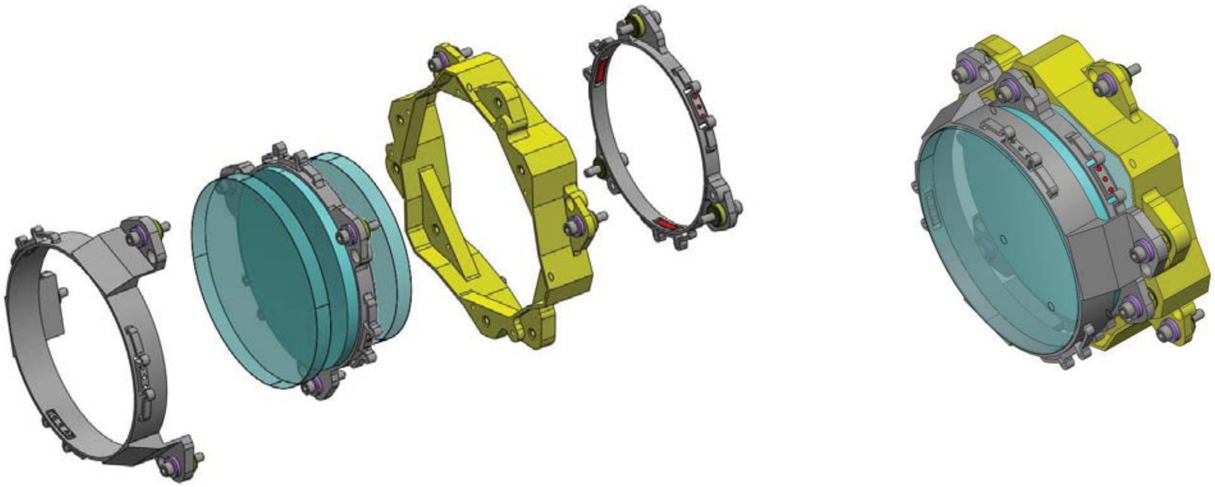


Grating contour. There are 165 lines between the two plotted lines.



Diffractive lens contour. There are ~10 lines between the two plotted lines.

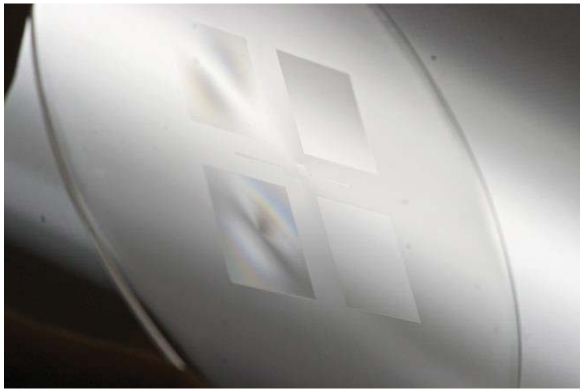
ASSEMBLY'S MECHANICAL DESIGN



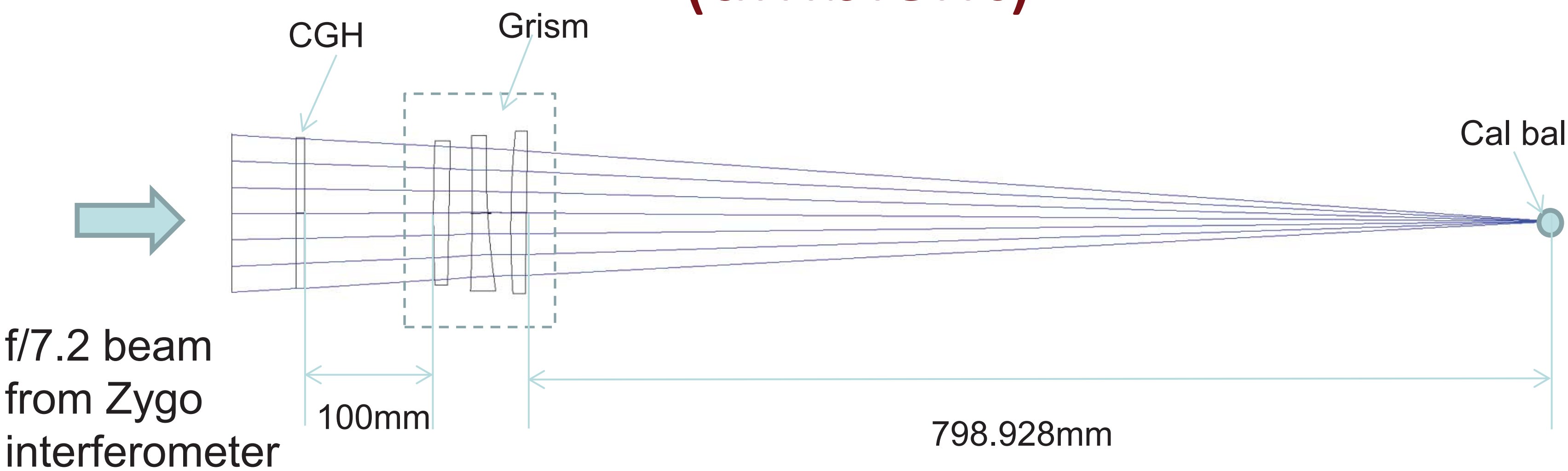
- Titanium is selected as element mount material to minimize the wavefront distortion at 170°K.
- A ring structure tested in similar environment for another project is used to further control CTE mismatch introduced wavefront degradation.
- 5 degrees of freedom are designed into two of the three elements to provide desired adjustment.

DIFFRACTION EFFICIENCY OF SAMPLES

- Four diffractive samples have been made in one fused silica wafer.
- The samples were designed for HeNe wavelength at 632.8nm in order to simplify the measurement.
- There are two diffractive lenses and two grating patterns on the wafer.
- The measured results show the diffraction efficiency is over 90%.

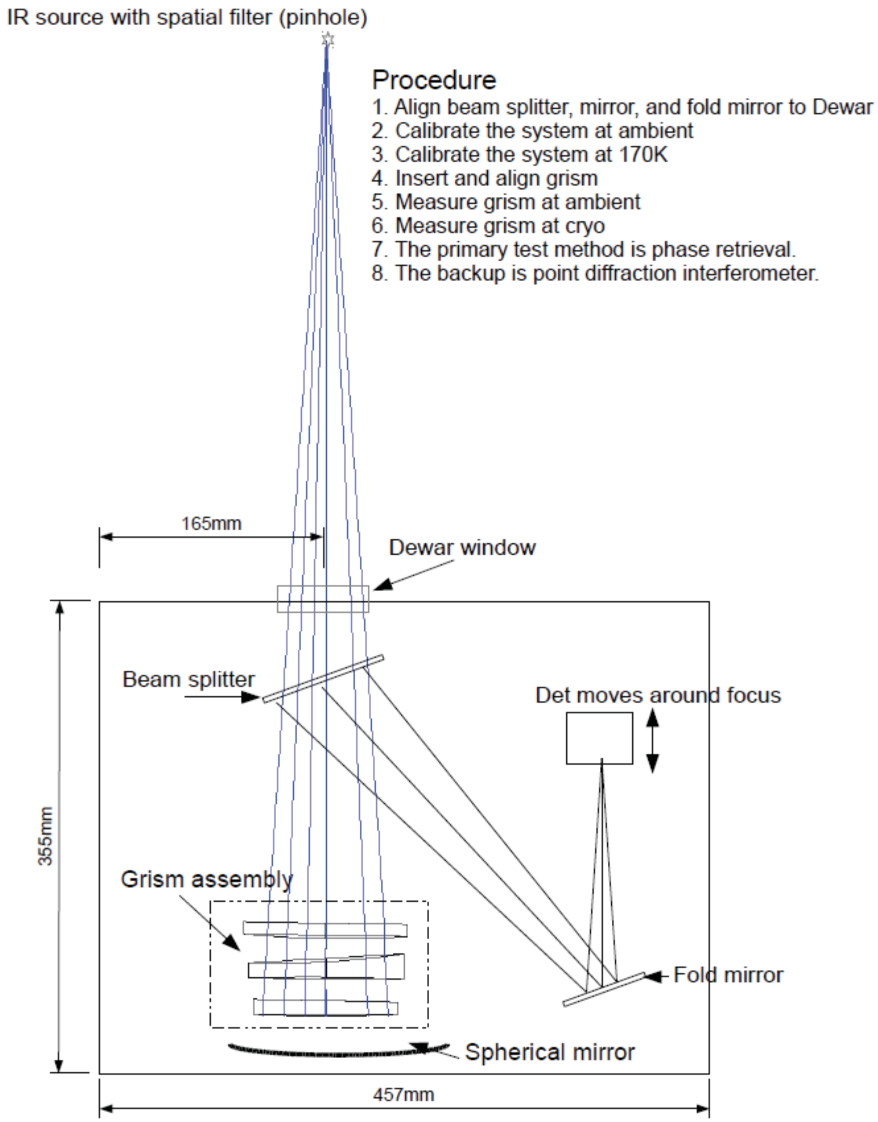


GRISM TEST CONFIGURATION (ambient)



- Ambient test will be performed using interferometer.
- Even though the grism is designed for NIR wavelength, it can be tested in visible at 632.8nm with the help of a specially designed Computer Generated Interferogram (CGH).

GRISM TEST CONFIGURATION (cryogenic)



- Phase retrieval will be used for final assembly test at cryogenic temperature at 170°K.
- A few IR wavelengths between 1.35μm and 1.95μm will be used during the test.

CONCLUSION

- The analysis shows that the grism with two diffractive surfaces solves the previous problem: grism is limited to small FOV, small spectral dispersion, and in non-collimated space.
- All three lens substrates have been made. We are working with vendors (RPC Photonics and JenOptik) to etch the diffraction patterns into the two flat surfaces.