

The Optical Thomson Scattering Diagnostic

National ICF Diagnostic Working Group Meeting

P. Datte, LLNL

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LLNL-PRES-XXXXXX

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The Optical Thomson Scattering (OTS) Team

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A phased approach to Optical Thomson Scattering (OTS) will mitigate the risk presented by background levels

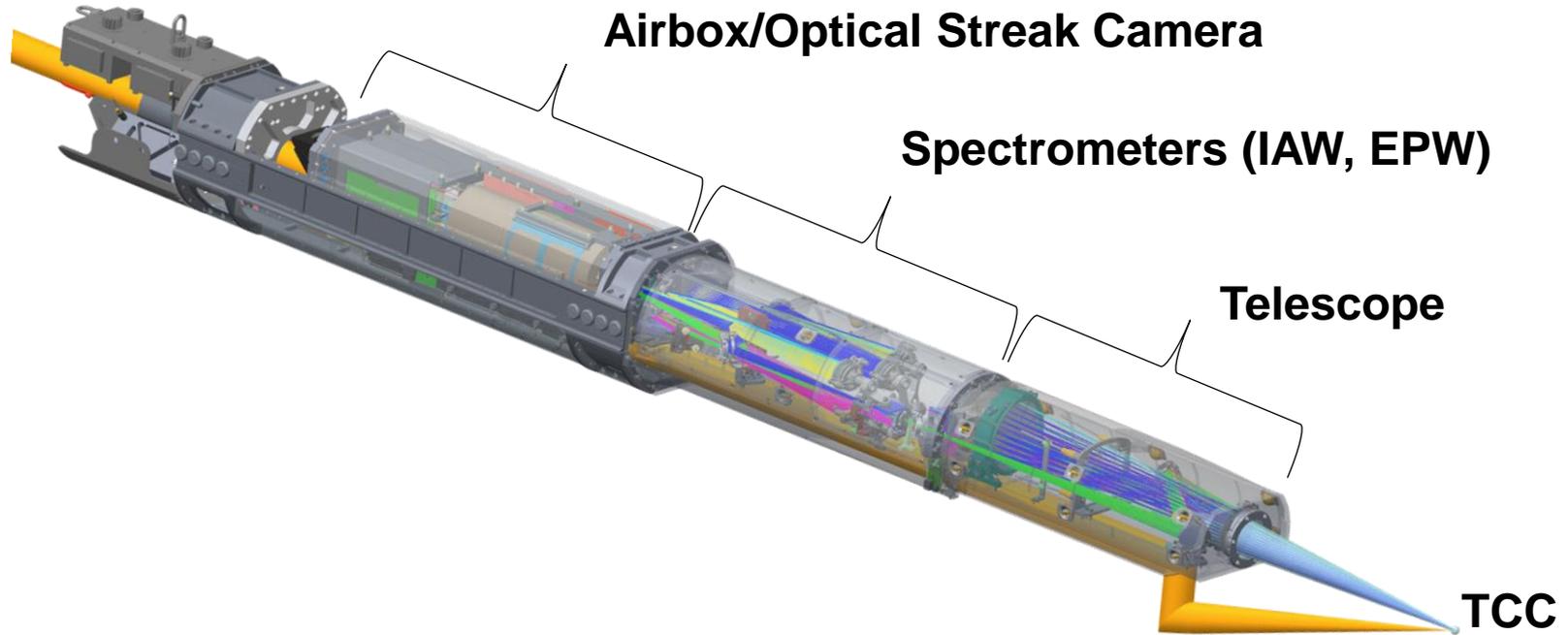
- **Phase I**
 - **Assess background levels** around potential probe wavelengths
 - Design and field an **optical collection system**
 - Supporting Electron Feature not to preclude Ion Feature
 - Alignment to 250 microns for different target types
 - Utilize existing NIF beams for the probe on “simple” experiments (Quartraums, Collisionless Shocks, etc.)
- **Phase II**
 - Using the background measurements from Phase I **validate the probe beam** requirements
 - Design and field a Thomson scattering system with a dedicated probe beam to allow measurements on all platforms

Based on the recommendations of the two diagnostic workshops we have developed a phased approach.



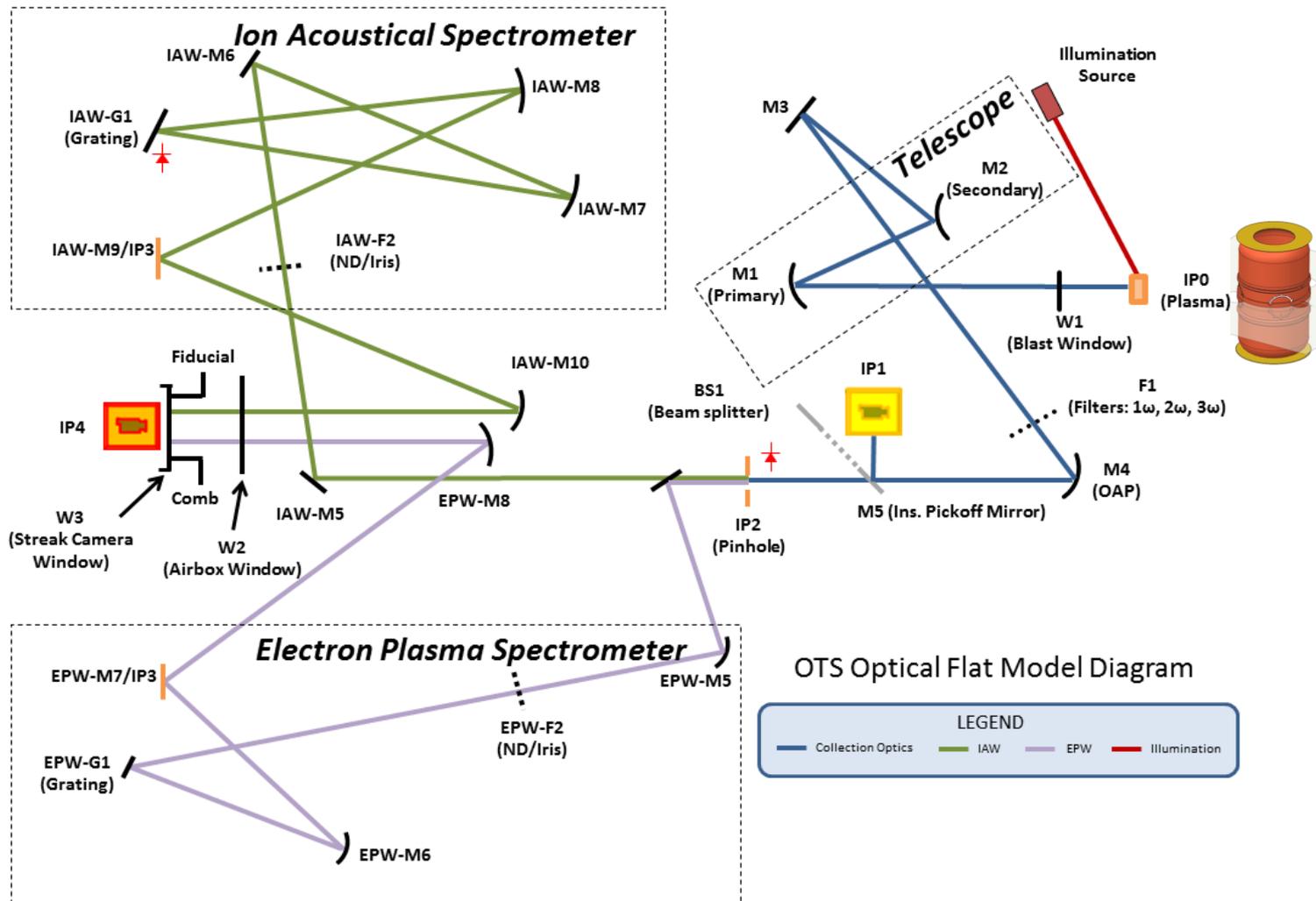
OTS DIM based diagnostic assembly

- Optical Thomson Diagnostic is a DIM based diagnostic platform designed to operate in the polar and equatorial locations. Simultaneously records both the electron plasma wave (EPW) and the ion acoustical wave (IAW).

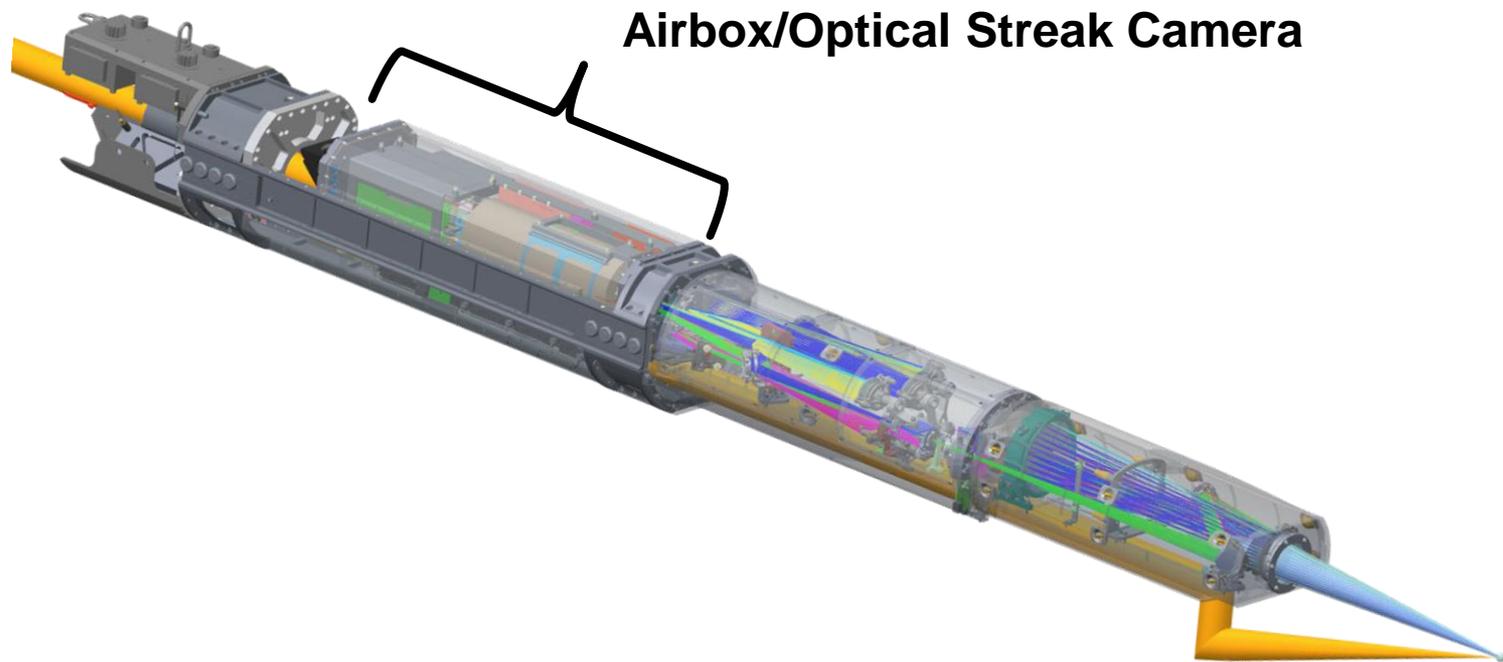


OTS diagnostic DIM platform, telescope, spectrometers, optical streak camera

OTS optical layout diagram describing optical components of the DIM collection system

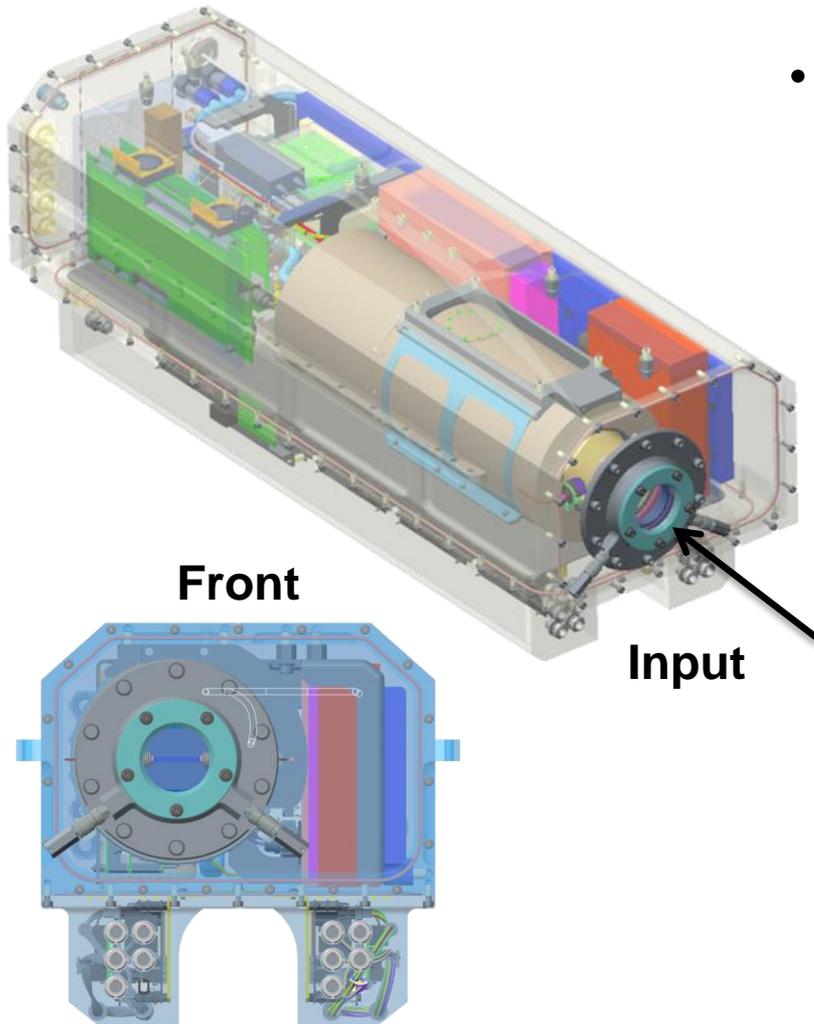


OTS airbox assembly is the first of three key modules in the detector assembly



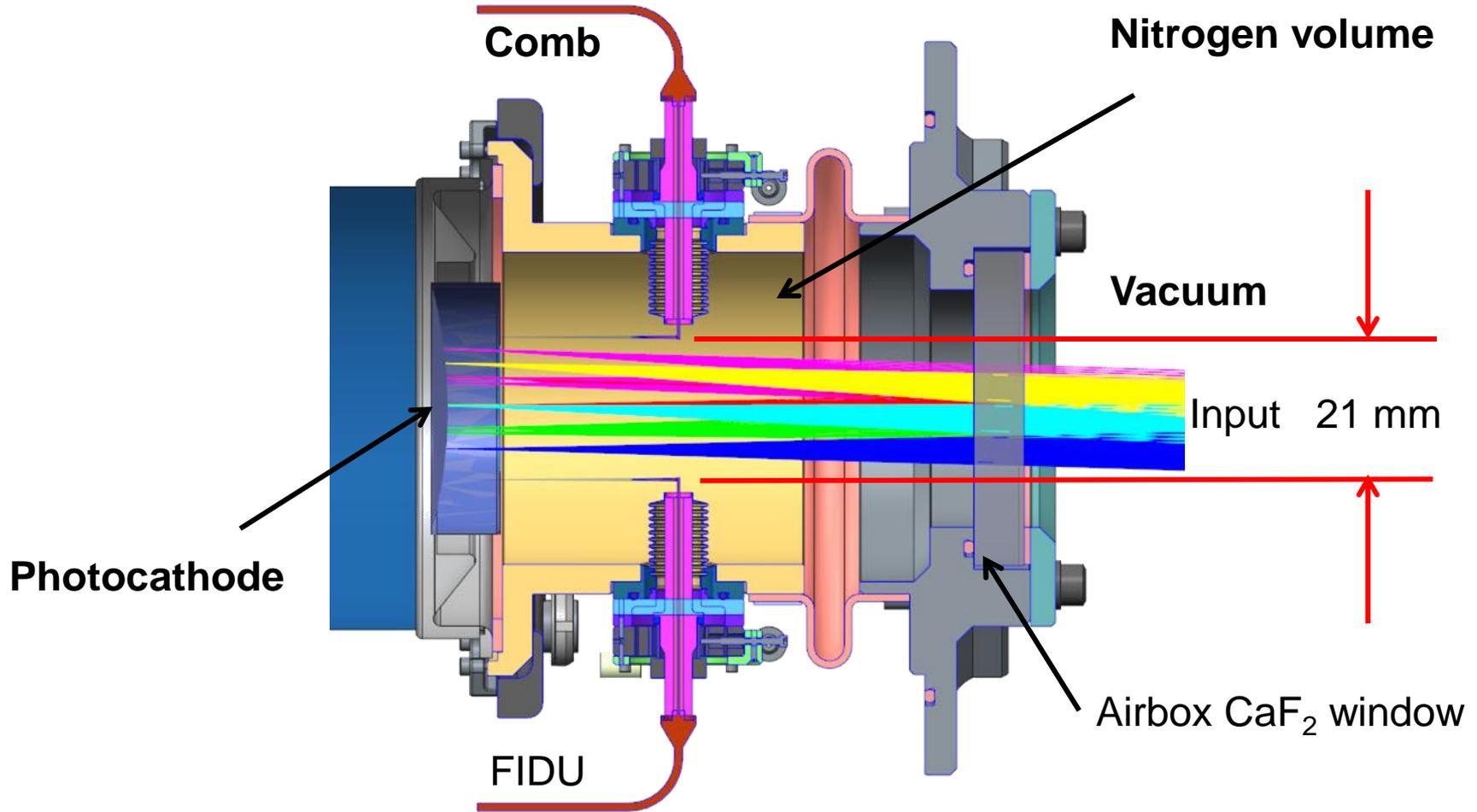
The airbox is assembled off line prior to installation in the final assembly

OTS airbox configuration describing the complete streak camera assembly

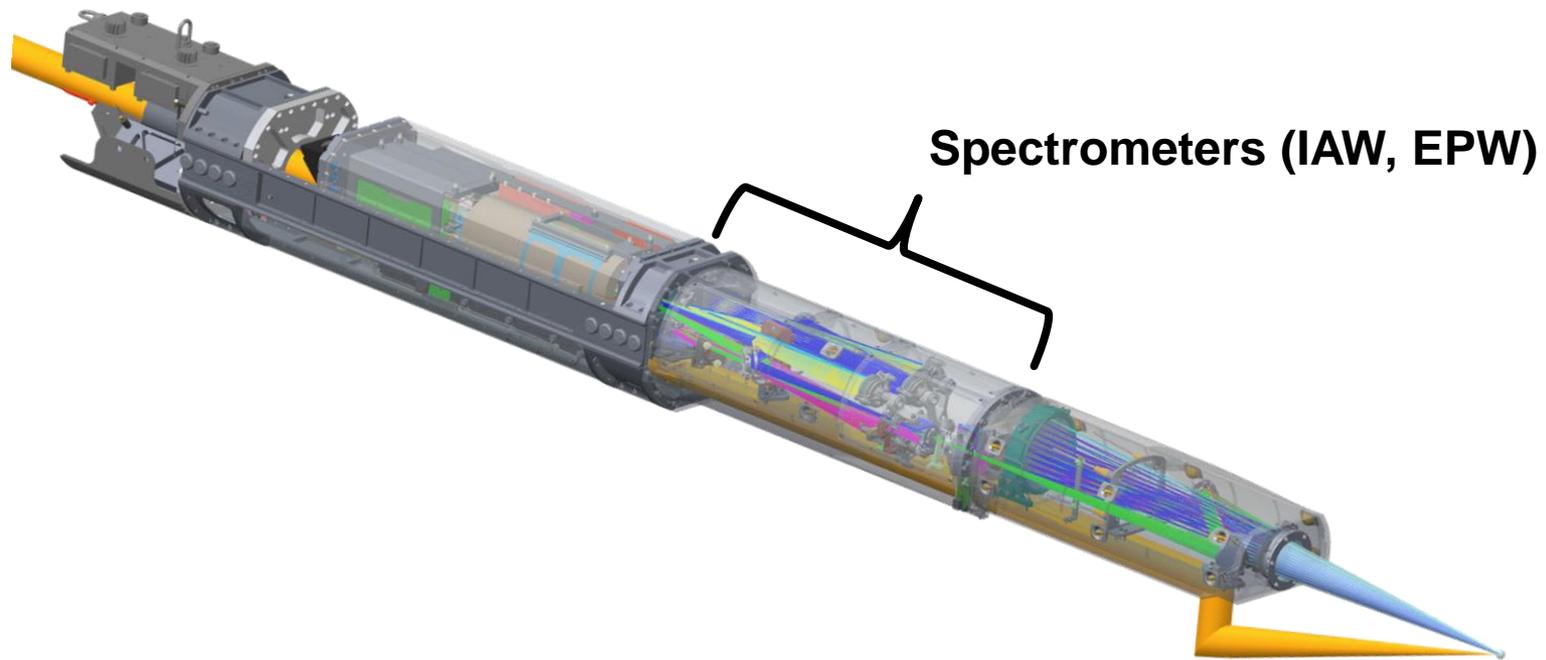


- Optical streak camera configuration
 - 21 mm spatial region for IAW & EWP spectrum
 - Resolution element ~ 100 $\mu\text{m}/\text{pixel}$
 - FIDU and Comb imprinted on data image
 - Gated cathode operation
 - 4 selectable sweep speeds (5,10,15,35) ns
 - CaF_2 cathode window
 - N_2 beam path from window to optical path

Clear aperture for streak tube window relative to the comb and FIDU injection

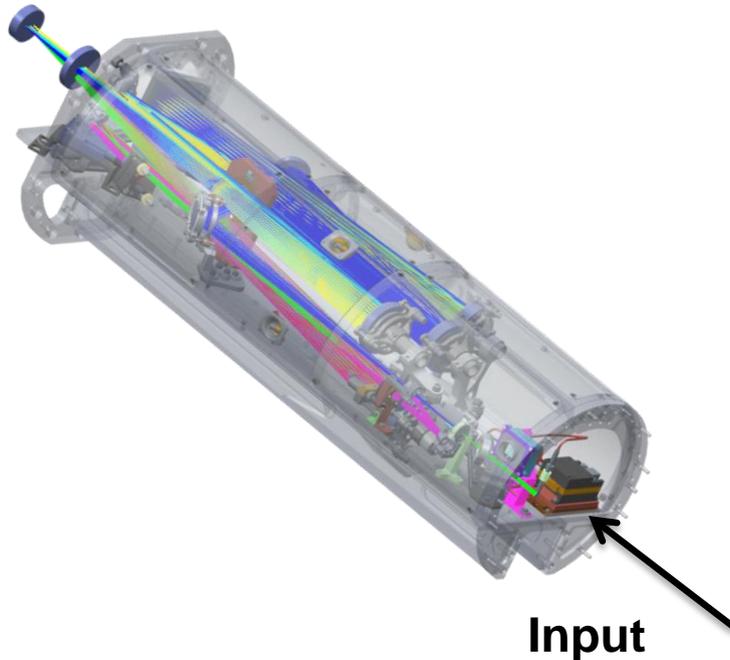


OTS spectrometer assembly is the second of three modules in the detector assembly



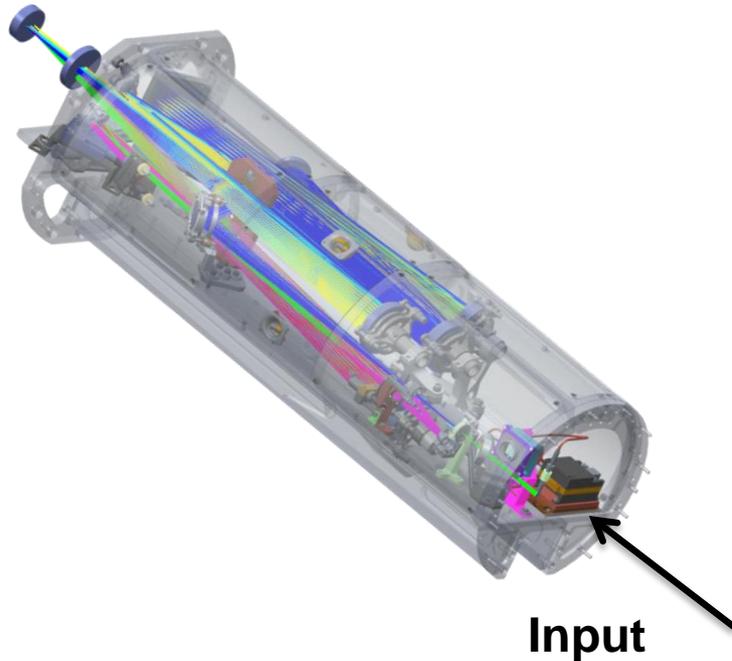
The spectrometer is assembled as an individual module, and characterized prior to assembly into the final DIM assembly.

OTS spectrometer group summary



- **Spectrometer group features**
 - EPW & IAW spectrometers (Czerny-Turner type), adjustable gratings
 - 135 μm entrance hole (shared by both spectrometers)
 - Two diodes (entrance and exit) for transmission reference
 - Automated IRIS for each leg (filters)
 - λ_0 line masking for IAW
 - Alignment camera at pin hole
 - ATLAS alignment SMRs

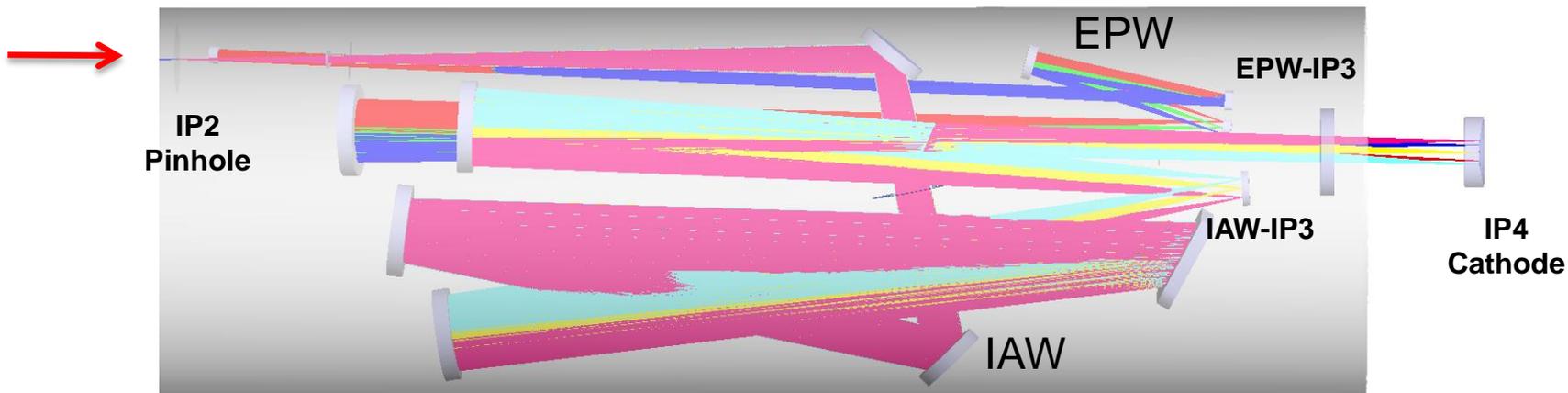
OTS spectrometer group summary



- **Spectrometer Operational Specifications**
 - Spectrometers
 - IAW: 206-214 (nm)
 - EPW: 150-200 (nm)
 - Measurement Bandwidth:
 - IAW- 4 nm, EPW- 50 nm
 - Resolution ($\delta\lambda/\lambda$):
 - IAW-0.0001, EPW-0.01
 - Time resolution: 200 ps
 - Time delay between IAW and EPW: 4.9

Spectrometer ray trace diagram for the EPW and IAW optical paths to photocathode

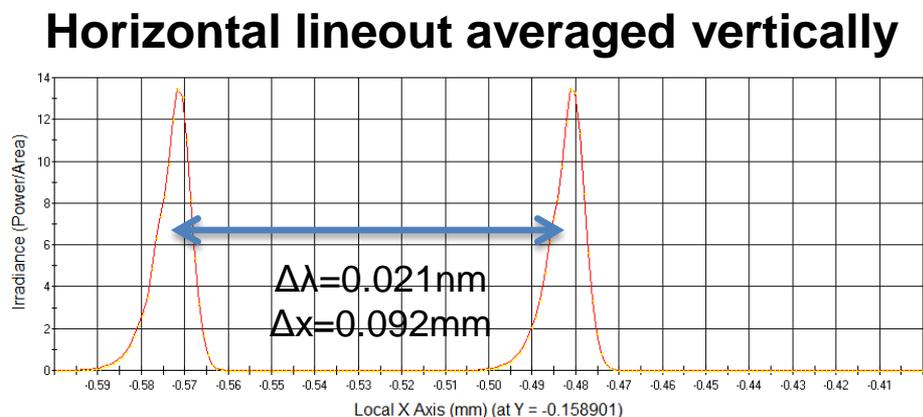
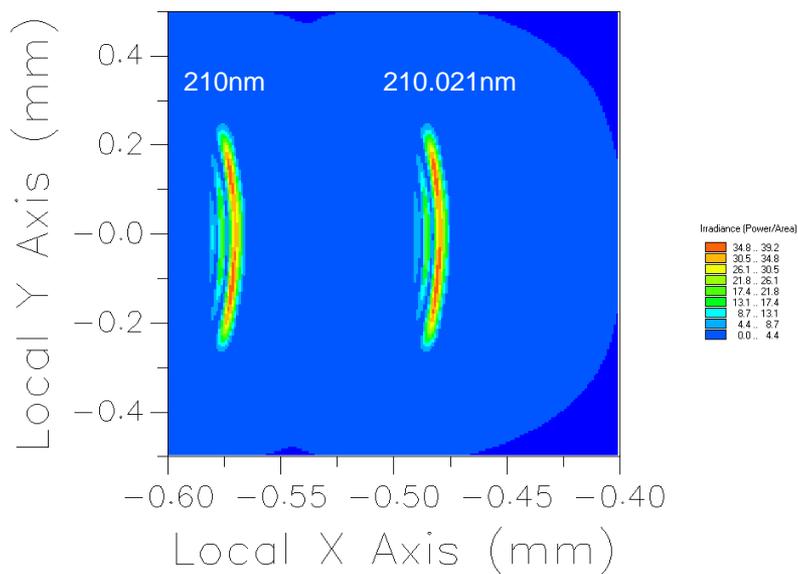
From Telescope



Spectrometer	Ray Color	Wavelength
EPW	Blue	150nm
EPW	Green	175nm
EPW	Red	200nm
IAW	Teal	208nm
IAW	Yellow	210nm
IAW	Pink	212nm

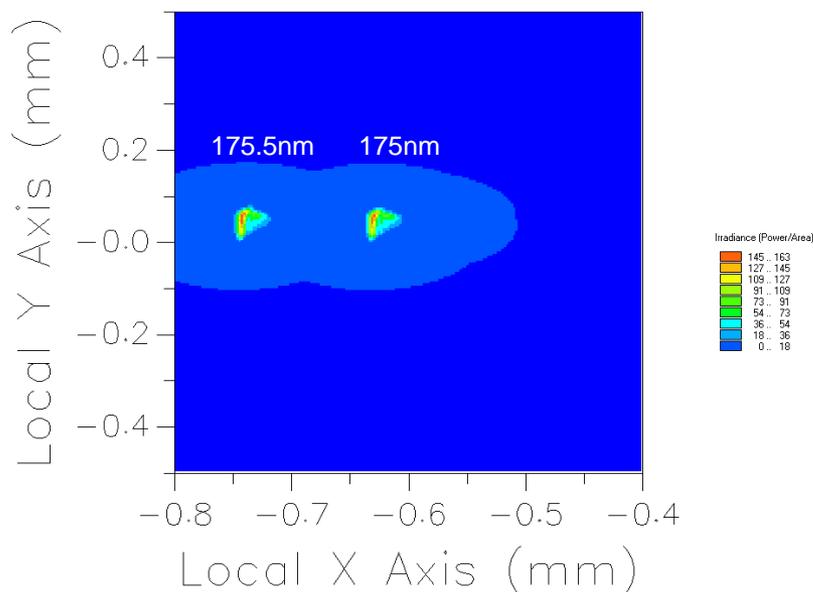
IAW performance – point spread function at the photocathode

- IAW (~ 0.6 meter), 2400 I/mm (2nd order)
- Point source at center of pinhole, two wavelengths 210nm and 210.021 nm
- Reciprocal linear dispersion at photocathode = 0.2293nm/mm

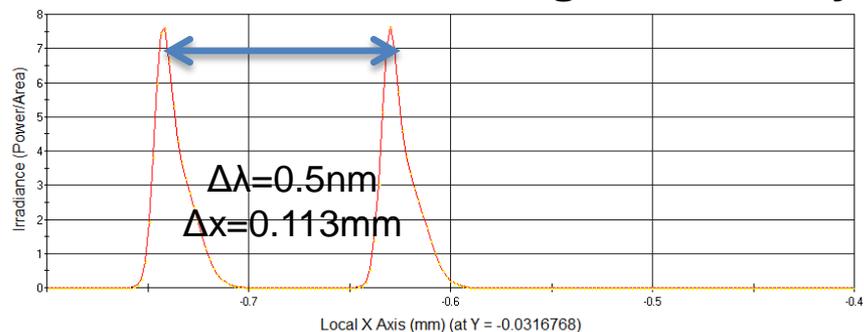


EPW performance – point spread function at the photocathode

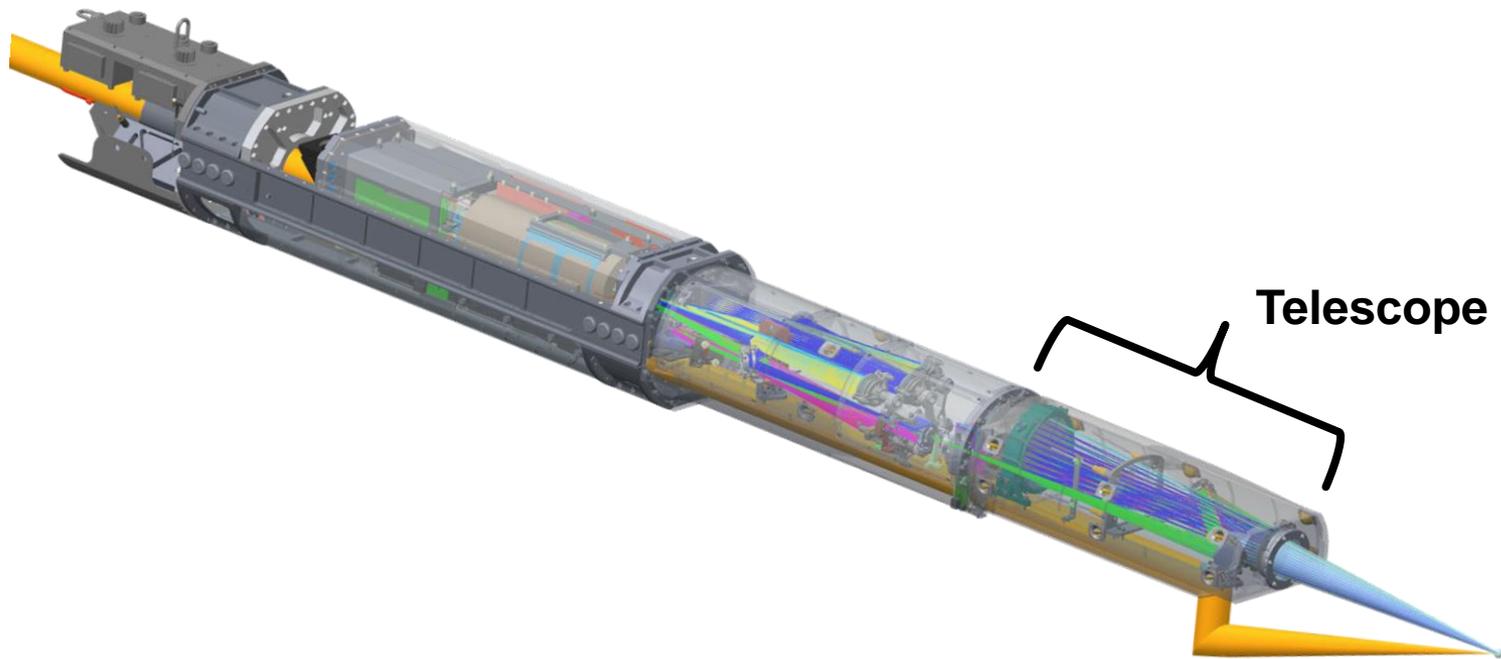
- EPW (~0.14 meter), 1200 l/mm (1st order)
- Point source at pinhole with two wavelengths 175 nm and 175.5 nm
- Reciprocal linear dispersion at photocathode = 4.437nm/mm



Horizontal lineout averaged vertically

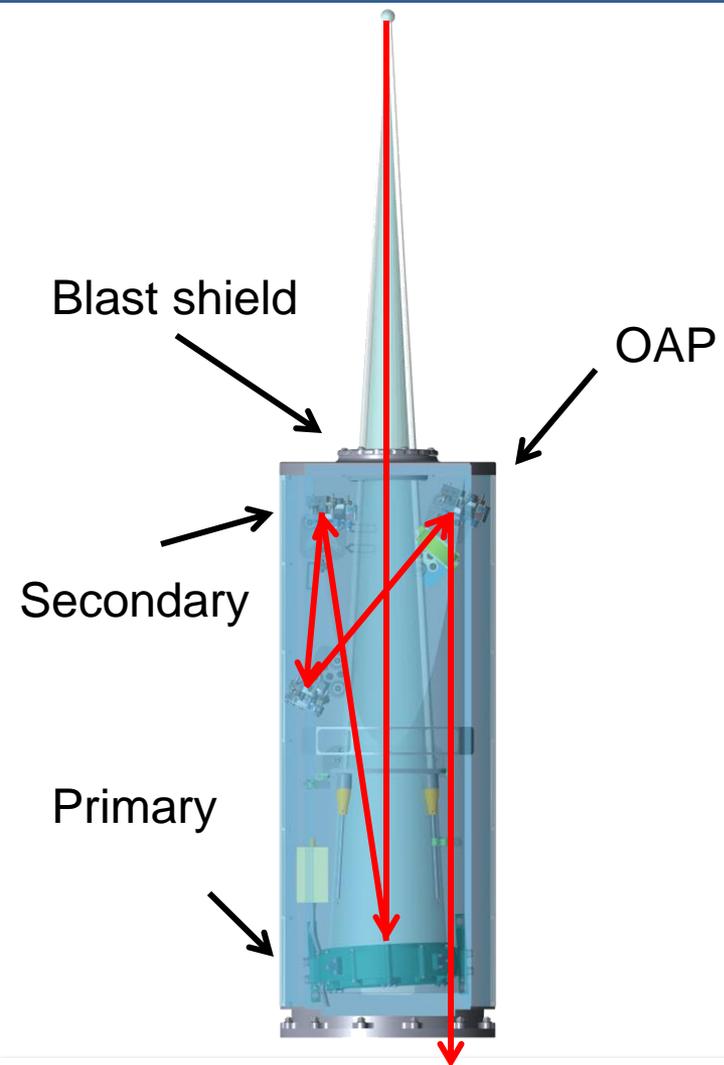


OTS telescope assembly is the third of three key modules in the detector assembly



OTS telescope assembly is assembled and aligned offline prior to being installed in the final DIM assembly.

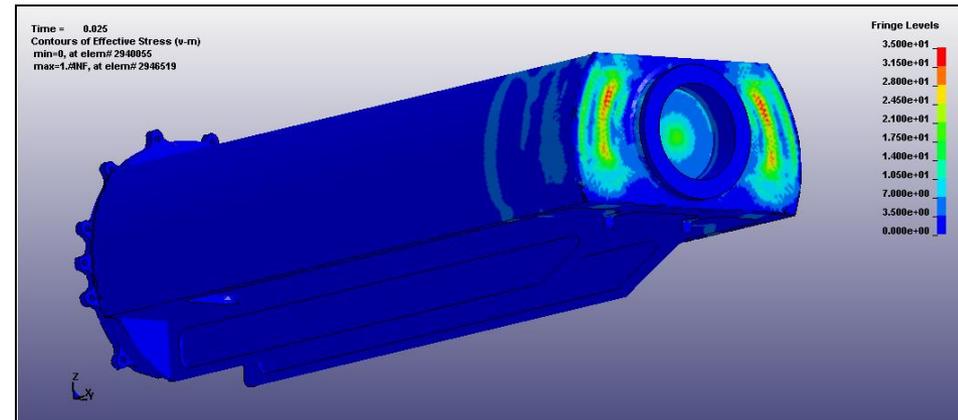
OTS telescope assembly



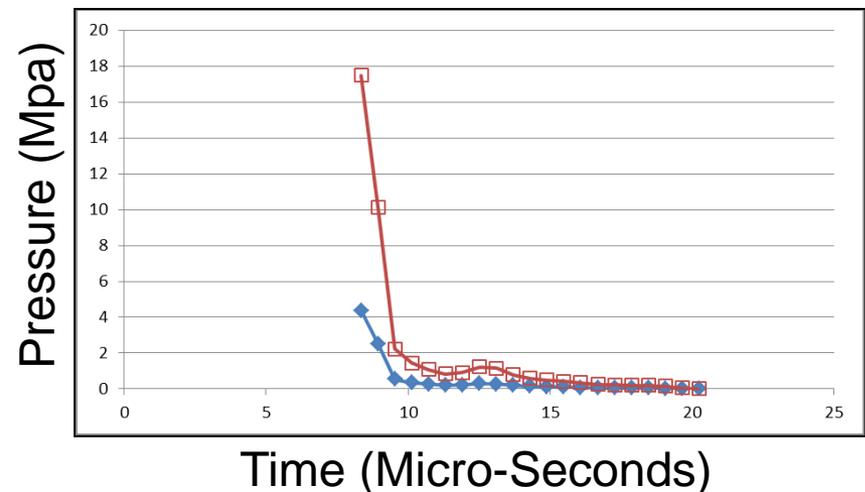
- Telescope assembly
 - MgF2 blast shield
 - Off-axis Schwarzschild telescope (f/8.3)
 - **FOV at TCC: (+/-) 3 mm, (+/-) 8 mm 50% vignetting**
 - Magnification: **2.7**
 - Illumination laser diodes (660nm)
 - Band-pass filters
 - Off-axis parabola
 - ATLAS alignment SMRs

OTS telescope assembly debris wind analysis shows a factor of 6 safety margin for NIF

- Simulation covers a front window and telescope face plate. Pressure time history is analyzed.
- Analysis shows peak stress in the Aluminum housing is 35MPa, yielding a 6X safety factor
- The blast window stresses are approximately 21MPa
- Evaluation of the MgF2 material is in process, preliminary data show 8mm thickness will provide adequate safety margin.

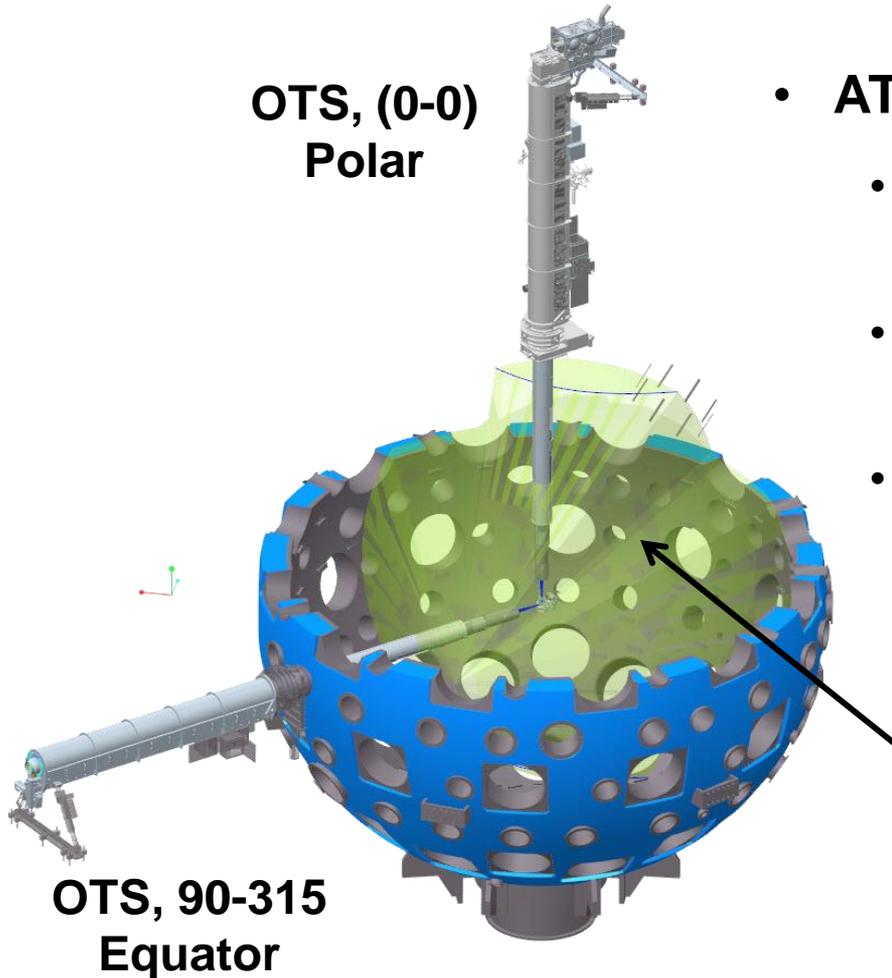


Debris Wind Loading



OTS diagnostic external alignment tool (ATLAS) will position OTS in the NIF chamber

OTS, (0-0)
Polar

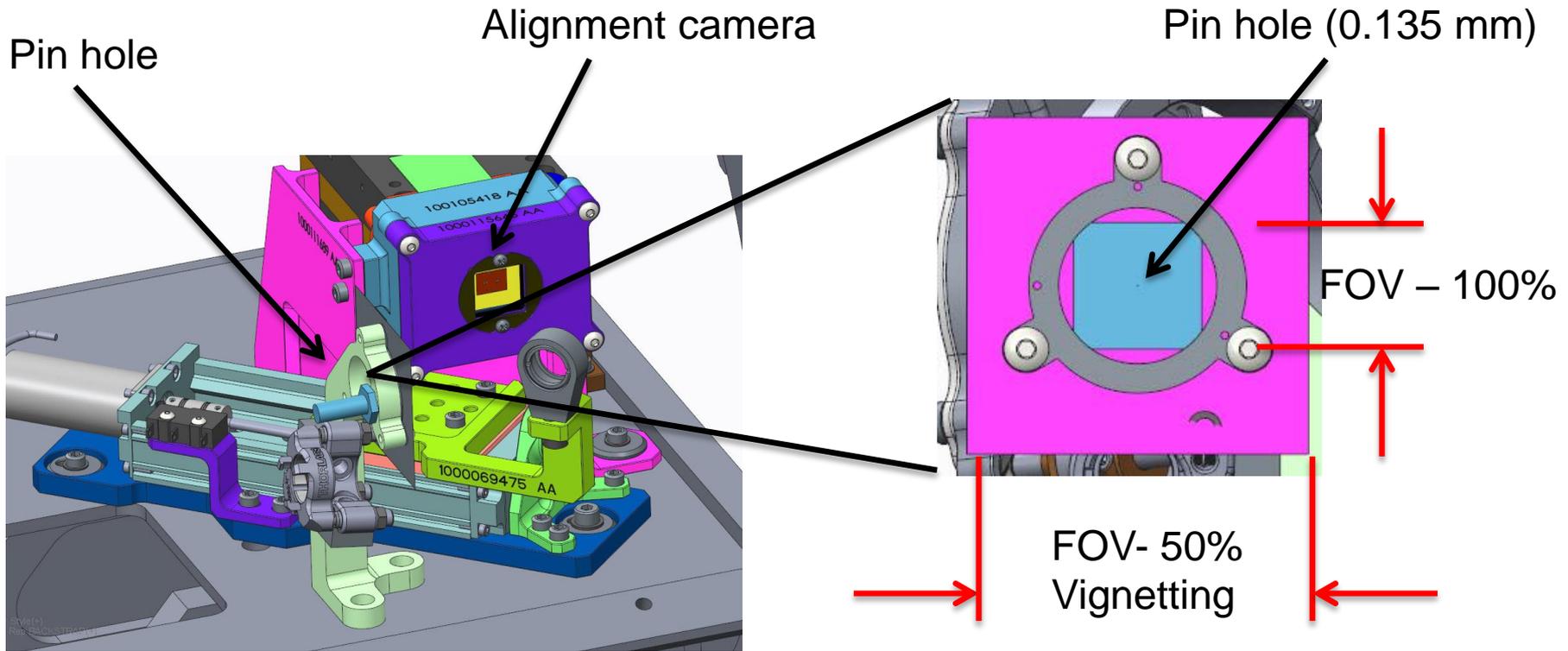


- **ATLAS external alignment interfaces**
 - ATLAS alignment can view equator and polar locations
 - ATLAS SMRs are placed for two different location.
 - ATLAS placement of DIM is ($< 200 \text{ um}$). System is being commissioned and will have better numbers in a few months.

ATLAS view of DIM based diagnostics

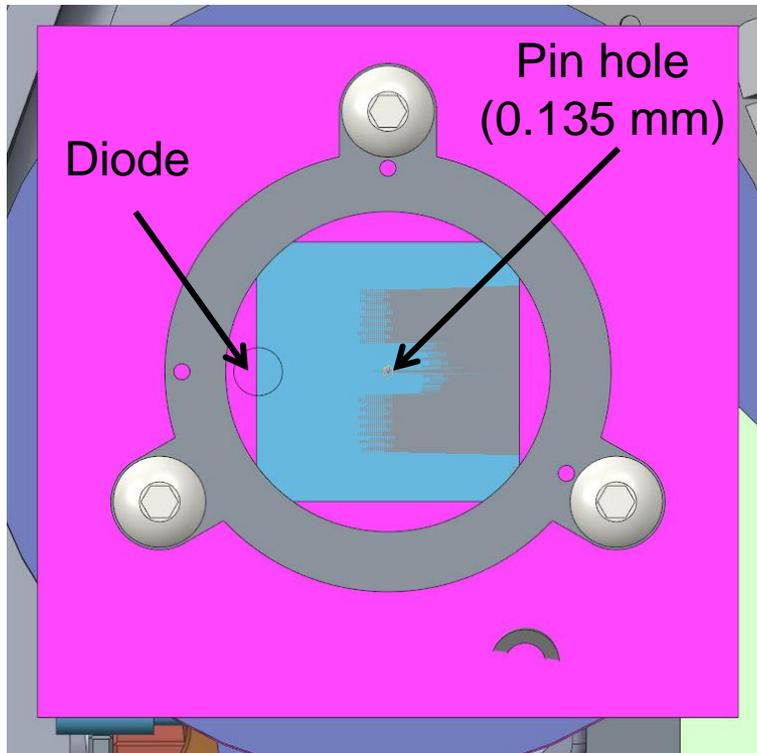
OTS, 90-315
Equator

OTS diagnostic telescope incorporates an internal alignment camera as one of two alignment aids for OTS

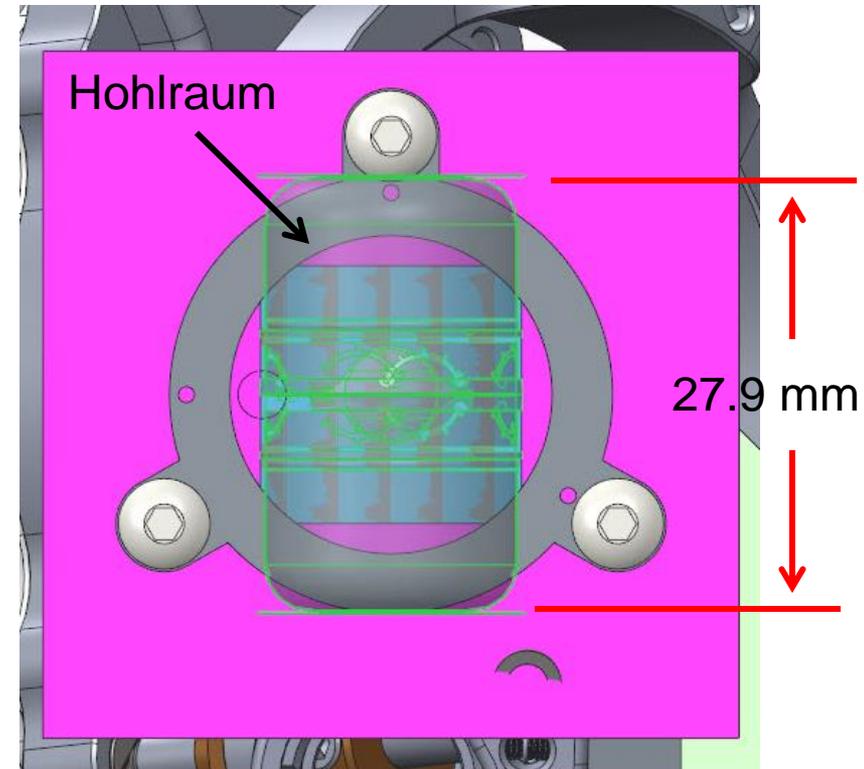


OTS telescope field of view at the pin hole based on a magnification of x2.7. The FOV at TCC is +/- 3 mm at TCC and +/- 8 mm at TCC with 50% vignetting.

Image plane at spectrometer pin hole that is viewed by internal alignment sensor for final target alignment.

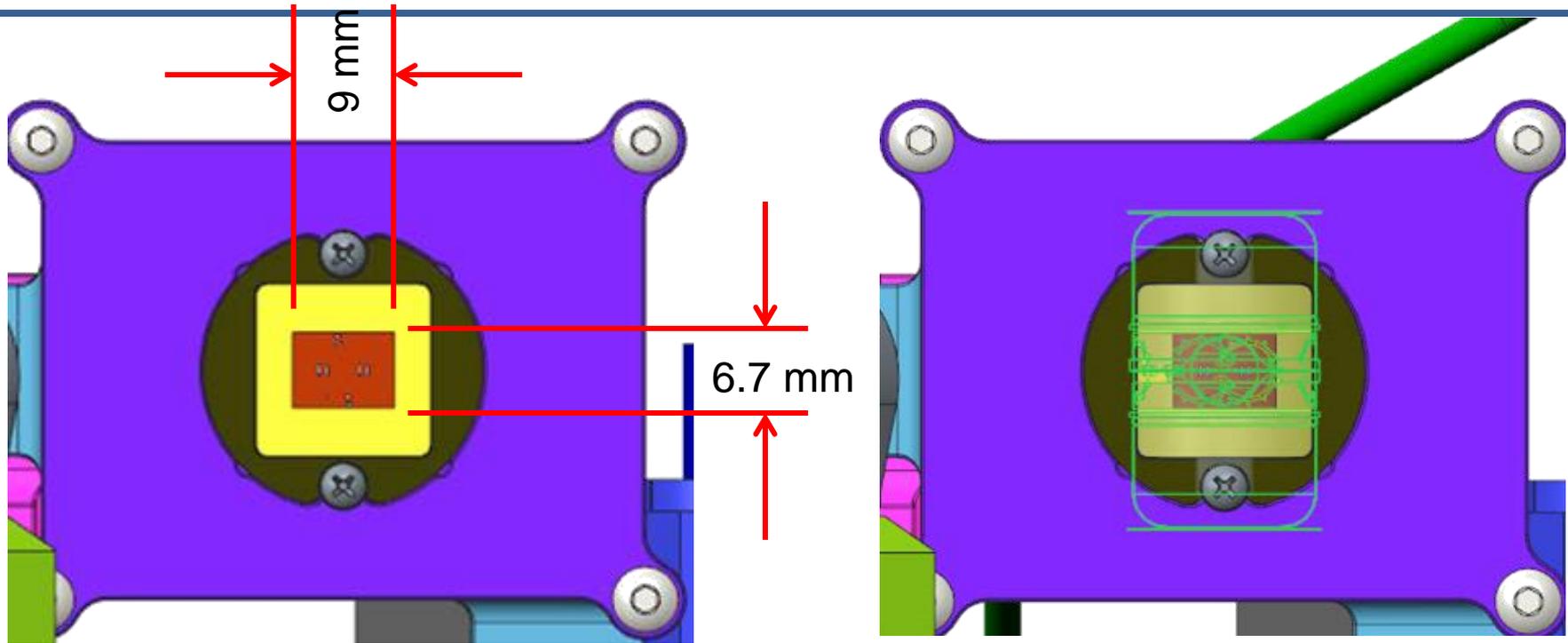


Telescope FOV at the IP2/pin hole.
Pin hole is 0.135 mm, 50 μ m at TCC



Hohlräum target at TCC imaged at
IP2 pin hole after x2.7 magnification,
equatorial view

Hohlraum at TCC viewed by the OTS alignment camera, equatorial view

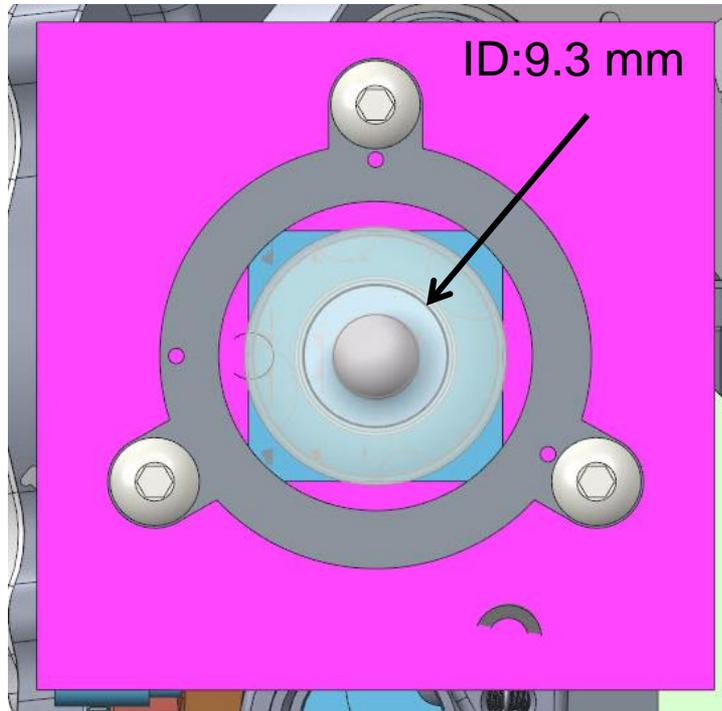


Alignment CCD sensor active area

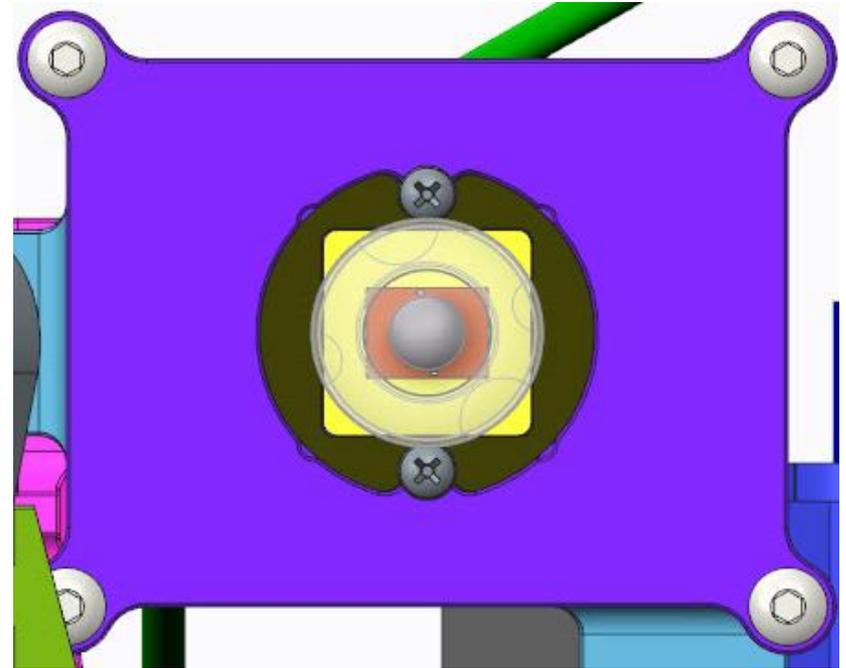
Target overlay on CCD sensor, equatorial view

Alignment sensor-Sony (ICX285AL) 6.45um pixel pitch, 1:1 image relay, corresponding to ~21 pixels across the pin hole. This provides 2.5 mm vertical coverage at TCC.

Hohlraum at TCC viewed by the OTS alignment camera, polar view



Target overlay at pin hole after x2.7 magnification, polar view



Hohlraum target at TCC imaged at IP2 pin hole after x2.7 magnification, polar view

Alignment sensor specification for the OTS alignment camera, including illumination response

SONY

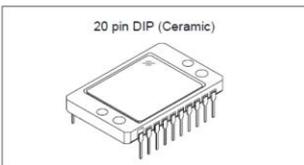
ICX285AL

Diagonal 11 mm (Type 2/3) Progressive Scan CCD Image Sensor with Square Pixel for B/W Cameras

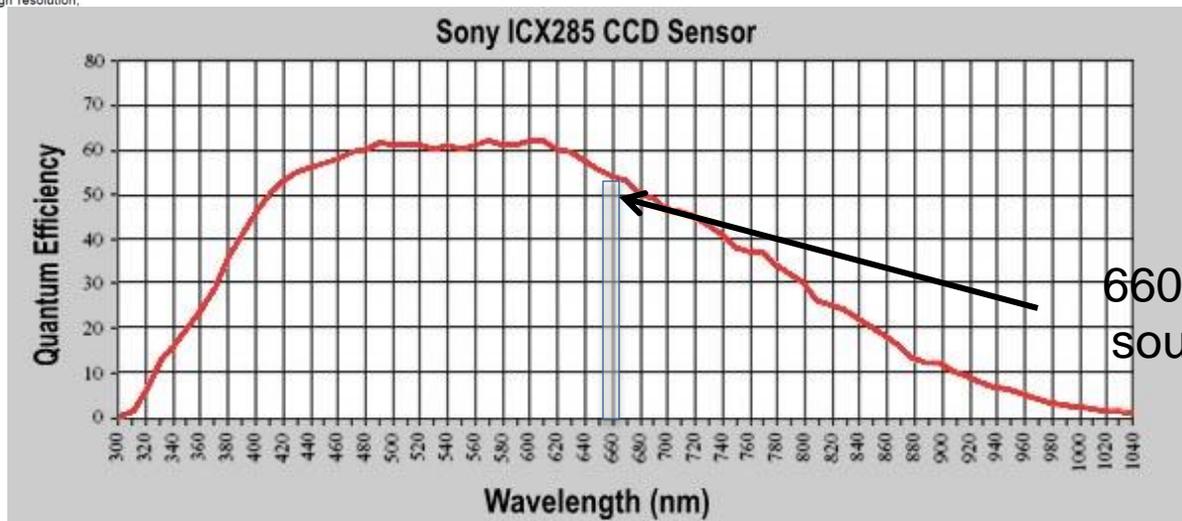
Description

The ICX285AL is a diagonal 11 mm (Type 2/3) interline CCD solid-state image sensor with a square pixel array. High sensitivity and low smear are achieved through the adoption of EXview HAD CCD technology. Progressive scan allows all pixel's signals to be output independently within approximately 1/15 second. Also, the adoption of high frame rate readout mode supports 60 frames per second. This chip features an electronic shutter with variable charge-storage time which makes it possible to realize full-frame still images without a mechanical shutter.

This chip is suitable for image input applications such as still cameras which require high resolution, etc.



SENSOR	
Sensor	Sony ICX285
Type	Inter Line Transfer (ILT)
Resolution	1392(H) x 1040(V) Color & Mono
Pixel Pitch	6.45 μm x 6.45 μm
Active Area	8.98. mm x 6.70. mm - 11.2 mm diagonal
Max Datarate	28 MHz



Alignment sensor-Sony (ICX285AL) 6.45um pixel pitch, and provide 2.5 mm vertical coverage at TCC.

Remaining physics and engineering issues for OTS

- Blanking studies for debris window
- Improved mechanical stress models for window material
- Coating damage studies
- Completing the gated circuit prototype
- Background estimate model improvement

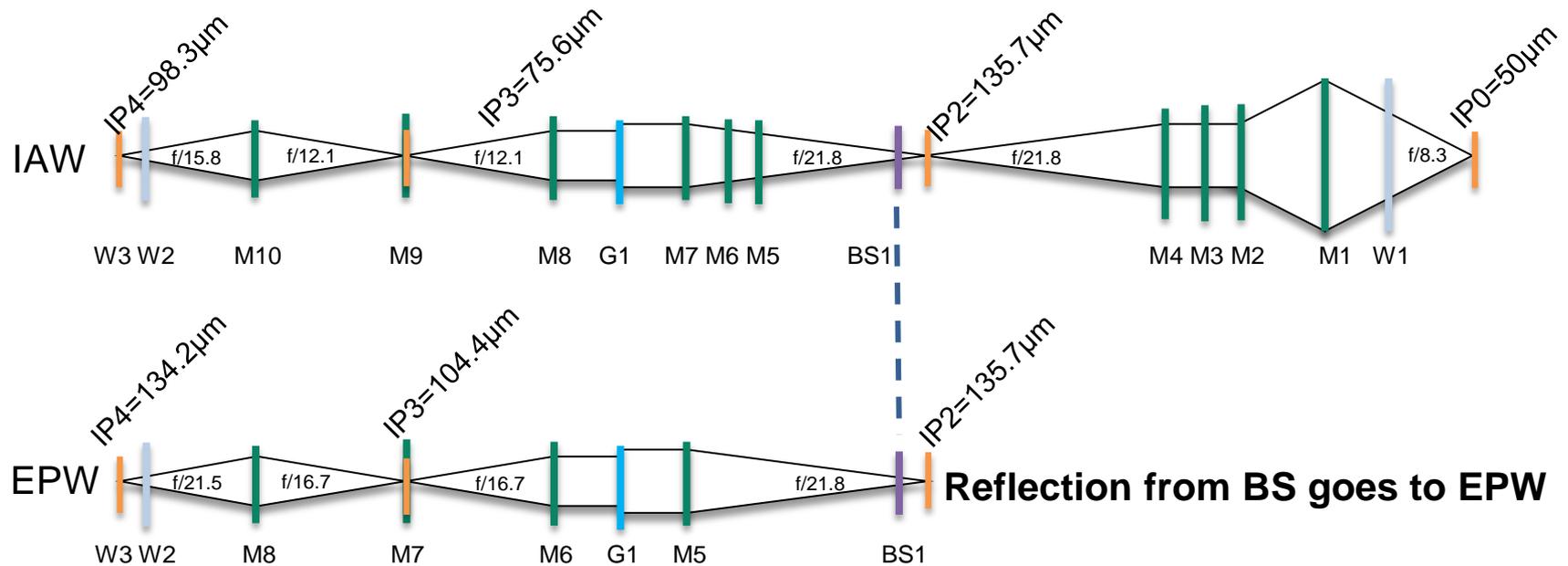
OTS high level schedule for remaining phase 1 and the addition of phase 2

	FY2016				FY2017				FY2018			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
System and Risk Mitigation	OTs Req. Rev.		xtal test review		Background Review and Req. update	System FDR				First shot		OQ
1w Laser	Initial xtal test	Req & PCDR		CDR	FDR			NIF Laser ATP				
Detector	FDR			Init. background measurements	Detector V2 complete				Laser shipped	Laser reassembled at NIF		
Beampath and Final Optics		Enclosure RR	FDR	Room Fabrication	Occupancy	Beampath to Polar/ Final Optics Install	Beam path available					
Controls HW and SW		RR	Development Testing		Release	Updates			Support			

Backup Slides



OTS unfolded optical layout describing the optical components in the measurement system



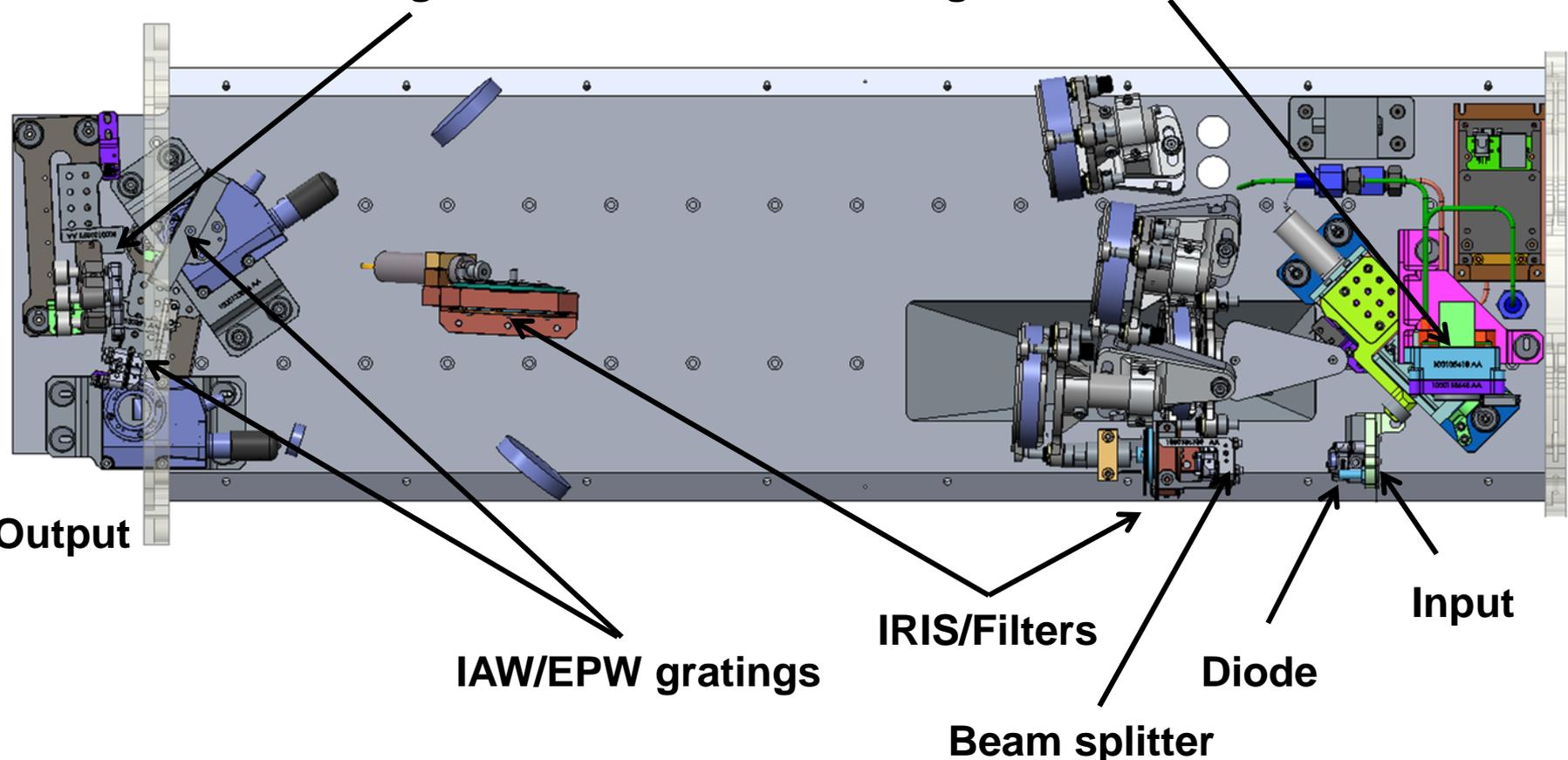
- Labeled f/#s are from using $D1=154.3\text{mm}$ (beam diameter at primary)
- The IAW magnification is optimized for the resolution element of recording systems.

OTS unfolded layout describes the optical components in the measurement system.

OTS spectrometer group assembly for the IAW and EPW

Wavelength mask

Alignment camera



Output

IAW/EPW gratings

IRIS/Filters

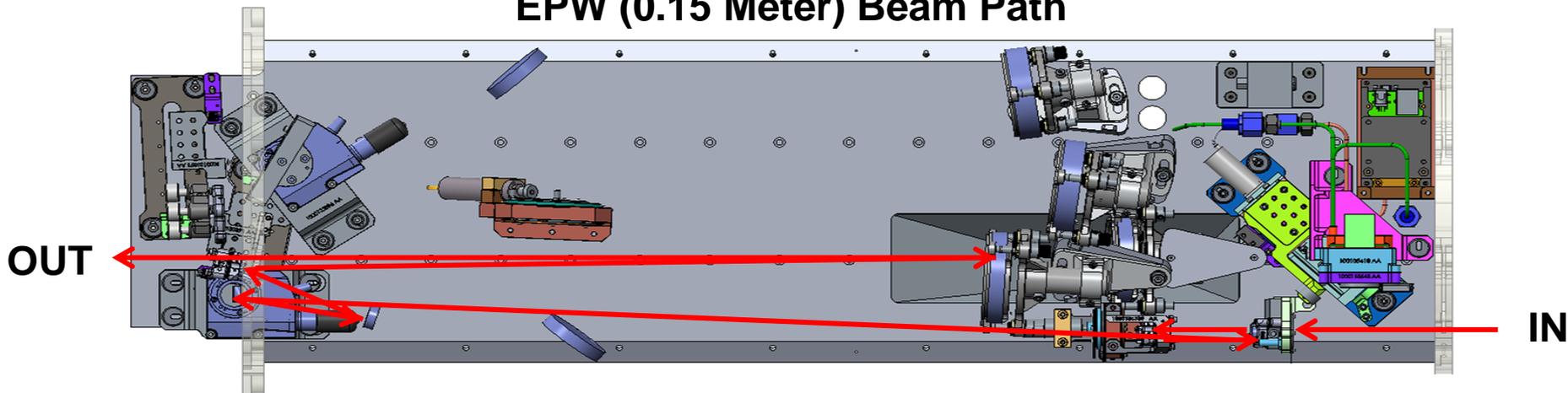
Beam splitter

Diode

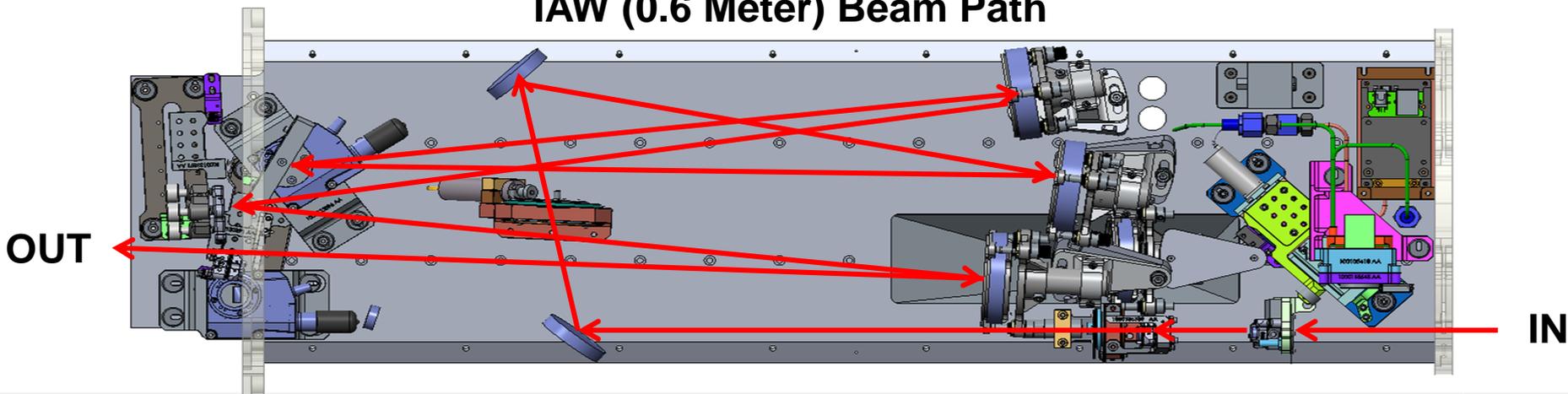
Input

OTS spectrometer group optical path diagram, (top view)

EPW (0.15 Meter) Beam Path



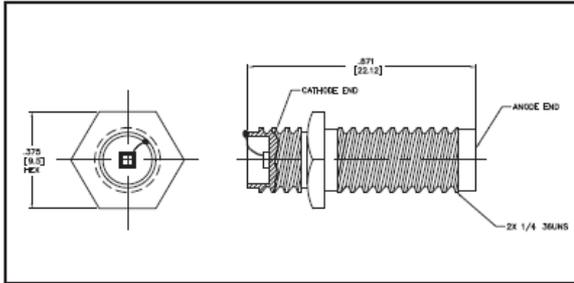
IAW (0.6 Meter) Beam Path



OTS diagnostic photodiode (SiC), light collection transmission monitor

PHOTODIODE 1 mm²

AXUVHS5



FEATURES

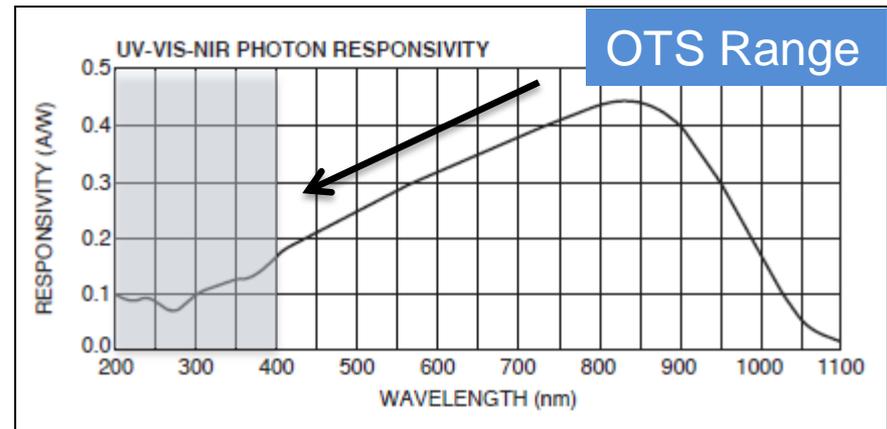
- SMA connector
- Ideal for electron detection
- 100% internal QE
- Ultra high speed

Dimensions are in inch [metric] units.

ELECTRO-OPTICAL CHARACTERISTICS AT 25°C

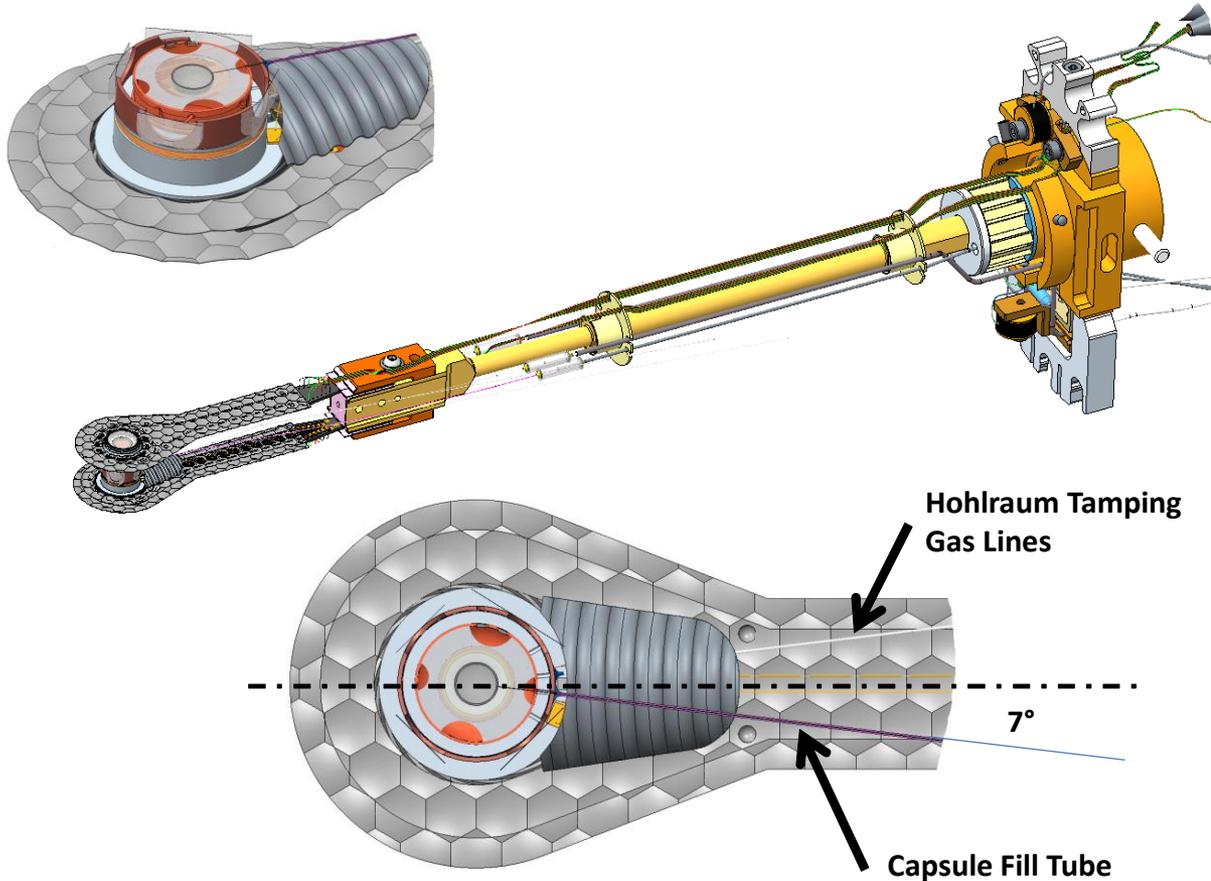
PARAMETERS	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Active Area	1mm x 1mm		1		mm ²
Responsivity, \mathcal{R}	(see graphs on next page)				A/W
Reverse Breakdown Voltage, V_R	$I_R = 1\mu A$	55			Volts
Capacitance, C	$V_R = 0V$			40	pF
Rise Time	$R_L = 50\Omega, V_R = 52V$			700	psec
Dark Current	$V_R = 52V$	0		1	nA

- SiC photodiode is used as a transmission monitor for the diagnostic.
- Diode locations
 - Pin hole
 - IAW-G1, “0 order” reflection



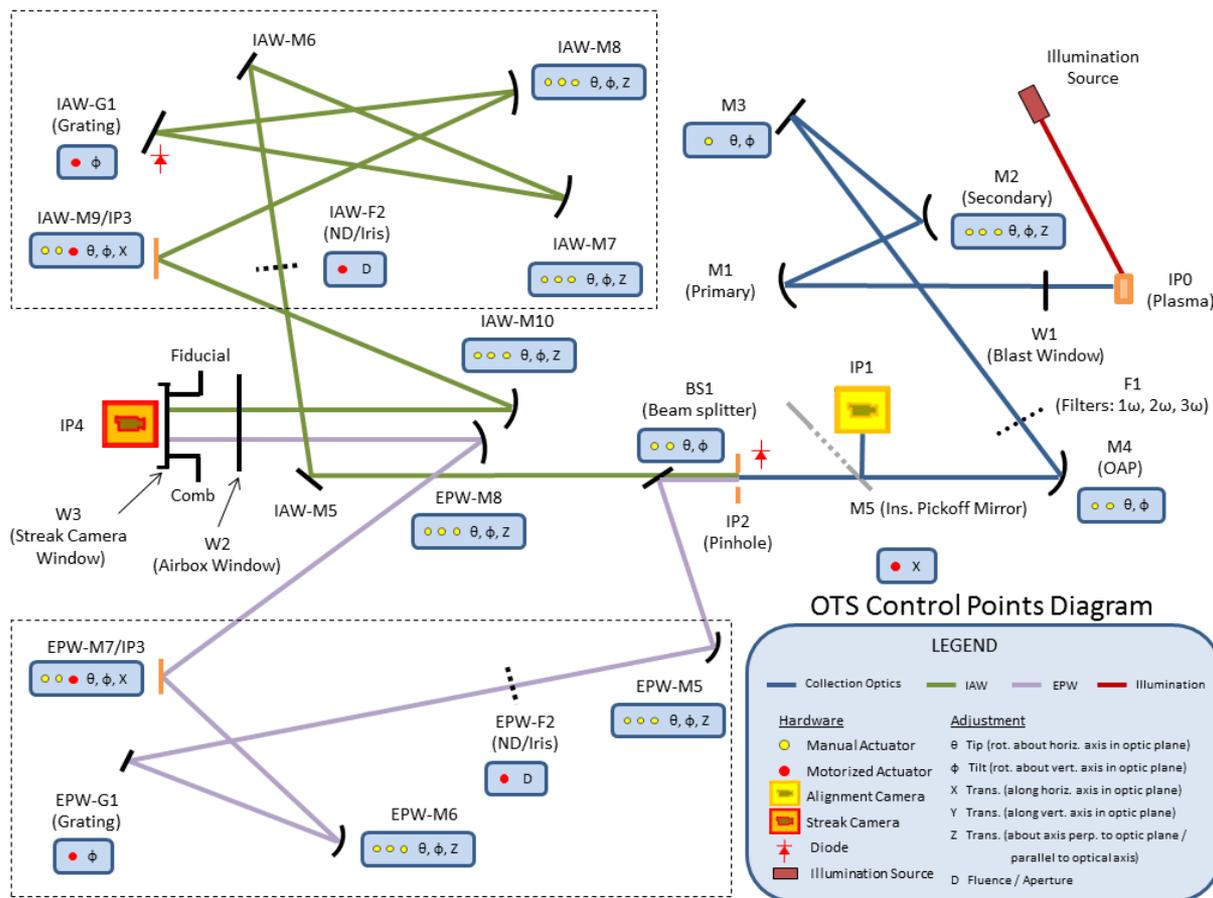
Typical Holhraum target

THD_Au_575.1013_337_HDC5.9_C_14-104187



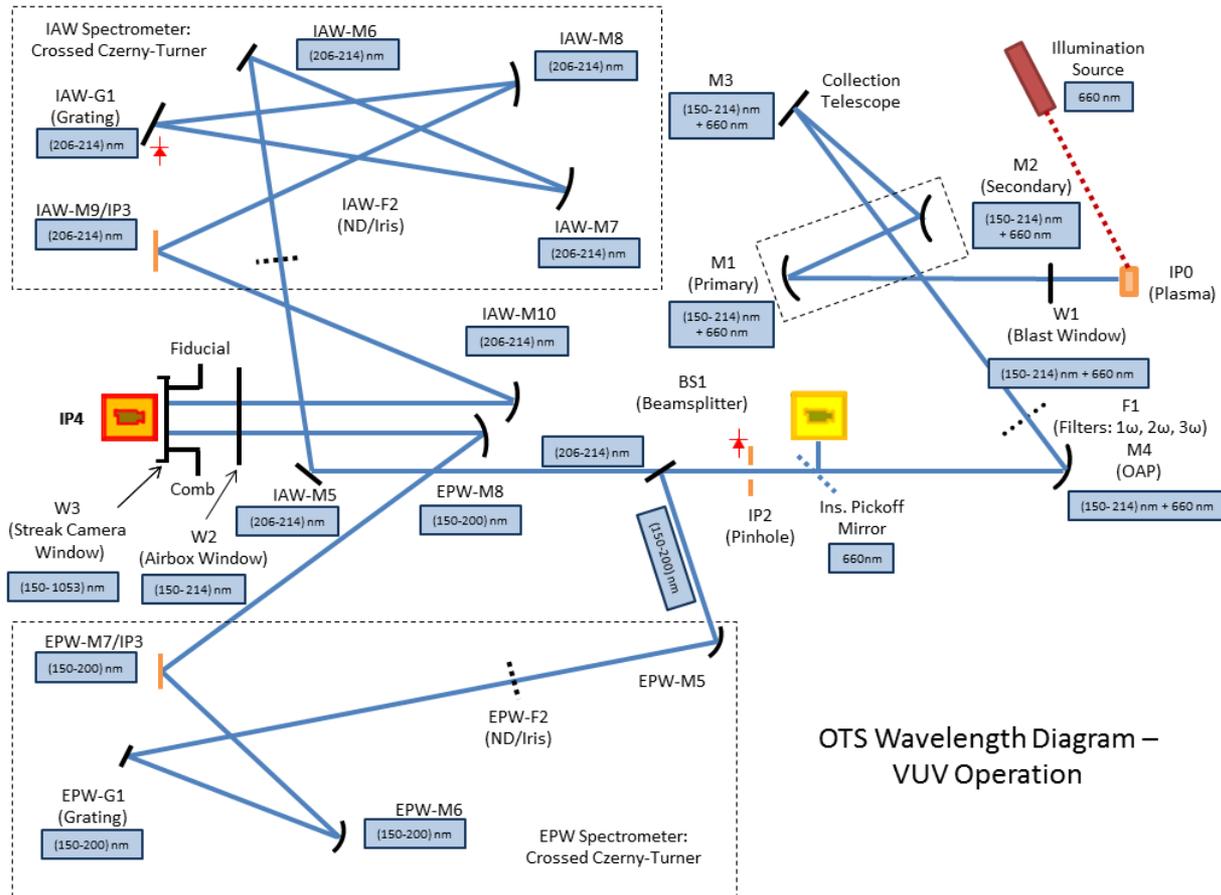
Target Dimensions
Length: 10.3 mm
Width: TBD

OTS controls point diagram that describes the DIM based automation



Optical Thomson Diagnostic is a DIM based diagnostic platform designed to operate in the polar and equatorial locations. All the controls will operate at both locations.

OTS wavelength diagram describing the optical band-pass for telescope and spectrometers



OTS wavelength diagram describes the band-pass of the optical collection systems.

