Optical Diagnostic Suite (Schlieren, Interferometry, and Grid Image Refractometry) on OMEGA EP Using a 10-ps 263-nm Probe Beam

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Project Overview:

- A 10-ps, 20-mJ, 4ω probe laser is in the process of being implemented on OMEGA EP
- An f/4 collection system provides access to high-density, large-scale-length laser-produced plasmas
- The system will initially be configured for
  - schlieren/shadowgraphy
  - grid-imaging refractometry*
  - interferometry
- Design presents options for expanded optical diagnostics
- Advanced optical-design tools are being adapted to provide synthetic diagnostic images for experimental setup and analysis

The three diagnostics coupled with detailed optical modeling of the system will provide a novel diagnostic platform for detailed plasma measurements.

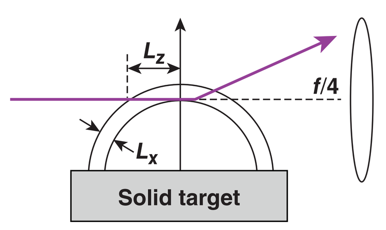
*R. S. Craxton *et al*., Phys. Fluids B 5, 4419 (1993).

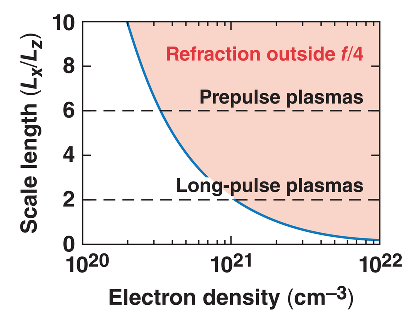
Collection System

The Optical Collection System will Provide Access to High Density Laser-Produced Plasmas

An f/4 system:

- long-pulse plasmas ($L_x/L_z \sim 2$): $n_e = 10^{21}$ cm^{-3}
- prepulse plasmas ($L_x/L_z \sim 6$): $n_e = 10^{20}$ cm^{-3}





An f/4 system will provide access to highly refractive plasmas.

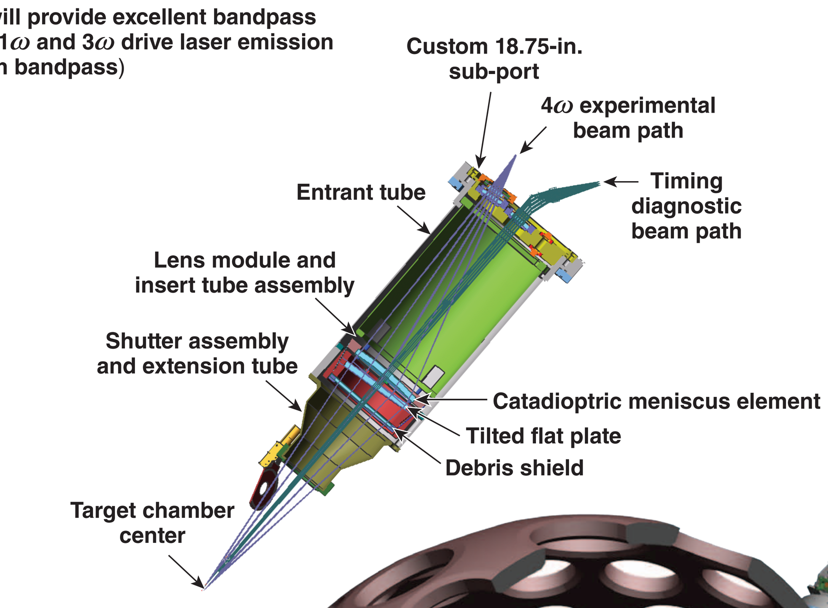
Laser System:

- Laser energy: 20 mJ at 4ω
  - overcomes calculated background plasma emission around 263 nm
- Pulse width: 10 ps
  - provides temporal resolution on the hydrodynamic time scales
- IR to 4ω timing accuracy: 10 ps

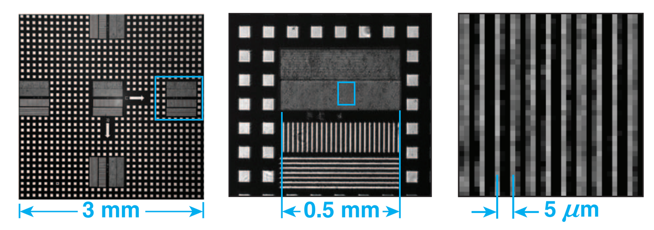
Catadioptric Collection System

The f/4 Collection System will Provide <5 μm Resolution over the 5-mm Field of View (FOV)

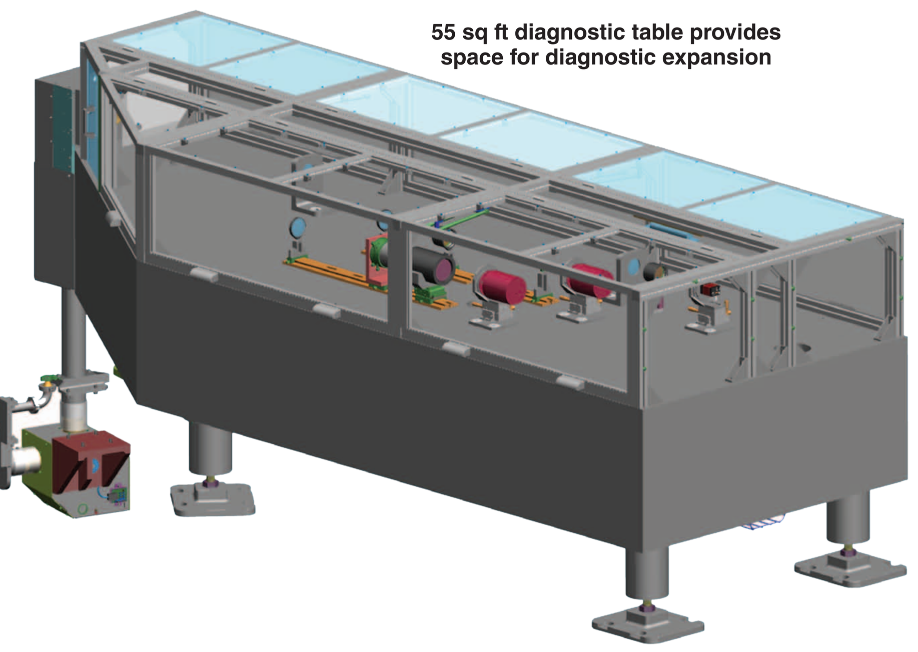
- A collimated section will provide excellent bandpass rejection to overcome 1ω and 3ω drive laser emission (10,000: 1 outside 2-nm bandpass)

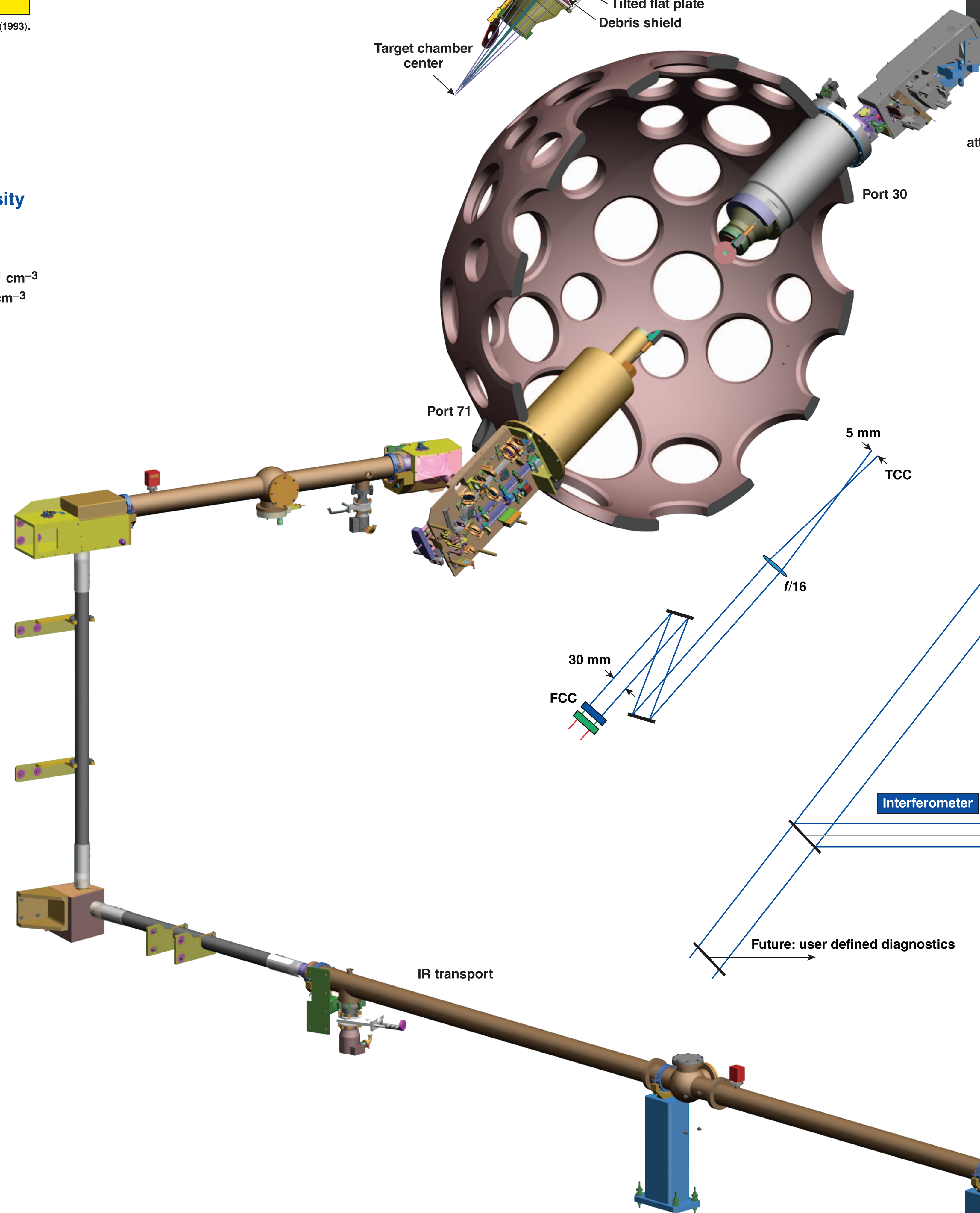


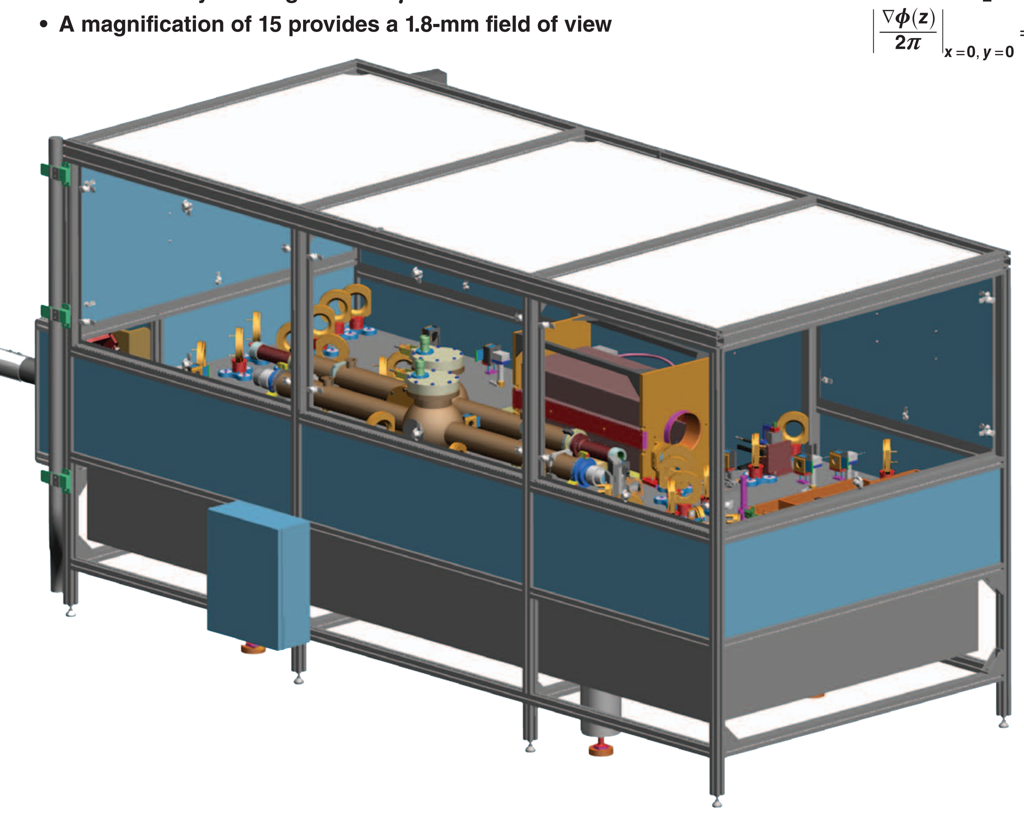
A 100-μm^2 Region Delivers 2.7-μm Resolution; the Objective is to Achieve this Performance over the 5-mm^2 FOV



FWHM = 2.7 μm; diffraction limit = 1.0 μm

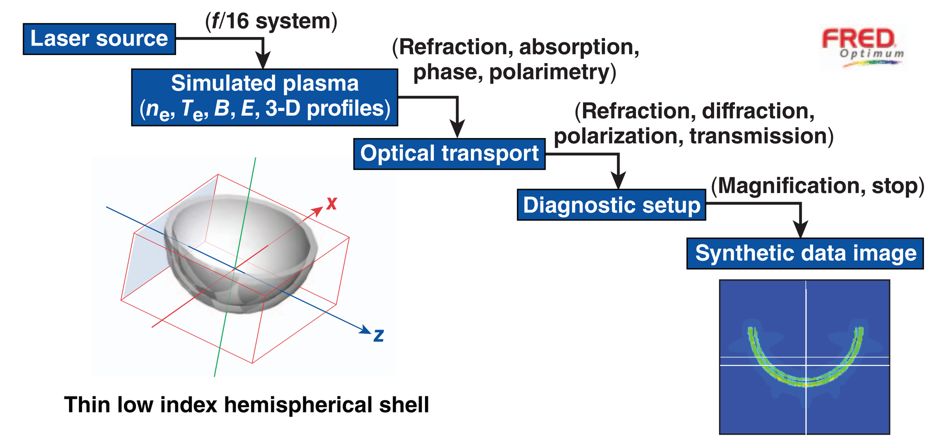




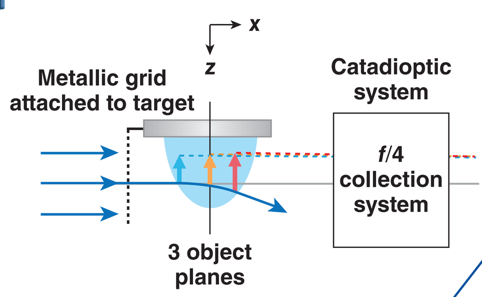


Optical Modeling

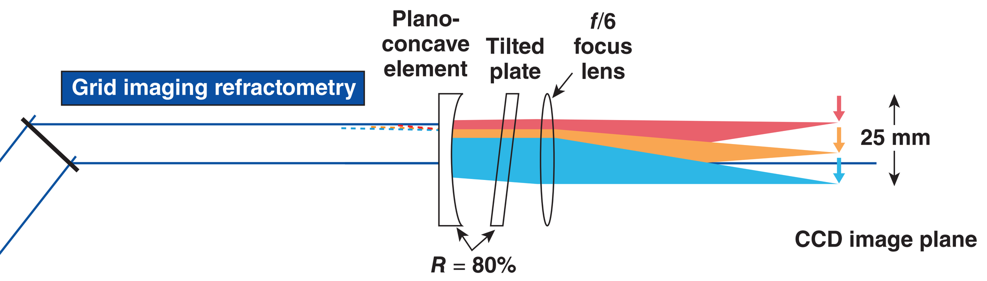
A Complete Analysis Package is being Developed to Provide Experimental Design and Complex Data Reduction

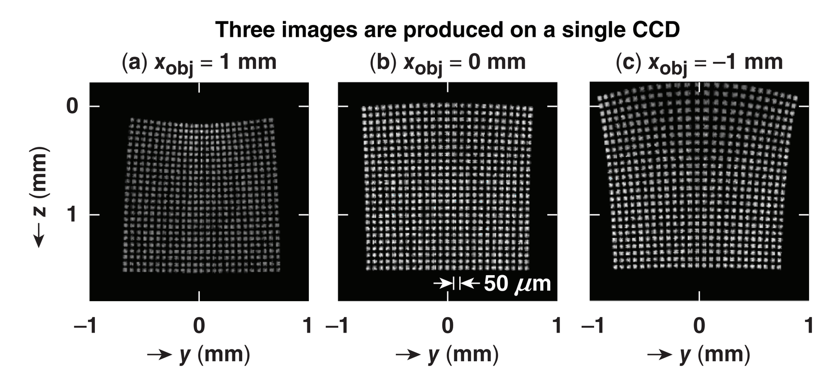


This infrastructure will be available for experimental planning, data analysis, and advanced diagnostic design.



Grid imaging refractometry

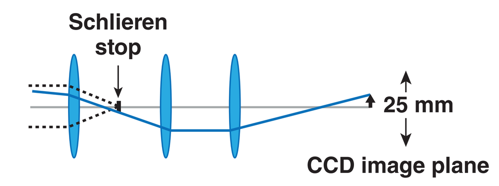




Grid-Imaging Refractometry (GIR) Measures the Refraction of Beamlets at Three Locations within the Plasma

- GIR extends the density measurements to 10^{21} cm^{-3} in long-scale-length plasmas
- Three longitudinal objects in the plasma are imaged to a single CCD
- The system is designed to have <50-μm resolution over a 5-mm field of view
- Maginification of 2

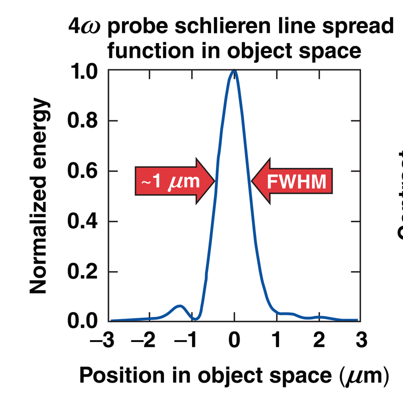
Schlieren/shadowgraphy

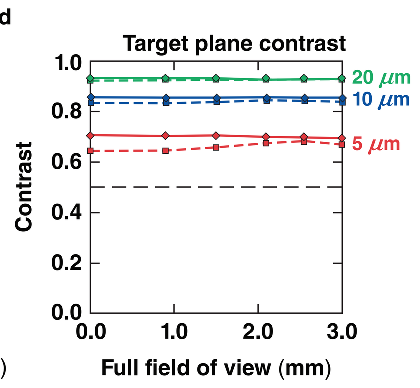


Modeling Indicates the Schlieren Optical Design can Produce 1-μm Resolution in the Plasma Plane

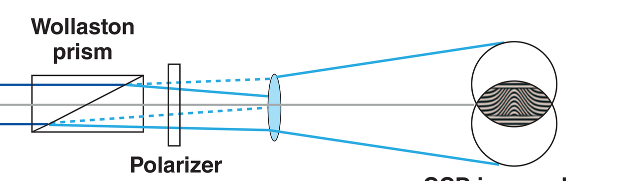
- Convolved with the CCD pixels and alignment realities, a <10-μm resolution is anticipated
- A magnification of M = 7 provides a ~2.5-mm field of view

The system is designed to produce high resolution over the 2.5-mm field of view.





Interferometer



Interferometry is Limited to Electron Densities Below ~4 × 10^{20} cm^{-3} in Laser-Produced Plasmas

- Interferometry is designed for 5-μm resolution
- A magnification of 15 provides a 1.8-mm field of view

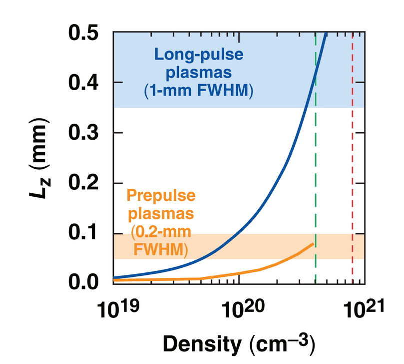
Experimental Design Considerations

- probe beam must overlap plasma with vacuum
- polarization will be rotated to align fringes with experimental configuration
- scale lengths (L_x, L_z) limit the maximum accessible density

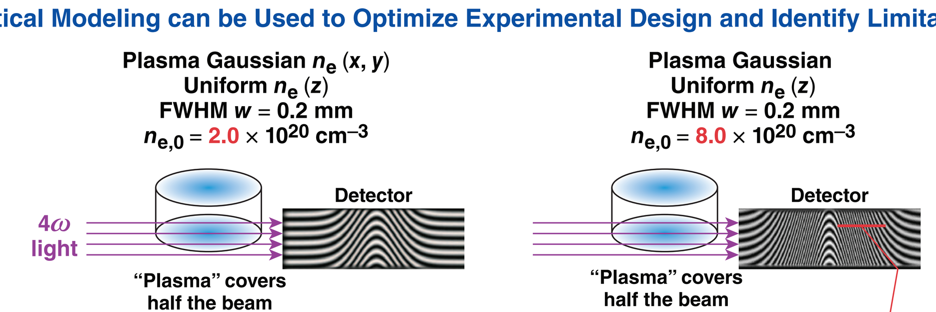
$$\left|\frac{\nabla\phi(x,z)}{2\pi}\right|_{max} < \frac{1\ \text{wave}}{8\ \text{pixels}}$$

$$\left|\frac{\nabla\phi(x)}{2\pi}\right|_{x=\frac{w}{2}} = \frac{\sqrt{\pi \ell n(2)}}{2\lambda}\left(\frac{n_{e,0}}{n_{cr}}\right) < \frac{1}{8\ \text{pixels}} \longrightarrow n_{e,0} < 7 \times 10^{20}\ \text{cm}^{-3}$$

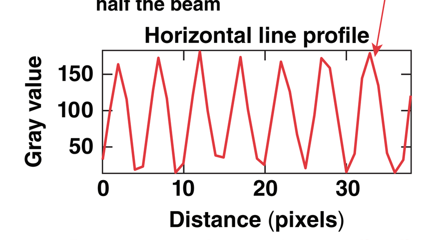
$$\left|\frac{\nabla\phi(z)}{2\pi}\right|_{x=0,\,y=0} = \frac{\sigma\sqrt{\pi}}{2\lambda}\left(\frac{n_{e,0}}{n_{cr}}\right)\left(\frac{1}{L_z}\right) < \frac{1}{8\ \text{pixels}} \longrightarrow n_{e,0} < 4 \times 10^{20}\ \text{cm}^{-3}$$



Optical Modeling can be Used to Optimize Experimental Design and Identify Limitations



- used to idnetify diagnostic limitations
- used to optimize experimental design
- used for advanced post-shot analysis
  - optical model includes refraction



Danger zone: close to the sampling limit!