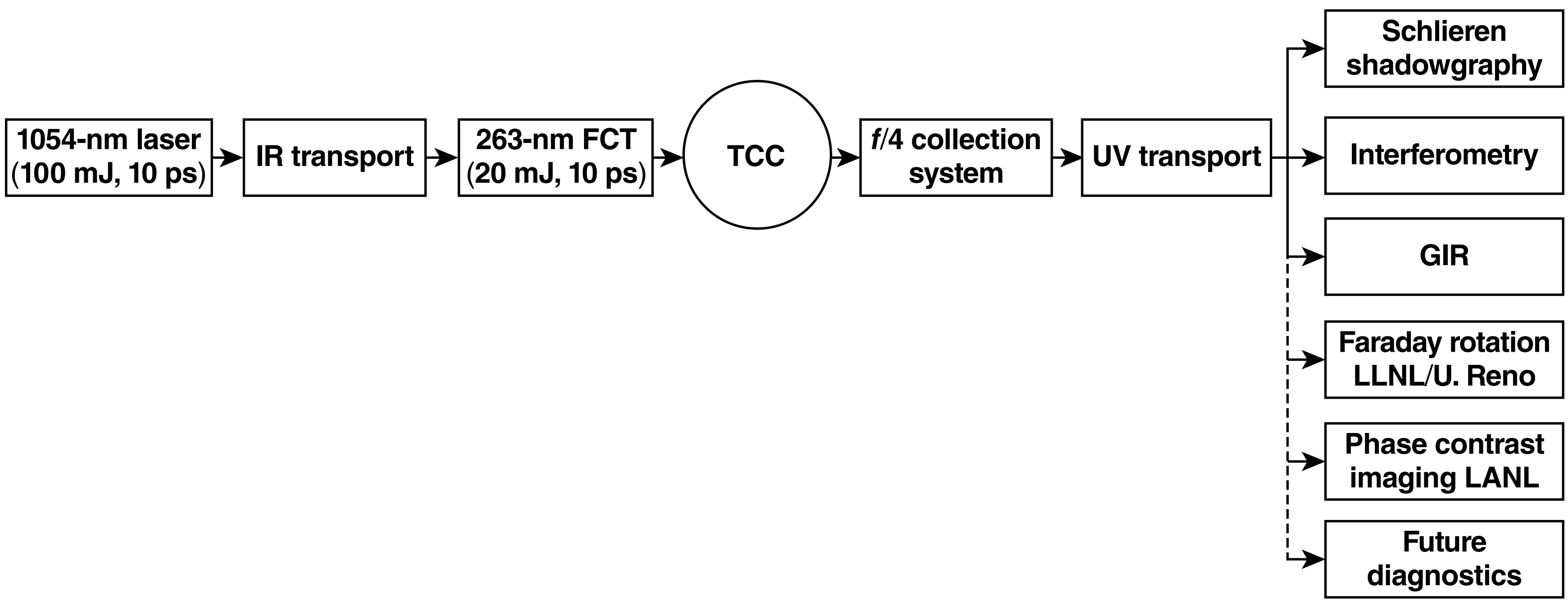
The OMEGA EP
4ω Probe Diagnostic



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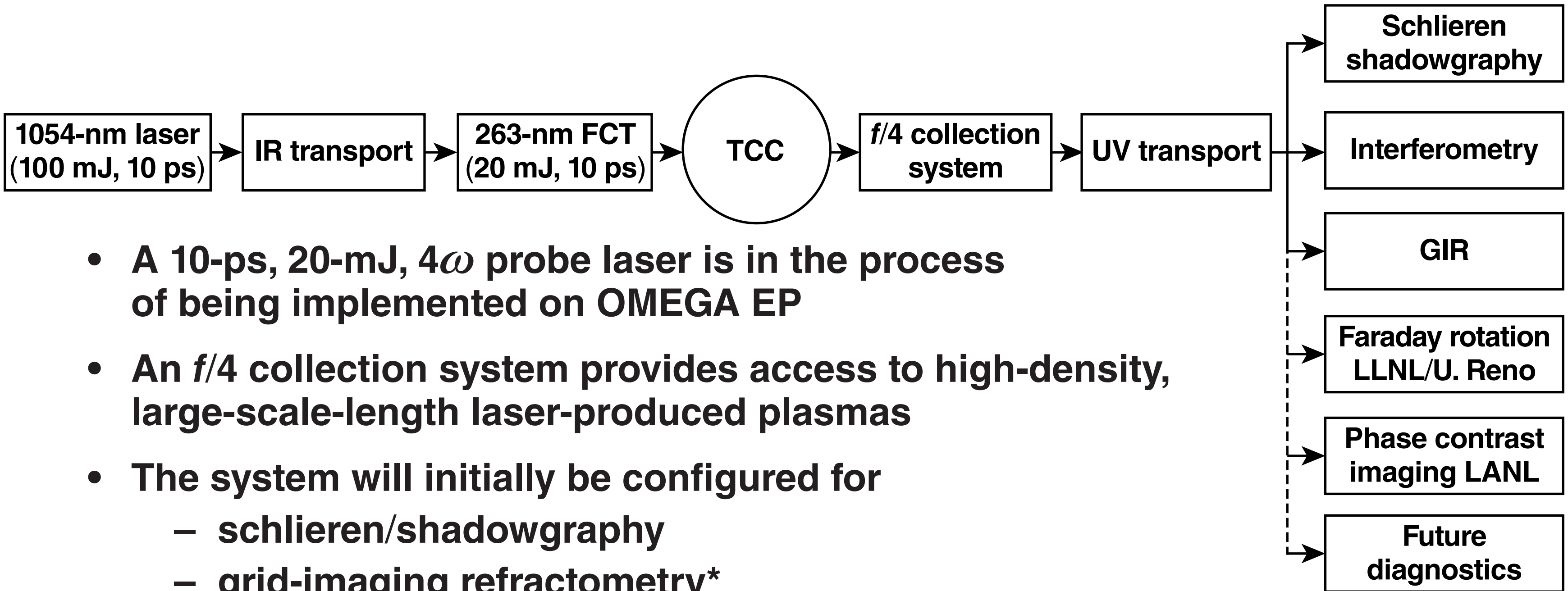
Omega Laser Facility
Users' Group Workshop
Rochester, NY
27–29 April 2011

Summary

The 4ω diagnostic on OMEGA EP will be activated by the end of FY11 and be ready for users by January 2012



- 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.

E19791

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

The 4ω team

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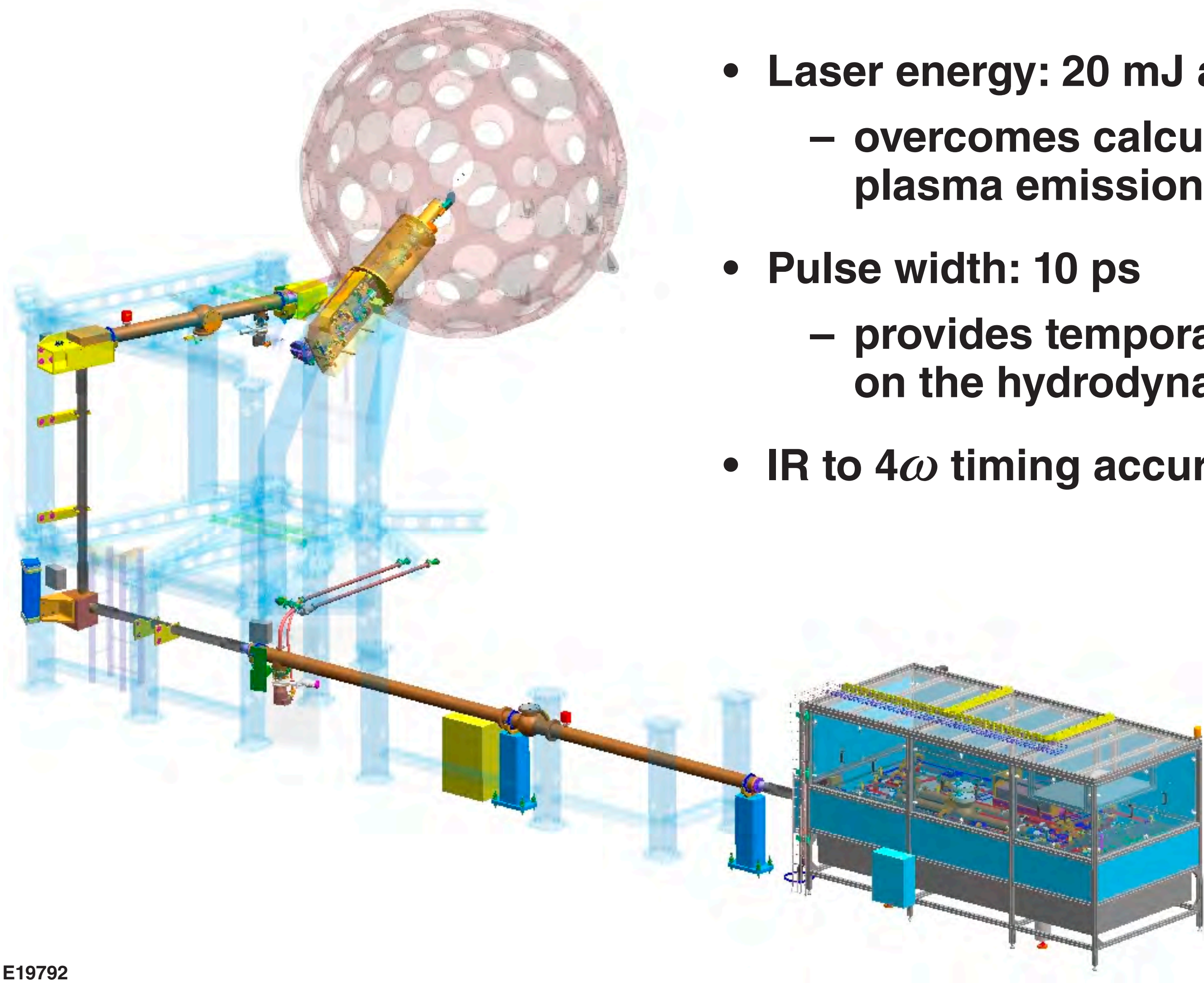
A 263-nm (4ω) laser is currently being qualified on OMEGA EP and will be operational this summer

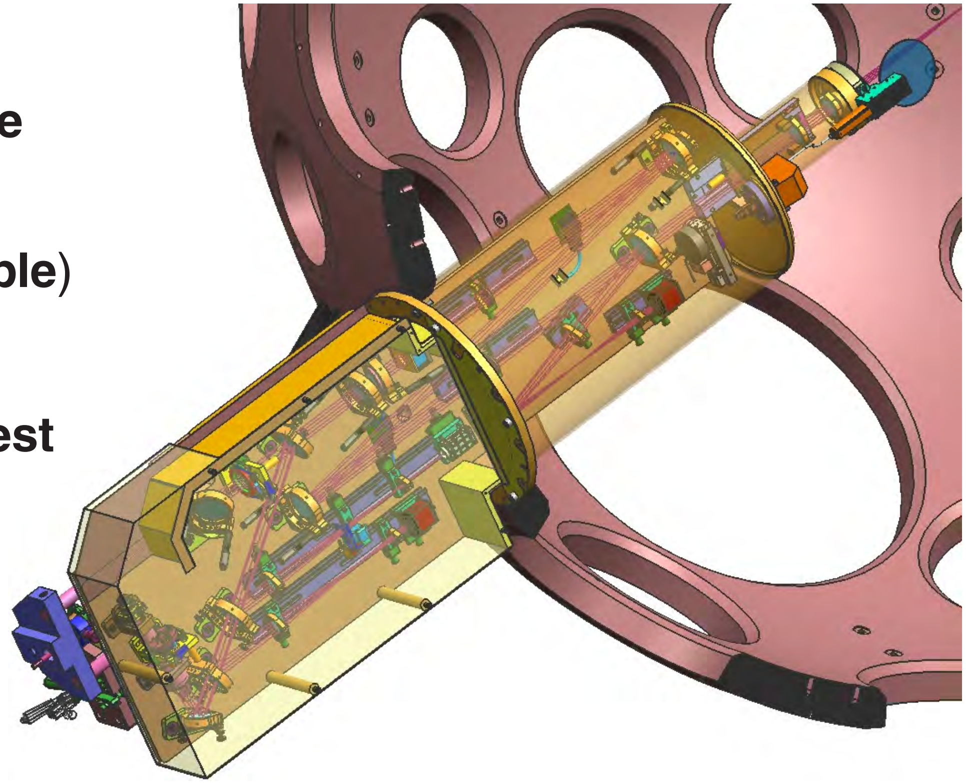


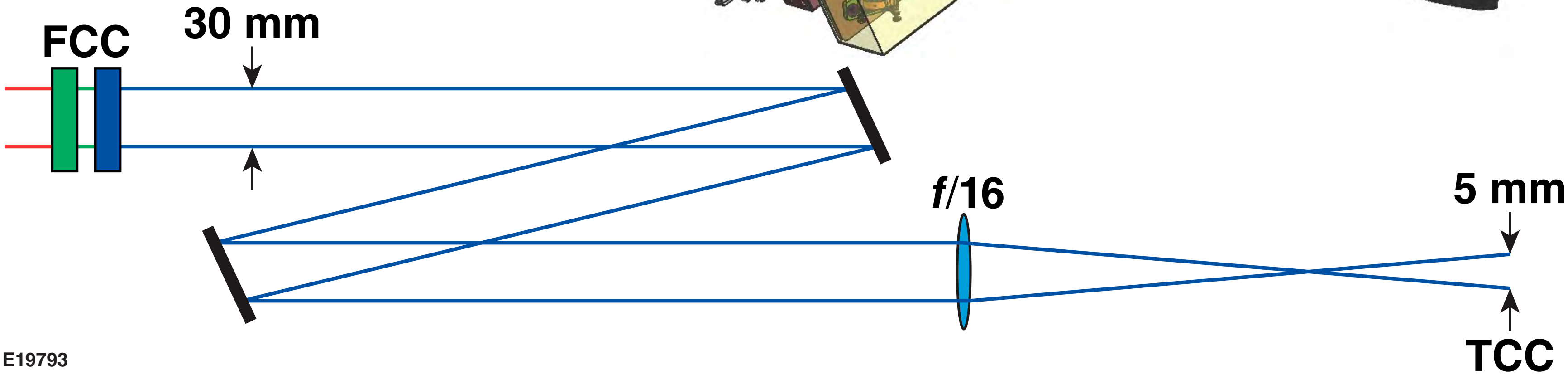
- Laser energy: 20 mJ at 4ω
  - overcomes calculated background plasma emission around 263 nm
- Pulse width: 10 ps
  - provides temporal resolution on the hydrodynamic time scales
- IR to 4ω timing accuracy: 10 ps

E19792

The laser system will deliver a 5-mm spot to target chamber center with high spatial uniformity

- High-quality spatial-beam profile
  - <20% modulation at TCC
- Polarization is controlled (variable)
- System can be focused at TCC
- Enters from port 71 chamber west



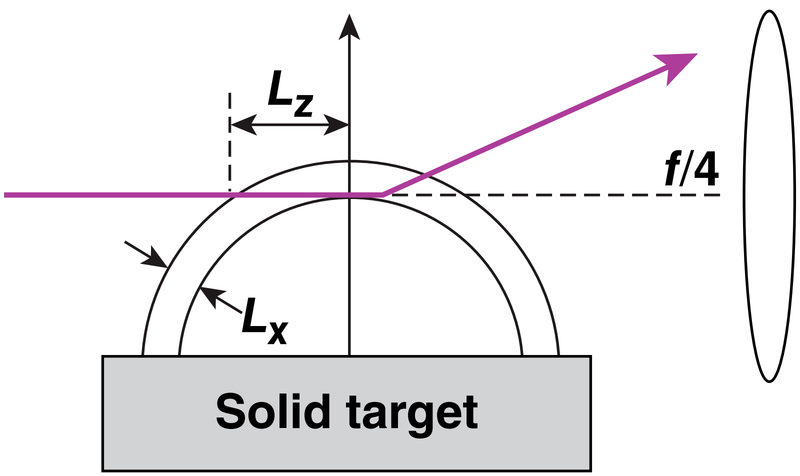


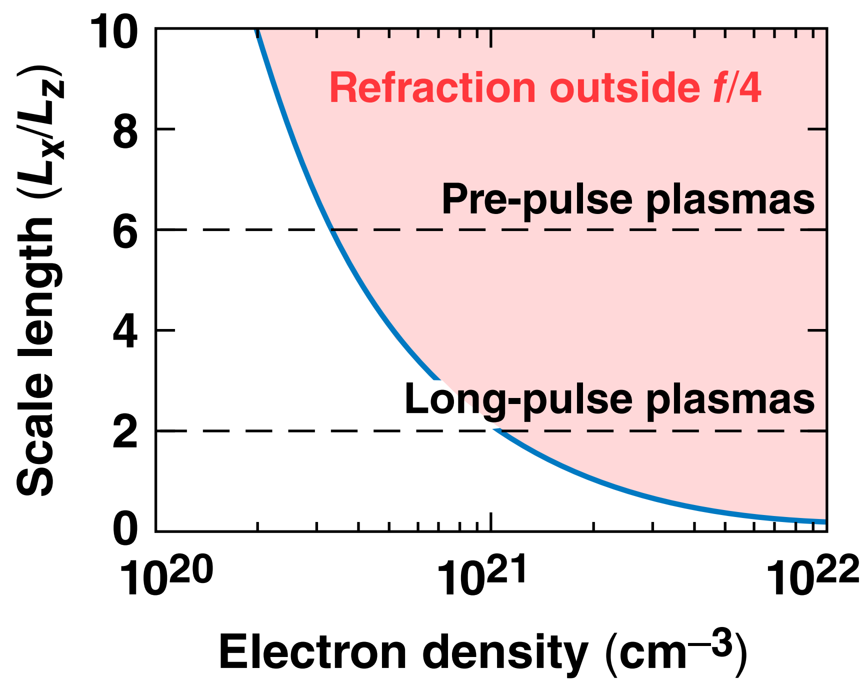
E19793

The optical collection system will provide access to high density laser-produced plasmas

An $f/4$ system:

- long-pulse plasmas ($L_x/L_z \sim 2$): $n_e = 10^{21}\ \mathrm{cm}^{-3}$
- prepulse plasmas ($L_x/L_z \sim 6$): $n_e = 4 \times 10^{20}\ \mathrm{cm}^{-3}$

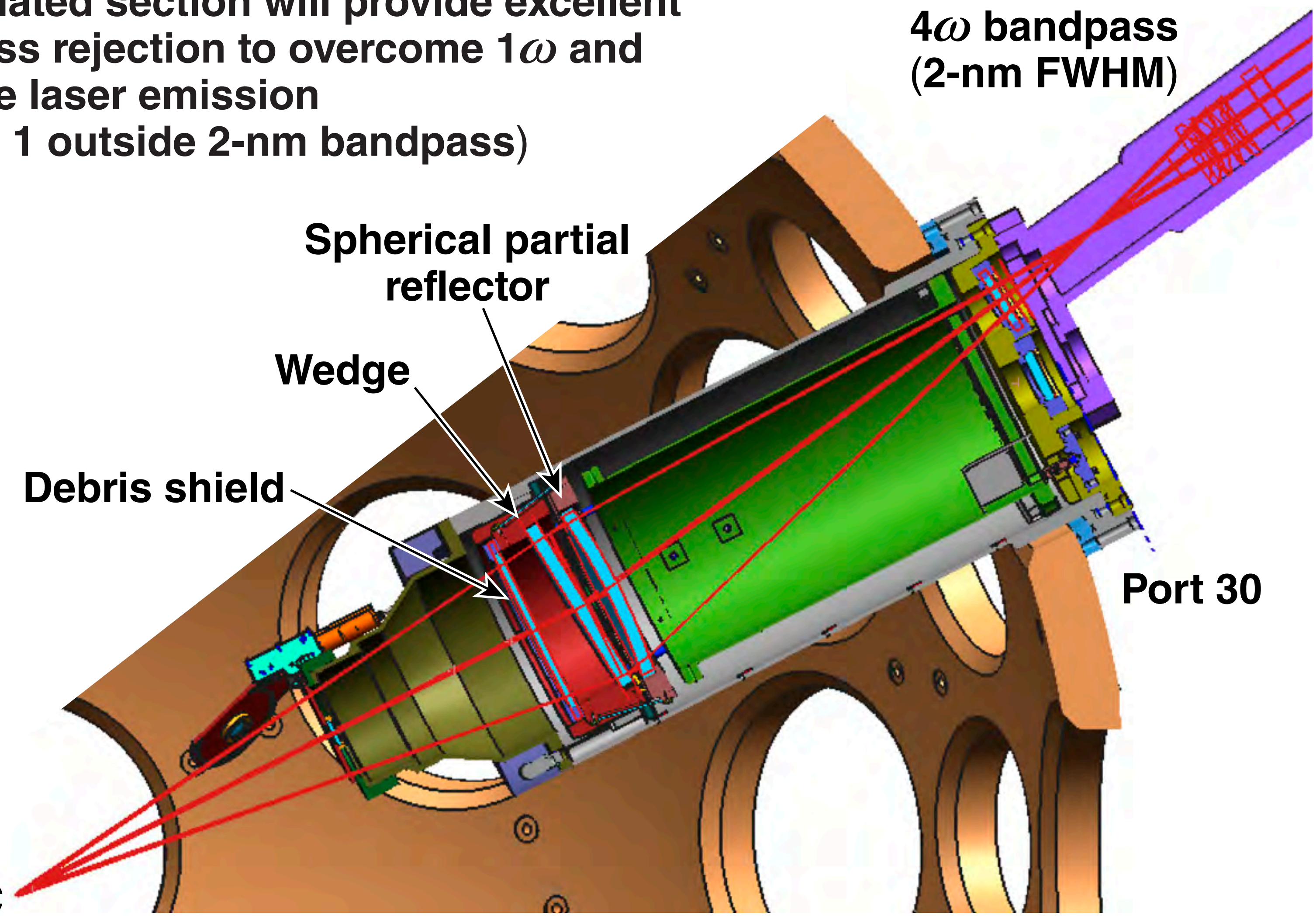




An $f/4$ system will provide access to highly refractive plasmas.

The *f*/4 collection system will provide <5 μm resolution over the 5-mm field of view

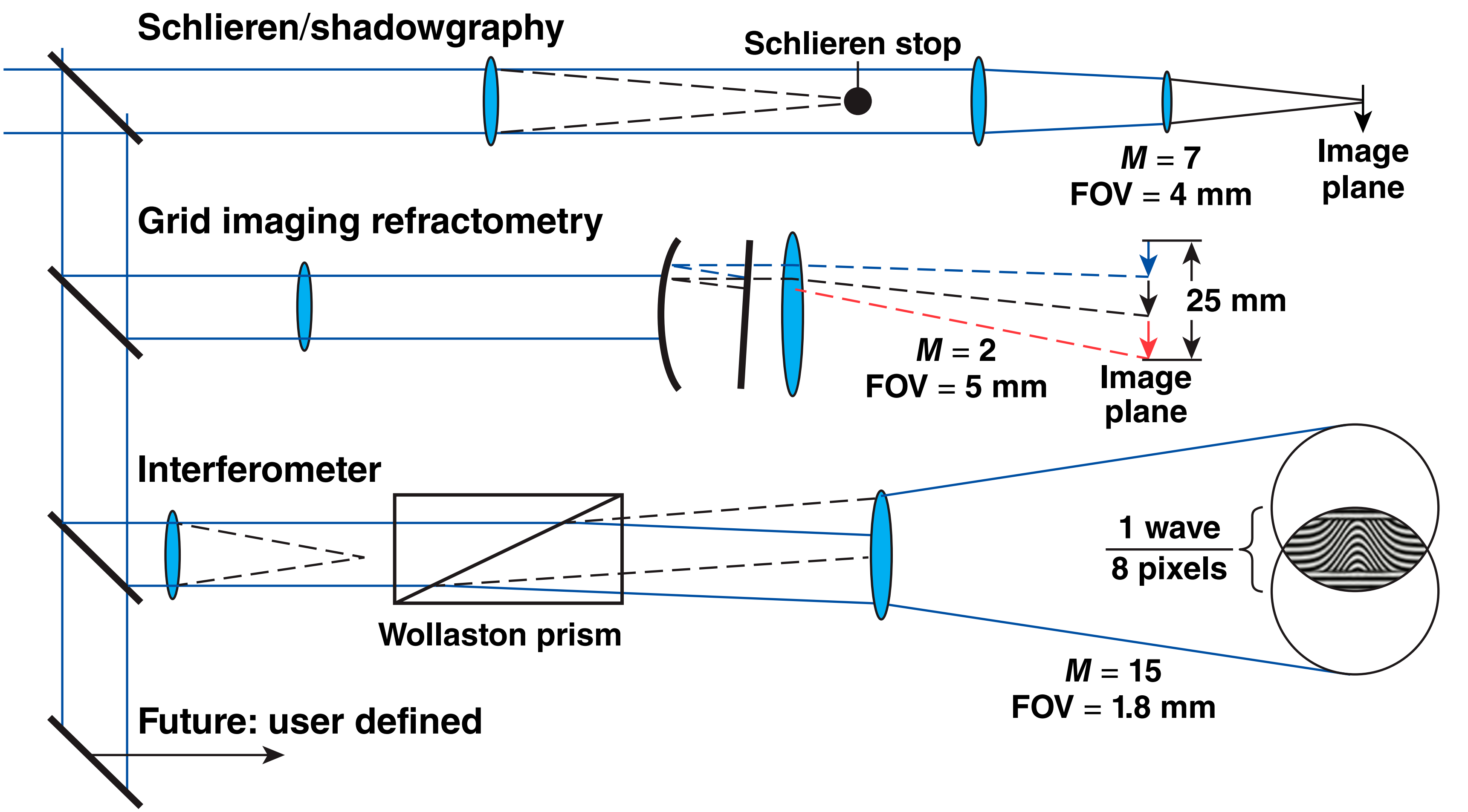
- **A collimated section will provide excellent bandpass rejection to overcome 1ω and 3ω drive laser emission (10,000: 1 outside 2-nm bandpass)**



f/4 catadiotroptric collection system

E19829

The optical transport accommodates multiple diagnostics and has built-in flexibility

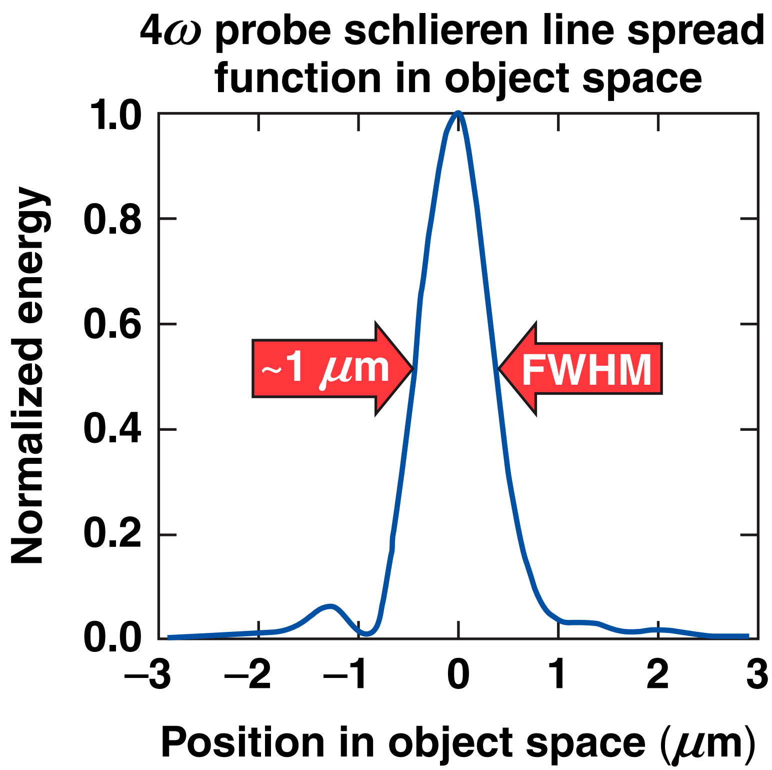


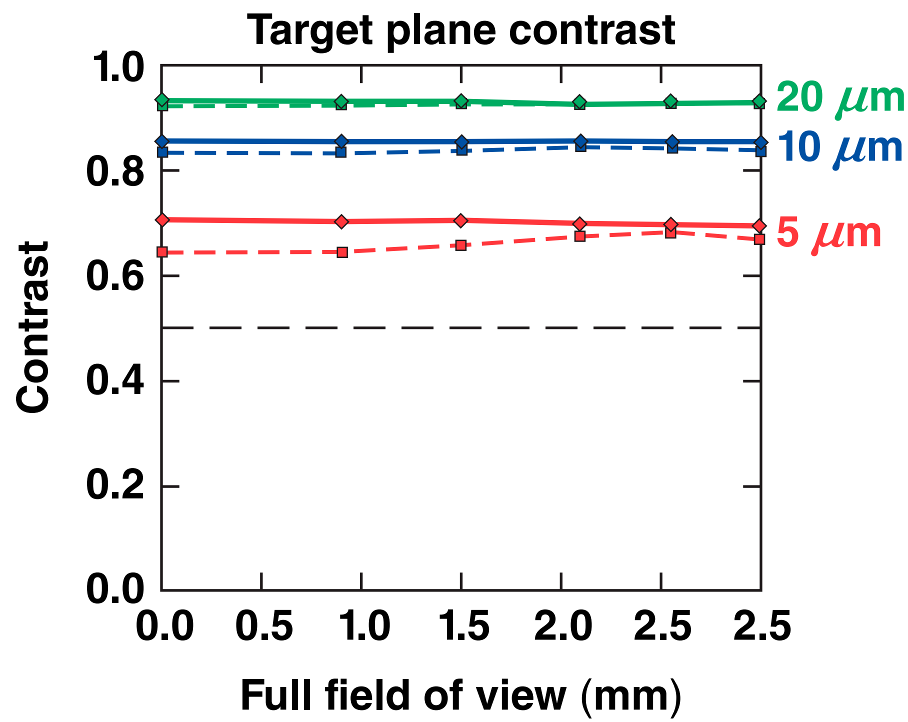
The 55-sq-ft diagnostic table provides space for diagnostic expansion.

E19795

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.

E19796

A complete analysis package is being developed to provide experimental design and complex data reduction

An optical transport model is being developed to propagate a complex optical-vector field through the complete system

Laser source

(*f*/16 system)

Simulated plasma (n_e, T_e, B, E, 3-D profiles)

(Refraction, absorption, phase, polarimetry)

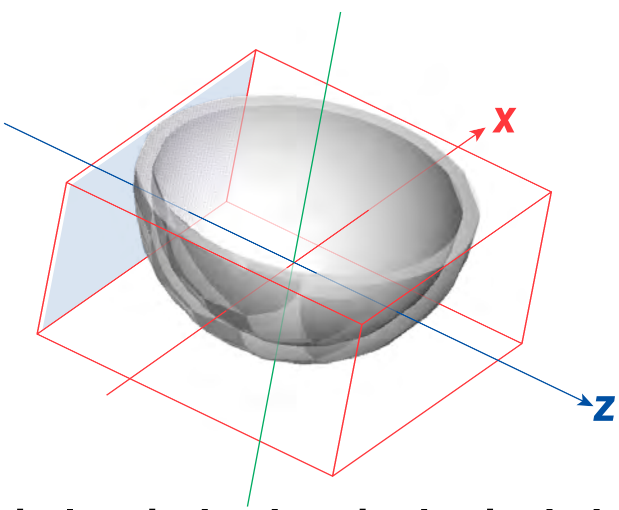
Optical transport

(Refraction, diffraction, polarization, transmission)

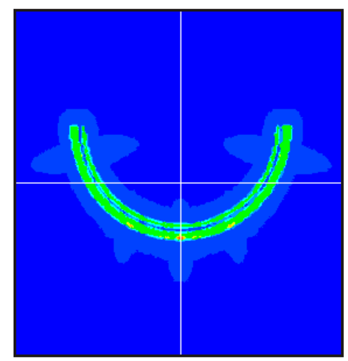
Diagnostic setup

(Magnification, stop)

Synthetic data image



Thin low index hemispherical shell



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

E19797

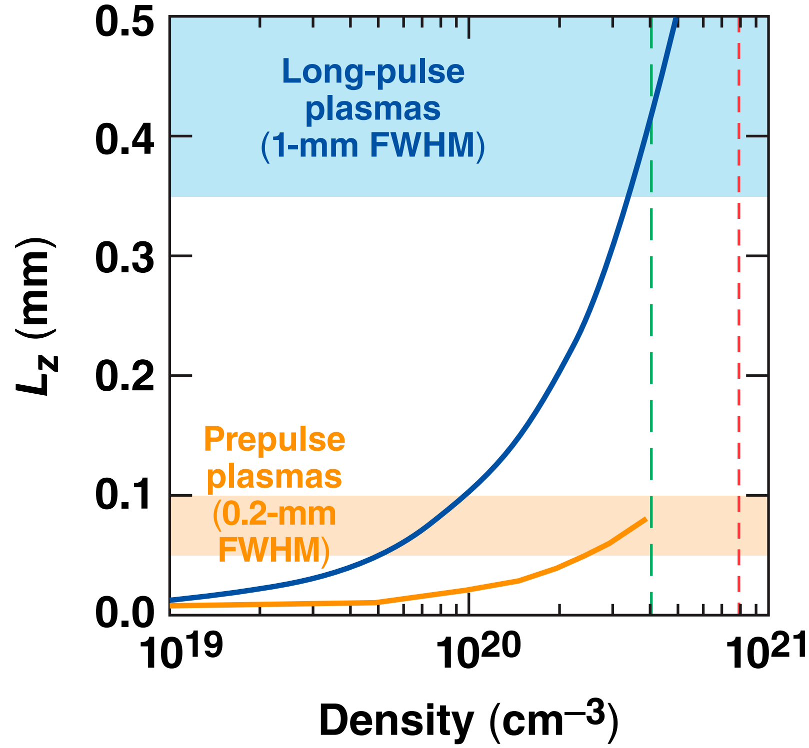
Interferometry is limited to electron densities below ~4×10^{20} cm^{-3} in laser-produced plasmas

UR LLE

- Interferometry has been 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



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

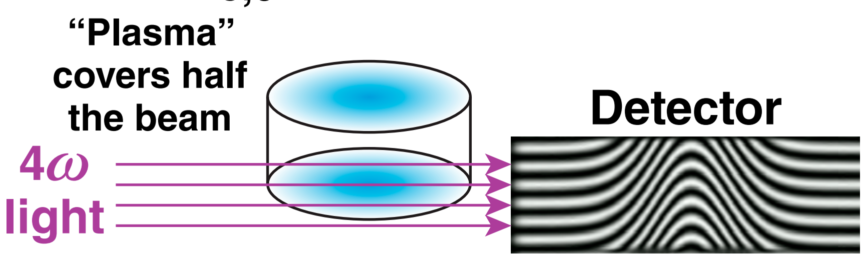
$$\left|\frac{\nabla\phi(x)}{2\pi}\right|_{x=\frac{w}{2}} = \frac{\sqrt{\pi \ln(2)}}{2\lambda}\left(\frac{n_{e,0}}{n_{cr}}\right) < \frac{1}{8 \text{ pixels}} \longrightarrow n_{e,0} < 7 \times 10^{20} \text{ cm}^{-3}$$

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

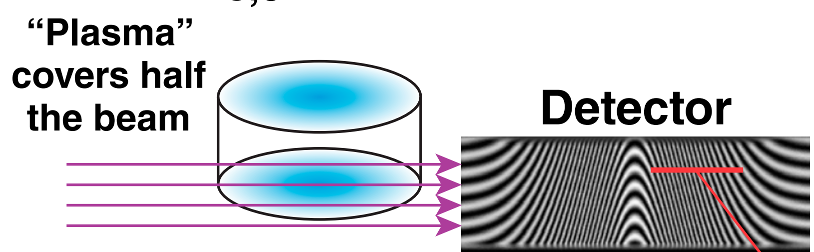
E19798

Optical modeling can be used to optimize experimental design and identify limitations

Plasma Gaussian n_e (*x*, *y*)
Uniform n_e (*z*)
FWHM w = 0.2 mm
$n_{e,0}$ = 2.0 × 10^{20} cm^{-3}

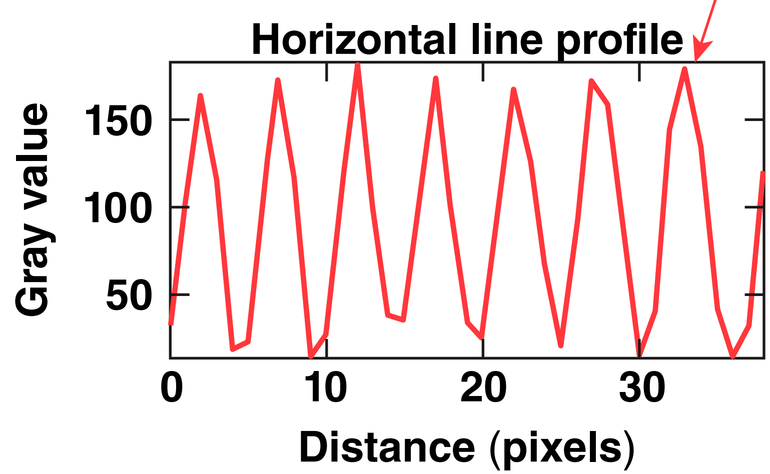


Plasma Gaussian n_e (*x*, *y*)
Uniform n_e (*z*)
FWHM w = 0.2 mm
$n_{e,0}$ = 8.0 × 10^{20} cm^{-3}



Optical model

- **Used to identify diagnostic limitations**
- **Used to optimize experimental design**
- **Used for advanced post-shot analysis**
  - **optical model includes refraction**



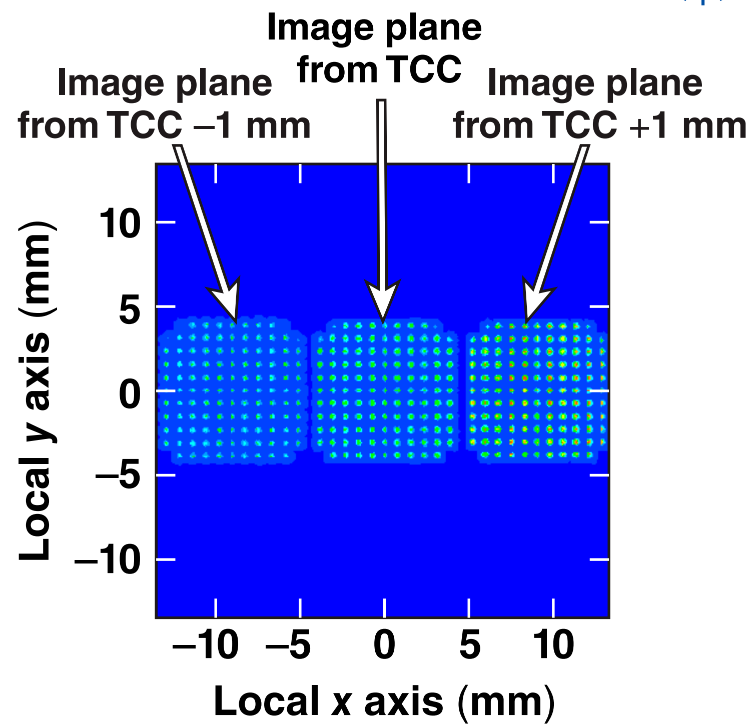
Danger zone:
close to the sampling limit!

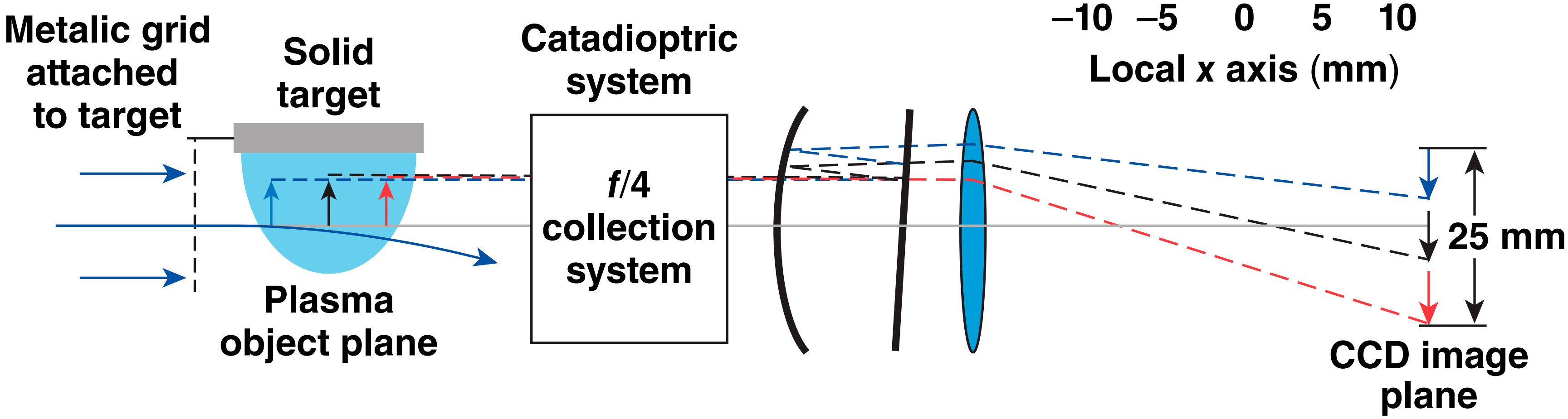
E19799

See poster by N. Kugland

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
- Magnification of 2





E19800

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

Summary/Conclusions

The 4ω diagnostic on OMEGA EP will be activated by the end of FY11 and be ready for users by January 2012

1054-nm laser (100 mJ, 10 ps) → IR transport → 263-nm FCT (20 mJ, 10 ps) → TCC → *f*/4 collection system → UV transport →

- Schlieren shadowgraphy
- Interferometry
- GIR
- Faraday rotation LLNL/U. Reno
- Phase contrast imaging LANL
- Future diagnostics

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