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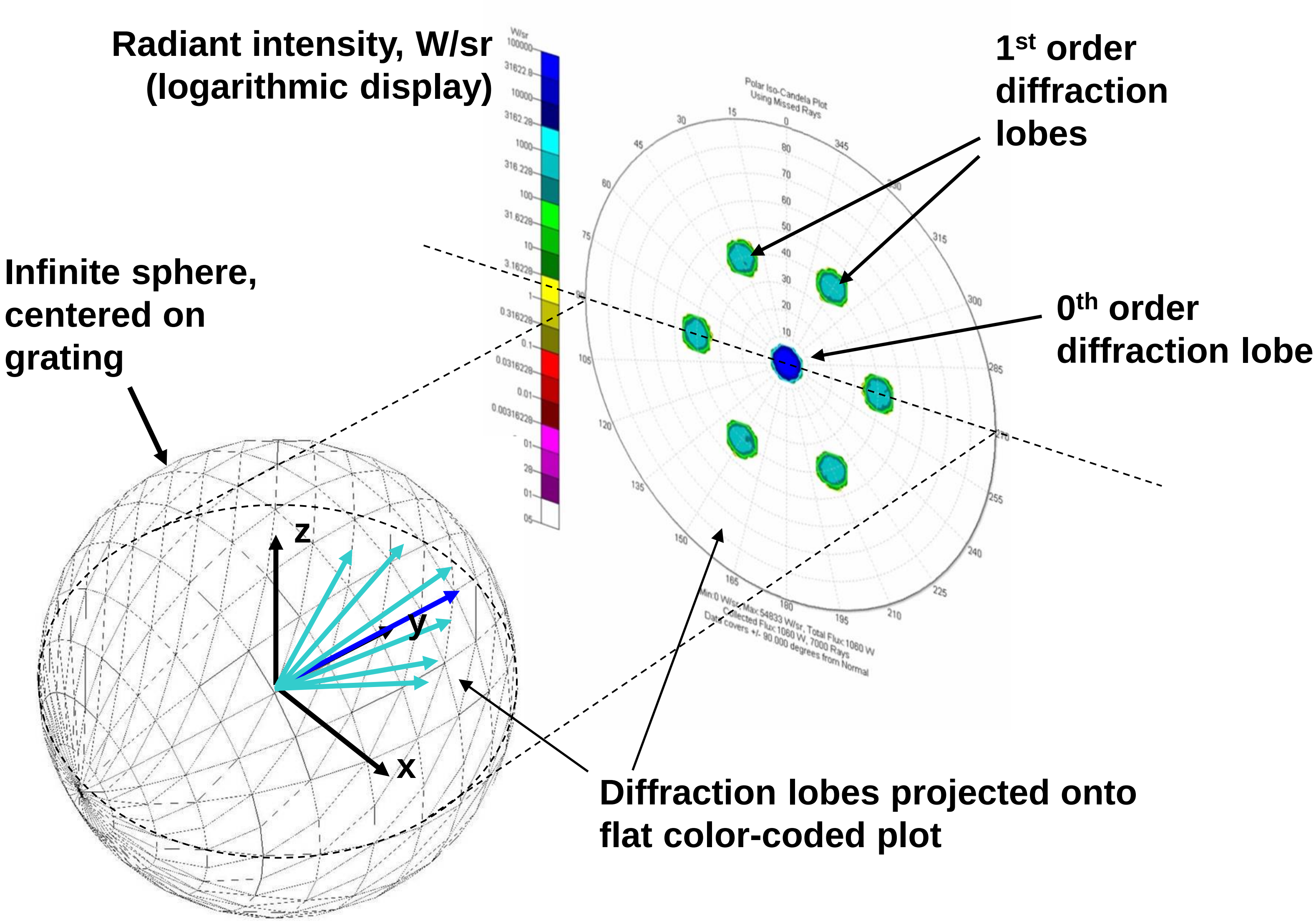
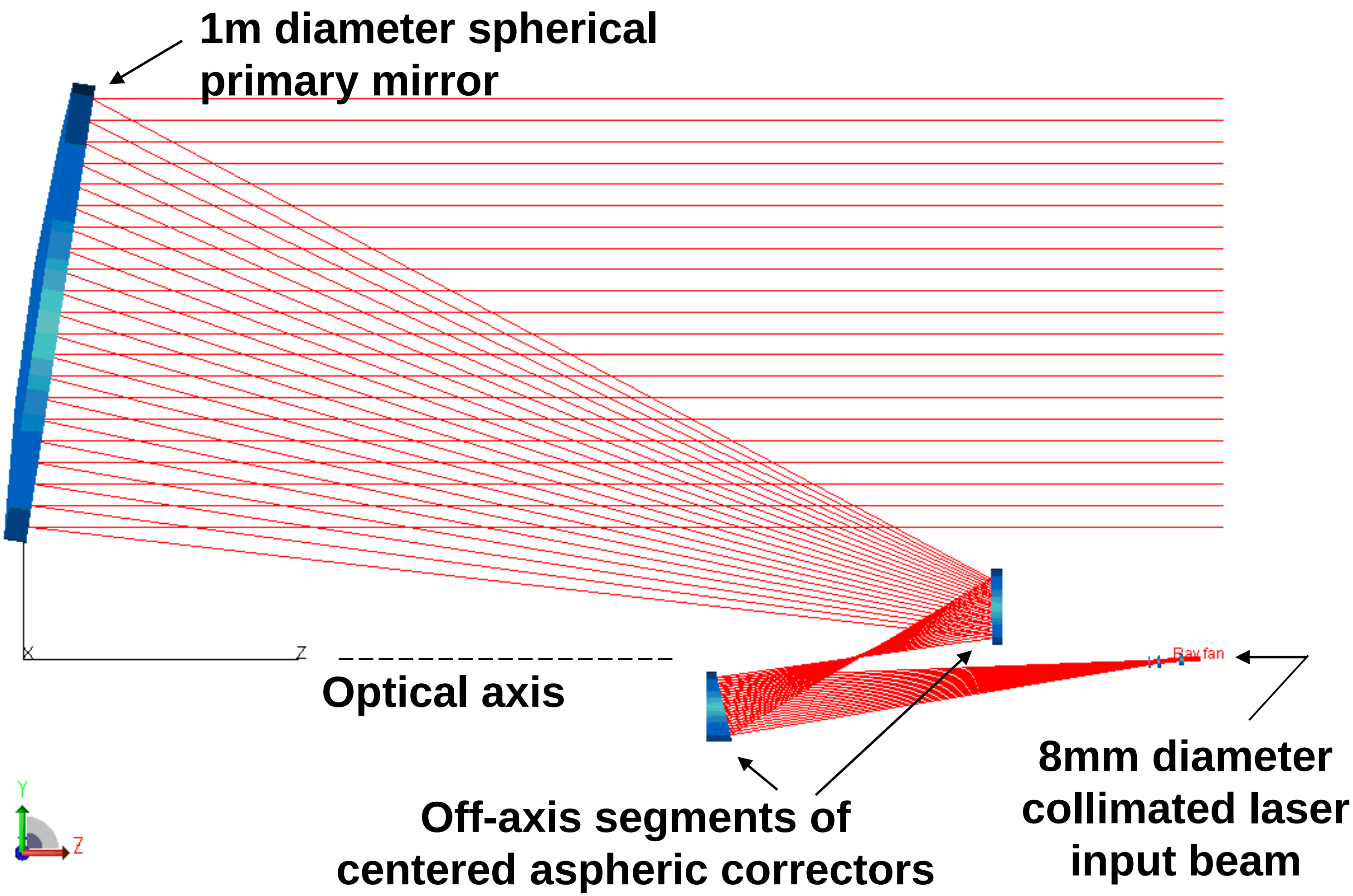
Diffracted Light Visualization



1m Aperture Aberration-corrected 125x Laser Beam Expander

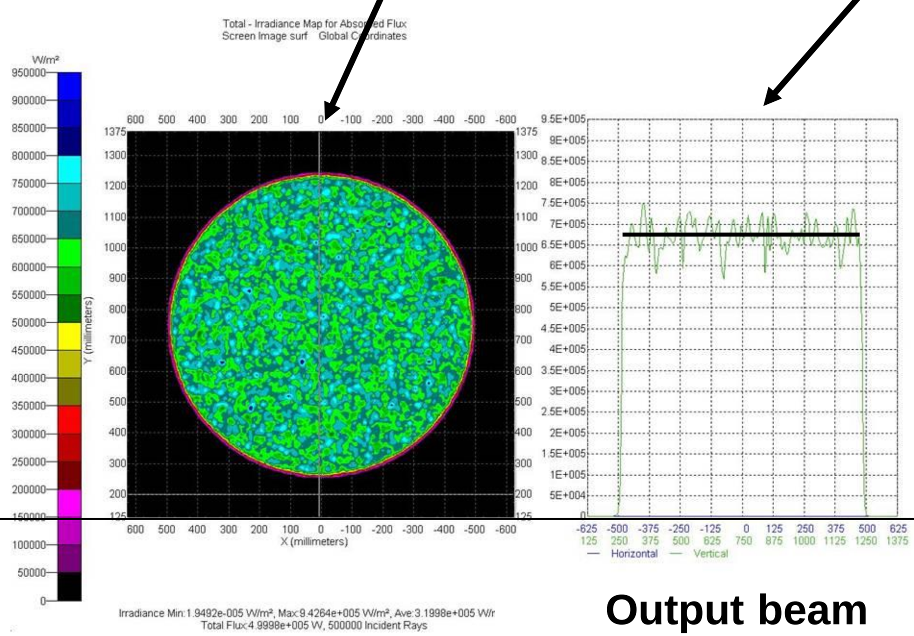


Near-field Irradiance Profile of 125x Laser Beam Expander

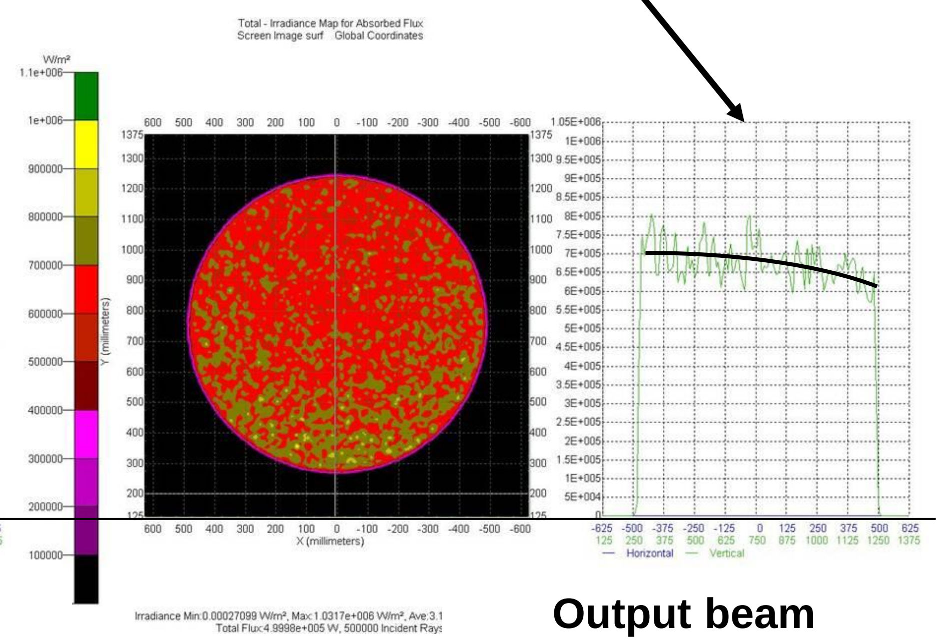
Coma-corrected design vs. typical off-axis parabola

1 m dia. output beam

Vertical slice through projected beam



Output beam intensity profile is uniform

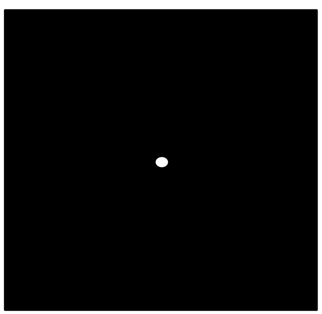


Output beam intensity profile is NOT uniform

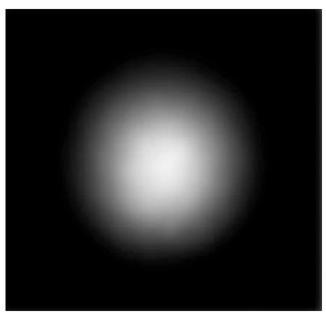
Simulating Image Degradation due to Atmospheric Turbulence Effects

- **Atmospheric turbulence (*e.g.*, astronomical "seeing") reduces angular resolution of optical instrumentation**
- **Time-averaged blur has Gaussian intensity distribution**
- **Size of Gaussian distribution is proportional to magnitude of atmospheric turbulence**

No turbulence



With turbulence



Time-averaged image of point source, in the presence of atmospheric turbulence

No turbulence

With turbulence

Time-averaged image of extended source, in the presence of atmospheric turbulence

Atmospheric Turbulence

- **Atmospheric turbulence is characterized by the atmospheric refractive index structure constant C_n^2**
- **C_n^2 values are typically 1×10^{-14} at night and 2×10^{-14} during the day**
- **Fried's parameter r_0 is the statistically averaged maximum effective aperture diameter over which diffraction-limited resolution is possible**
- **r_0 is related to C_n^2 by the equation**

$$r_0 = (0.423\, C_n^2\, k^2\, z)^{-3/5}$$

where C_n^2 has units of $m^{-2/3}$, $k = 2\pi/\lambda$, wavelength λ and range z are expressed in meters

- **Time-averaged angular diameter (FWHM in radians) of the "seeing-induced" PSF (point spread function) is given by**

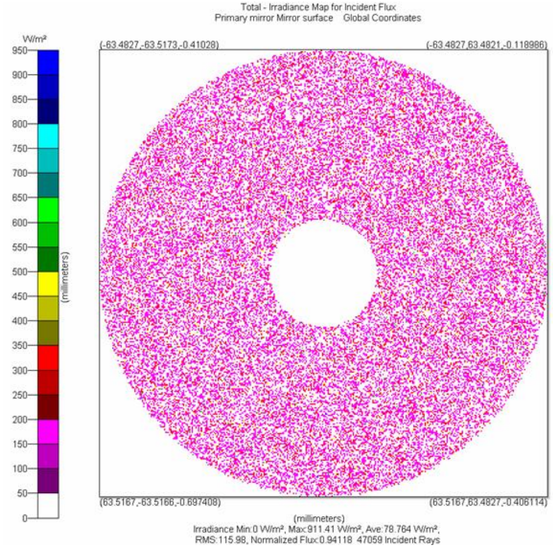
$$\text{FWHM} = 0.98\, \lambda / r_0$$

where r_0 and λ are expressed in the same units

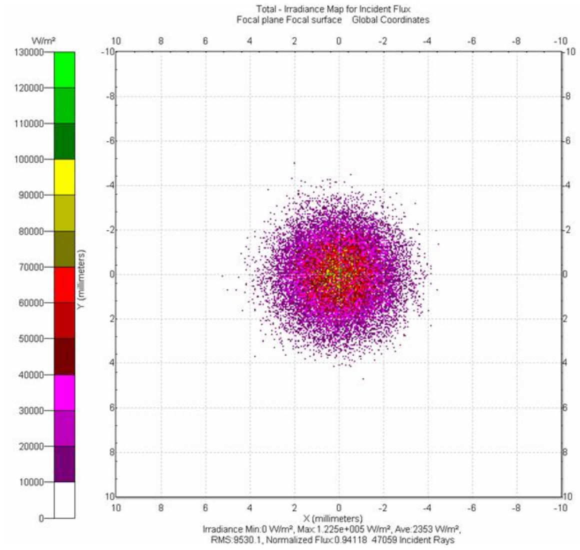
Modeling Atmospheric Turbulence

- For analytical modeling (e.g., ray tracing) time-averaged atmospheric turbulence may be modeled as a Gaussian distribution of ray arrival angles across the entrance pupil, with uniform irradiance across the entrance pupil
- Produces Gaussian PSF (intensity distribution) at focal plane

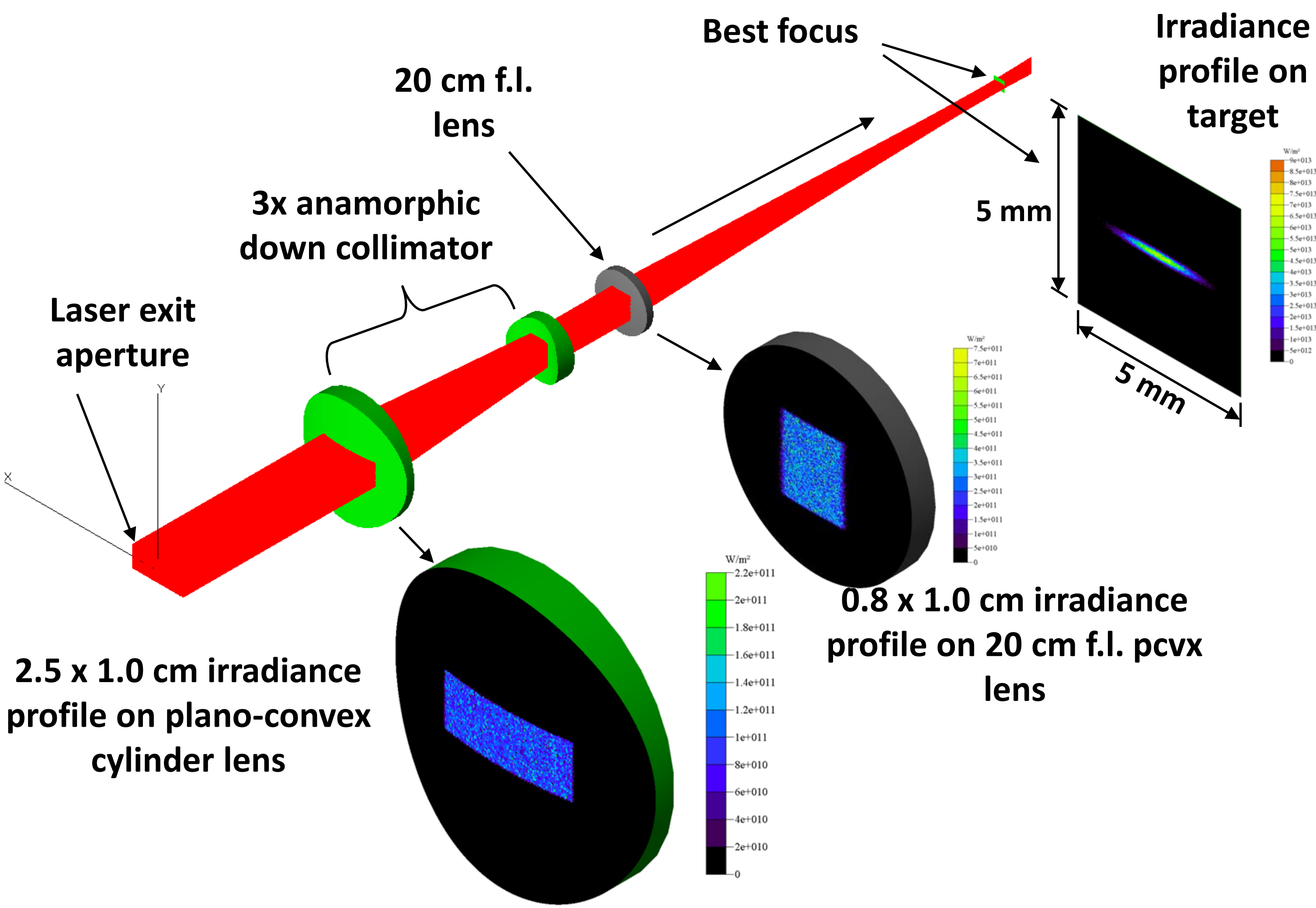
Uniform intensity on centrally-obscured entrance pupil



Focal plane PSF has Gaussian intensity distribution

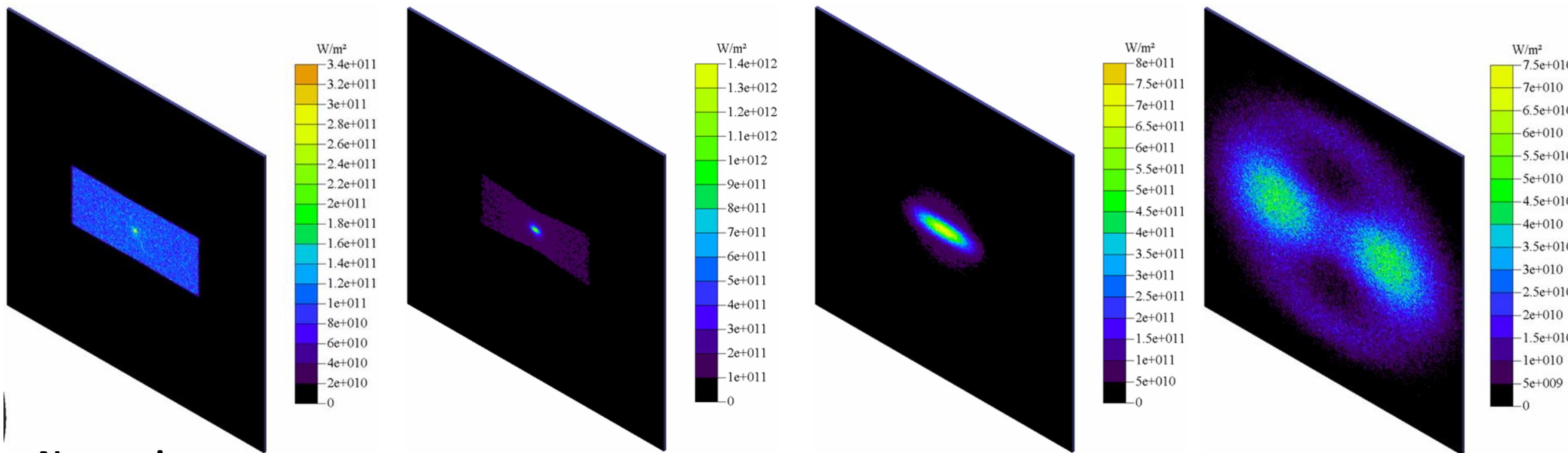


Optical Modeling of Excimer Laser Beam



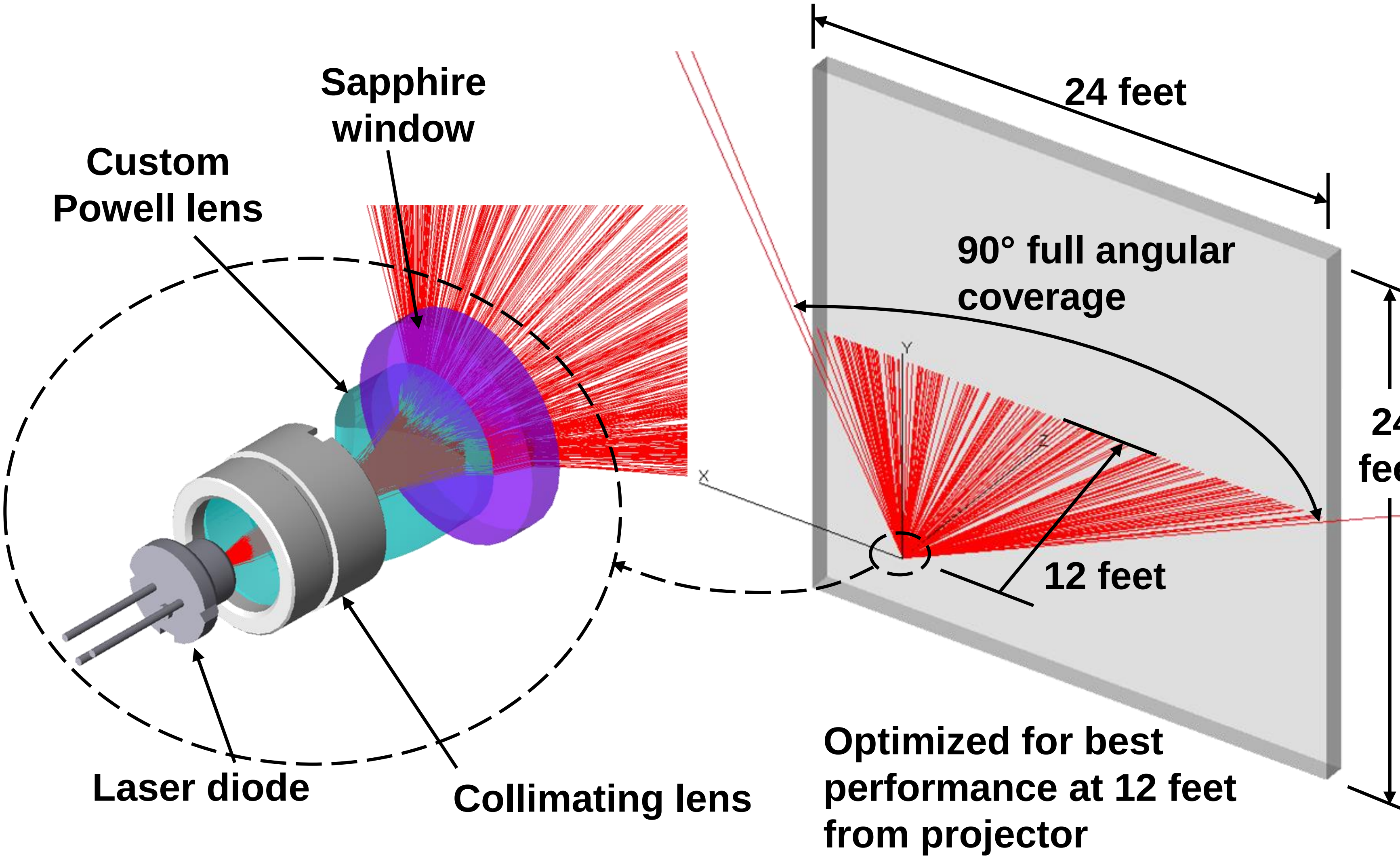
Optical Modeling of Excimer Laser Beam

50 mm x 50 mm target at various distance from refractive axicon

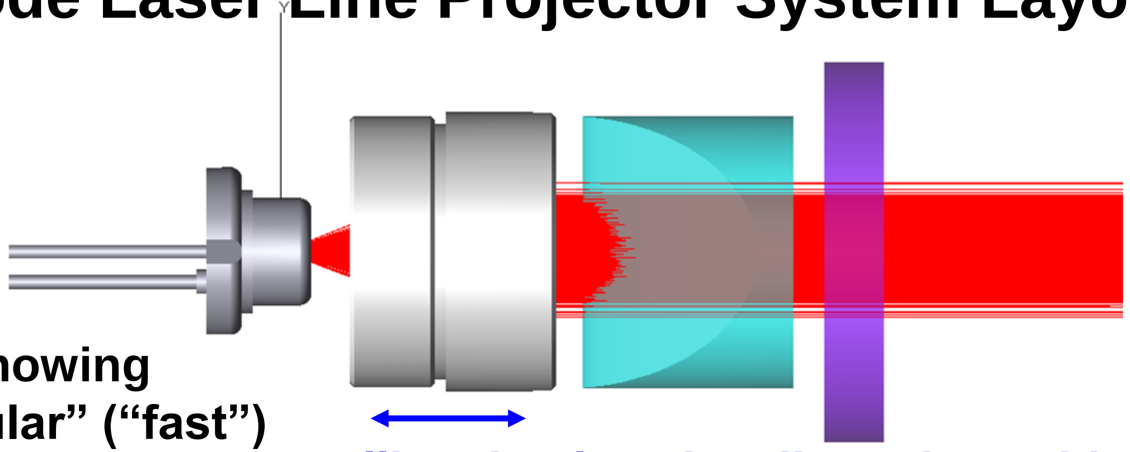


Near axicon (Z = 0.1 m) | **Z = 0.4 m** | **Z = 2.0 m** | **Z = 4.5 m**

Diode Laser Line Projector

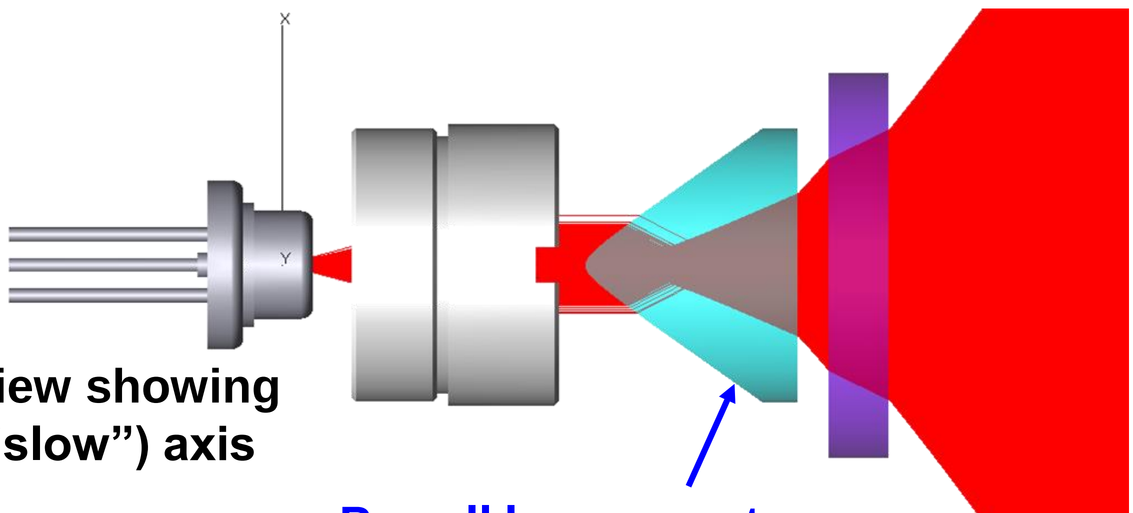


Diode Laser Line Projector System Layout



Side view showing "perpendicular" ("fast") axis divergence

Collimating lens is adjusted to achieve best "perpendicular" ("fast") axis focus at 12 feet

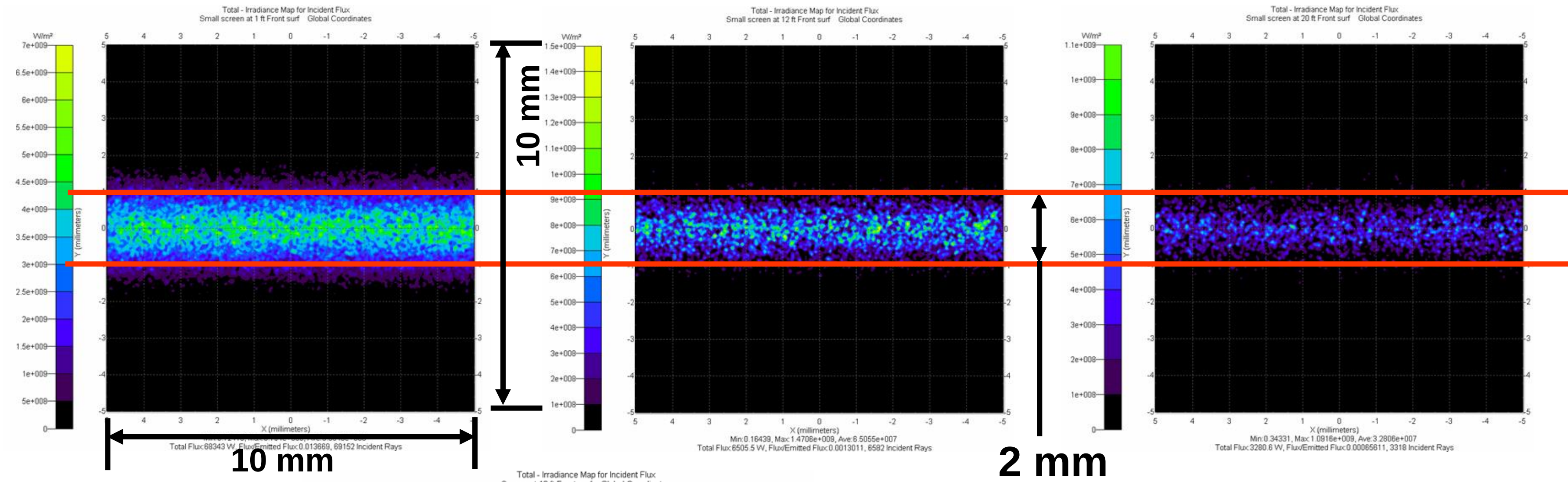


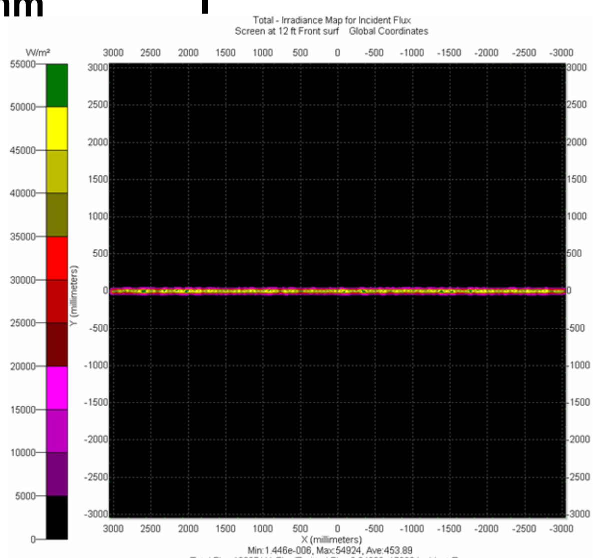
Overhead view showing "parallel" ("slow") axis divergence

Powell lens operates on "parallel" ("slow") axis

Diode Laser Projected Beam Characteristics

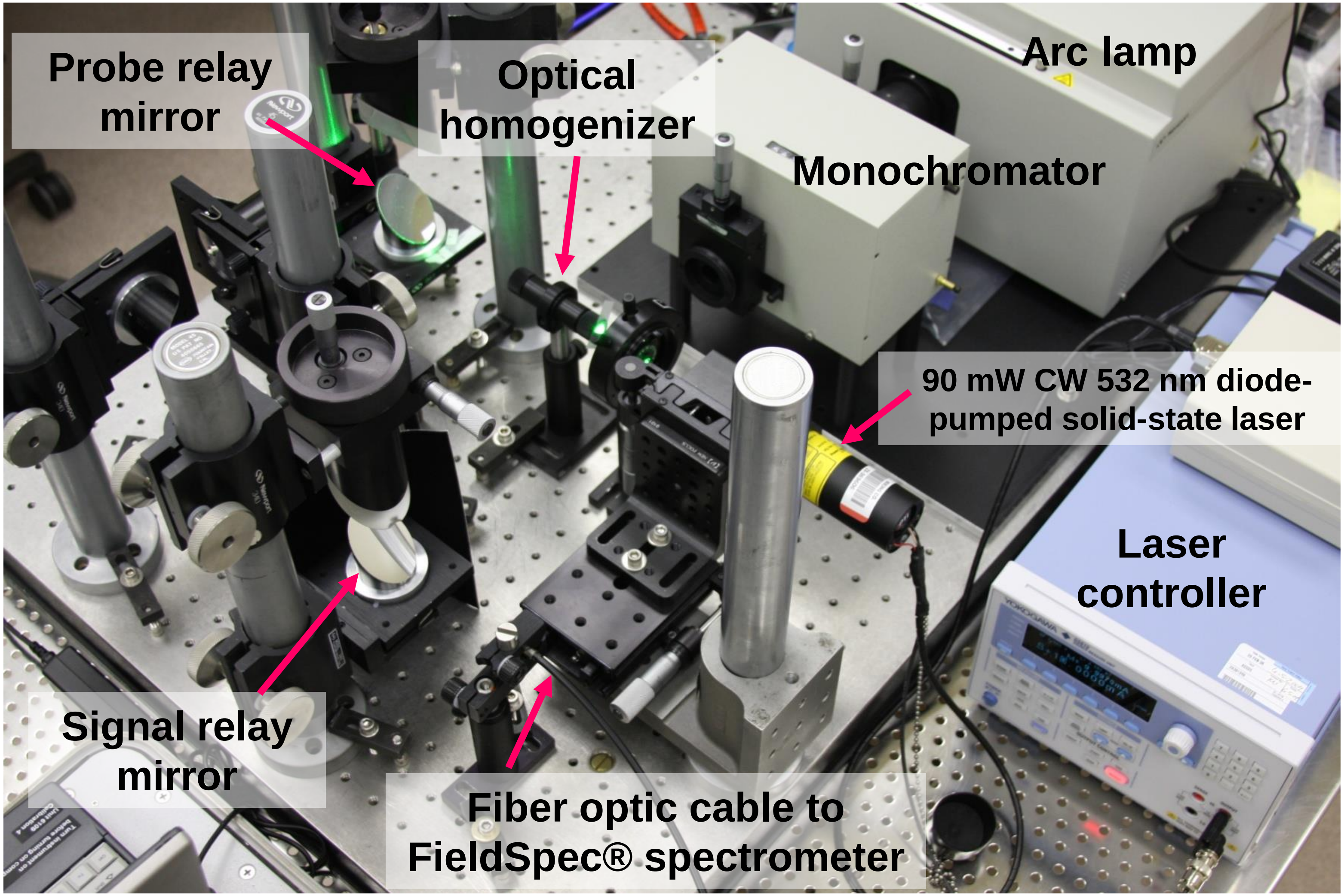
Distance = 1 Foot **12 Feet** **20 Feet**



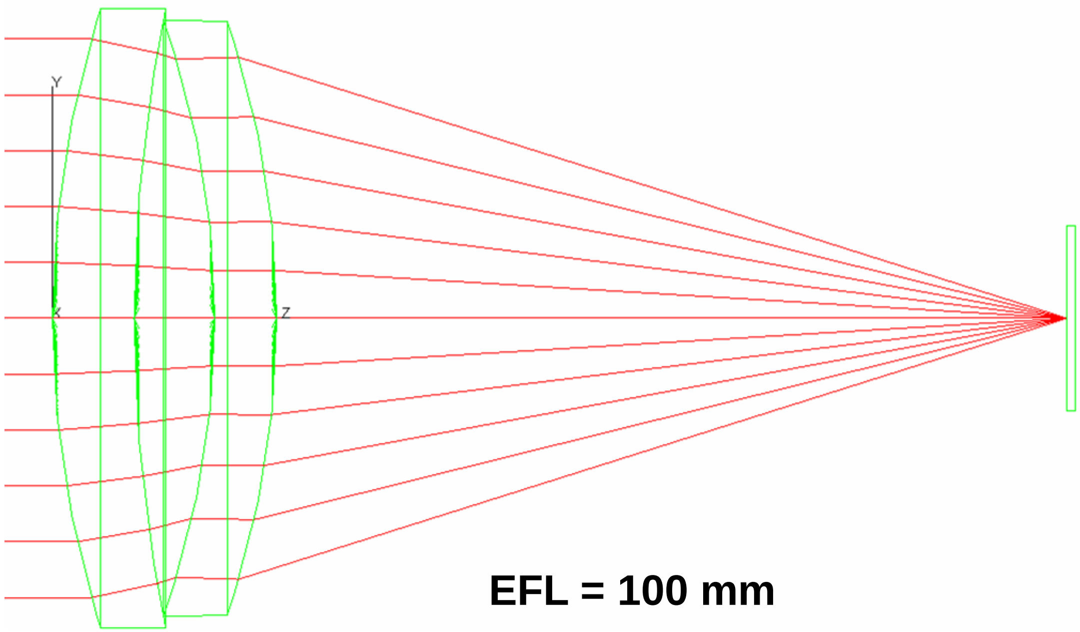


Projected line has uniform intensity over entire length

Fluorescence Measurement



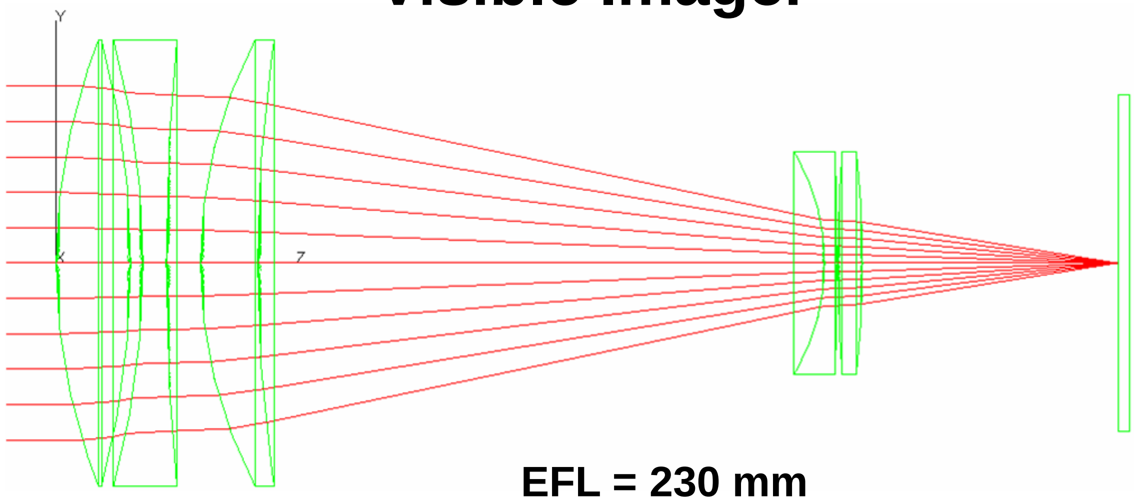
IR Imager (8 – 12 μ)



EFL = 100 mm

Radius	Thickness/spacing	Material	Nd index of refraction	V-no	Semi-aperture
109.180	8.790	Germanium	4.003	868.0	33.3
163.990	8.710	air	1.0		33.3
-95.310	6.670	Zinc Sulfide	2.200	23.0	32.0
-98.200	85.114	air	1.0		32.0

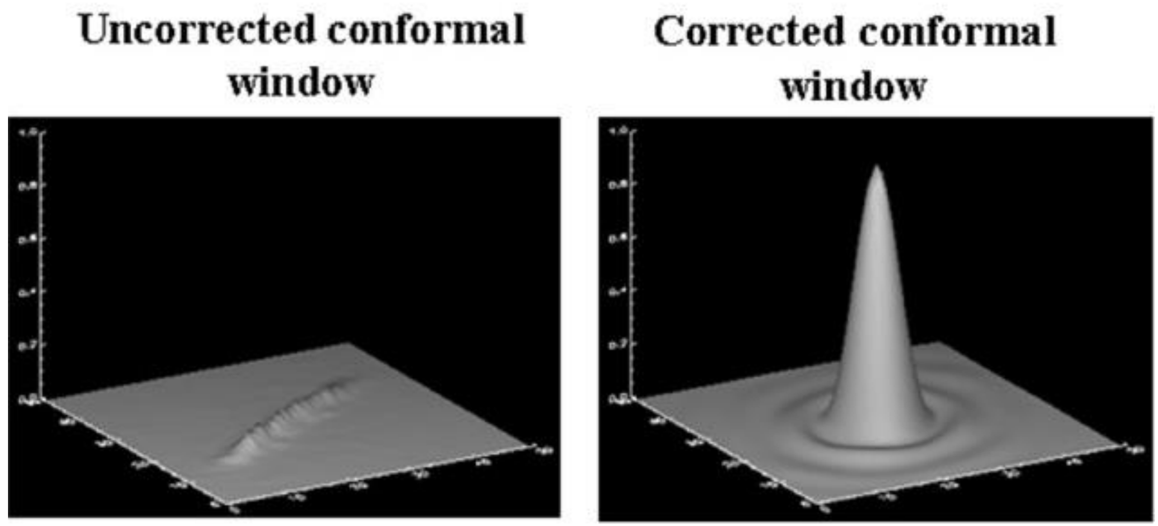
Visible Imager

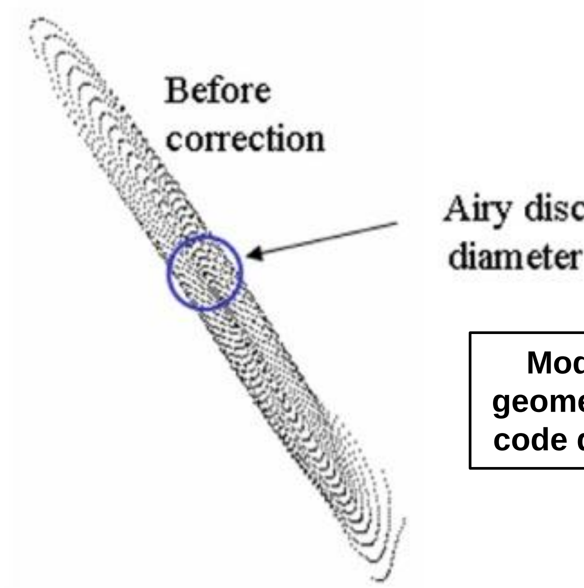


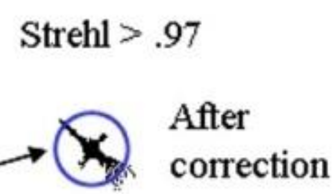
EFL = 230 mm

Per design of Sei Matsui, USP #4338001

Radius	Thickness/spacing	Material	Nd index of refraction	V-no	Semi-aperture
125.546	15.334	Hoya FCD1	1.497	81.6	41.17
-178.97	2.555	air	1.0		40.71
-176.405	4.729	Schott LAFN7	1.750	34.9	39.79
476.611	7.029	air	1.0		39.1
99.378	11.755	Schott N-SSK5	1.658	50.9	38.64
309.221	116.534	air	1.0		37.26
-44.763	2.555	Schott K3	1.518	59.0	20.7
-702.779	0.129	air	1.0		21.85
280.340	5.111	Hoya TAF2	1.794	45.4	22.31
-205.337	52.583	air	1.0		22.54



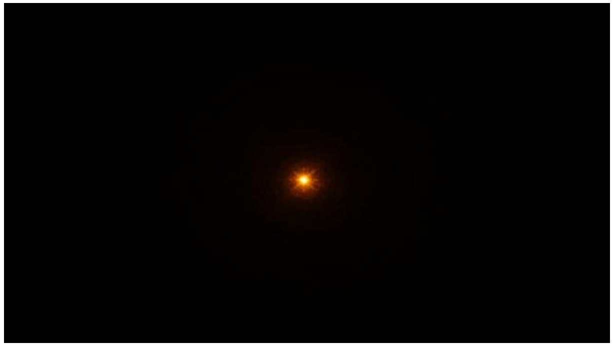




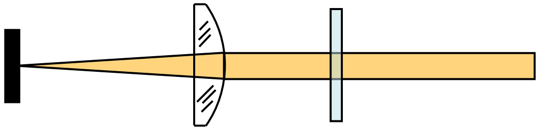
Modeled with LADSWin, a proprietary geometrical and physical optics computer code developed by Kerry Optical Systems

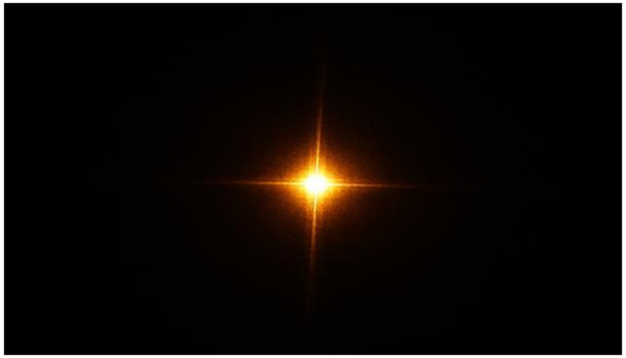
Measurement of Small-angle Scatter

- **The point spread function (PSF) is the response of an imaging system to a point source or point object (e.g., collimated laser beam)**
- **The degree of spreading (blurring) of the PSF is a measure of the quality of an imaging system, and can be used to quantify small-angle scatter**
- **Mathematically related to modulation transfer function (MTF)**

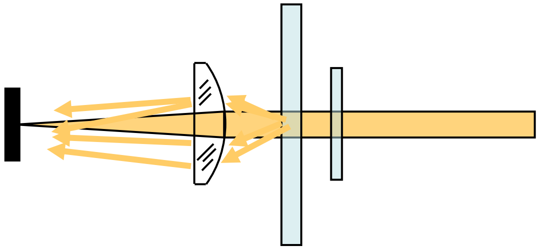


Point spread function for optical test set-up without test object

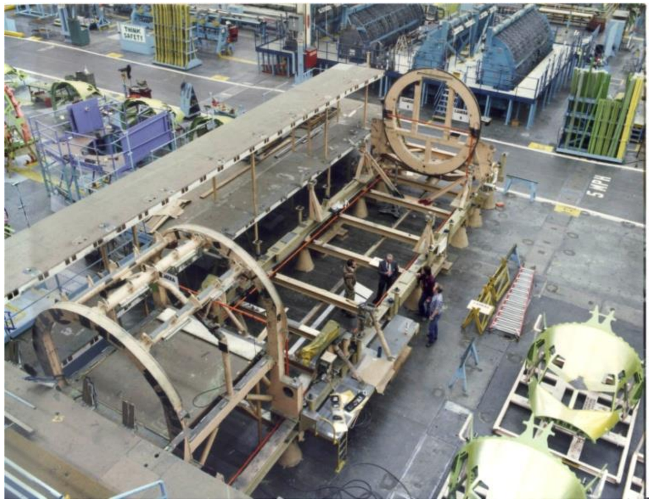




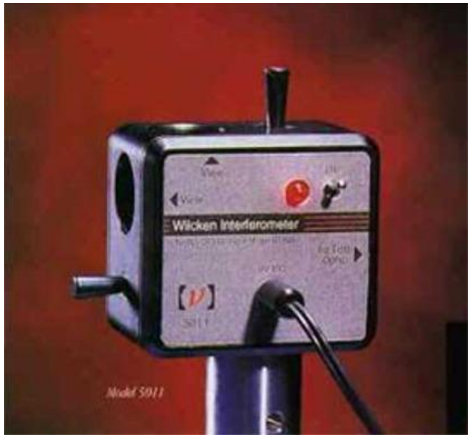
Point spread function for optical test set-up including test object



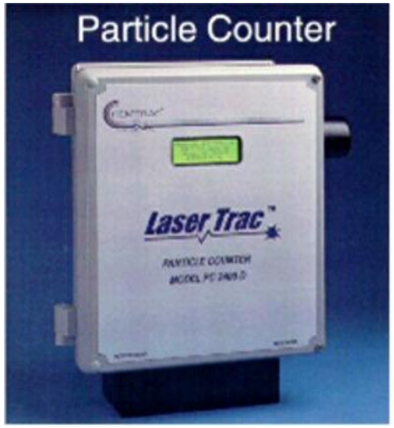
ISS windows (Image courtesy of NASA)



Patented Laser Alignment System

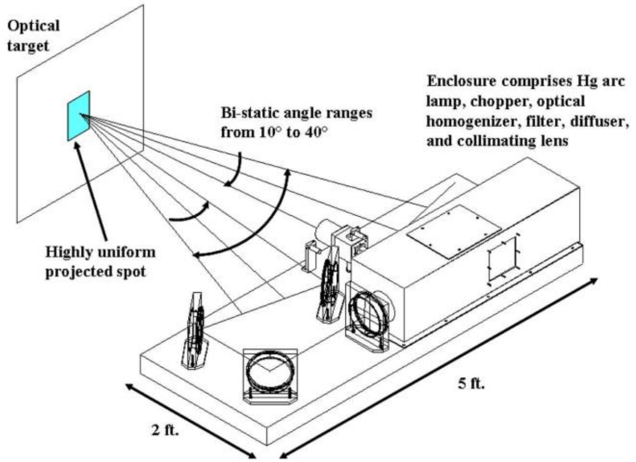


Patented interferometer

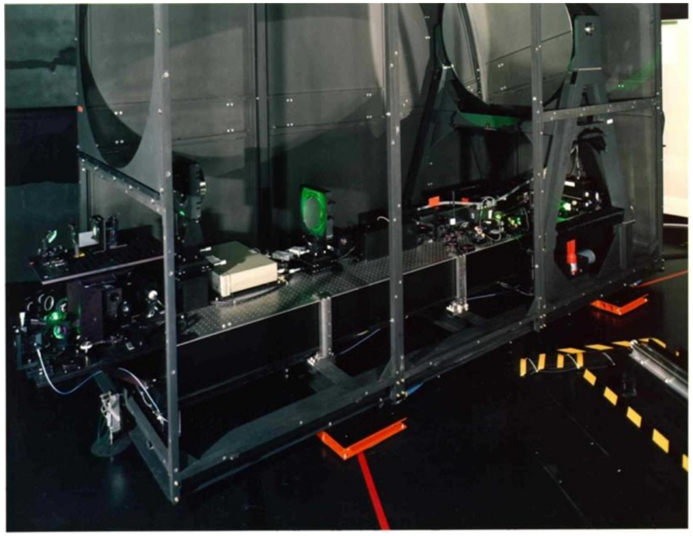


Patented particle counter

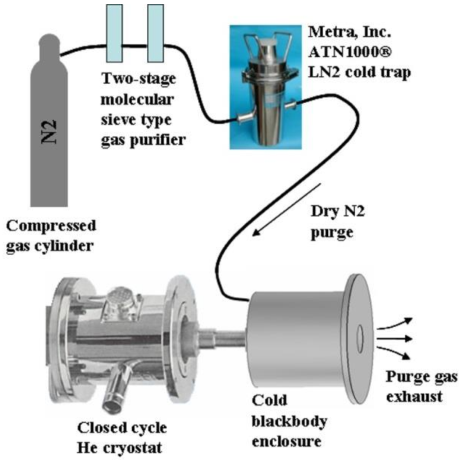
Patented turbidimeter



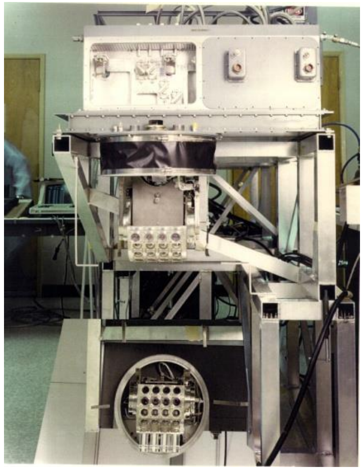
Projection system



1m aperture laser projector



Patented cold blackbody



SLCAIR laser projector

Patents

1.) “Laser Alignment System” (U.S. Patent 4,889,425), 26 December 1989
2.) “Passive, Gravity-referencing, Fluid-damped, Two-stage Pendulum Optical Mount” (U.S. Patent 5,220,455), 15 June 1993
3.) “Point-diffraction Interferometer Utilizing Separate Reference and Signal Beam Paths” (U.S. Patent 5,457,533), 10 October 1995
4.) “Spherical Bearing Optical Mount” (U.S. Patent 5,506,424), 9 April 1996
5.) “Hand-held Nephelometric Turbidimeter Utilizing Non-imaging Concentrator” (U.S. Patent 5,872,361), 16 February 1999
6.) “Lenslet/Detector Array Assembly for High Data Rate Optical Communications” (U.S. Patent 7,230,227), 12 June 2007
7.) “Hybrid RF/Optical Communication System with Deployable Optics and Atmosphere Compensation System and Method” (U.S. Patent 7,346,281), 18 March 2008
8.) “Low-temperature Adjustable Blackbody Apparatus” (U.S. Patent 7,598,506), 6 October 2009
9.) “Full Hemisphere Bi-directional Reflectance Distribution Function Instrument” (U.S. Patent 7,869,046), 11 January 2011
10.) “Fiber Optic Probe Scatterometer for Spectroscopy Measurements” (U.S. Patent 8,218,142), 10 July 2012
11.) “Fiber Optic Probe Scatterometers for Spectroscopy Measurements” (U.S. Patent 8,525,990), 03 September 2013
12.) “Anti-reflection Nanostructure Array and Method” (U.S. Patent 9,207,363), 08 December 2015
13.) “Agile Conformal Scanner” (U.S. Patent 9,244,270), January 26, 2015
14.) “Method for Extracting Optical Energy from an Optical Beam” (U.S. Patent 9,274,344), 01 March 2016
15.) “Method and System for Imaging a Target (U.S. Patent 9,322,776), 26 April 2016