Gaussian Beam Optics

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OPTI 521 Tutorial

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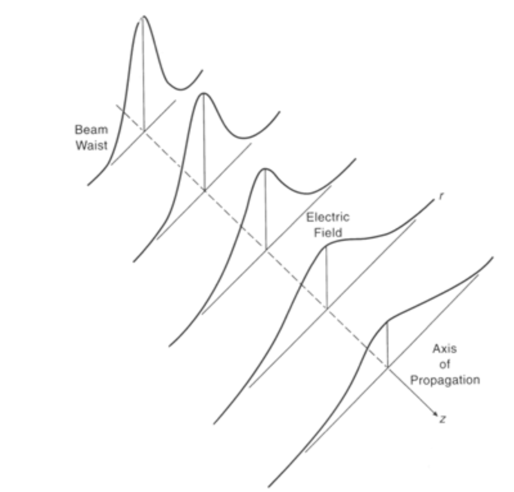
I. Theory

Why work with Gaussian beams?

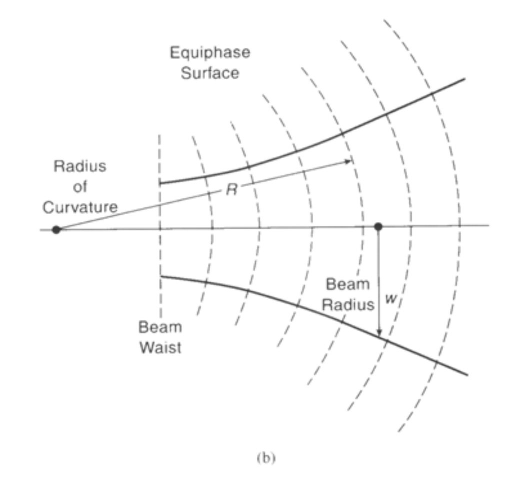
- Geometric vs. Diffraction-limited regimes
- System Scale vs. Wavelength
- Detector Technology

I. Theory

$$\left(\nabla^2 + k^2\right)\Psi = \frac{\delta^2 E}{\delta x^2} + \frac{\delta^2 E}{\delta y^2} + \frac{\delta^2 E}{\delta z^2} + k^2 E = 0$$



$$E(x,y,z) = u(x,y,z)e^{-jkz}$$



$$R = z + \frac{1}{z}\left(\frac{\pi w_0^{\,2}}{\lambda}\right)^2$$

$$w = w_0\sqrt{1+\left(\frac{\lambda z}{\pi w_0^{\,2}}\right)^2}$$

II. Beam Sizes – PoleSTAR LO

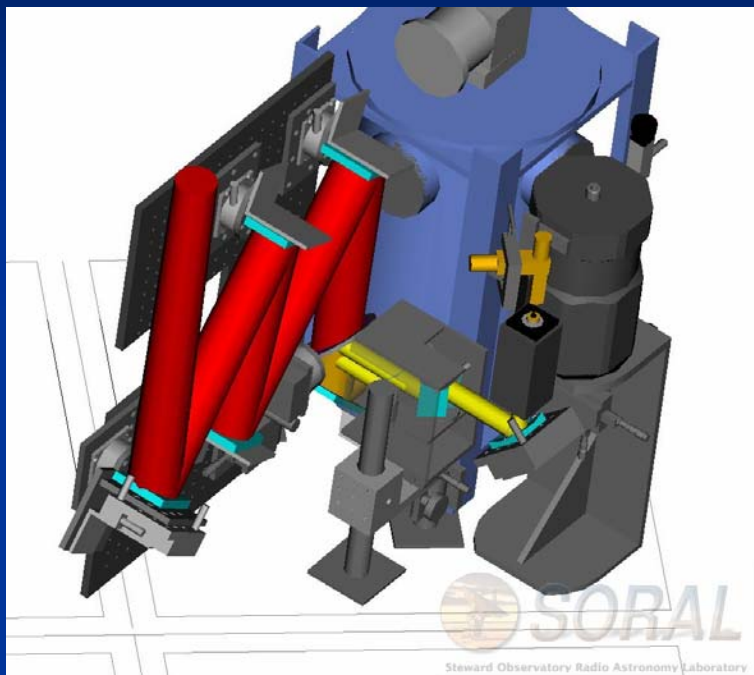
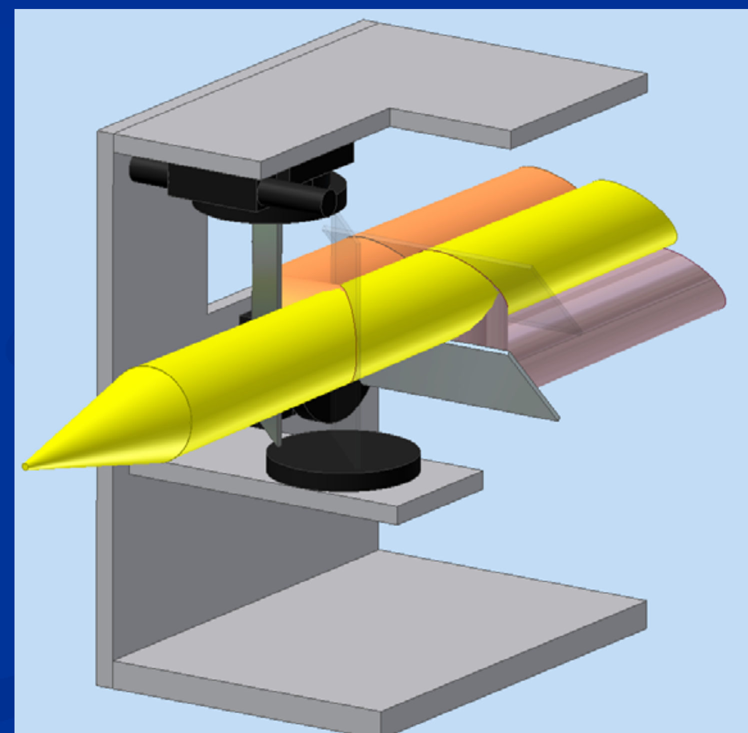


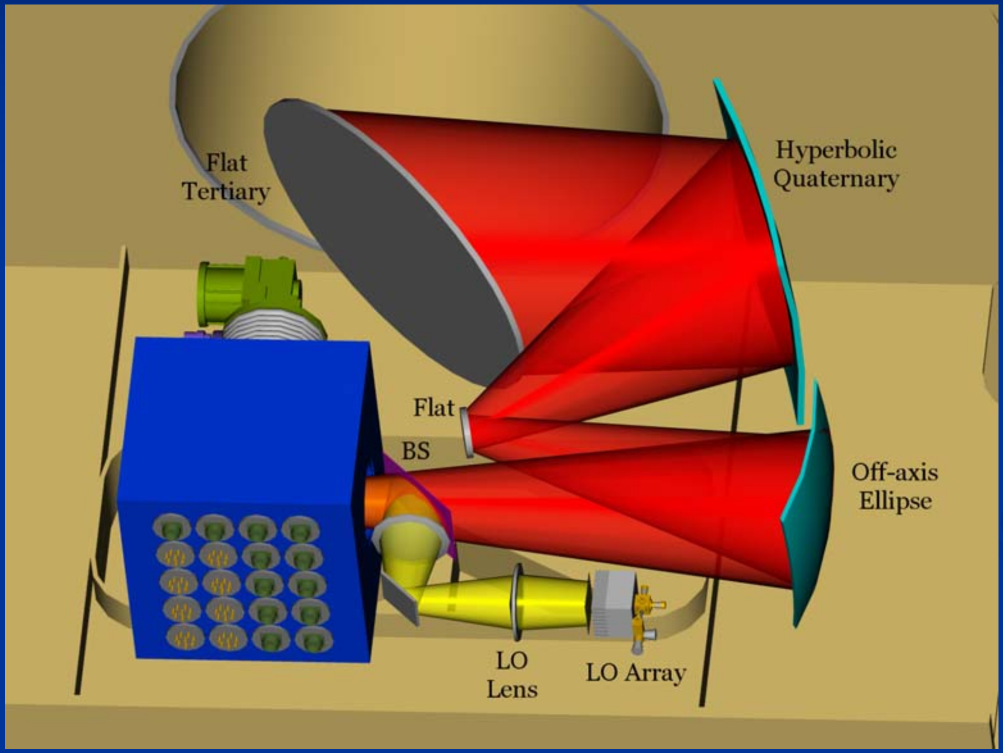
Figure 2: PoleSTAR on AST/RO

- PoleSTAR: 4-pixel 810 GHz Array

- LO 4-way Splitter



III. Tolerancing – SuperCam



- SuperCam: 64-pixel 345 GHz Array
- Typical tolerances are on the order of microns & milliradians.
- With wavelengths ~1000 times larger, tolerances are much more lenient.

III. Tolerancing – SuperCam

Optic	Shift (along axis) (mm)			
	-X	+X	-Y	+Y
Flat Tertiary	†	†	†	†
Hyperbola	-15.8	15.8	-21.5	17.4
Flat Fold	†	†	†	†
Ellipse	-16	16	-18.3	14.4

†Shift has no effect.

Optic	Rotation (around axis) (deg)					
	-X	+X	-Y	+Y	-Z	+Z
Flat Tertiary	-.72	3.2	-1.5	1.5	*	*
Hyperbola	-1.7	1.3	-1.7	1.7	-21.5	21.5
Flat Fold	-2.6	3.0	-3.1	3.1	*	*
Ellipse	-1.4	1.3	-1.3	1.3	-21.5	21.5

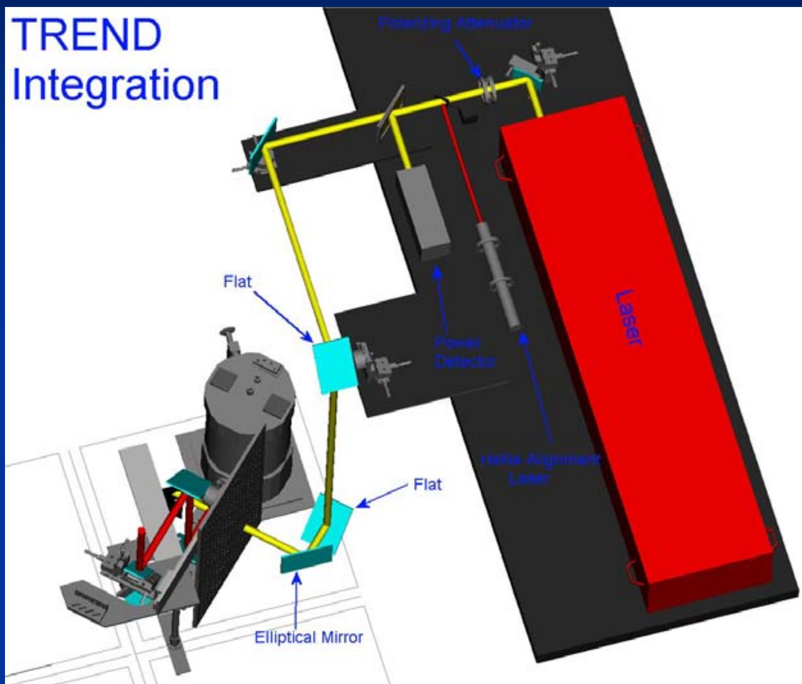
*Shift has no effect.

IV. Optical Manufacturing – SuperCam

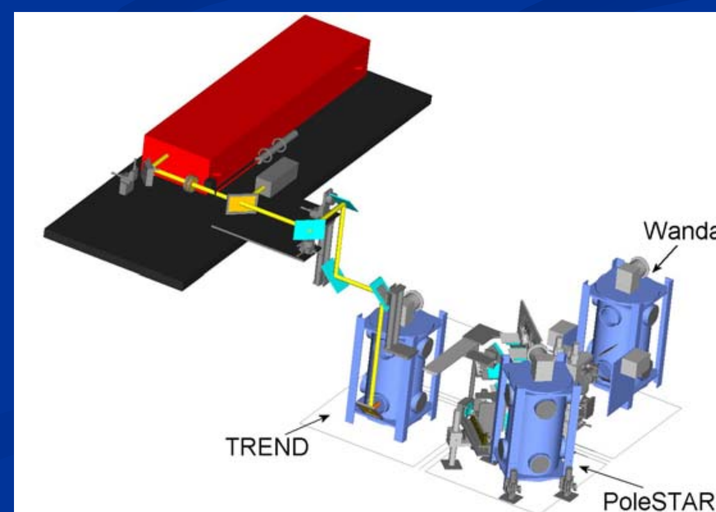
Optic	Surface Quality Quantity	Value	
Flat Tertiary	Curvature Error in Fringes	-.43	.57
Flat Tertiary	Irregularity in Fringes	-.28	.31
Hyperbola	Radius of Curvature (1692 mm Nominal)	-54	84.5
Hyperbola	Irregularity in Fringes	-1.67	1.4
Flat Fold	Curvature Error in Fringes	-3.2	2.9
Flat Fold	Irregularity in Fringes	-2.1	3
Ellipse	Radius of Curvature (772 mm Nominal)	-16.7	25.8
Ellipse	Irregularity in Fringes	-4.6	5.6

- Wavelength = 870 μm
- Fringe = 0.435 mm, flatness easy to achieve
- Radii ~3%, easy to manufacture

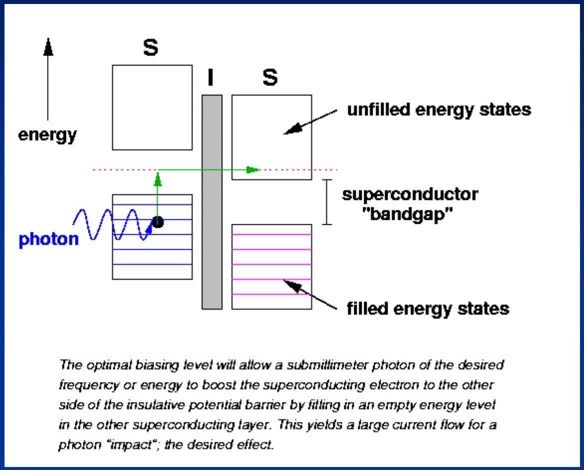
V. Vibration & Stability – TREND

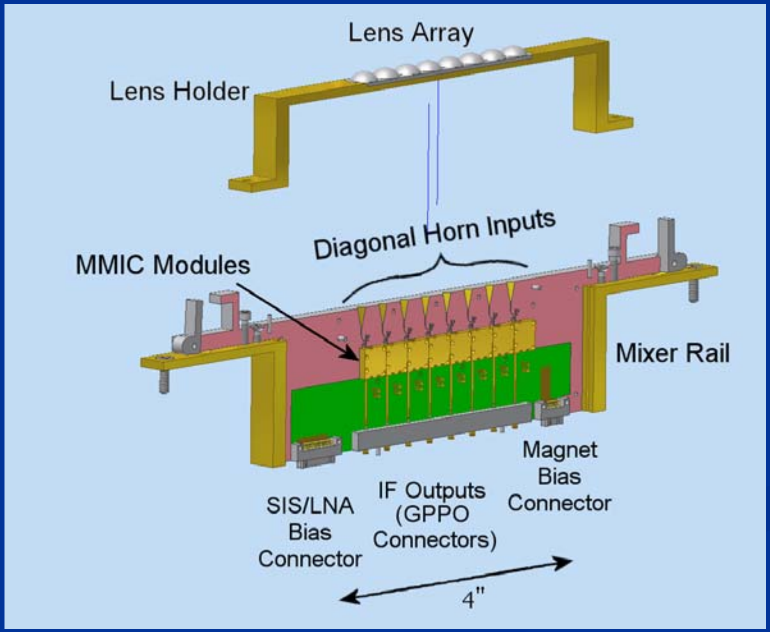


- TeraHertz REceiver with a NbN Device (TREND)
- FIR Laser LO Source
- Long lever arm
- LO Instability



VI. Cryogenics – SuperCam





- Superconductor-Insulator-Superconductor Detectors
- Require LHe temperatures (4K) or lower
- Mixer plane is kept at 4K
- Differential contraction becomes a significant factor

VI. Conclusions

- Just a sampling of the various issues working in this regime can introduce.
- As the FIR technology and radio technology approach each other, these differences must be recognized and reconciled.
- Terahertz technology in particular is growing quickly and will require knowledge of both regimes.