Optical Characteristics of a Tilted Spherical Lens

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Optics Rotation

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Outline

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3. ABCD Matrix Theory
4. Gaussian Optics
5. Experimental Setup and Results
6. Discussion
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Why Study a Tilted Spherical Lens?

- A tilted spherical lens along with a cylindrical lens has been shown to convert HG modes to LG modes. A model using the assumption of an effective focal length was used. Can this assumption be proven valid?

Beam2 Ray Trace Program

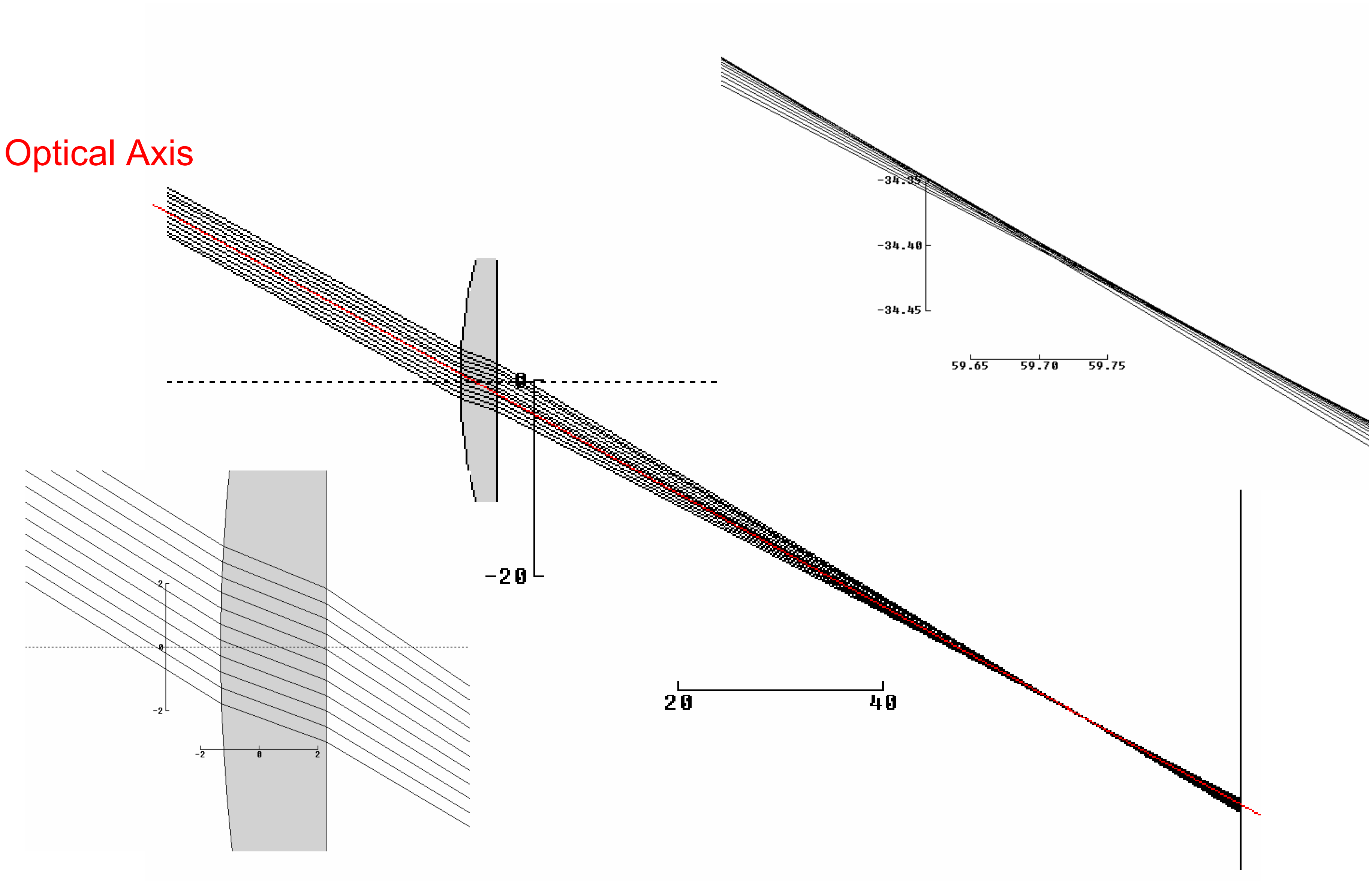
Beam Parameters:

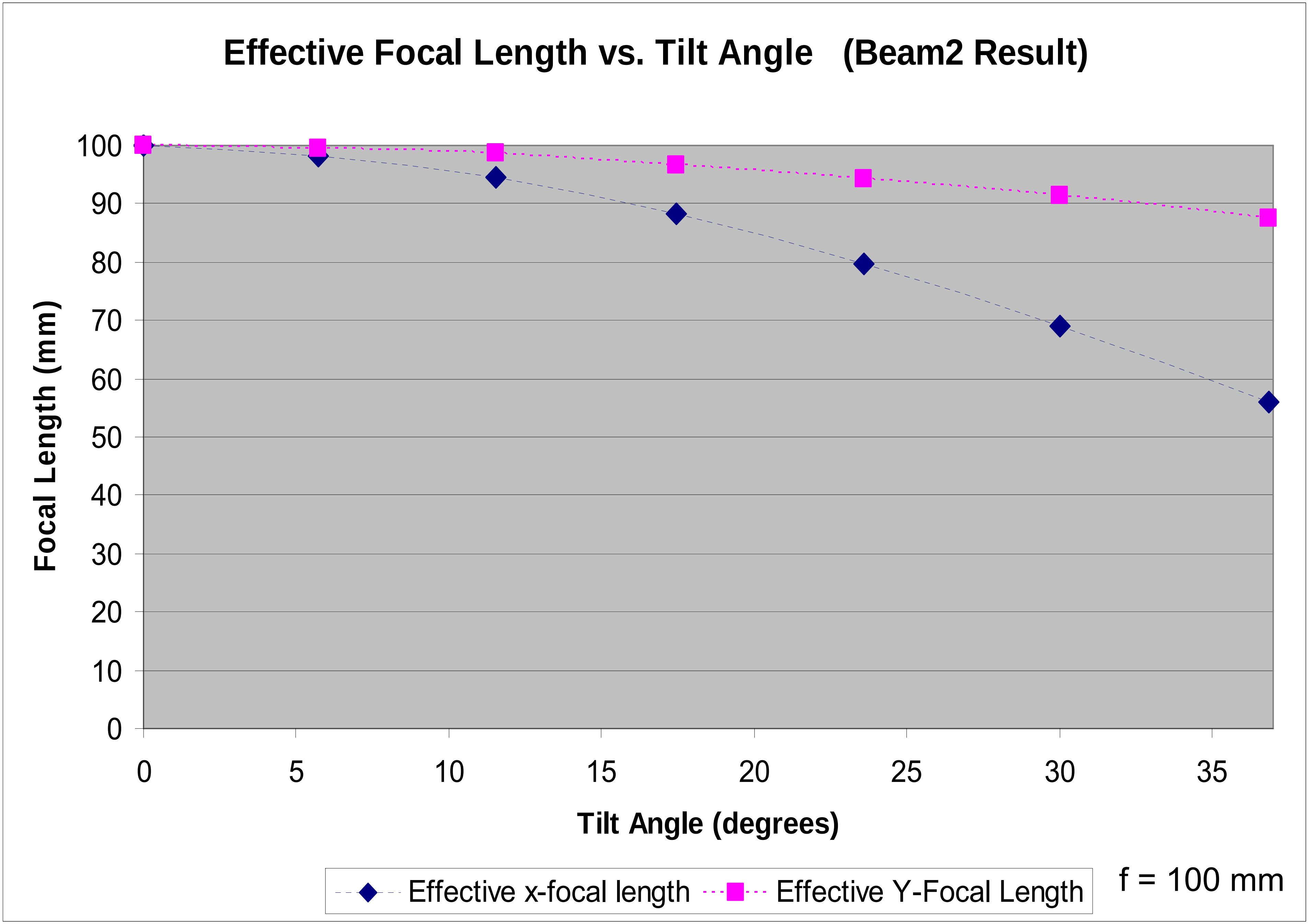
- 5 mm diameter beam of 11 straight rays.
- Ray angle is adjusted to simulate lens tilt with respect to Y-Z (Tangential) plane.

PCX Lens Parameters:

- R_1 = 51.51 mm, R_2 = infinity
- n = 1.515
- Lens diameter = 25 mm

Beam at 30° Tangential Plane





Effective Focal Length vs. Tilt Angle (Beam2 Result)
Focal Length (mm)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
Tilt Angle (degrees)
Effective x-focal length
Effective Y-Focal Length
f = 100 mm

C Matrix Element For Tilted PCX Lens

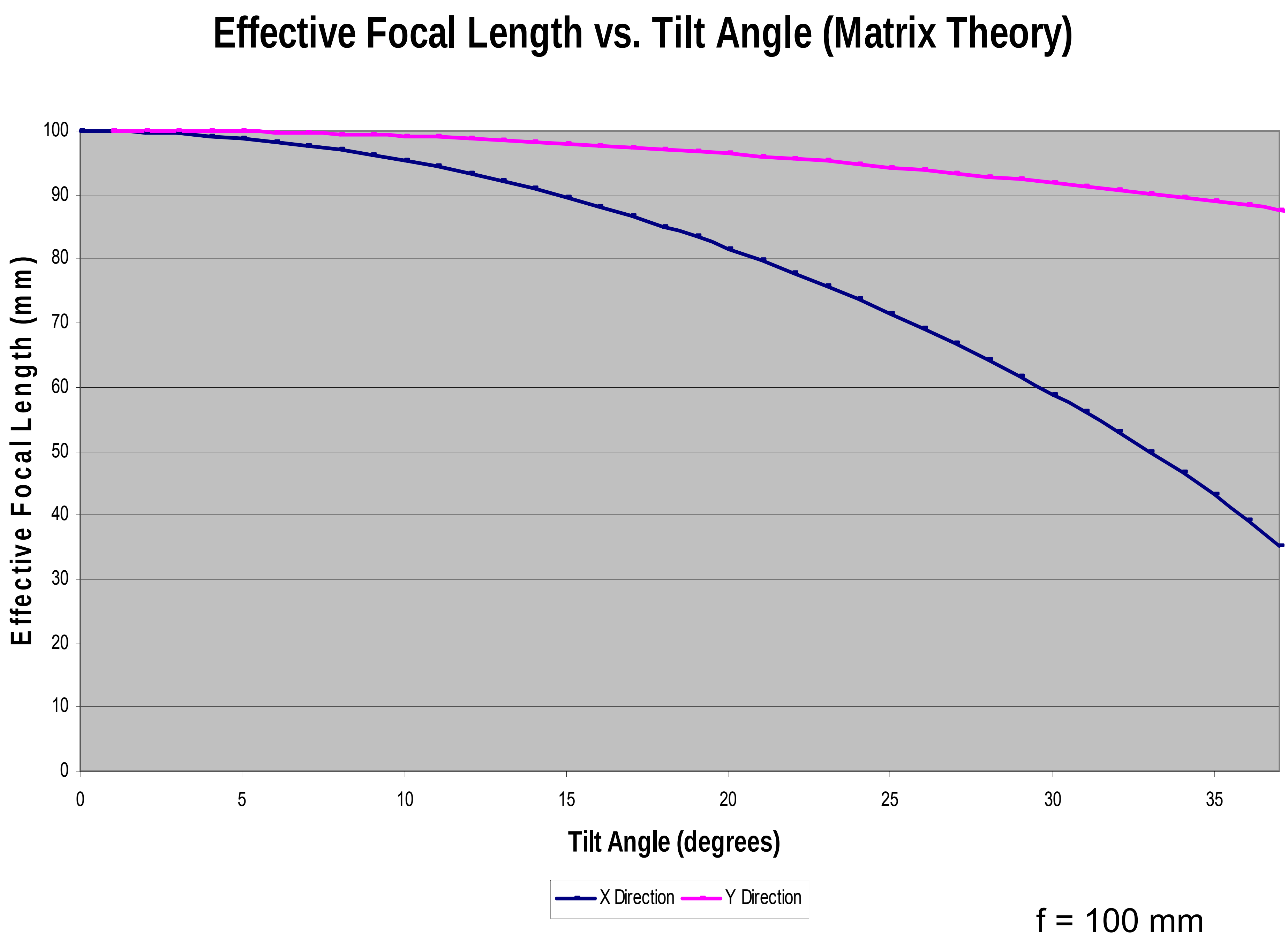
- Using matrix elements derived by Massey and Siegmann[1] and ABCD ray matrix theory, the C matrix element of the tilted PCX lens is derived.

$$C_s = \frac{\cos(\theta) - \sqrt{(n^2 - \sin^2(\theta)}}{R}$$

$$C_T = \frac{1}{\sqrt{(1/n)^2 - \sin^2(\theta)}} \frac{\cos(\theta) - \sqrt{n^2 - \sin^2(\theta)}}{R\sqrt{n^2 - \sin^2(\theta)}}$$

Thin lens approximation $C = \frac{-1}{f}$

1. Massey, G.A., Siegmann, A.E., "Reflection and Refraction of Gaussian Light Beams at Tilted Elipsoidal Surfaces." Applied Optics Vol. 5 No.8 May 1969



Effective Focal Length vs. Tilt Angle (Matrix Theory)
Effective Focal Length (mm)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
Tilt Angle (degrees)
X Direction
Y Direction
f = 100 mm

Laser Beam Characteristics

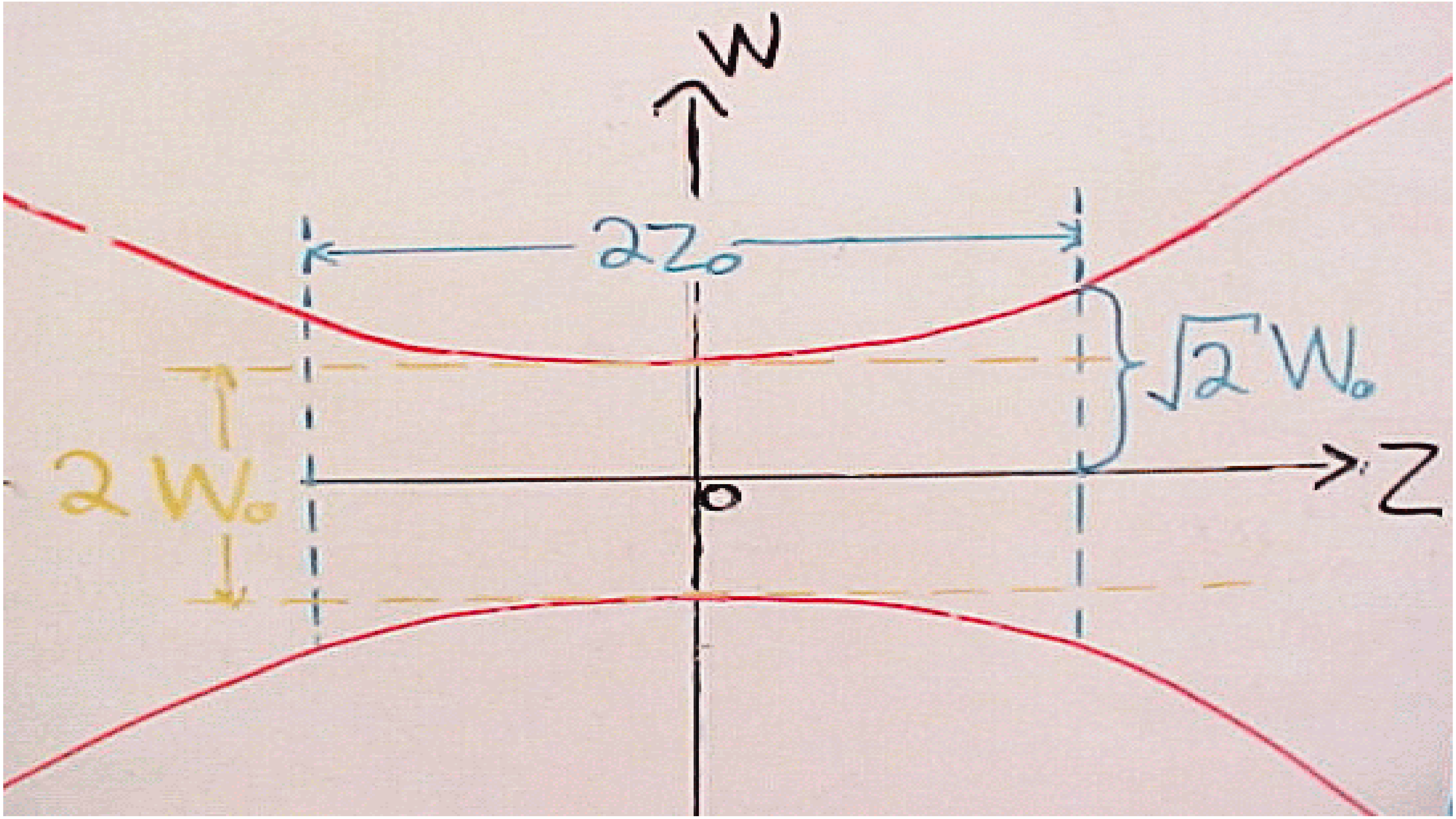
- The beam waist of a Melles-Griot HeNe laser was measured as a function of distance from the laser with a 5 μm pinhole and a detector mounted on a translation stage.

$$w(z) = w_0 \sqrt{1 + \frac{z}{z_0}}$$

$$z_0 = \frac{\pi w_0^2}{\lambda}$$

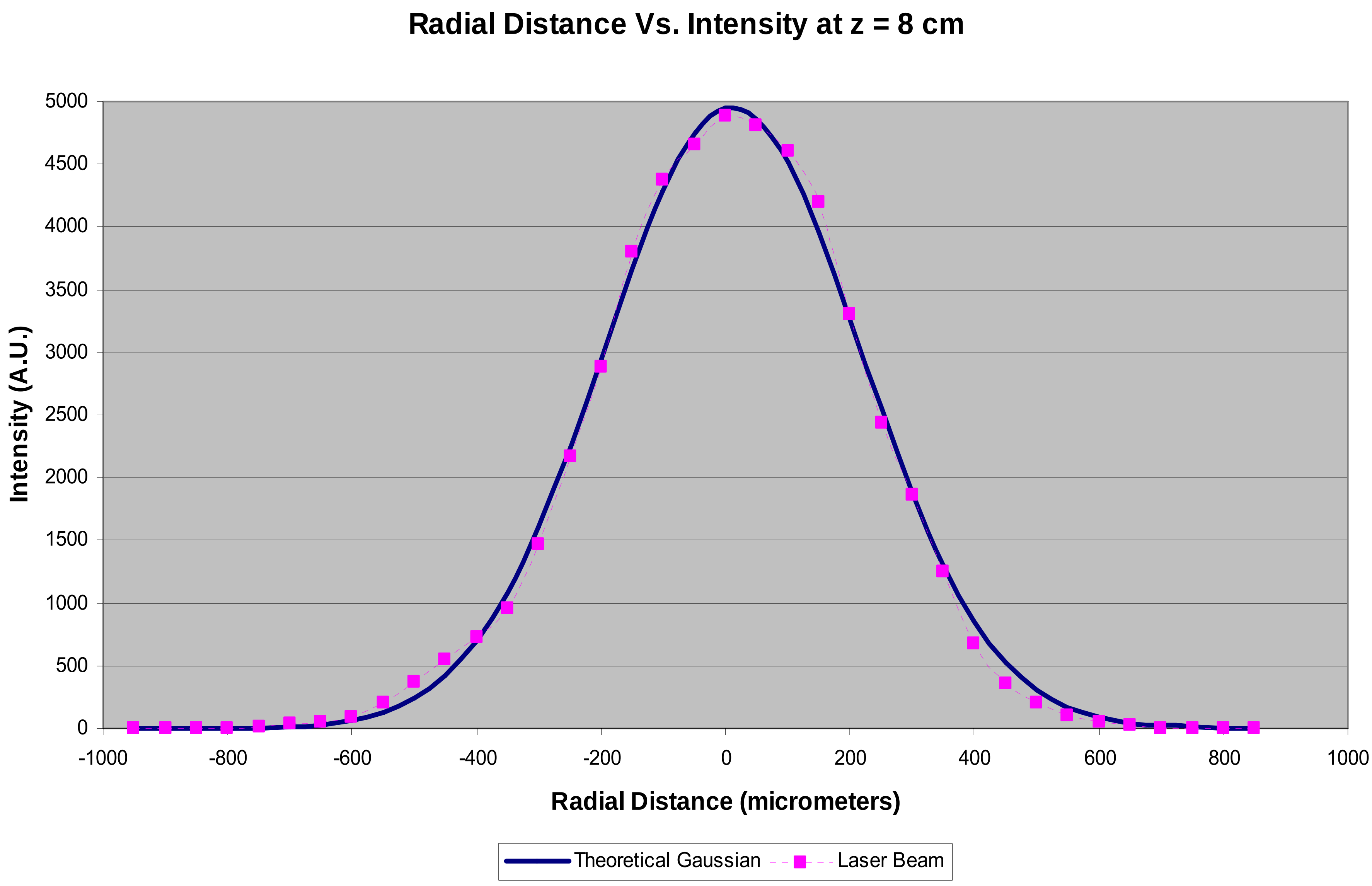
- From these equations w_0 and z_0 are 0.40 mm and 504 mm respectively.

Relationship Between Beam Characteristics



2 Deb Klein, "Learning How Laser Beams Propagate"
http://laser.physics.sunysb.edu/~wise/wise187/2005/reports/deb/report.html

Is the Laser Gaussian?



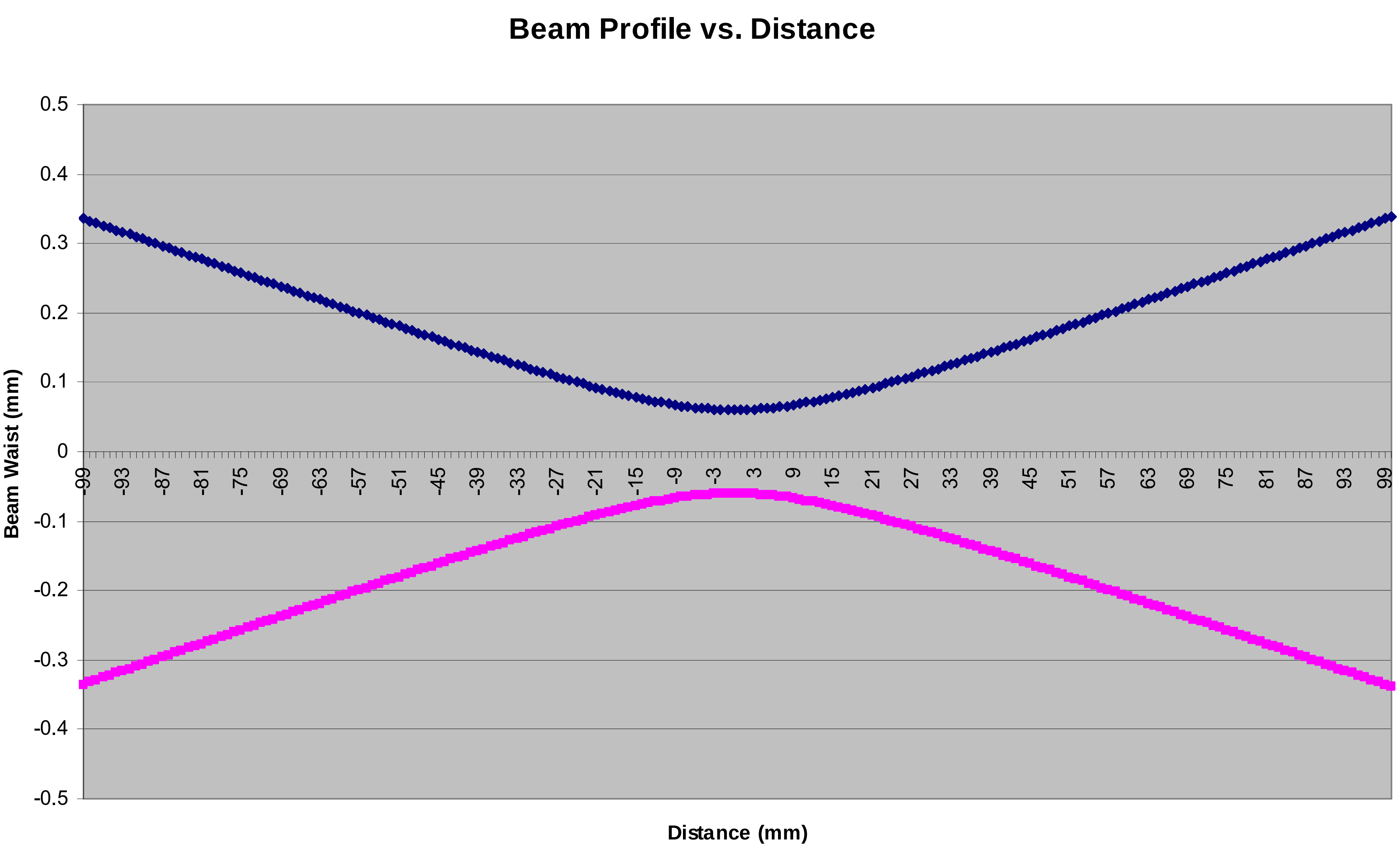
Propagating through a 150 mm Lens

$$w_0' = \frac{\lambda}{\theta\pi}$$

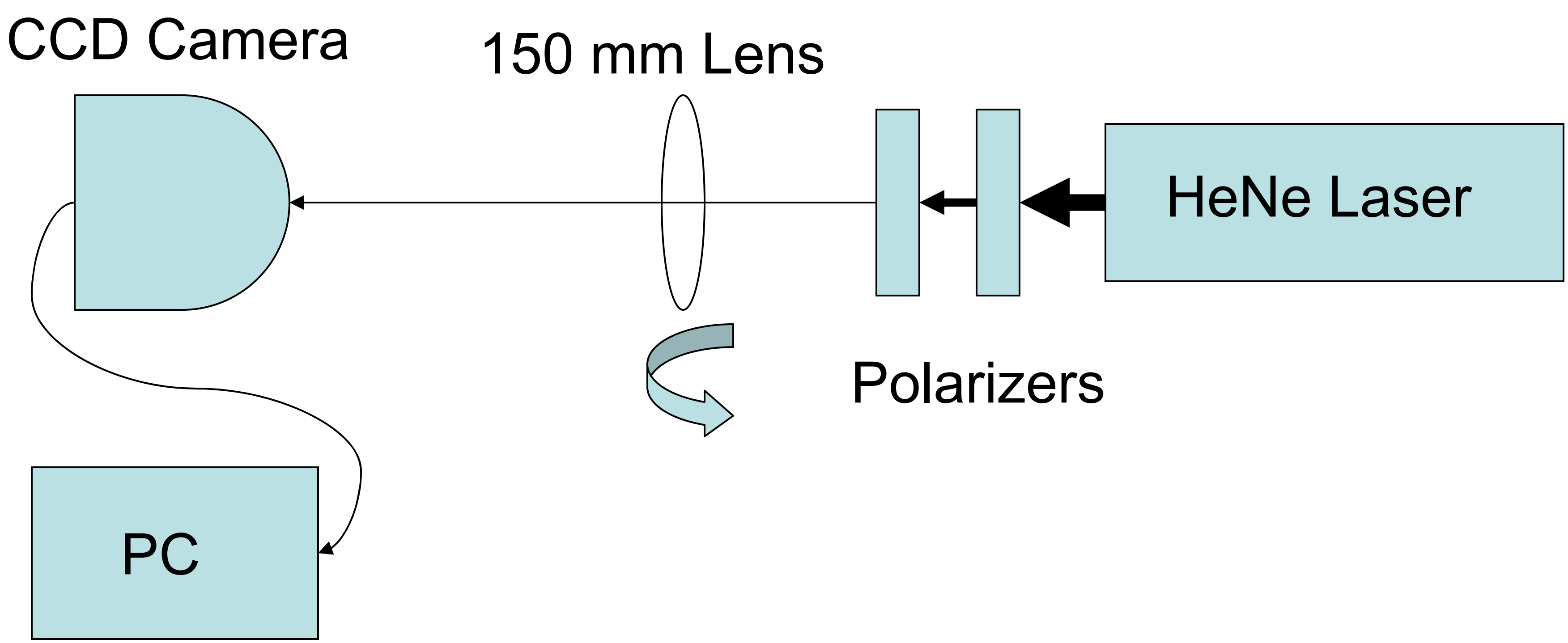
$$\theta = \tan^{-1}\left(\frac{w_0}{f}\right)$$

w'_0 and z'_0 for the beam focused by a 150 mm lens are 60.4 μm and 18.1 mm respectively.

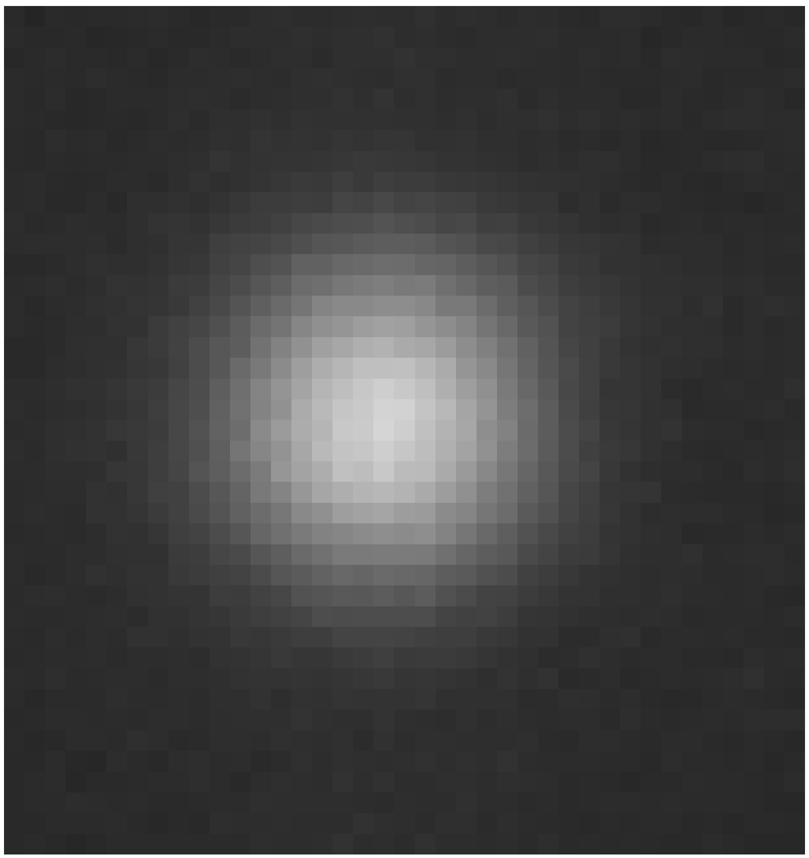
Focus with a 150 mm Spherical Lens

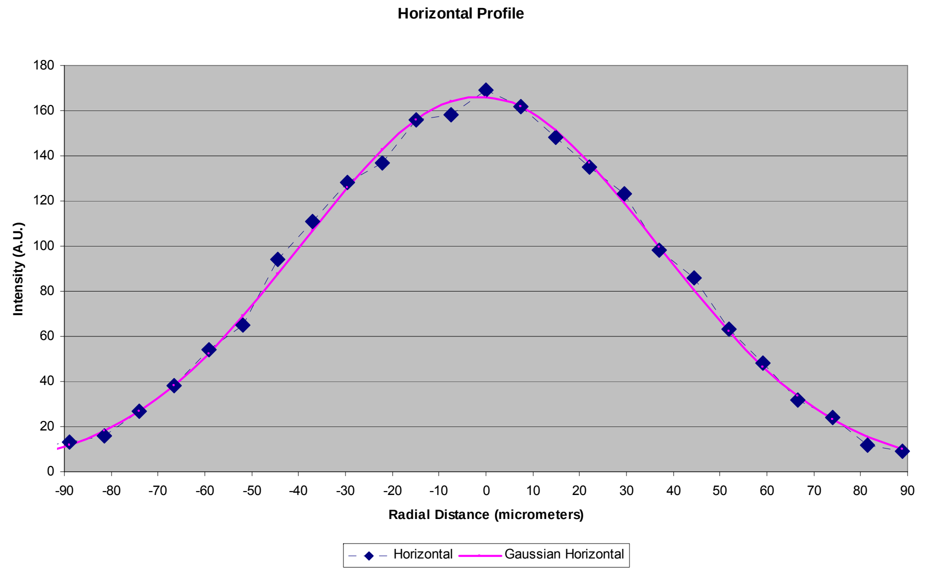


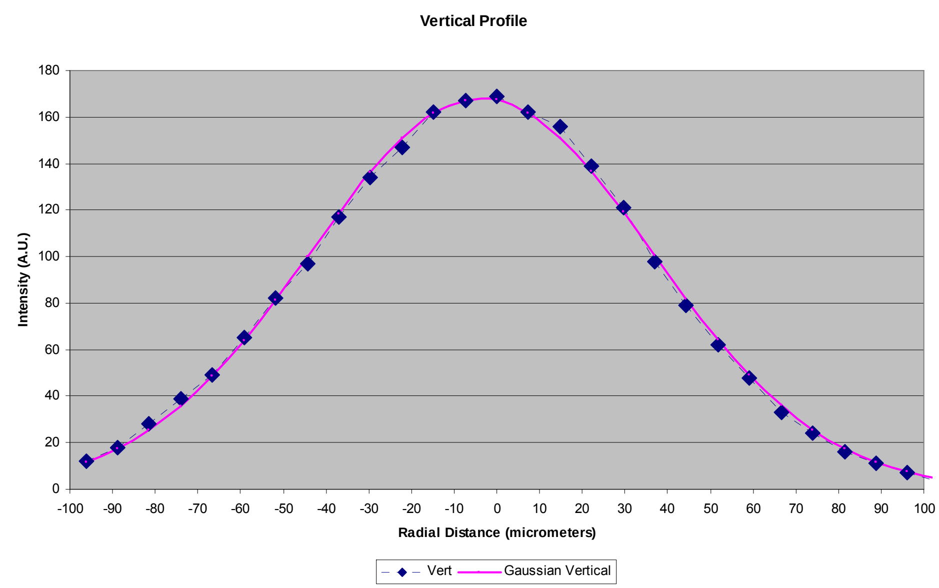
Experimental Setup



Beam at z = 150 mm 0° Tilt

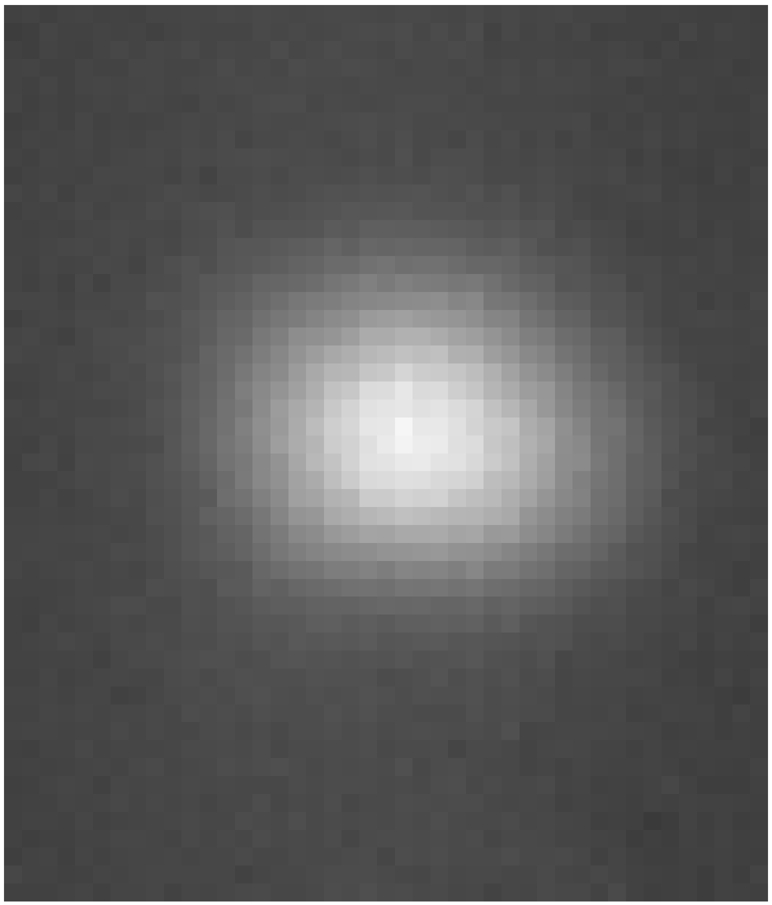




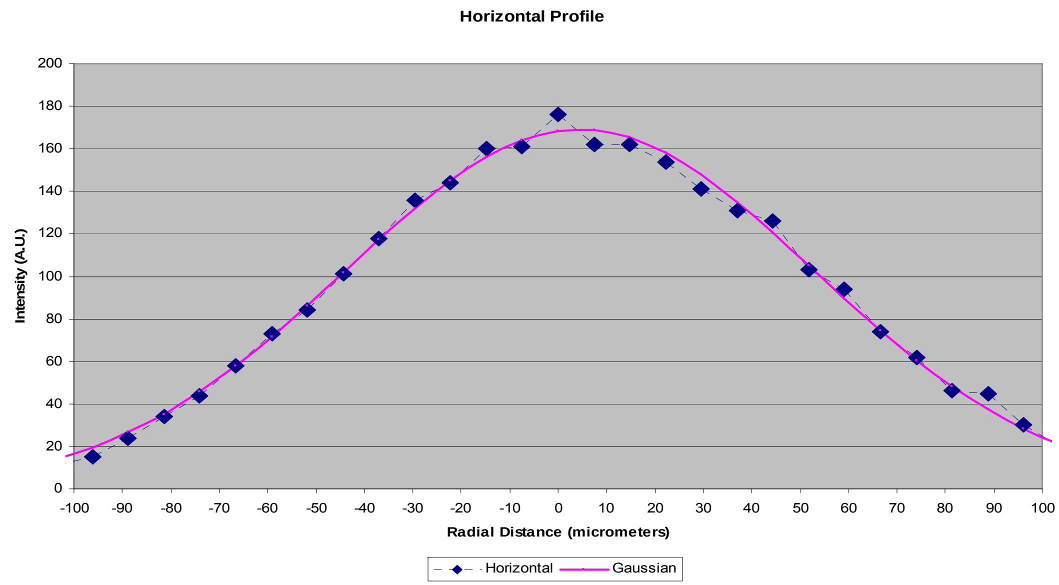


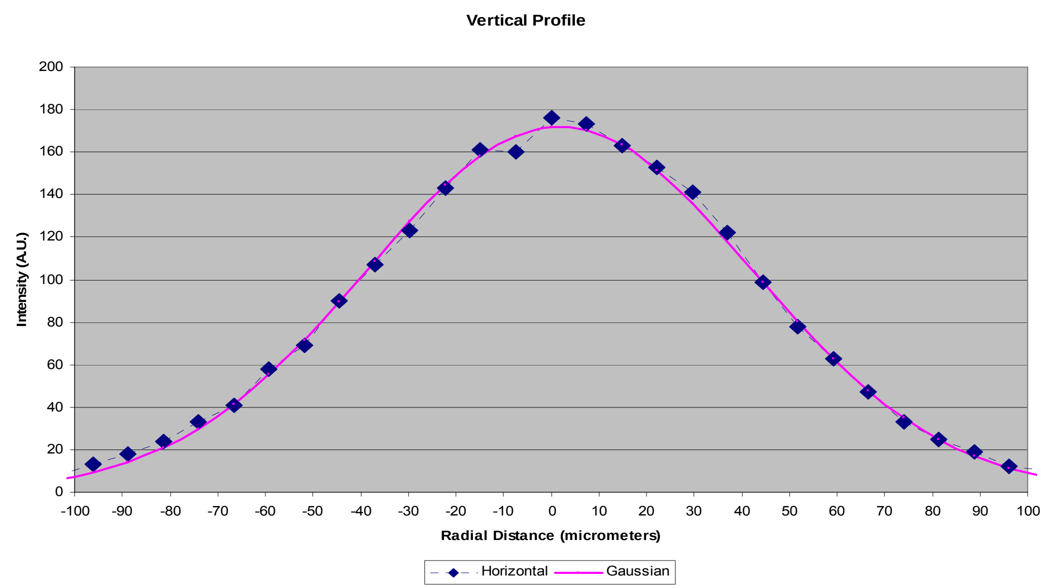
w_h= 76 µm w_v = 80 µm

Beam at z = 150 mm 18° Tilt

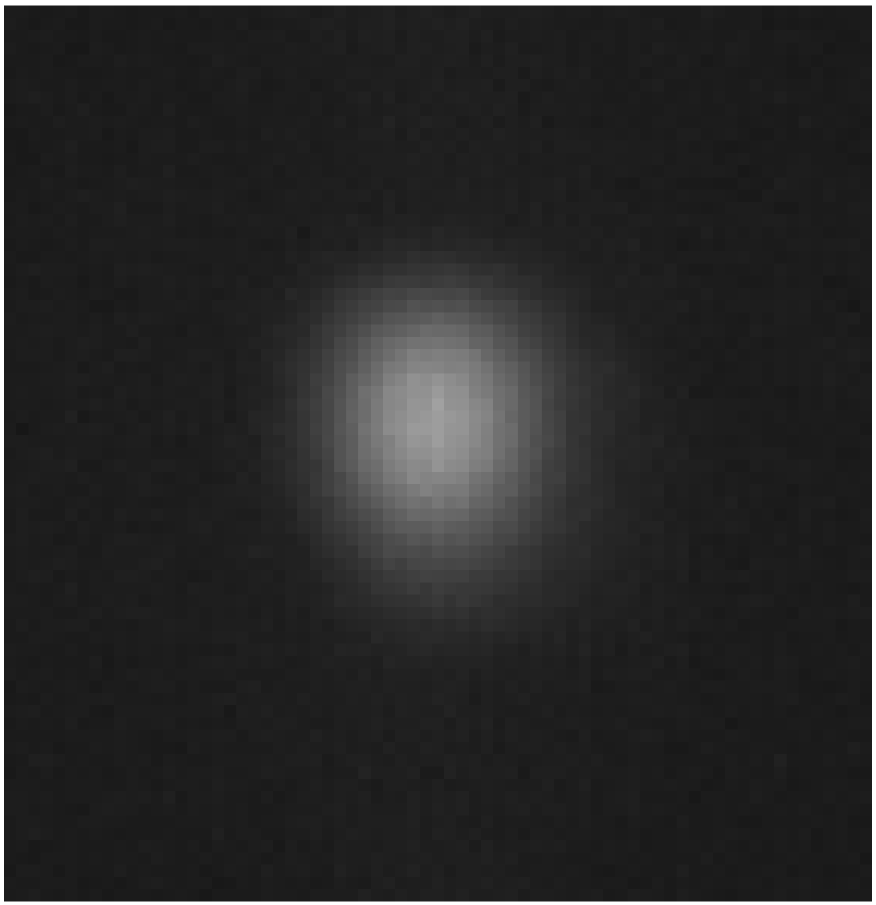


w_h= 97 µm w_v = 81 µm

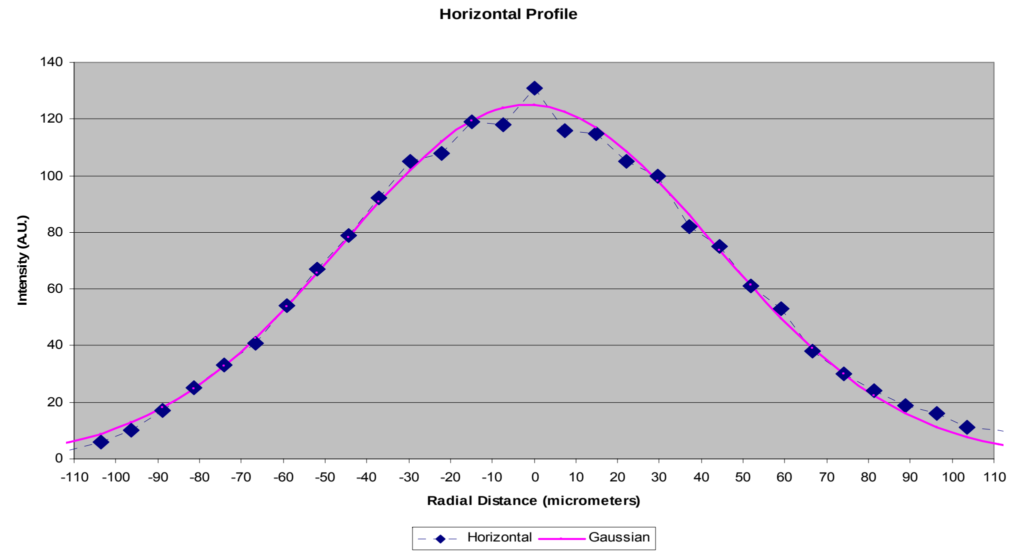


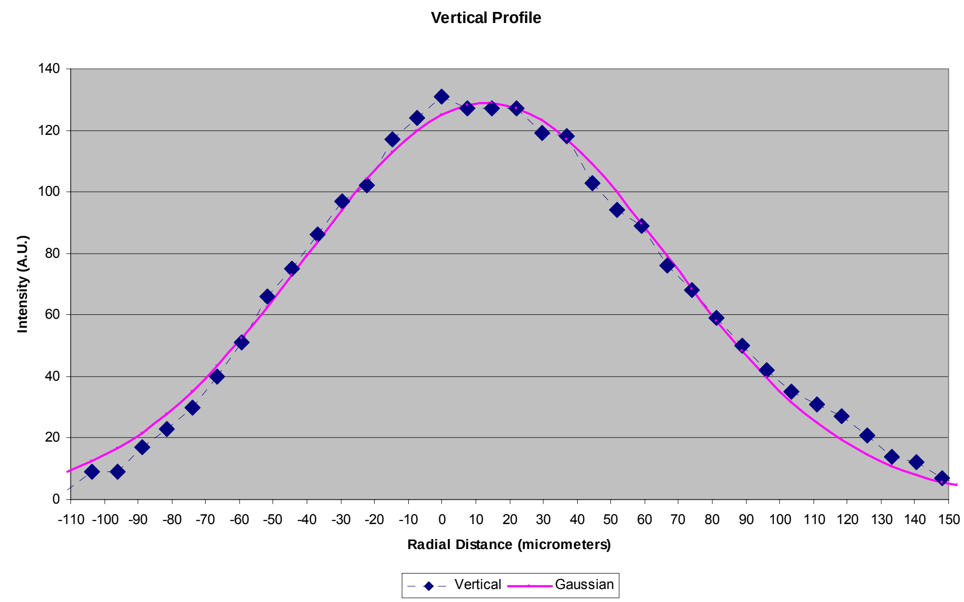


Beam at z = 105 mm 18°Tilt



w_h= 89 μm w_v = 108 μm





Discussion

- Horizontal waist changed dramatically with tilt of 18° about the vertical axis.
- Vertical waist changed only slightly with tilt of 18° vertical axis.
- Future work relating other ABCD matrix elements to the HG-LG conversion is needed.

Acknowledgments

- A special thanks to John and Marty for all of their insights and guidance over the course of this Optics Rotation.
- Also, thanks to the audience for being here today.

References

- Massey, G.A., Siegmann, A.E., “Reflection and Refraction of Gaussian Light Beams at Tilted Elipsoidal Surfaces.” Applied Optics Vol. 5 No.8 May 1969.
- Deb Klein, “Learning How Laser Beams Propagate” http://laser.physics.sunysb.edu/~wise/wise187/2005/reports/deb/report.html