“Modeling and Prototyping a Zoom Telescope for LIGO Optical Levers”

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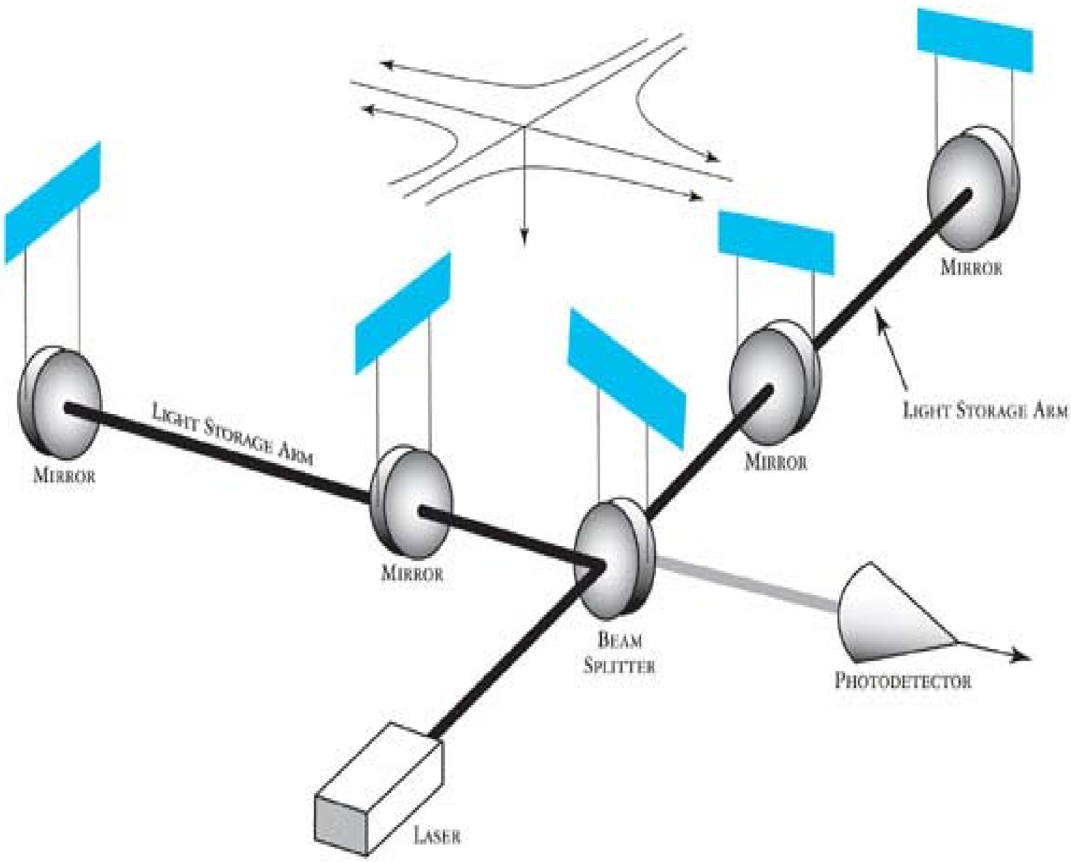
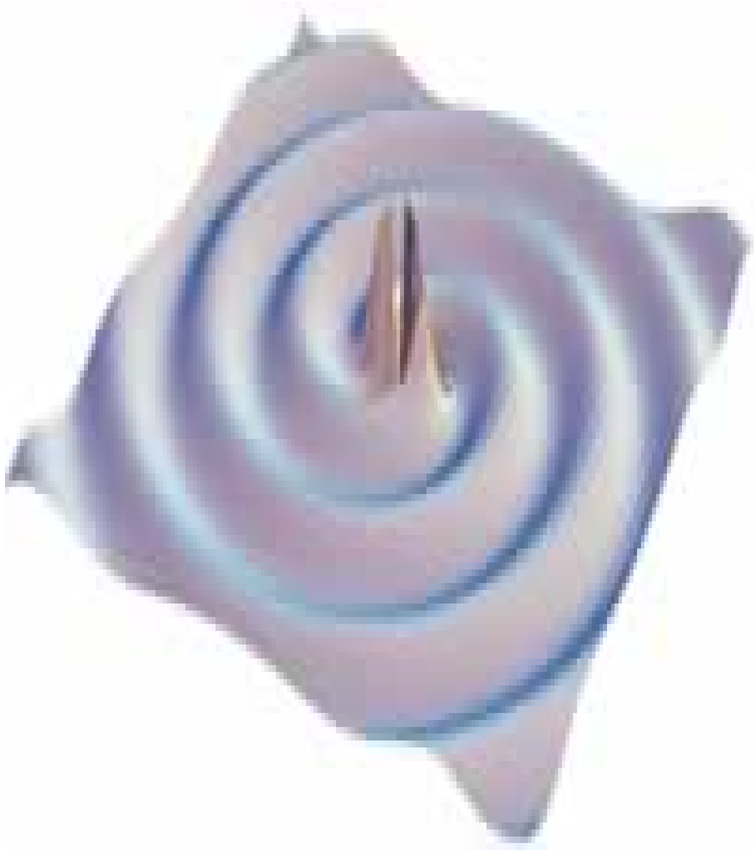
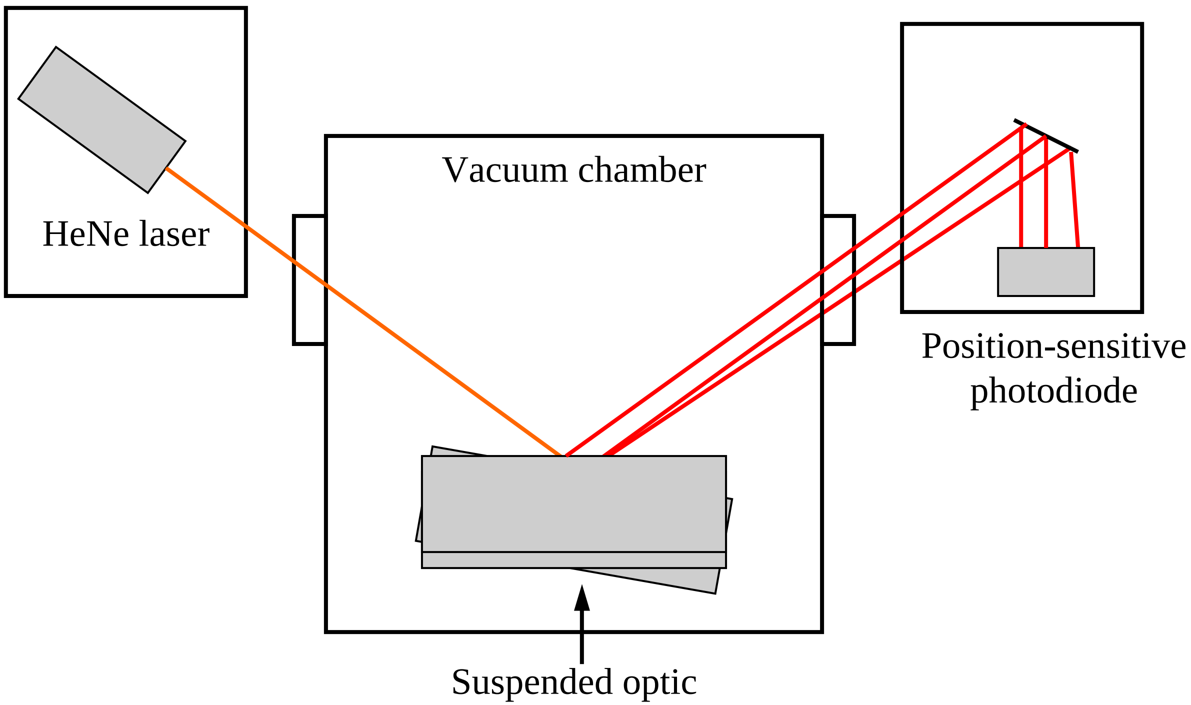
What is LIGO?


Mirror
Light Storage Arm
Mirror
Beam Splitter
Mirror
Mirror
Light Storage Arm
Photodetector
Laser

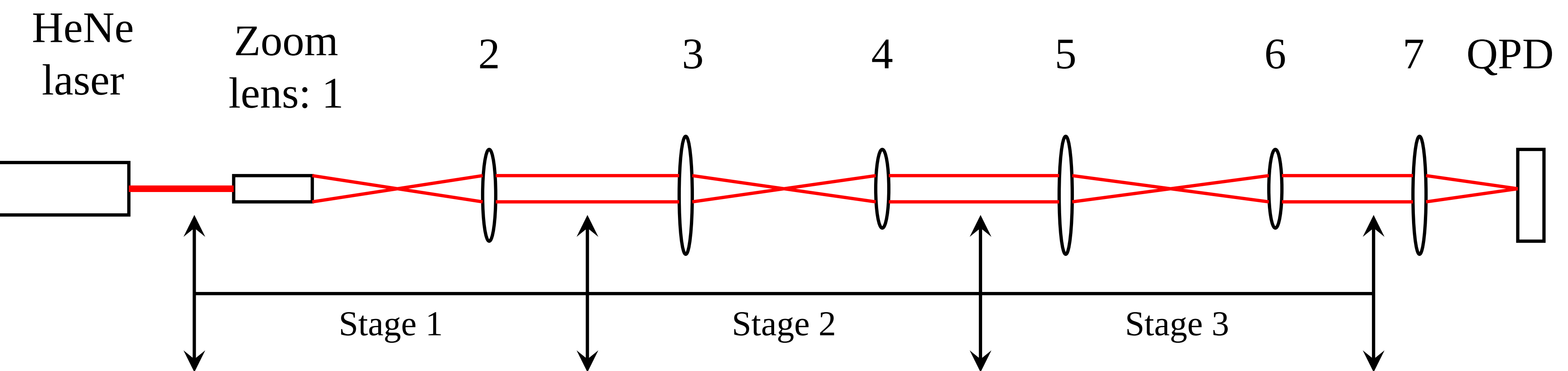


Alignment Sensing



Limits to sensitivity: coupling to axial motion

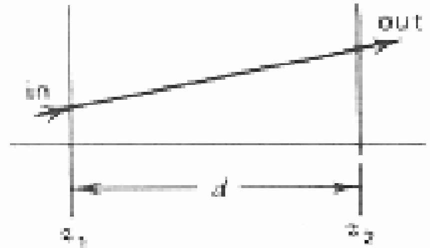
Zoom Objective Lens System



lens #	1	2	3	4	5	6	7
focal length (mm)	8 - 48	6	49.7	3.5	49.7	3.5	25.4
distance to next lens (mm)	53	2.6	51.6	3.1	47.3	27.5	distance to QPD: 25.4

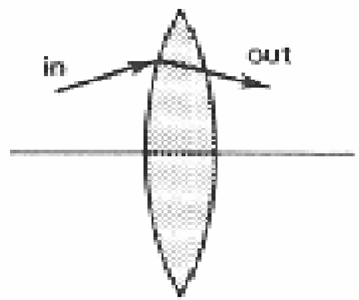
ABCD Matrix Modeling

(1) Homogeneous Medium:
Length d



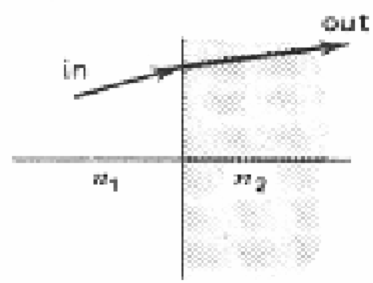
$$\begin{pmatrix} 1 & d \\ 0 & 1 \end{pmatrix}$$

(2) Thin Lens:
Focal length f
($f > 0$, converging;
$f < 0$, diverging)



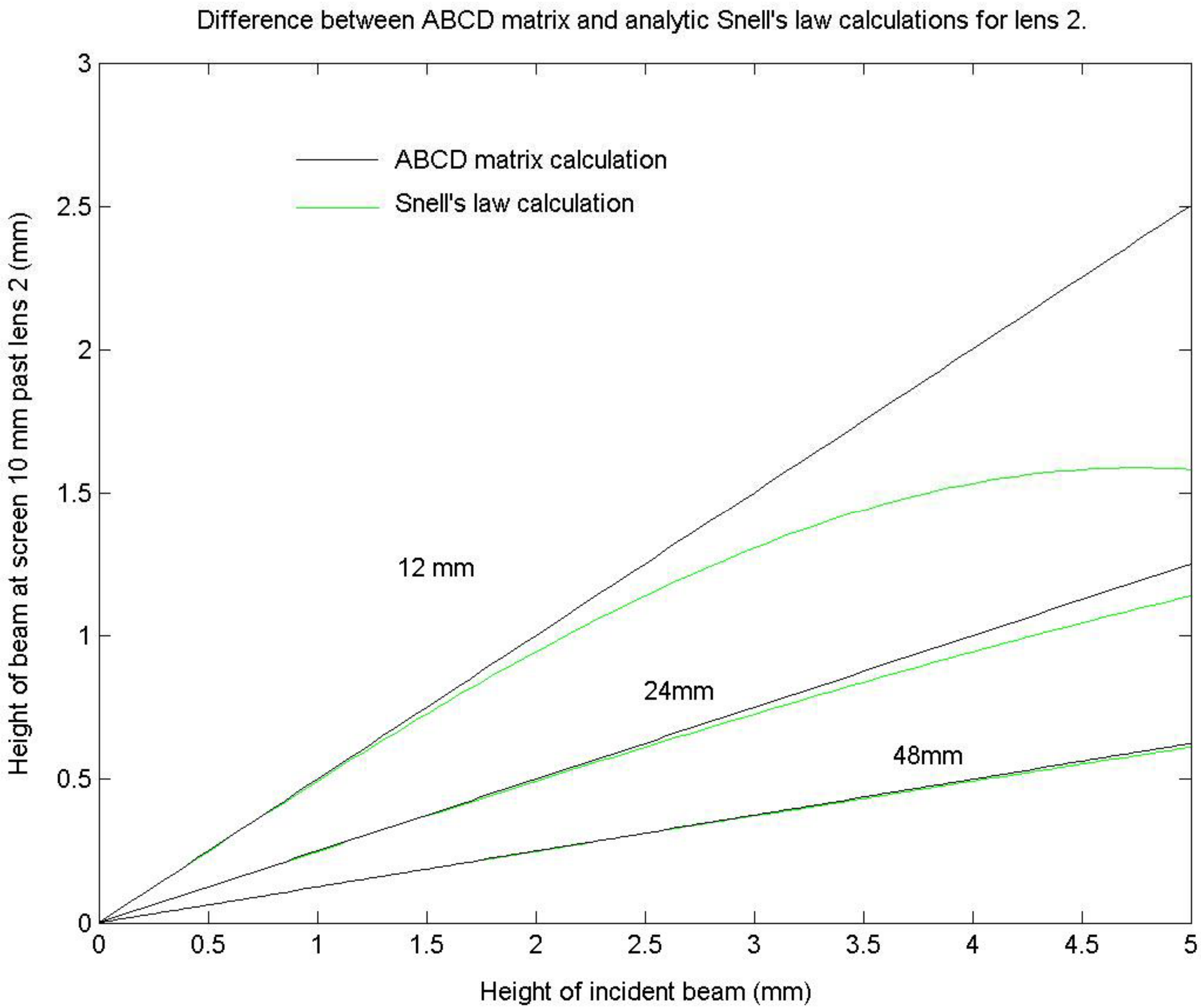
$$\begin{pmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{pmatrix}$$

(3) Dielectric Interface:
Refractive indices
n_1, n_2

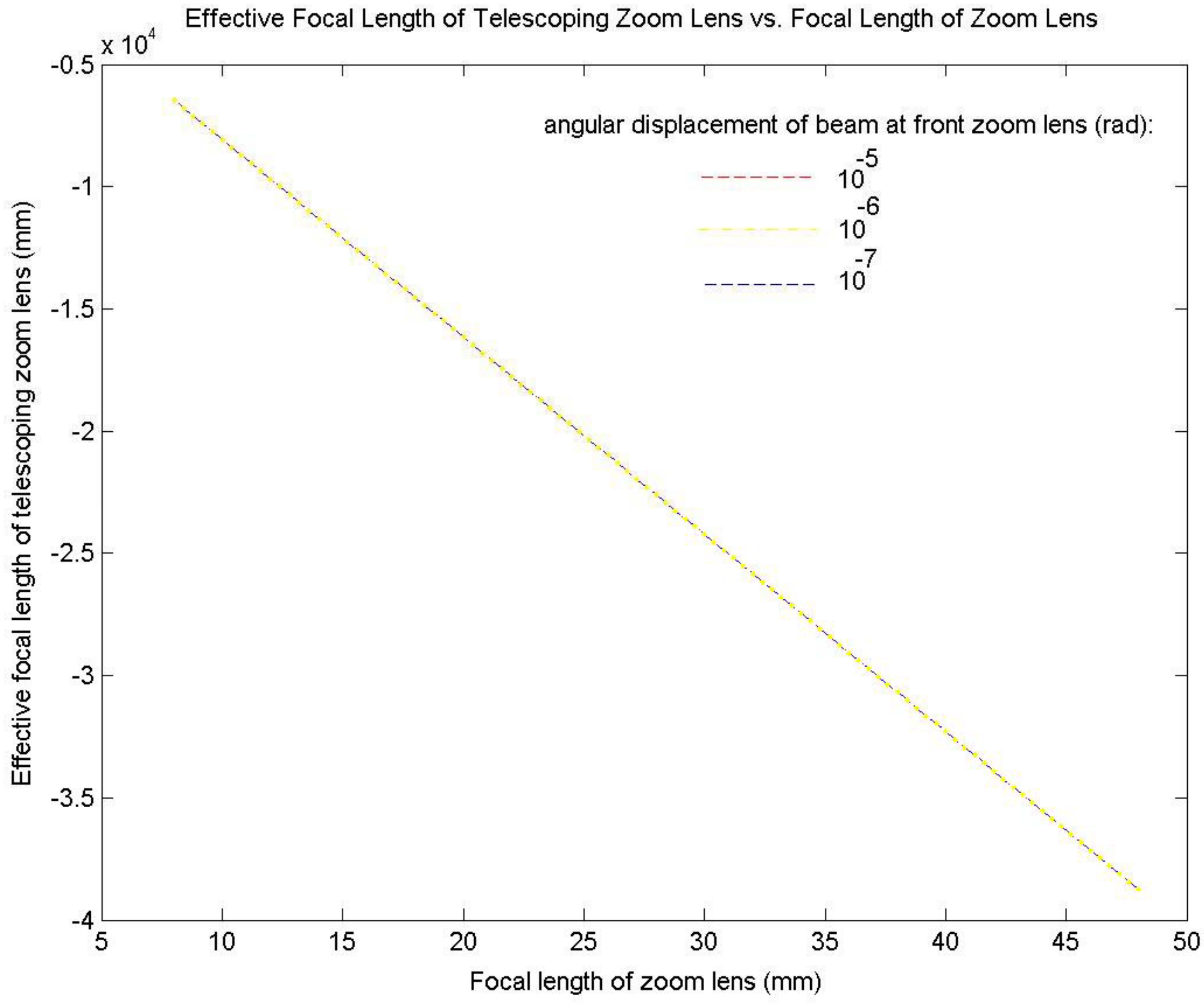


$$\begin{pmatrix} 1 & 0 \\ 0 & \frac{n_1}{n_2} \end{pmatrix}$$

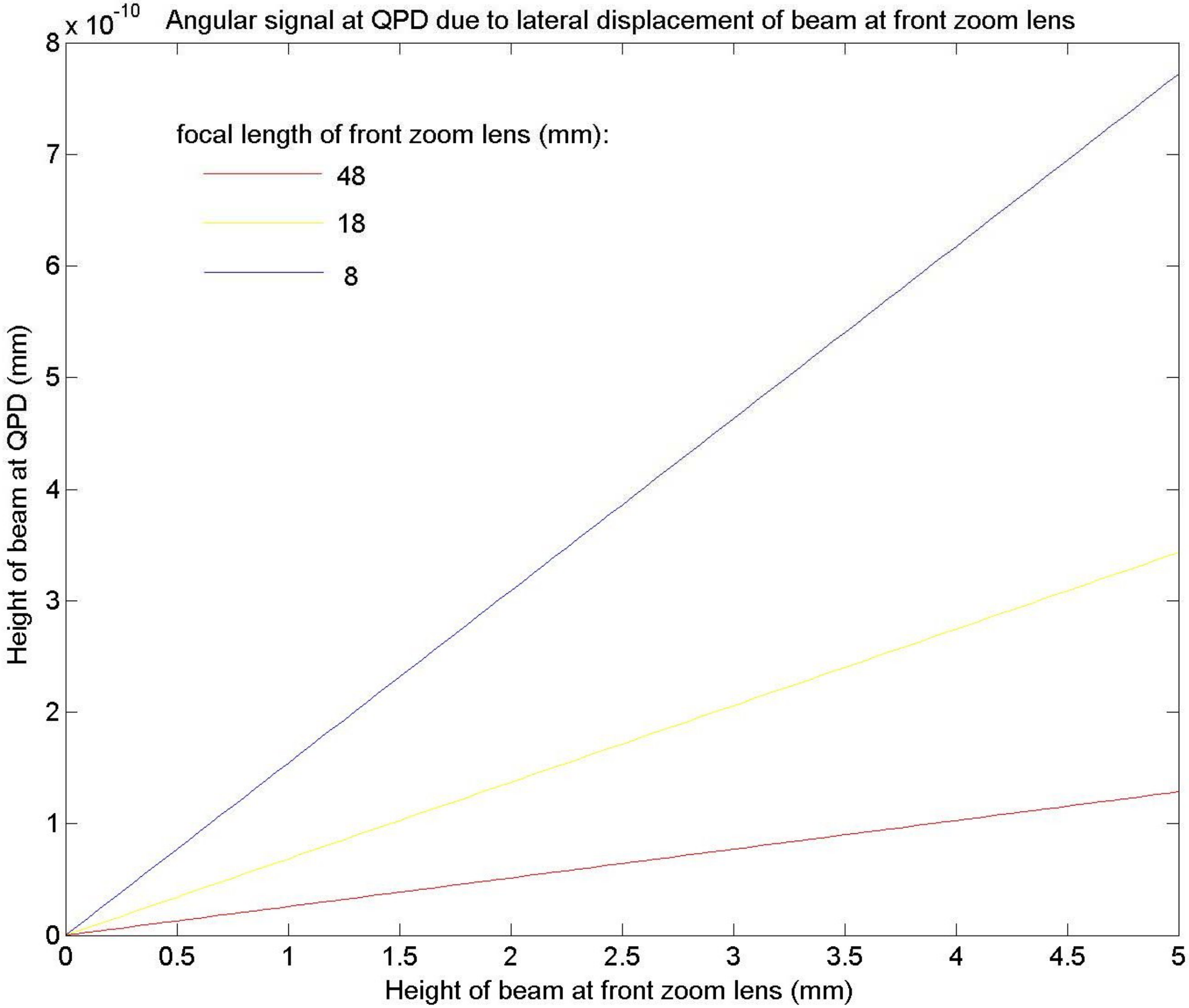
Snell's Law vs. ABCD



Effective Focal Length

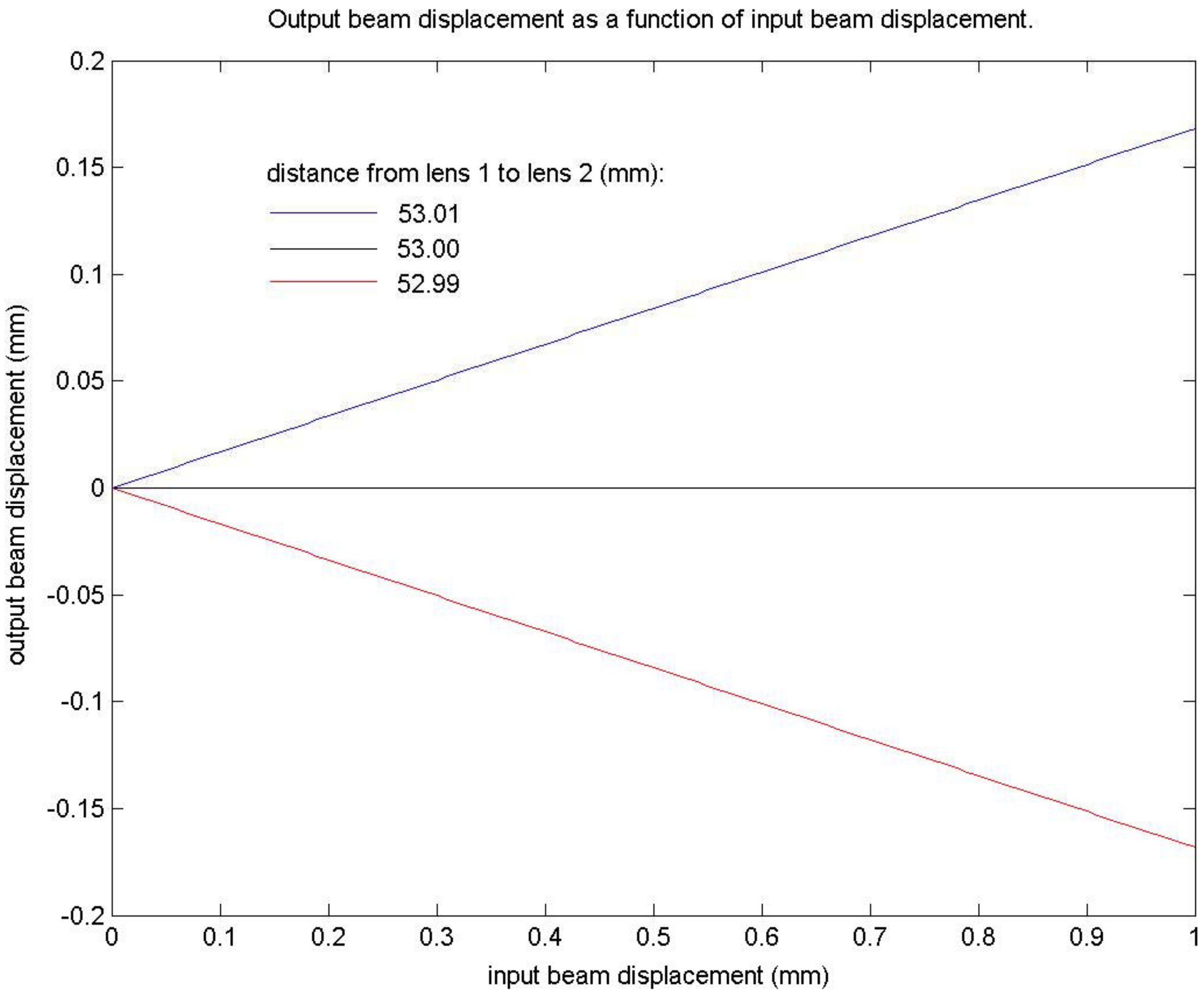


Axial Insensitivity



LI

Sensitivity to Lens 2



LIGO

Prototyping

TRINITY UNIVERSITY

Results

Telescope stages	Effective focal length	Sensitivity to translation
One	0.2 m	None
Two	3 m	Reduced by 1/2
Three	*	*

***** Problem: Overfocusing of Gaussian beam. The beam width after lens 4 is 26 microns, which gives a Rayleigh range of

$$z_R = \frac{\pi \omega_0^2}{\lambda} = 3.4 \text{ mm!}$$

Which brings us to…

- New approach: place emphasis on beam size at an arbitrarily large distance to reduce Gaussian effects.
- Redistribute magnification by increasing the number of telescope stages in order to decrease the rate at which the beam spreads.