Laser Adaptive Optics for Advanced LIGO

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Optics Session

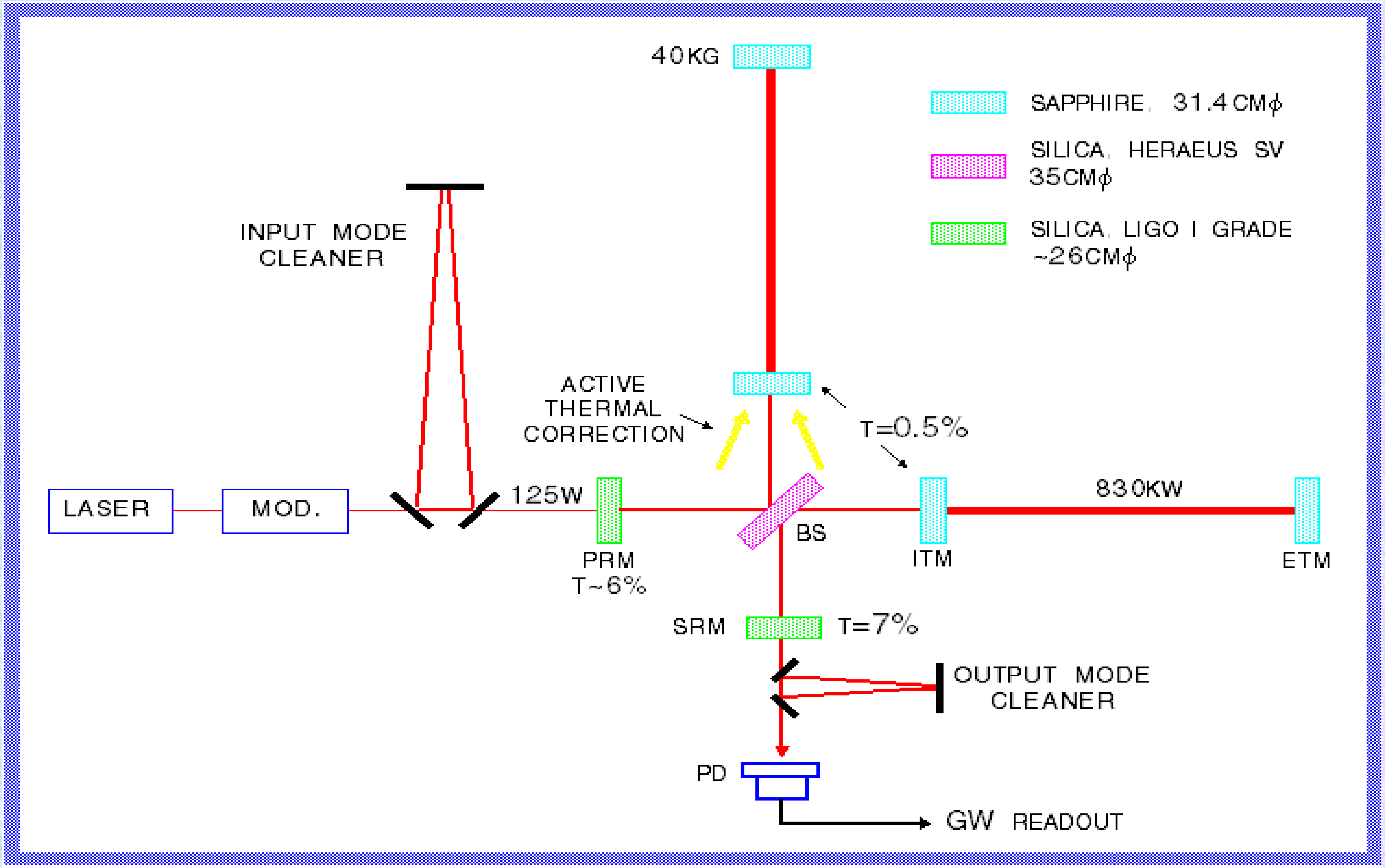
Acknowledgement

NSF
Lonnie Houck
Derek Kennedy
Jinho Lee
Christina Leidel
Rachel Parks
Luke Williams
Wan Wu

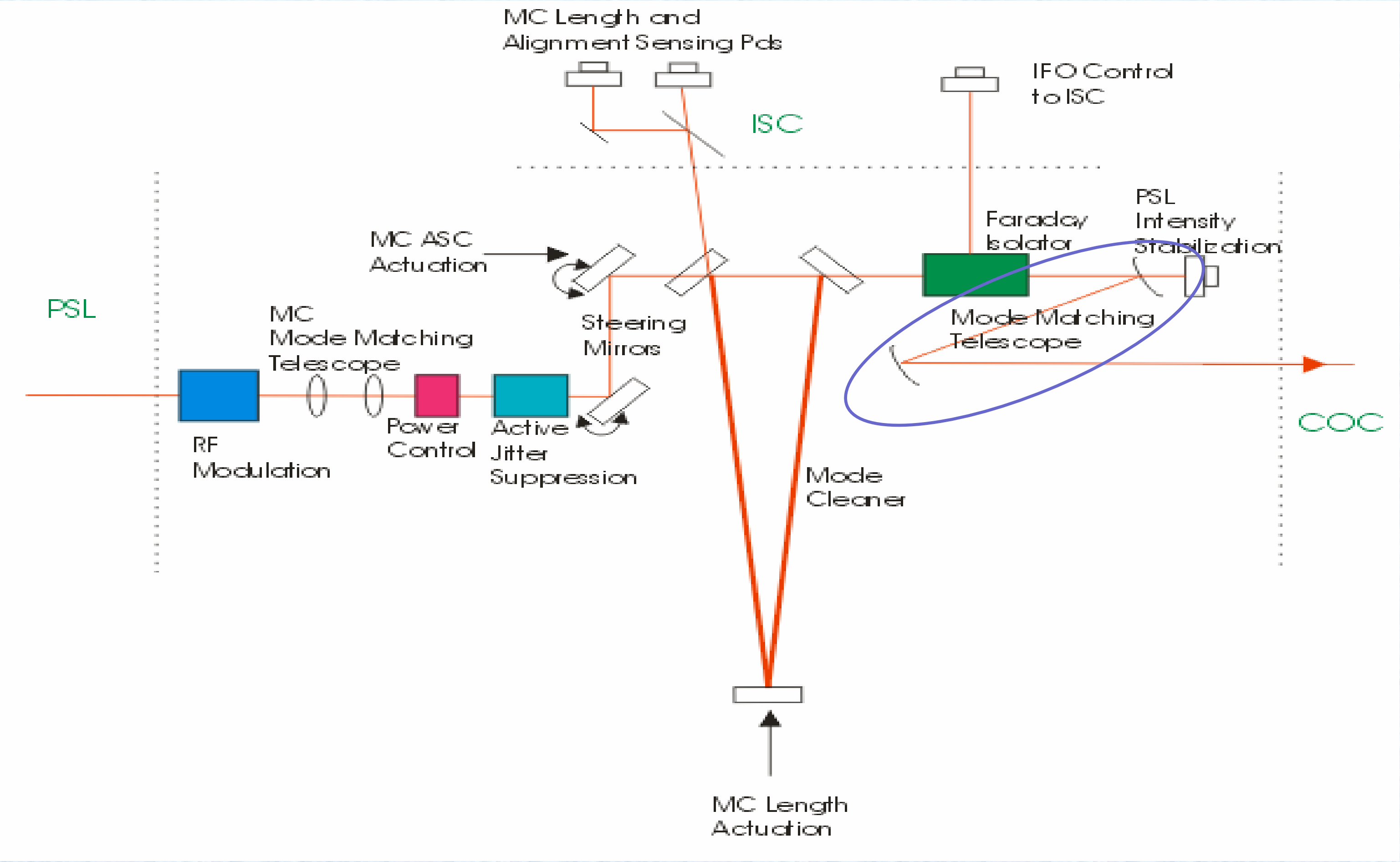
Outline

- Introduction
- Theory
- Experiment
- Future Work
- Conclusion

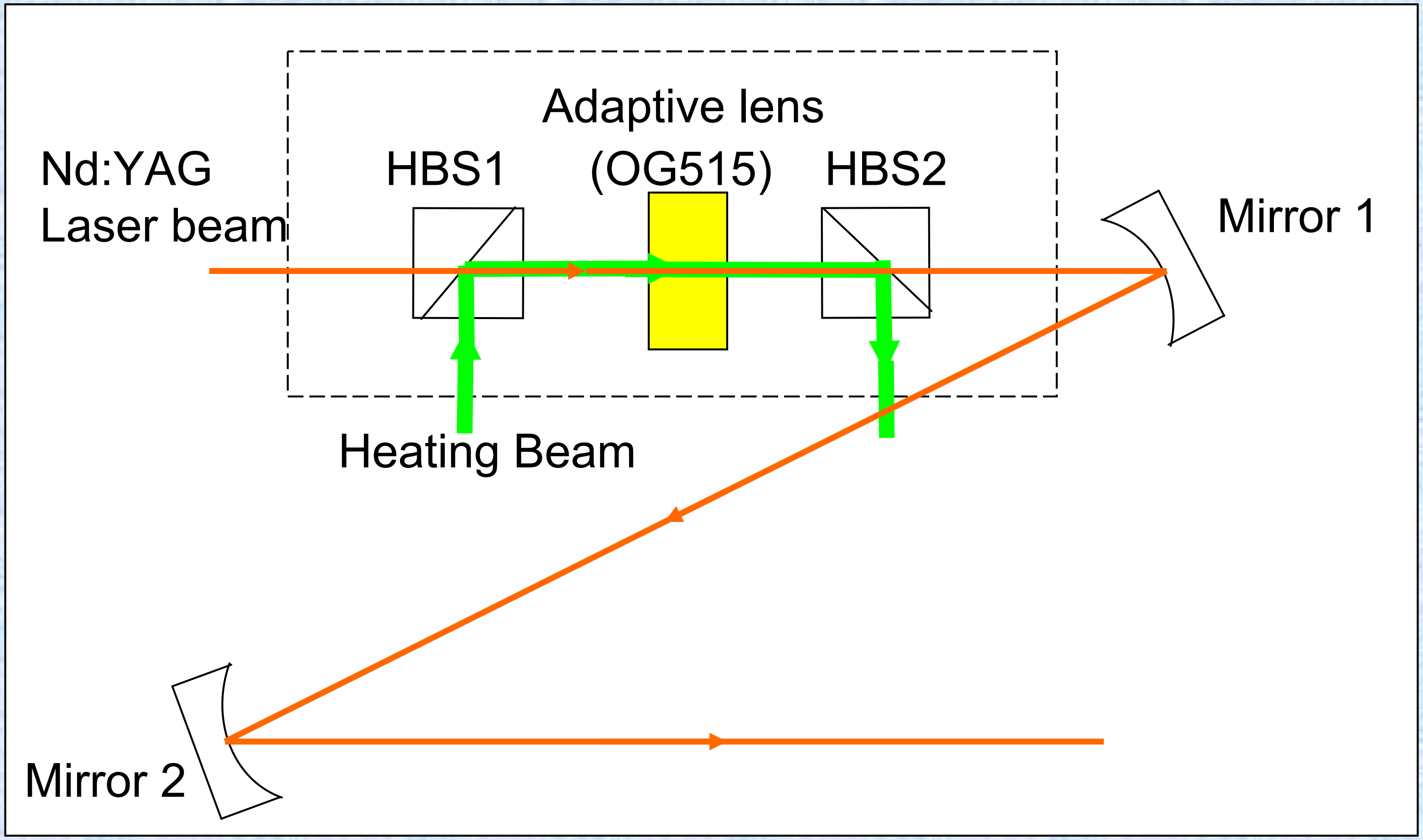
Optical configuration of Advanced LIGO



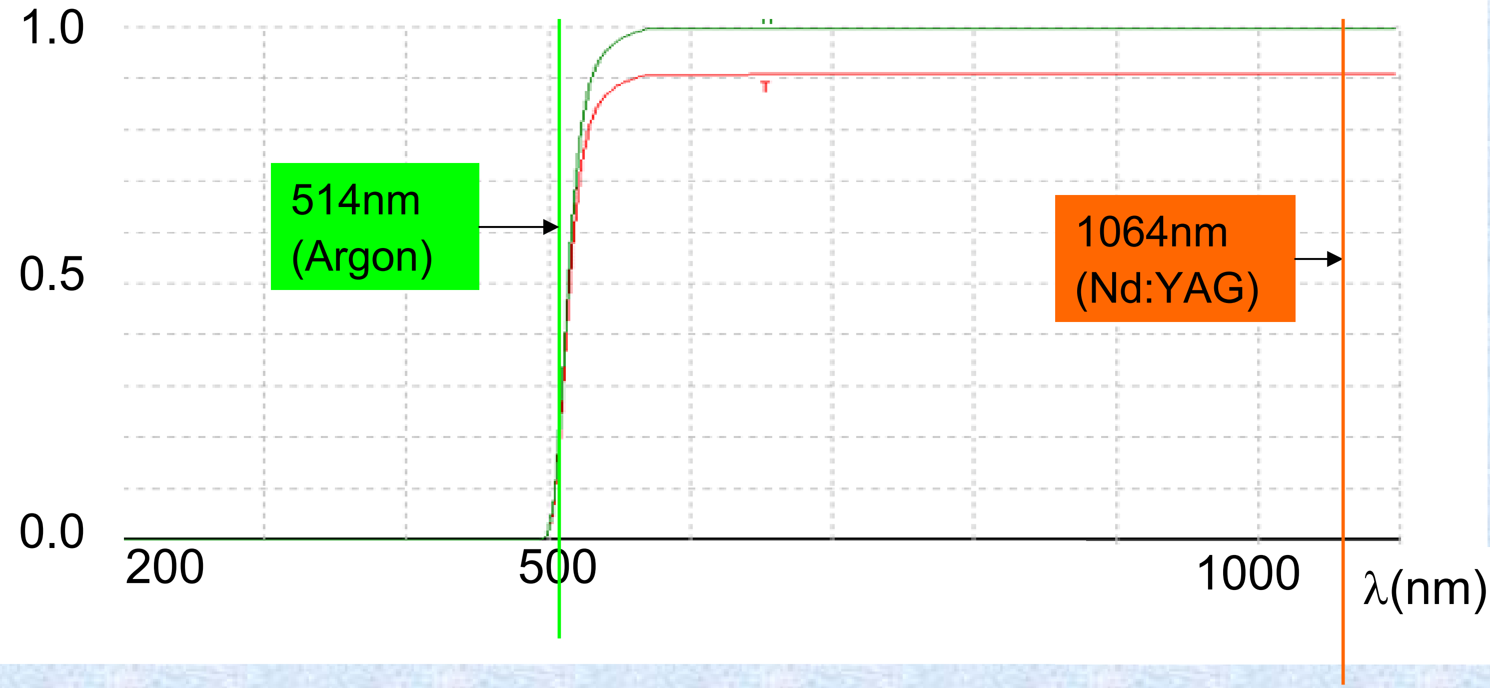
Input Optics subsystem



Schematic layout of adaptive-lens mode matching telescope



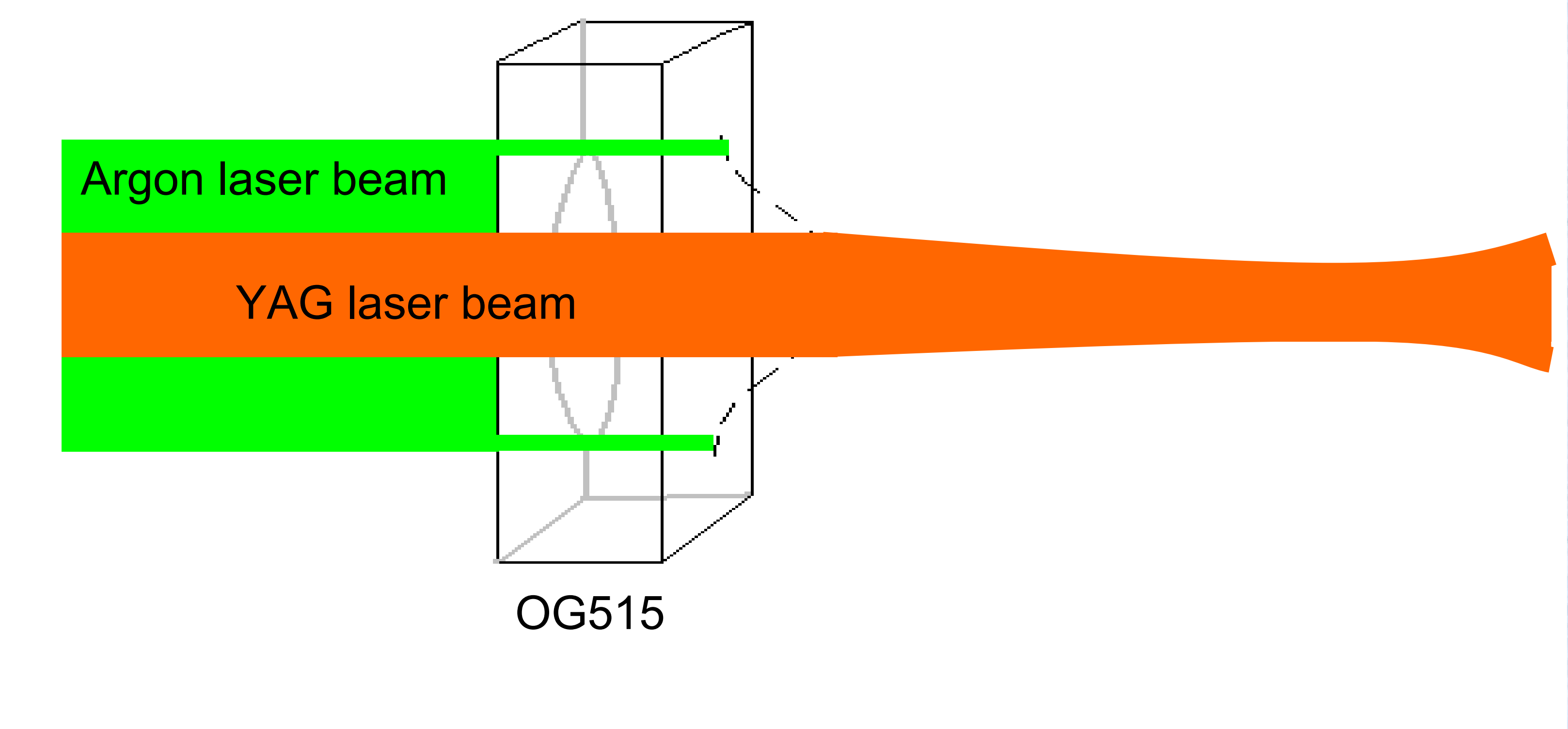
Transmittance of SCHOTT glass **OG515**



Thickness: 3 mm (sample)

Thickness: 15mm (experiment)

Thermal lensing in OG515



An Argon laser is used as heating beam; a YAG laser is used to 'read' the thermal lensing effect of OG515.

Optical path length (OPL) change due to thermal effects

- Temperature-dependent refractive index

$$\Delta OPL(r) = \frac{dn}{dT} L \Delta T(r)$$

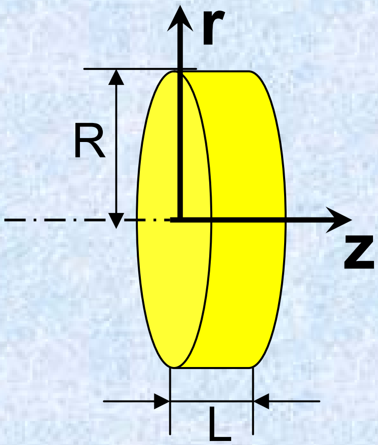
- Thermal Expansion

$$\Delta OPL(r) = \alpha (n-1) L \Delta T(r)$$

α: coefficient of thermal expansion .

- Photo-elastic Effect

Theoretical calculation of temperature profile
(from J. Lee and R. Parks (UF))



Boundary Conditions: $\Delta T\big|_{r=R} = 0$

$$\frac{\partial T}{\partial z}\bigg|_{z=0,L} = 0$$

$$\Delta T(r,z) = -\sum_{n=1}^{\infty} \frac{4\alpha P}{\pi K R^2 w^2} \frac{\int_0^R e^{-2\frac{r'^2}{w^2}} J_0\left(k_n \frac{r'}{R}\right) r' dr'}{(J_1(k_n))^2} J_0\left(k_n \frac{r}{R}\right) f_n(z)$$

P: power of the incident light

α: absorption coefficient

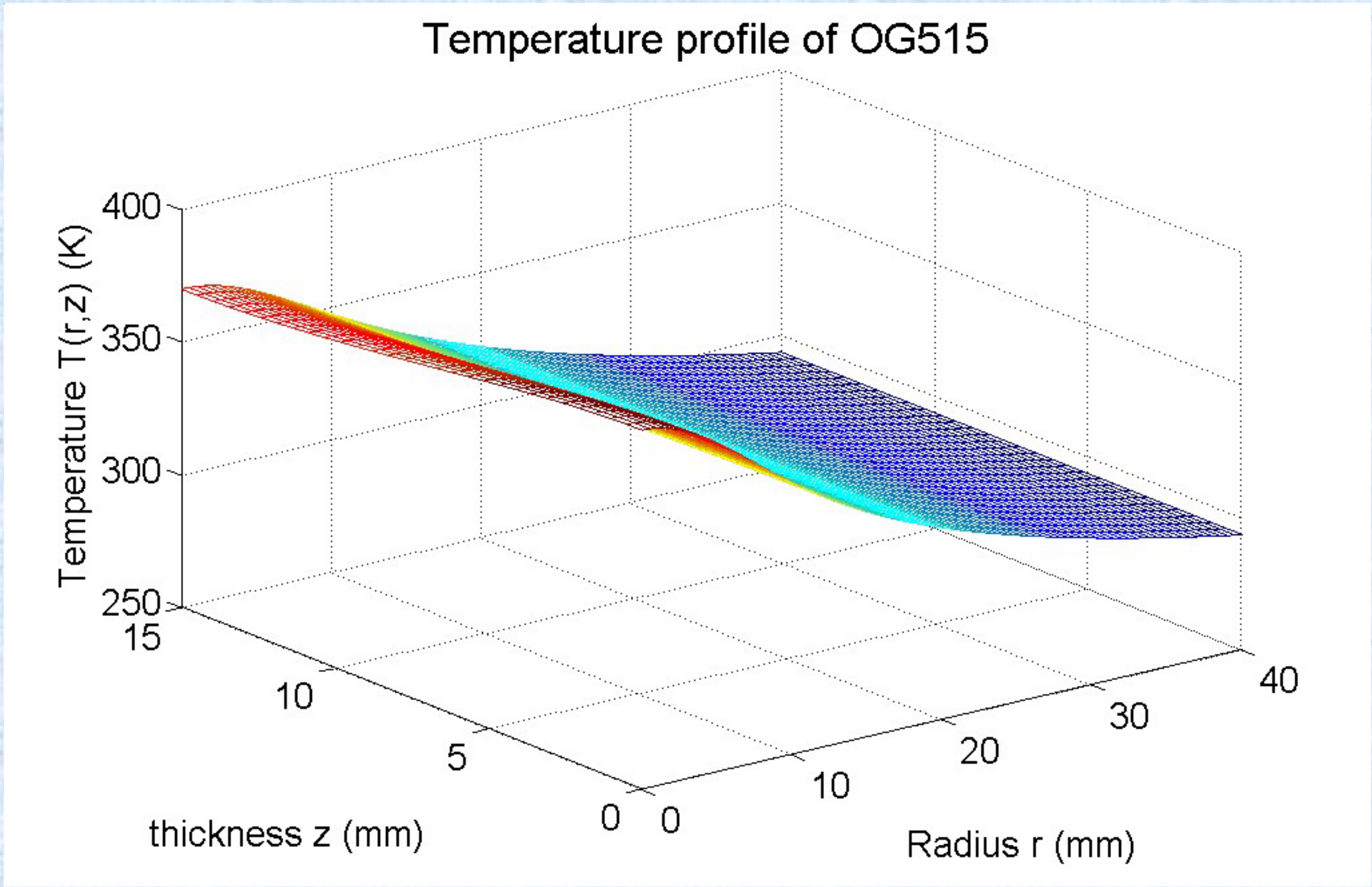
K: thermal conductivity

w: beam radius

R:radius of OG515

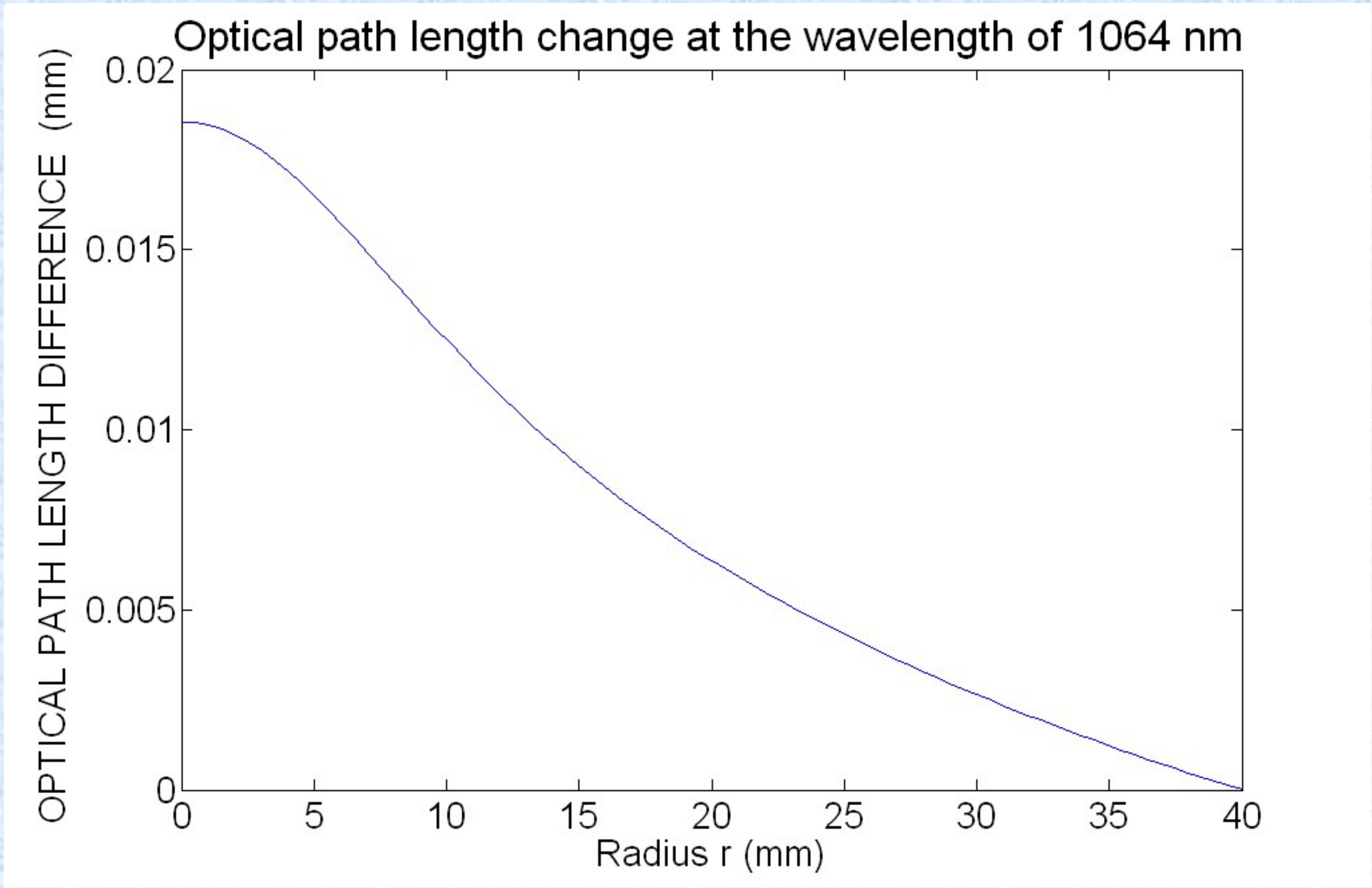
$$f_n(z) = \frac{1}{\alpha^2 - (\frac{k_n}{R})^2} \left\{ \frac{\alpha R}{k_n} \left[\frac{e^{(\frac{k_n}{R}-\alpha)L} - 1}{e^{2\frac{k_n L}{R}} - 1} e^{\frac{k_n}{R}z} - \frac{e^{-(\frac{k_n}{R}-\alpha)L} - 1}{e^{-2\frac{k_n L}{R}} - 1} e^{-\frac{k_n}{R}z} \right] + e^{-\alpha z} \right\}$$

Theoretical temperature profile

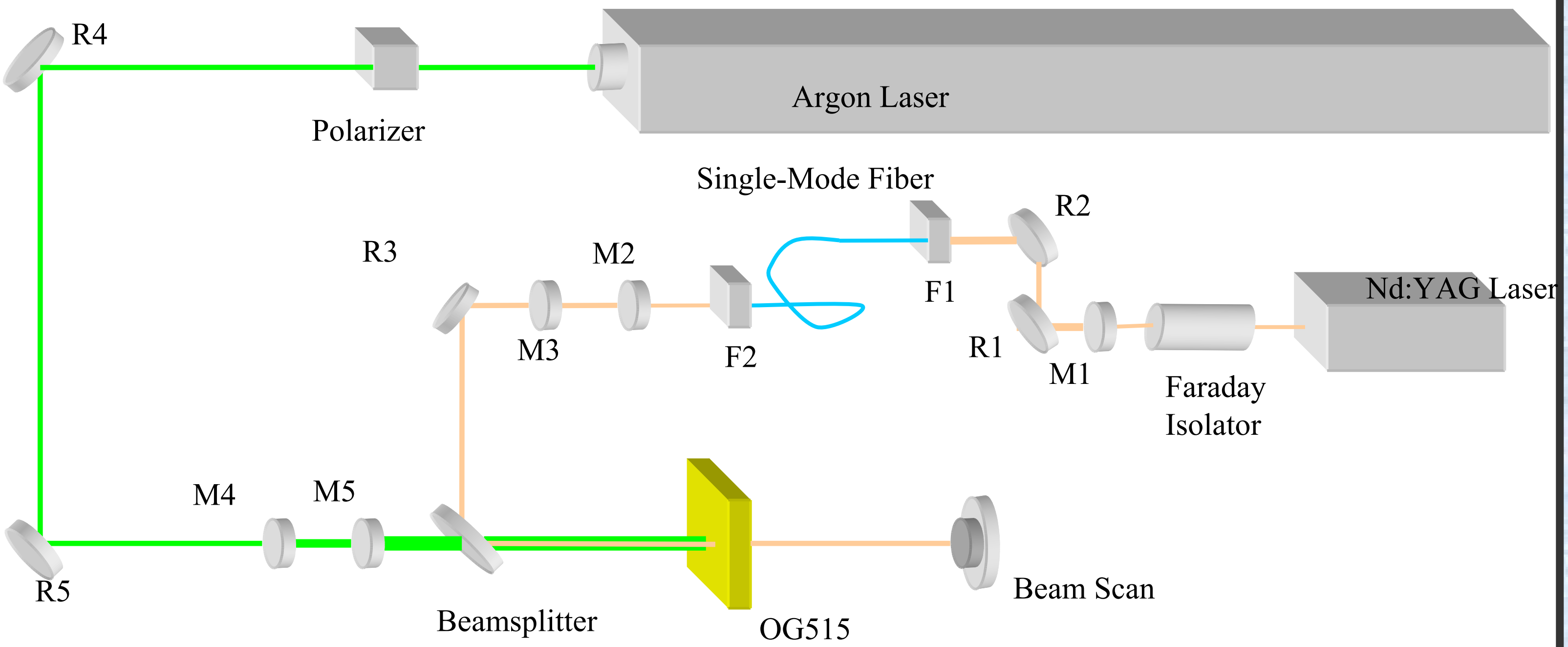


P (Argon laser): 6W T(room temperature): 293K.

Theoretical ΔOPL



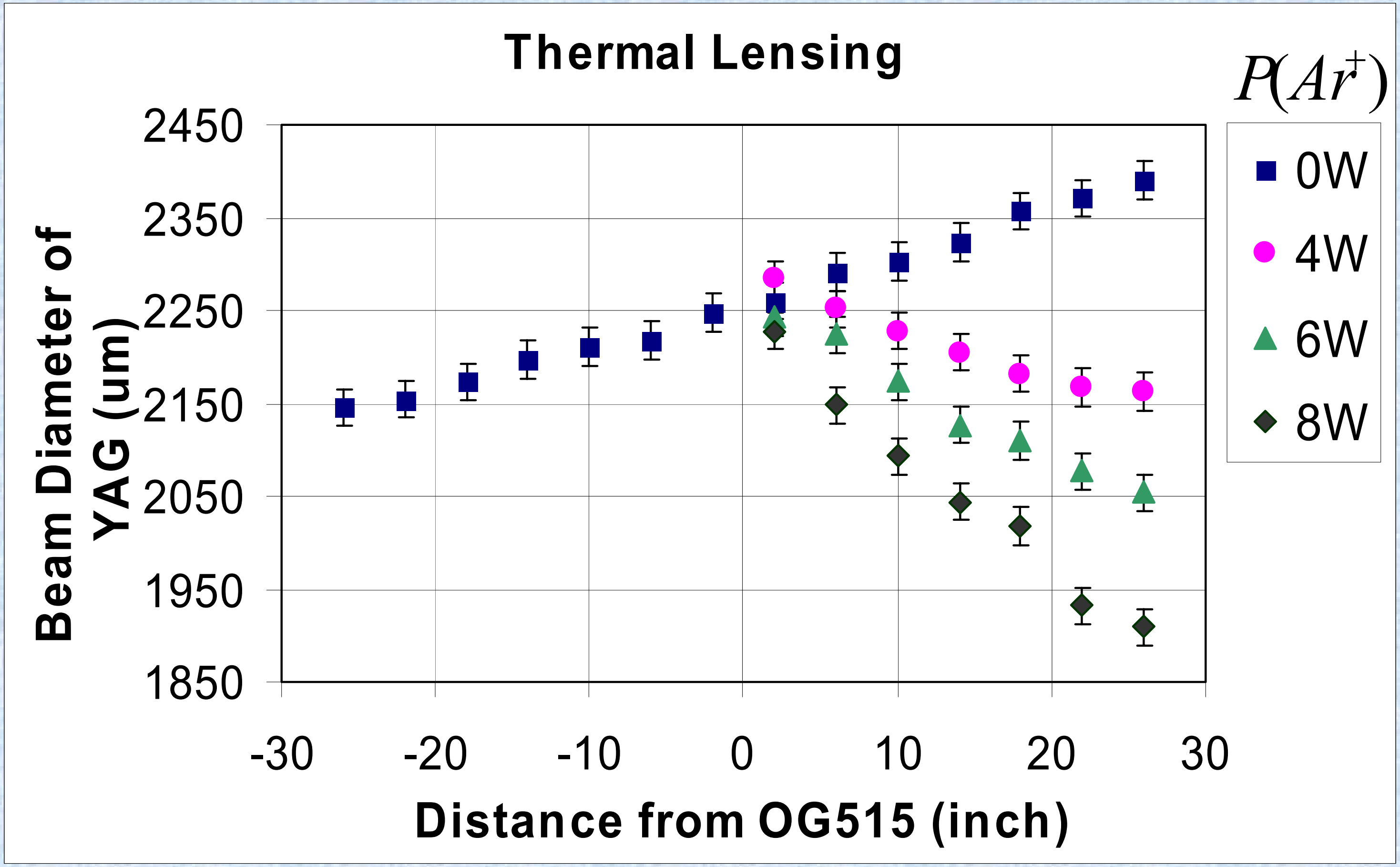
Experimental Setup



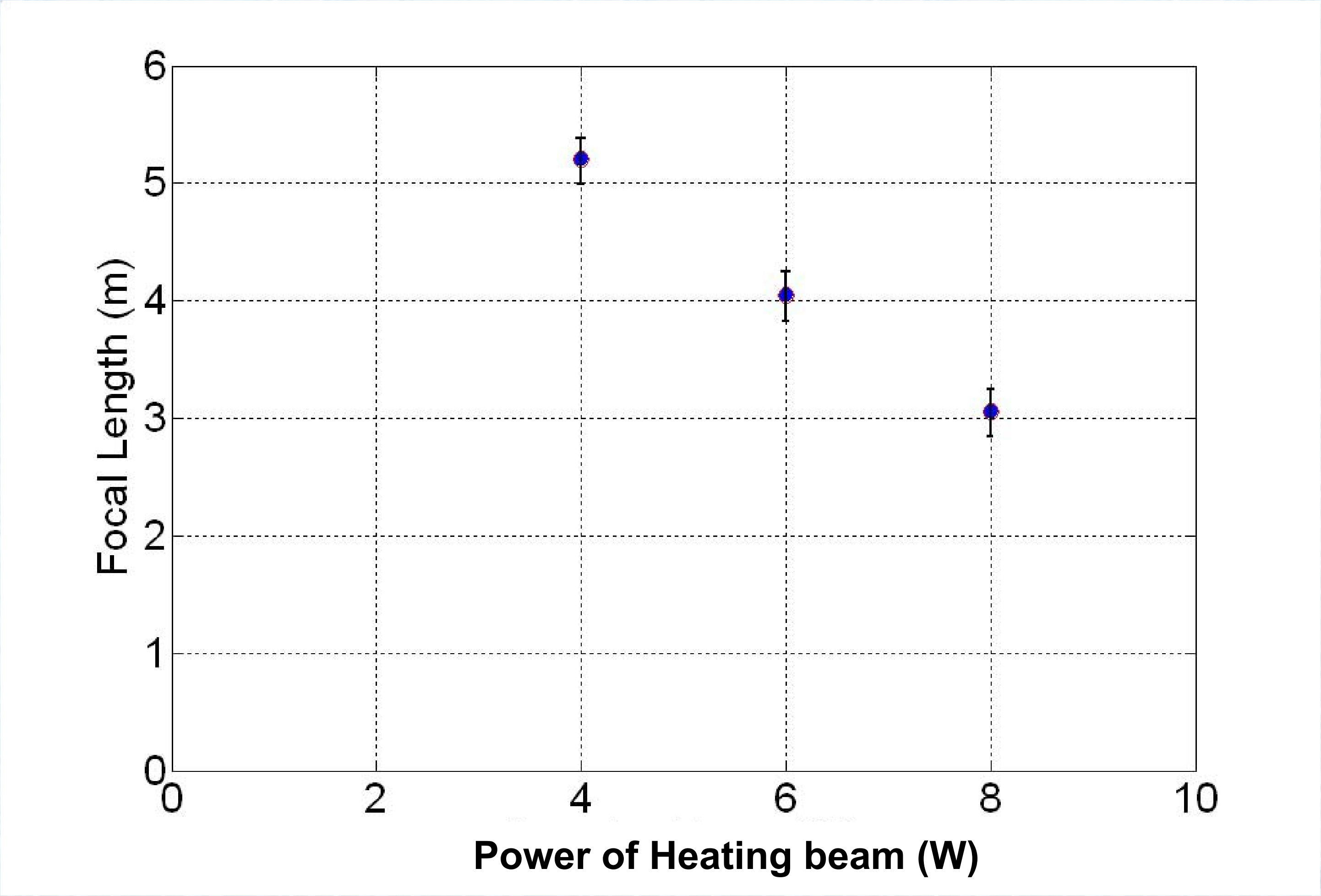
M1, M2, M3, M4, M5 are lenses; R1, R2, R3, R4, R5 are mirrors; F1 and F2 are fiber-optic couplers

The diameter of collimated Argon laser beam is 16 mm; the diameter of YAG laser on OG515 is 2mm.

Experimental results

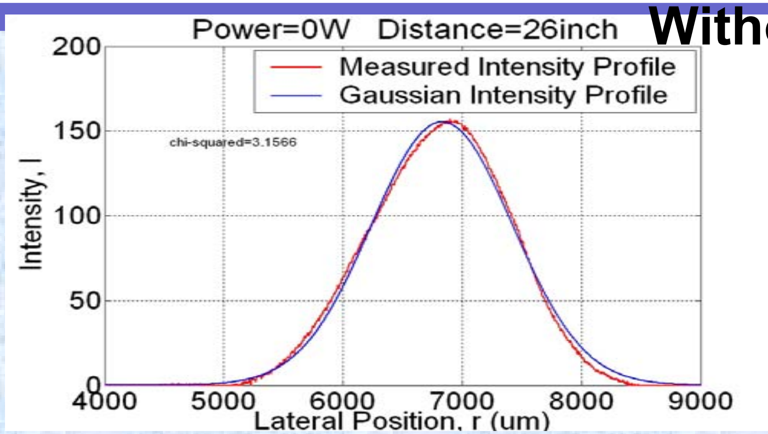


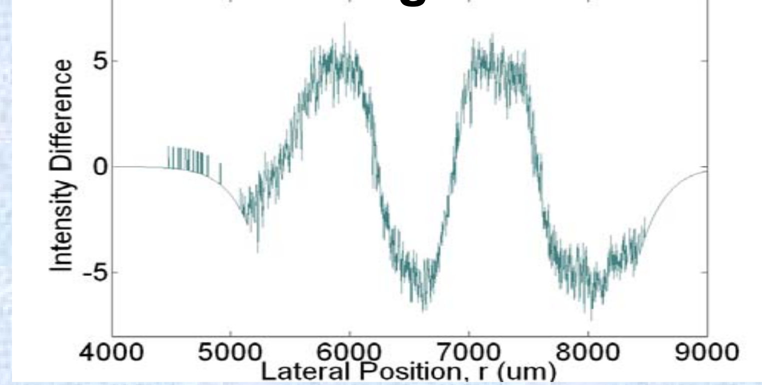
Focal length of adaptive lens



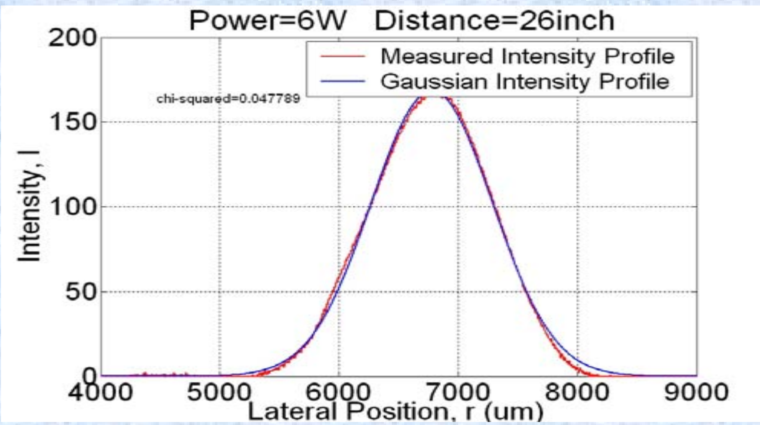
Beam Profile

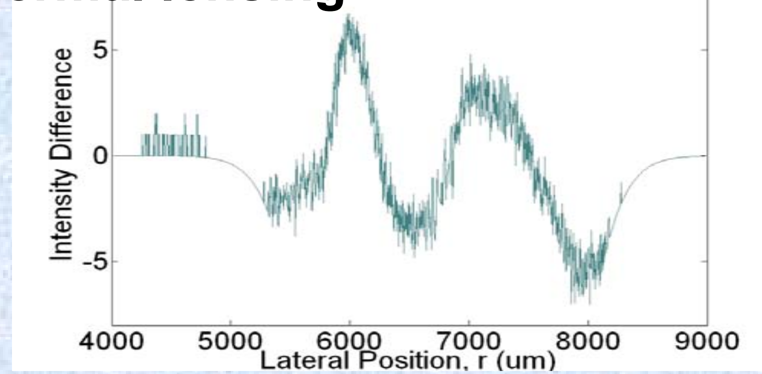
Without thermal lensing





thermal lensing





The thermal lens doesn't introduce large amplitude higher order Gaussian modes.

Future work

- OG515 in a vacuum chamber will be tested.
- Fabry-Perot cavity will be used to measure higher order modes mode matching.
- Bullseye wavefront sensor will be used to measure and correct mode-matching.

Conclusion

A variable thermal lens is formed using different powers of a pumping beam. It is possible to control this variable lens to compensate the thermal lensing effects of the optical elements in advanced LIGO.