Adaptive Heating for Thermal Compensation in Advanced LIGO

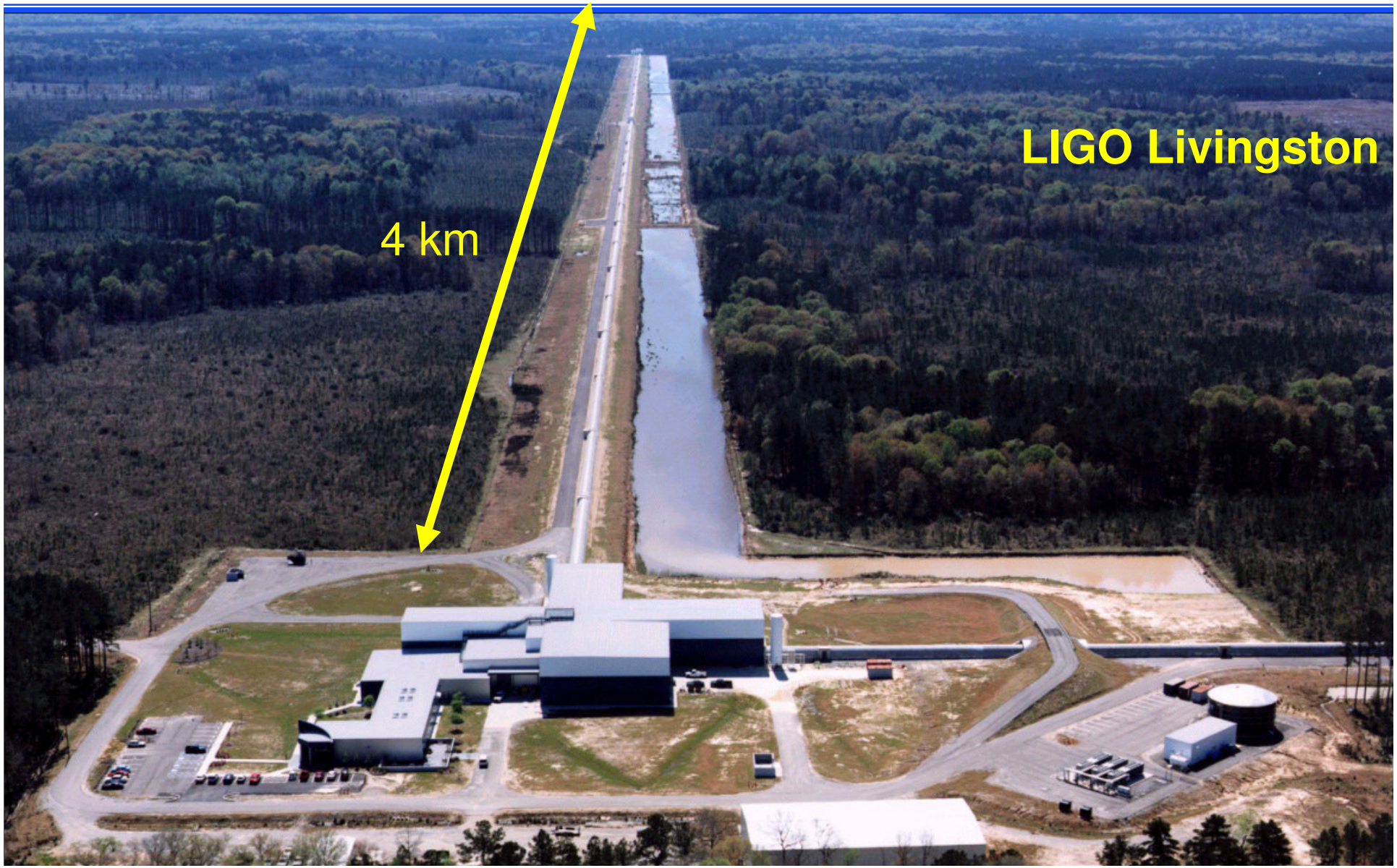
Muzammil A. Arain, Volker Quetschke, Luke F. Williams, **Guido Mueller,** D. B. Tanner, and D. H. Reitze
Department of Physics, University of Florida, Gainesville, Florida

Frontiers in Optics 2007, September 18, 2007

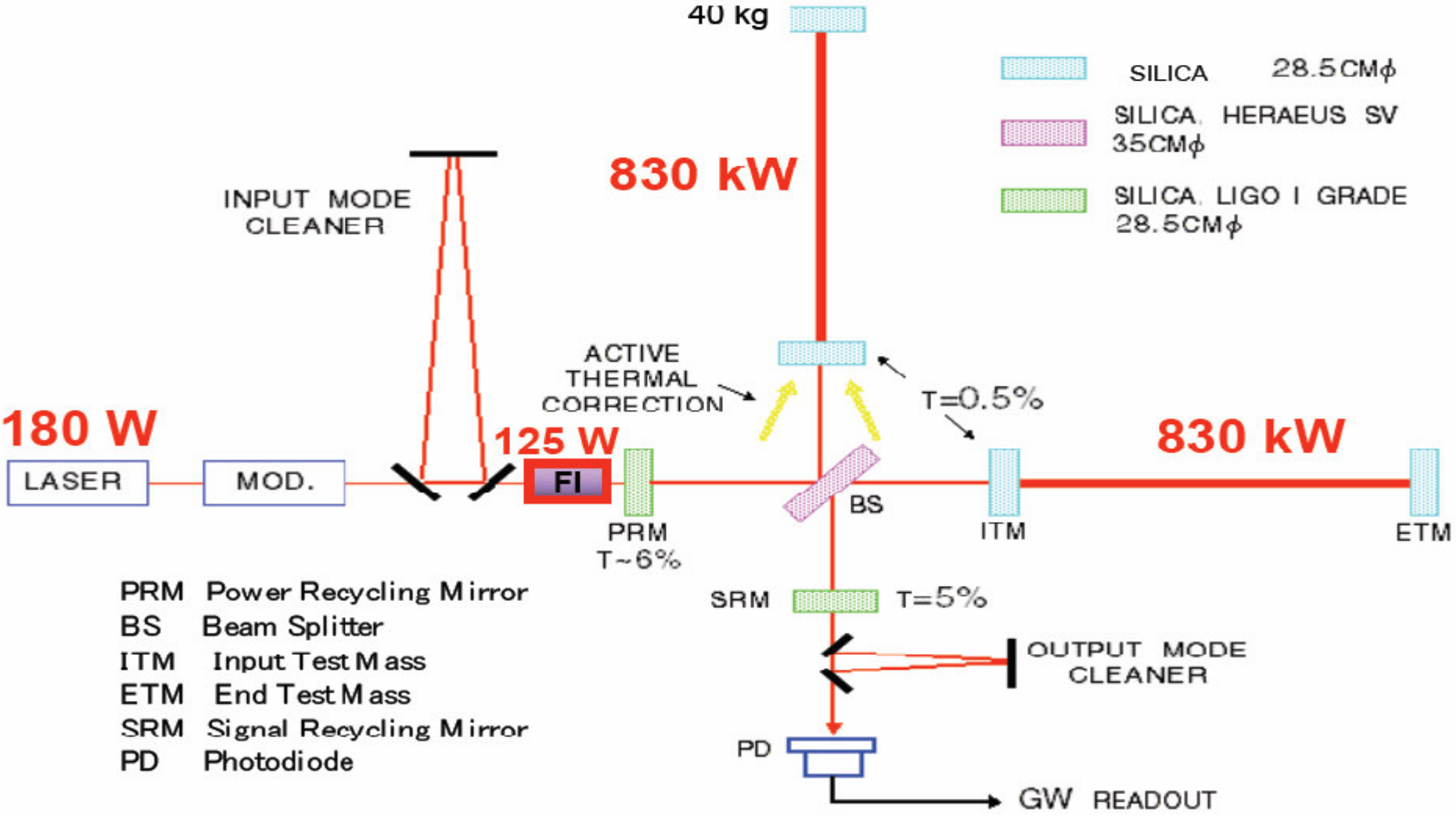
Research supported by The National Science Foundation
through grants PHY-0555453 and PHY-0354999

G070620-00-E

Initial LIGO-LIGO today

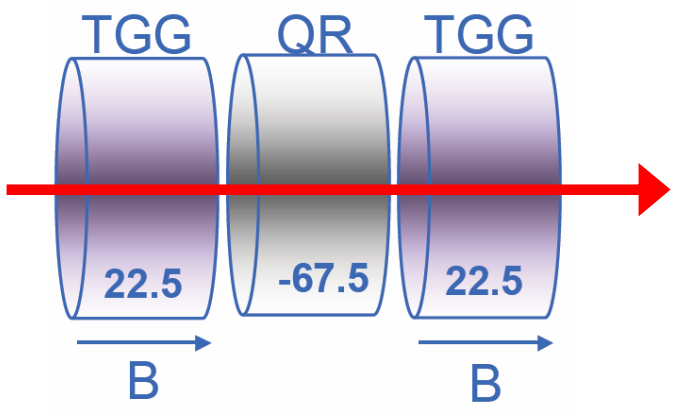


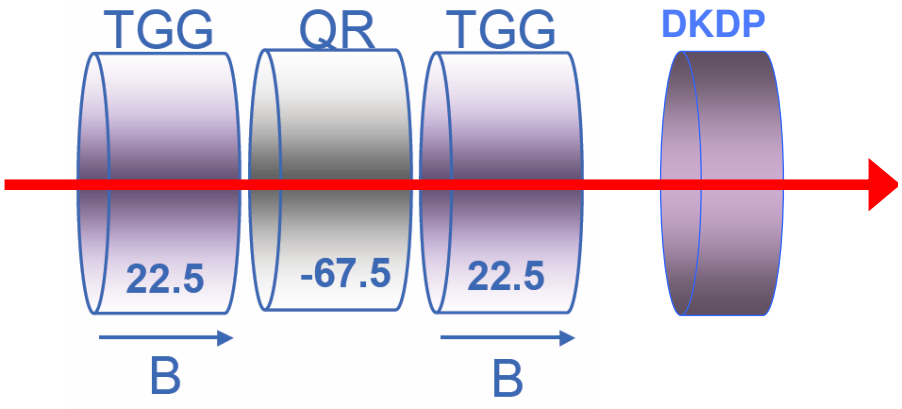
Optical Layout of Advanced LIGO



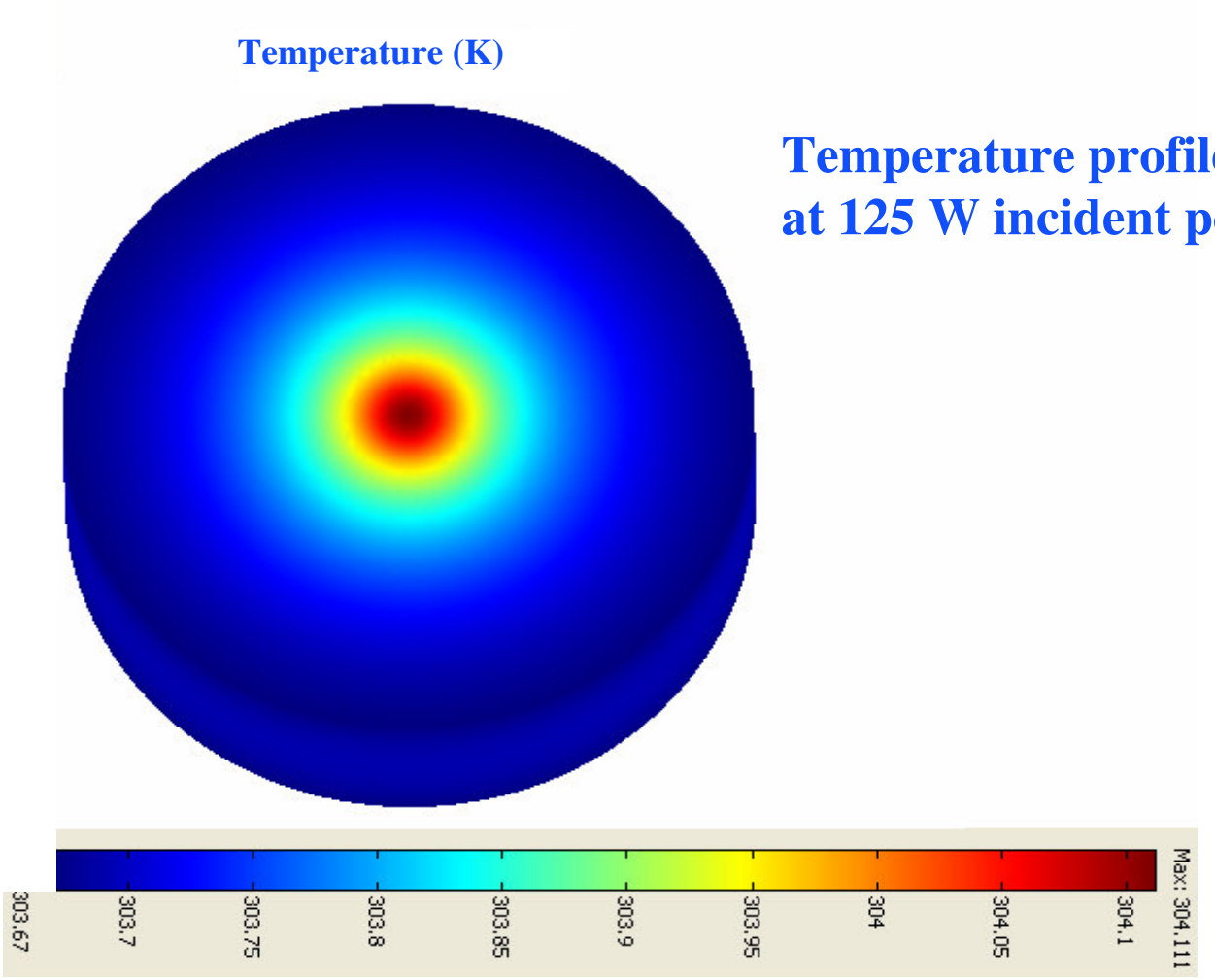
Thermal Lensing Management in FI

- FI Construction
  - » Two TGG
  - » One Quartz Rotator
- Expected Thermal lensing
  - » 10 m focal length at 125 W
  - » 2.1 mm beam size
- Passive compensation
  - » Negative dn/dT compensation
  - » DKDP with appropriate thickness
  - » Limitations
    - – Prior knowledge of absorption
    - – Fixed compensation





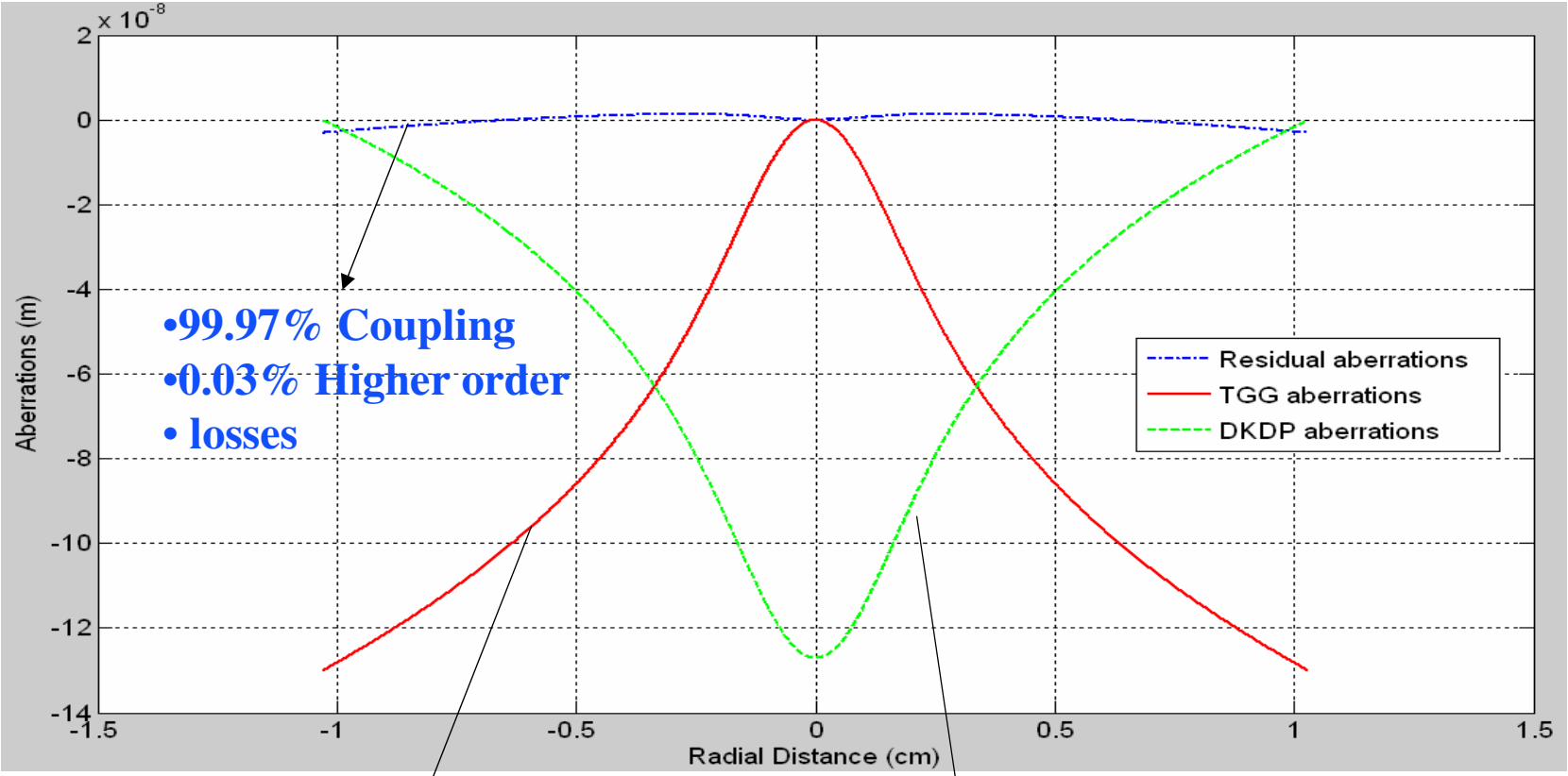
Temperature Profile in TGG



Temperature profile of TGG at 125 W incident power

UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

Passive Compensation with Optimal DKDP Thickness



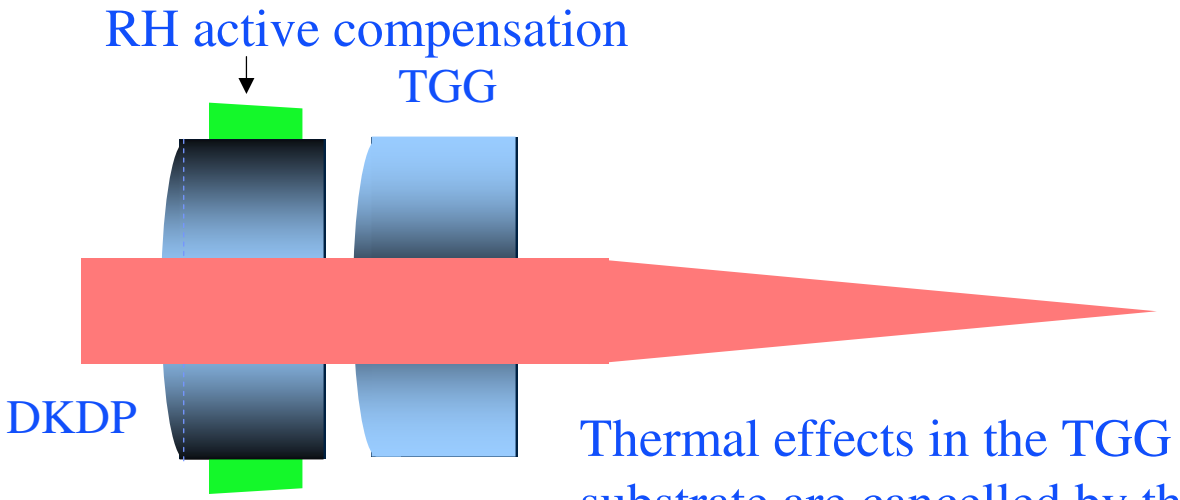
TGG thermal aberrations at 125 W and 2.1 mm beam size

+

DKDP aberrations through the same beam

DKDP Compensation

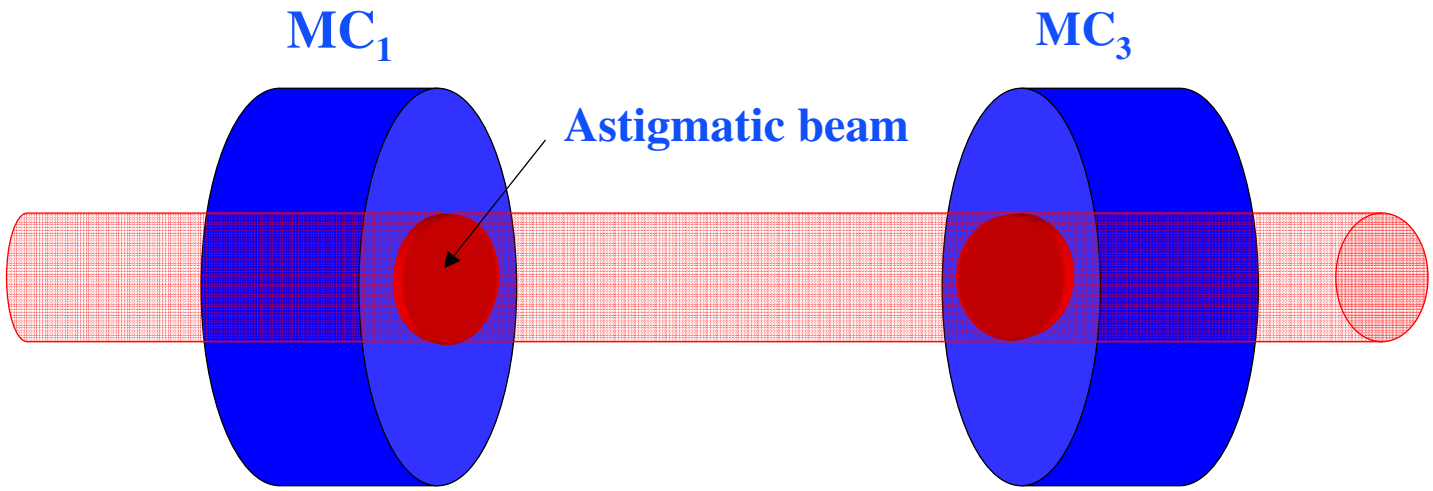
Application in Advanced LIGO



Thermal effects in the TGG substrate are cancelled by the DKDP plate. RHs provide active control.

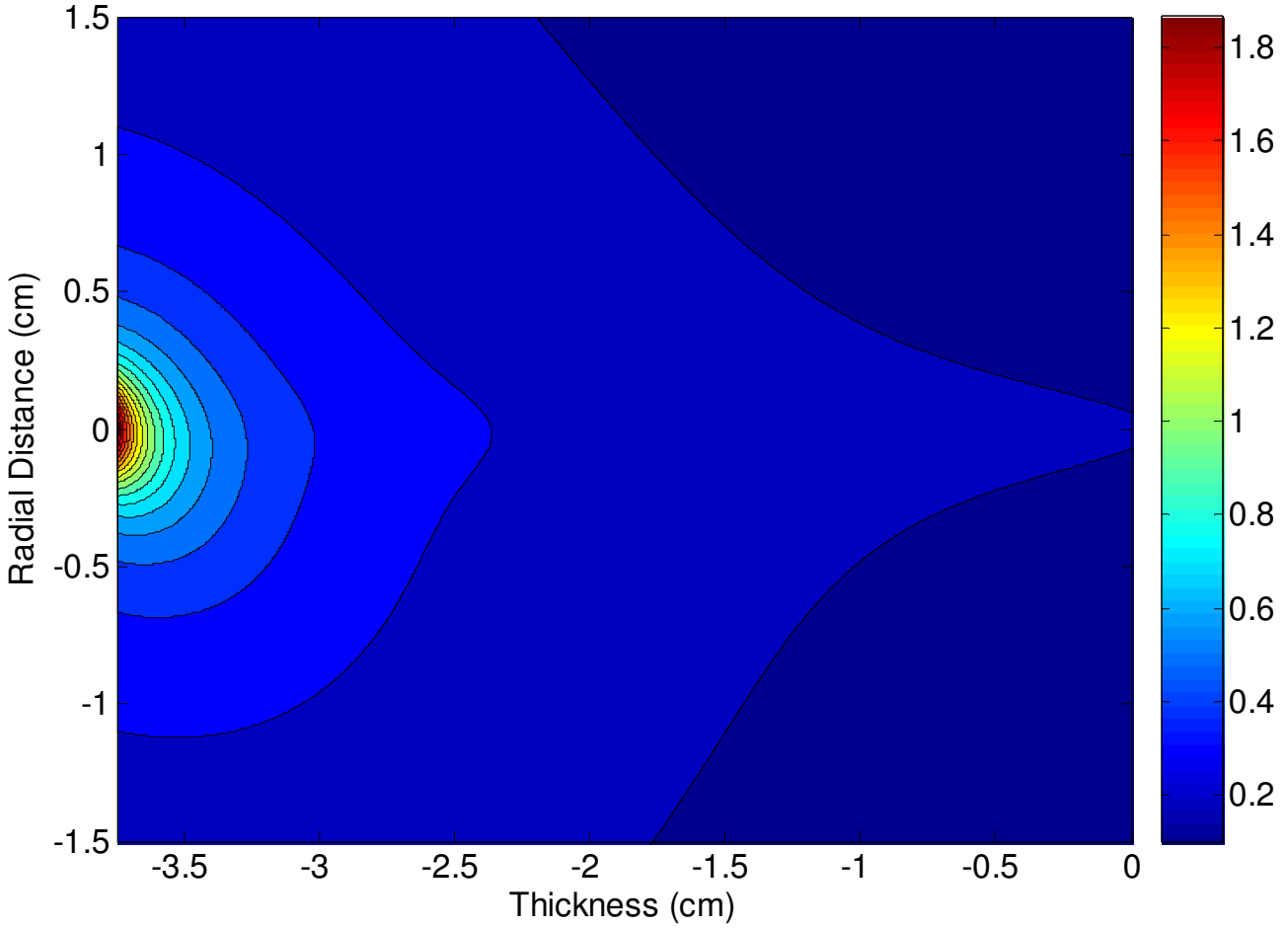
Thermal Lensing in Mode Cleaner

- MC is a ring cavity
- 45^0 angle of incidence at the flat mirrors
  - » Produces astigmatism
  - » Reduces mode coupling into IFO
- Produces astigmatism in the transmitted beam



Temperature Profile in MC Flat Mirrors

Temperature profile across the substrate of MC3.
The lines are contours of constant temperature. X-axis represents the distance from the center of the substrate that is 7.5 cm thick.

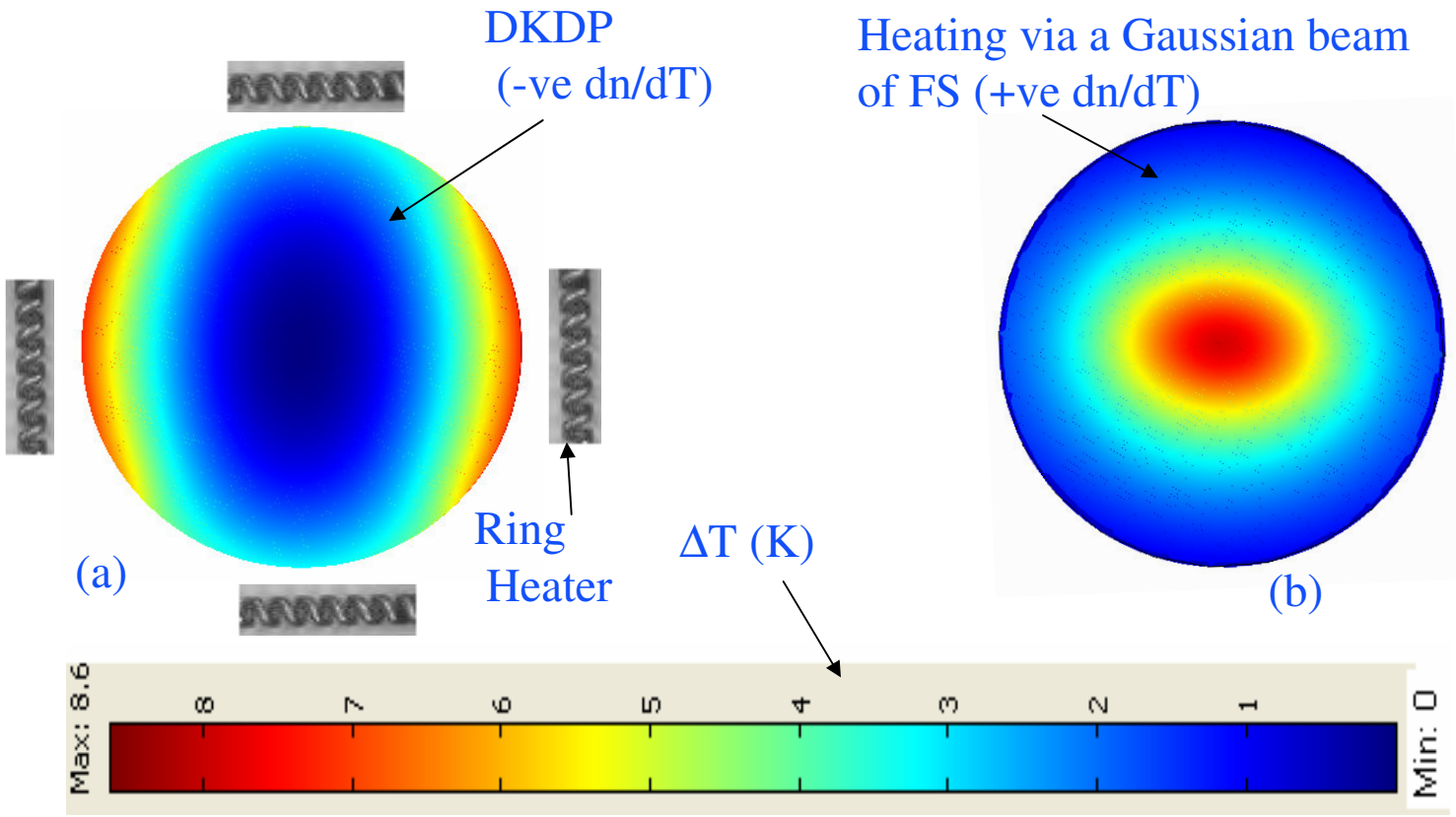


Compensation of Astigmatic Lens

- Four segment RH on DKDP
  - » DKDP is surrounded by four RHs that can be used to apply different heating along two orthogonal directions
  - » RHs are easy to manage because the control is electrical
  - » Can be mounted along the barrel of the optic holder
  - » Requires more heating
  - » Four segmented RH on DKDP
- Elliptical shaped CO_2 Heating Beam
  - » An elliptical beam can be used to compensate astigmatism
  - » The dynamic range is quite high
  - » Much more flexible than RHs
  - » Requires extra beam for heating
  - » More expensive than RH

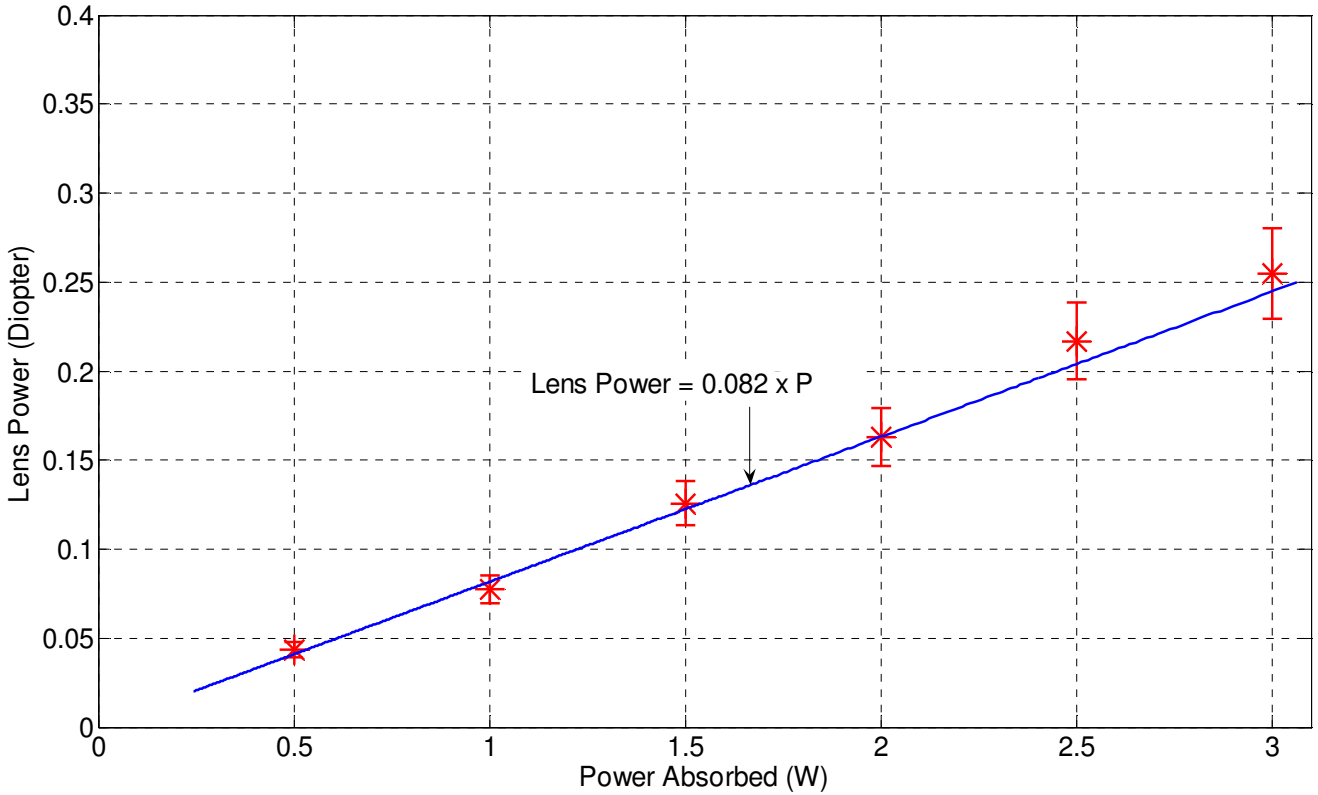
Simulation of Astigmatism Correction

Finite Element Analysis simulation using COMSOL



Adaptive heating Experiment using Fused Silica

Heating of fused silica plate with a CO_2 Laser



Muzammil A. Arain et. al., 'Adaptive Beam Shaping by Controlled Thermal Lensing in Optical Elements", Applied Optics, Vol. 46, Issue 12, pp. 2153-2165 (April 2007).

Summary

- Adaptive heating of optical components is a useful technique for thermal compensation in high power application
- Thermal aberrations in Advanced LIGO Input Optics can be corrected by adopting:
  - » Negative TOC compensation plate
  - » RH on DKDP
  - » Elliptically shaped CO_2 beam heating
- This technique can also be used to realize non-Gaussian beam compensation