Mitigating LIGO Point Absorbers with High-Order Thermal Compensation

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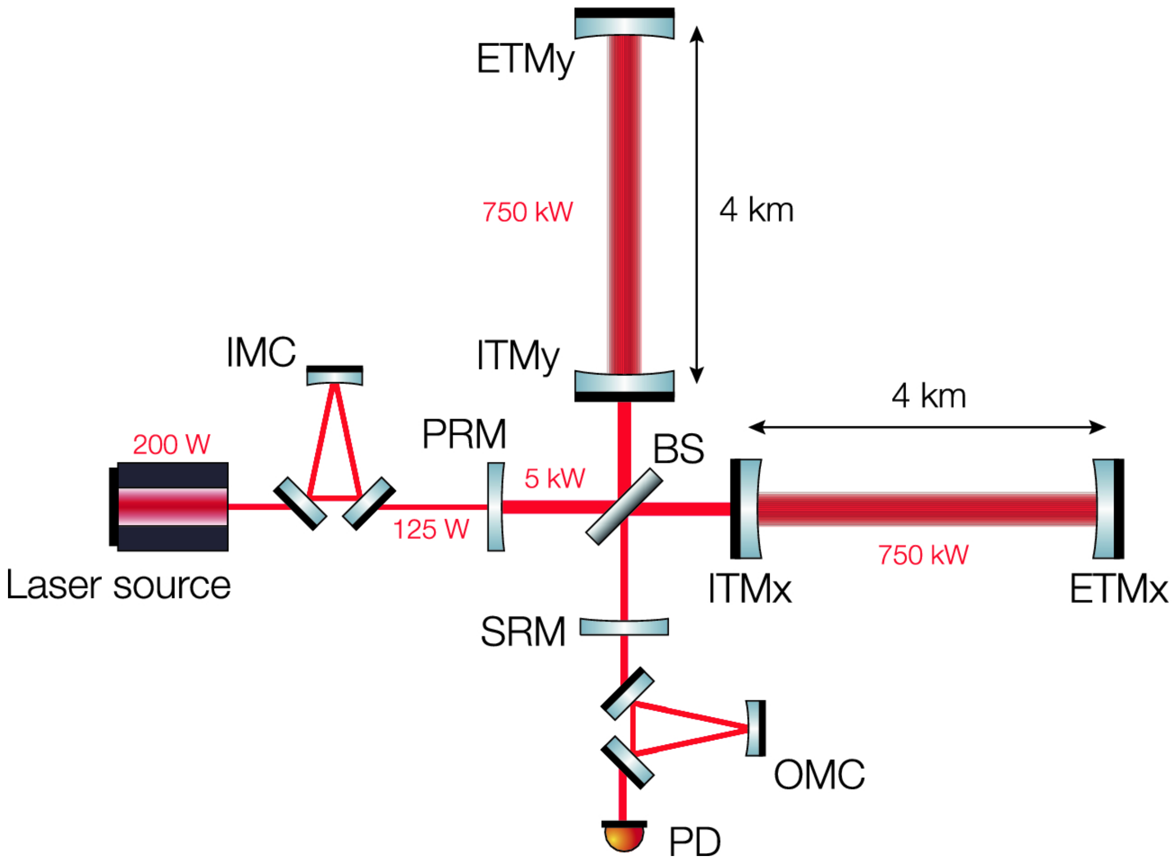
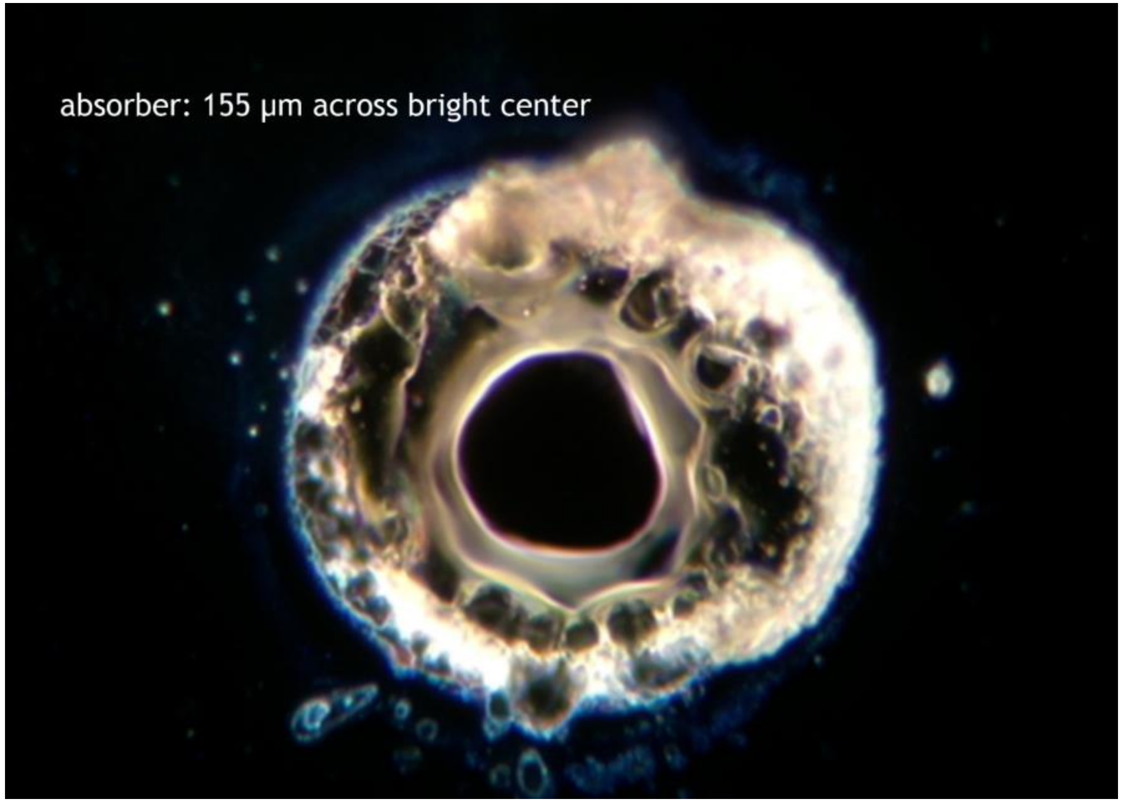
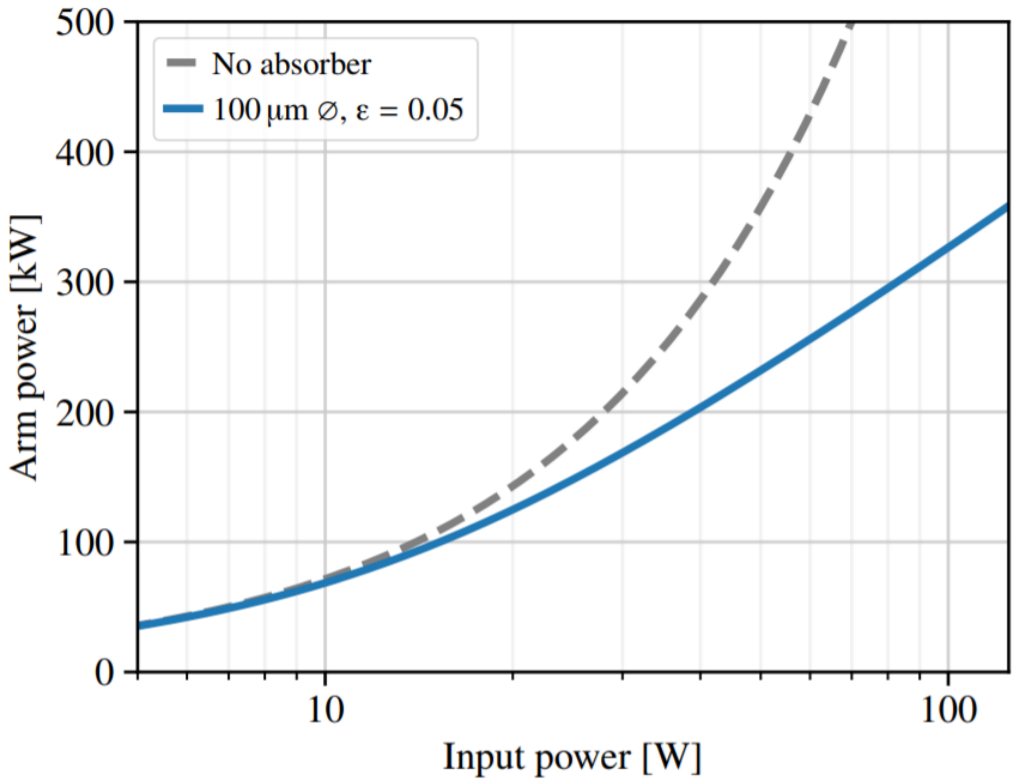
The role of optical cavities in GW detection



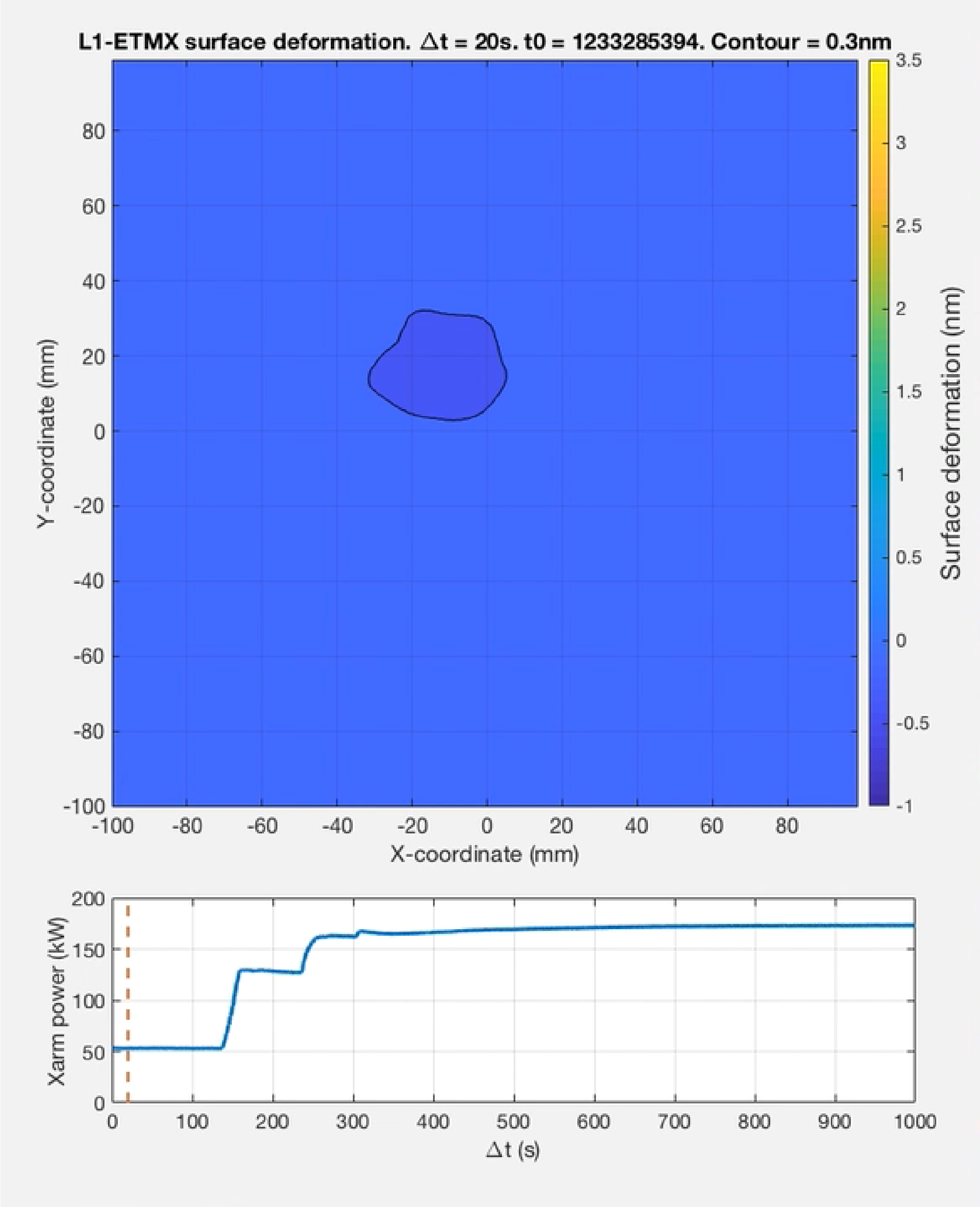
Álvarez M.D. (2019) Near-Unstable Cavities for Future Gravitational Wave Detectors. In: Optical Cavities for Optical Atomic Clocks, Atom Interferometry and Gravitational-Wave Detection. Springer Theses (Recognizing Outstanding Ph.D. Research). Springer, Cham

Point absorbers on the aLIGO test masses

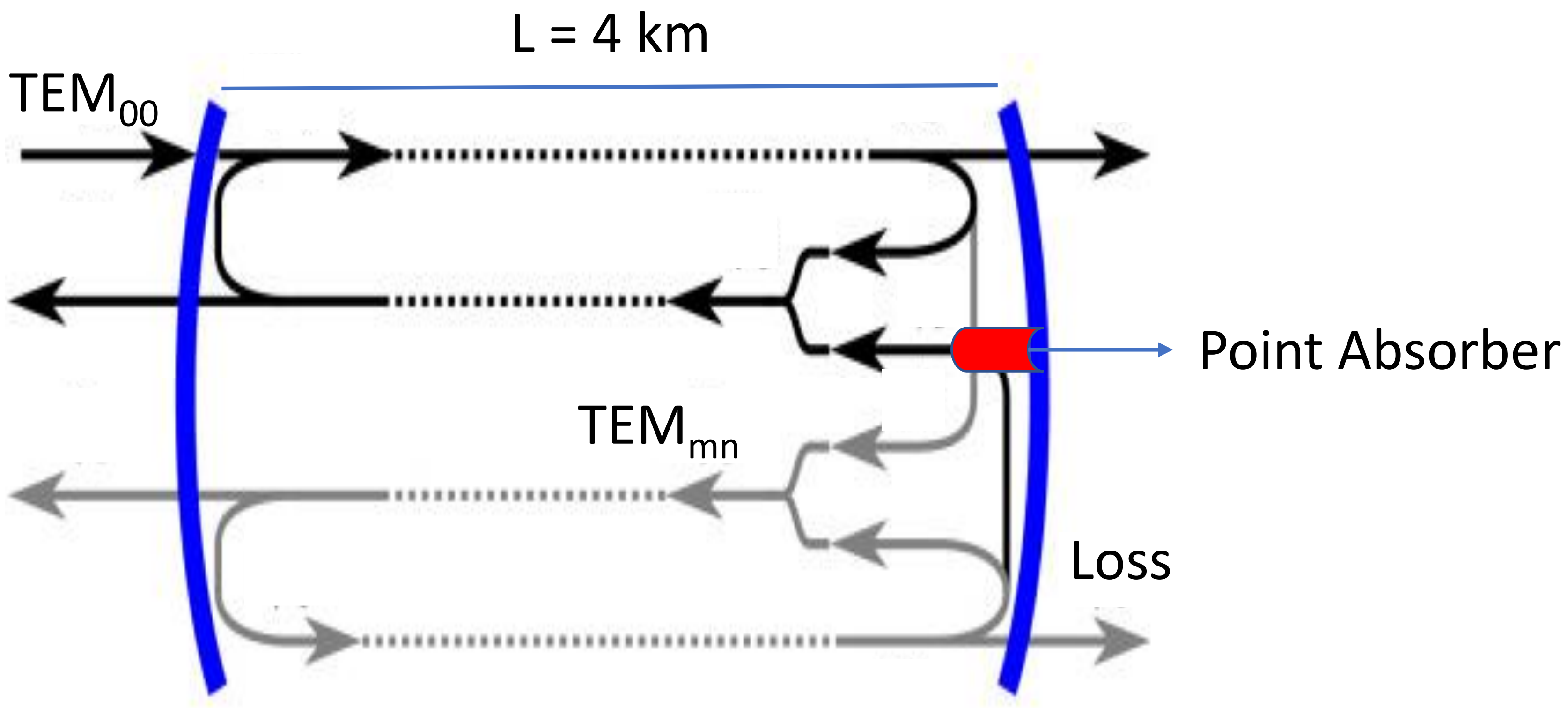




1. A. Brooks, G. Vajente et al., "The point absorbers," (2019), G1900203-v3.
2. E. D. Hall, "The effect of a point absorber in an arm cavity," (2019).

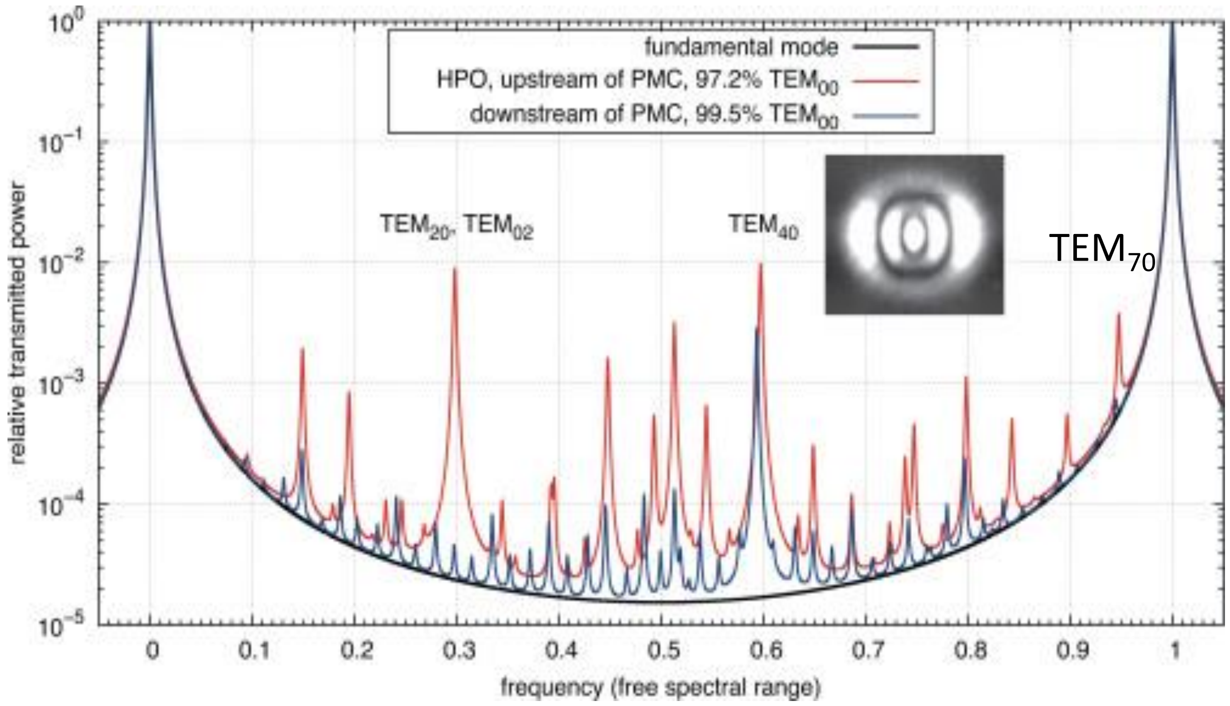

L1-ETMX surface deformation. Δt = 20s. t0 = 1233285394. Contour = 0.3nm
Y-coordinate (mm)
X-coordinate (mm)
Surface deformation (nm)
Xarm power (kW)
Δt (s)

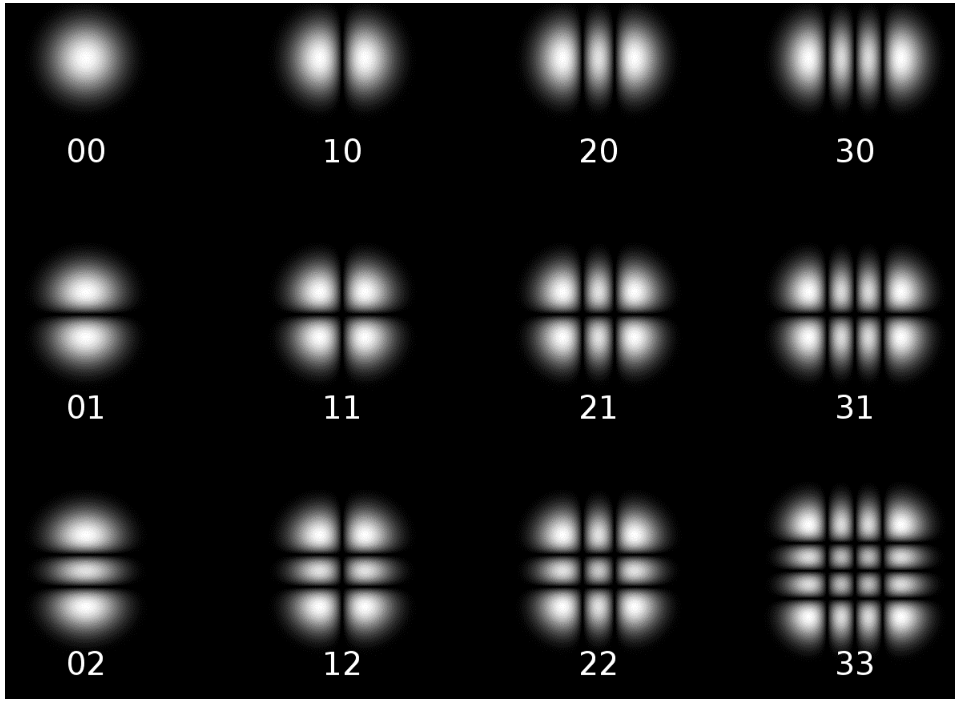
Higher order mode generation



G. Vajente, "In situ correction of mirror surface to reduce round-trip losses in Fabry–Perot cavities," Appl. Opt. 53, 1459-1465 (2014) [modified]

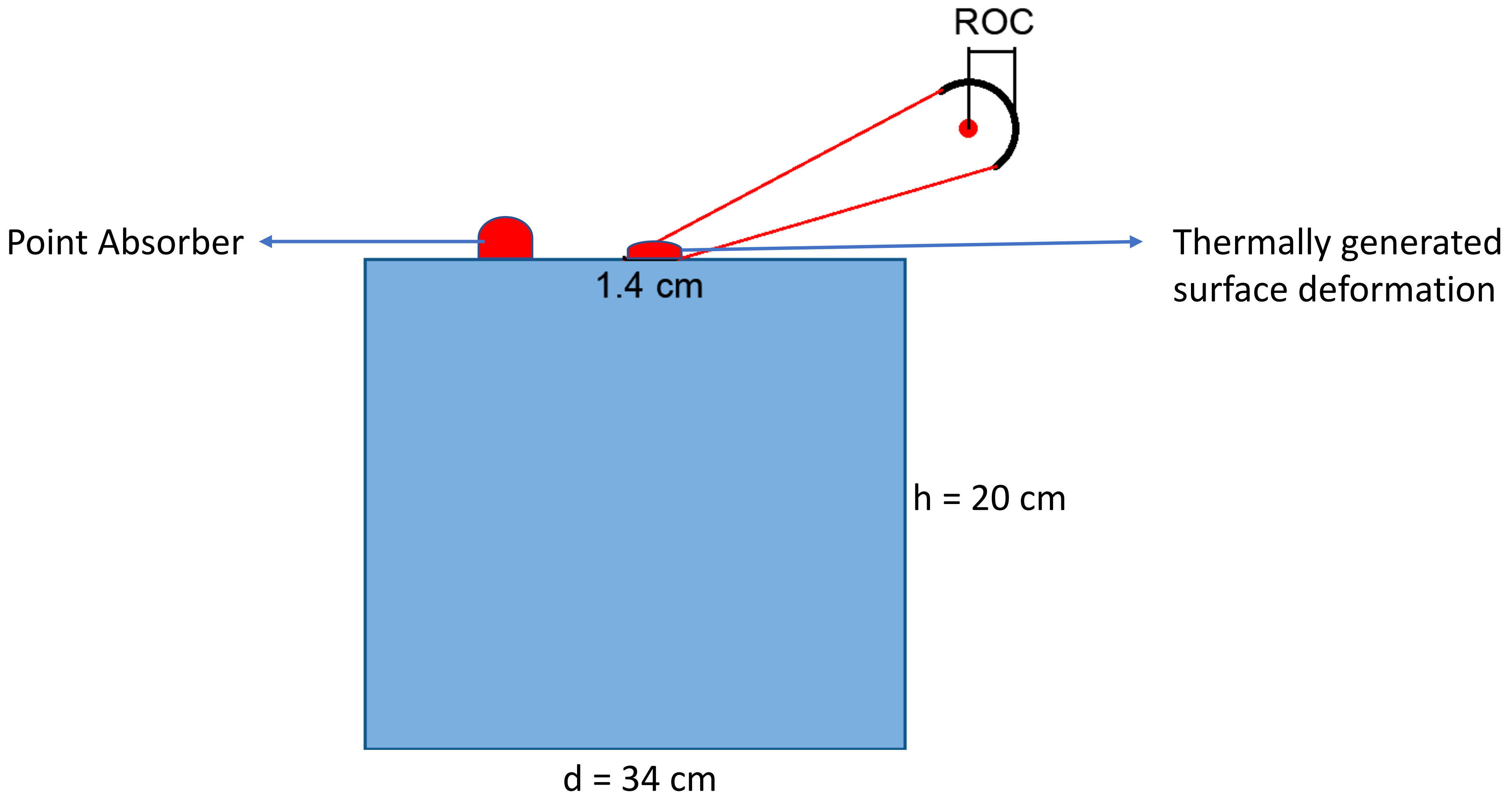
TEM Hermite Gauss propagation modes





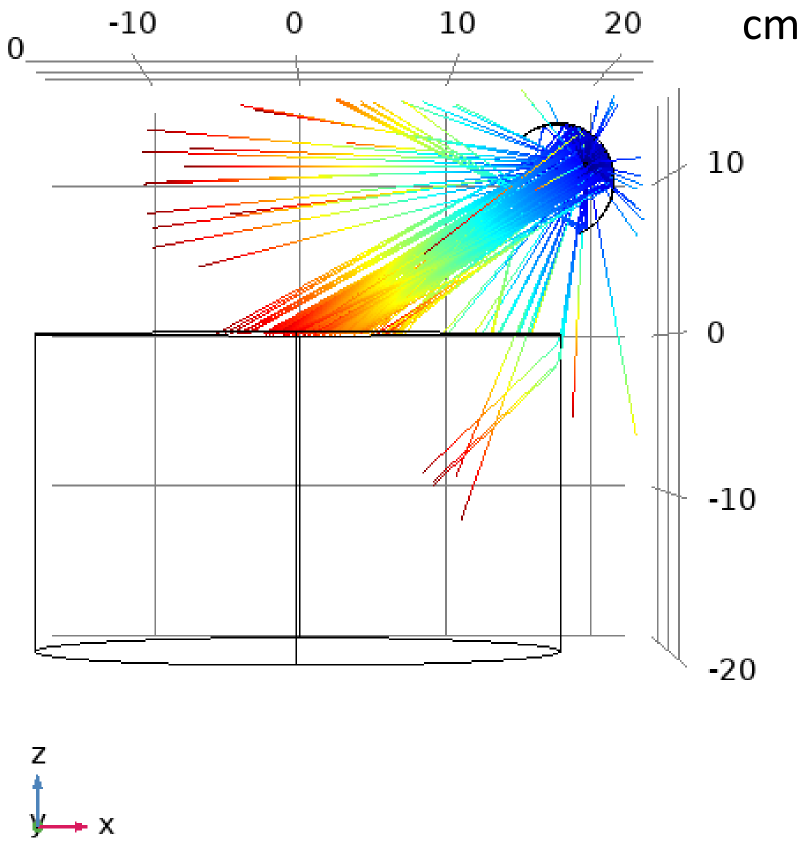
P. Kwee, C. Bogan, K. Danzmann, M. Frede, H. Kim, P. King, J. Pöld, O. Puncken, R. L. Savage, F. Seifert, P. Wessels, L. Winkelmann, and B. Willke, "Stabilized high-power laser system for the gravitational wave detector advanced LIGO," Opt. Express 20, 10617-10634 (2012)

Thermal compensation system design

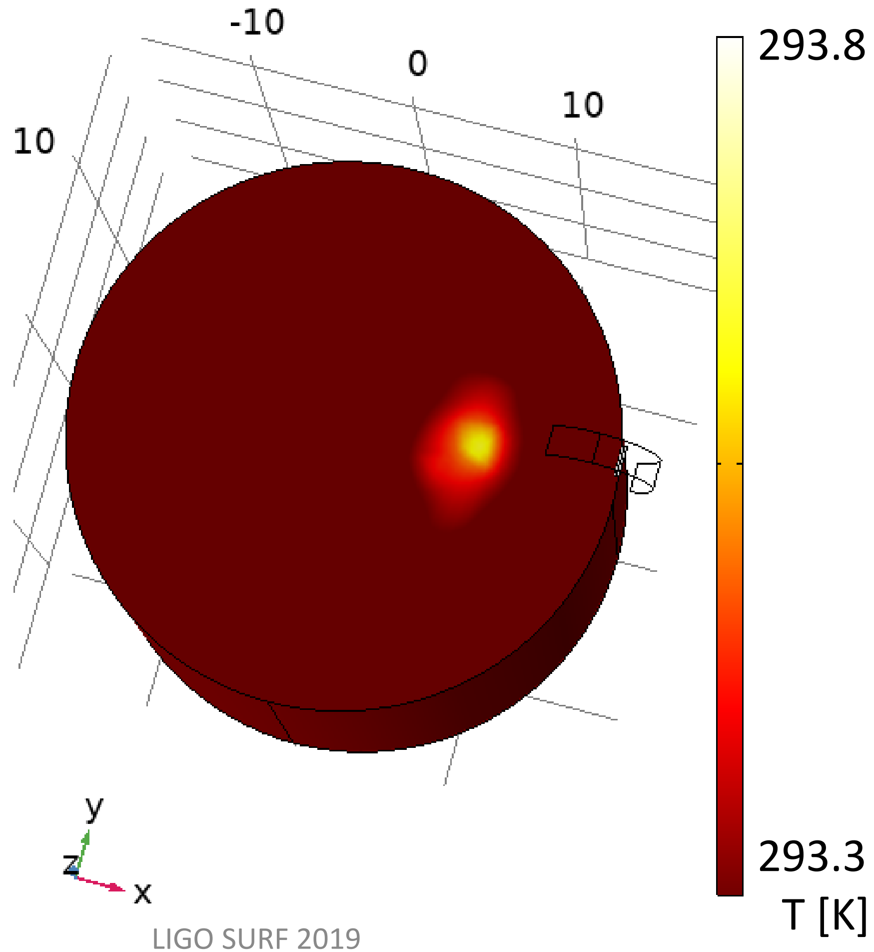


Finite-element analysis of design

Ray Trajectories



3D Temperature Profile



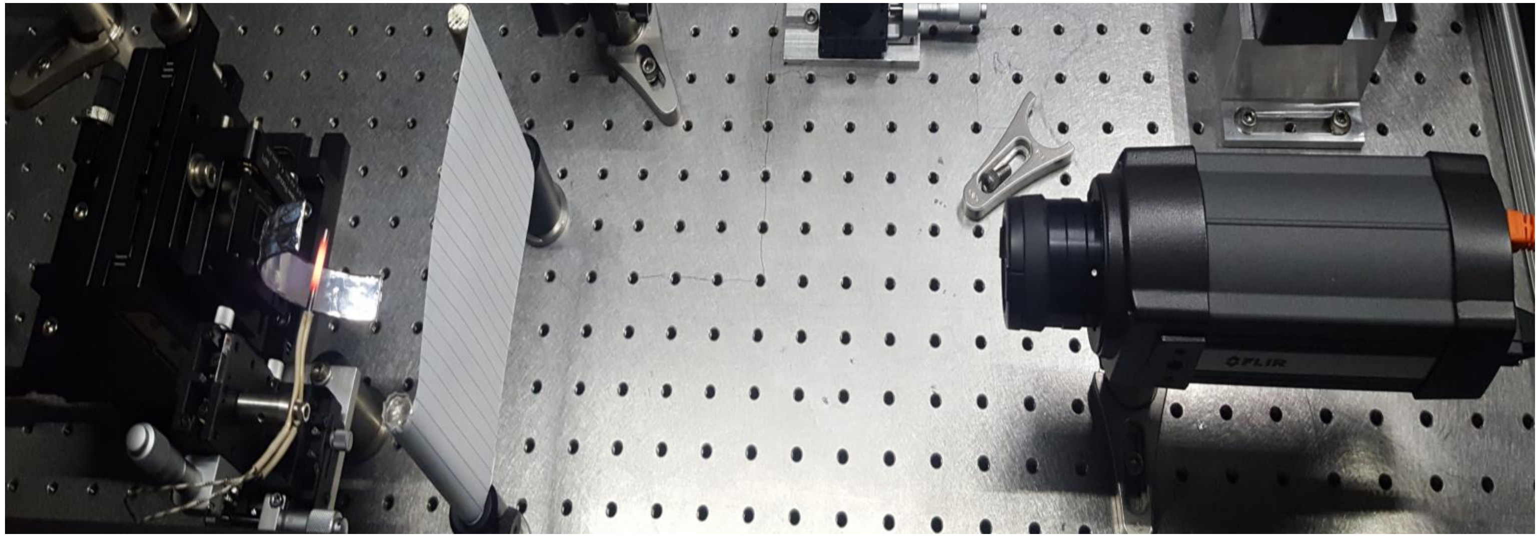
Optimized Parameters:

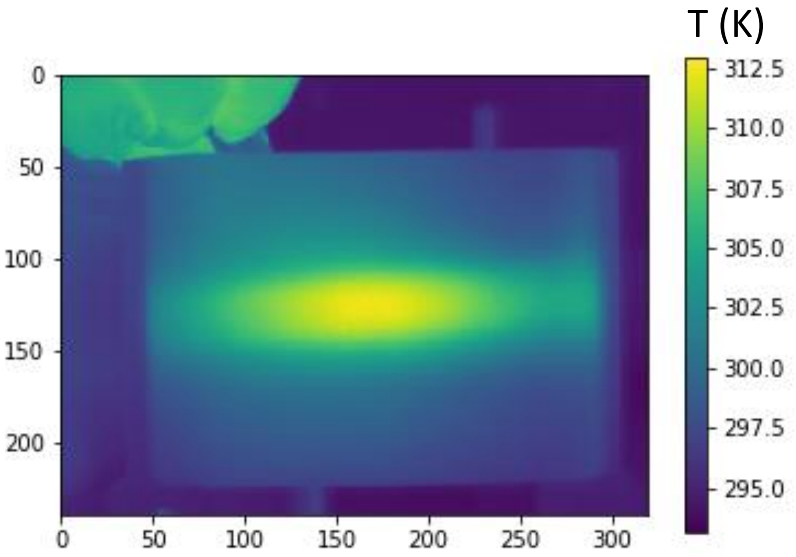
1. ROC
2. Reflector Geometry
3. Height (z)

Constraints:

1. Delivery distance
2. Heater position
3. x-position > $R_{test\ mass}$

Measuring the heat distribution

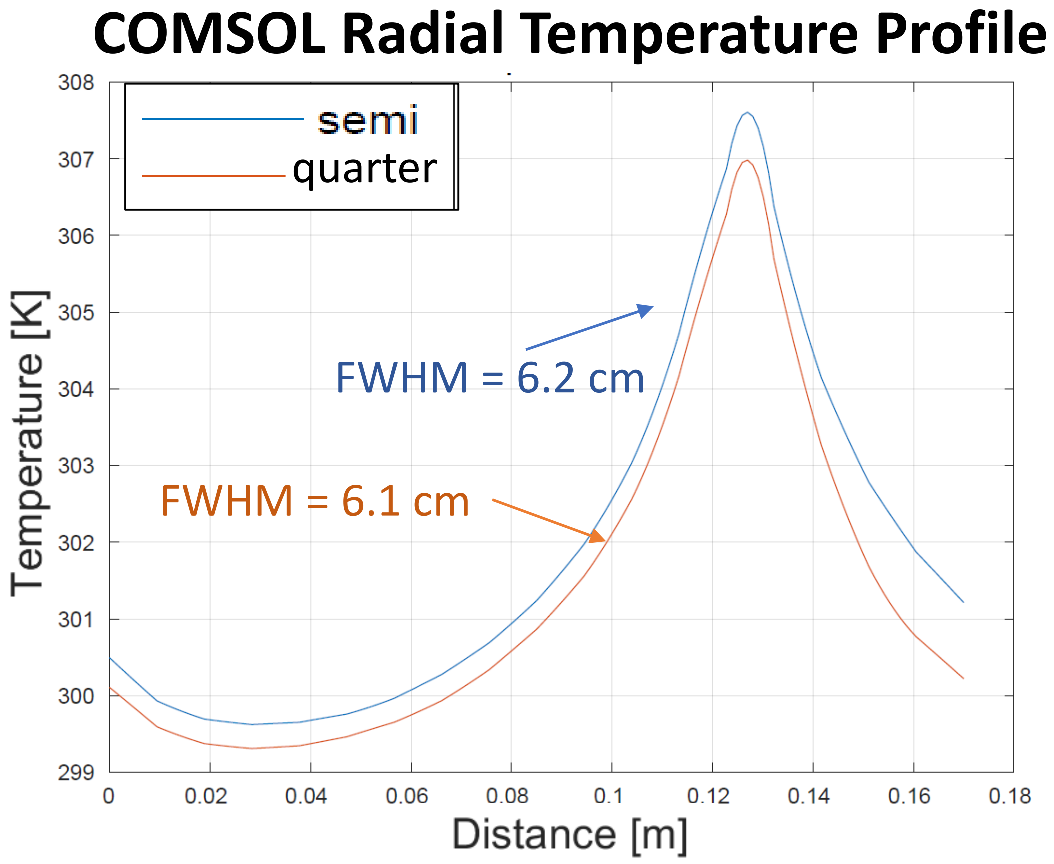


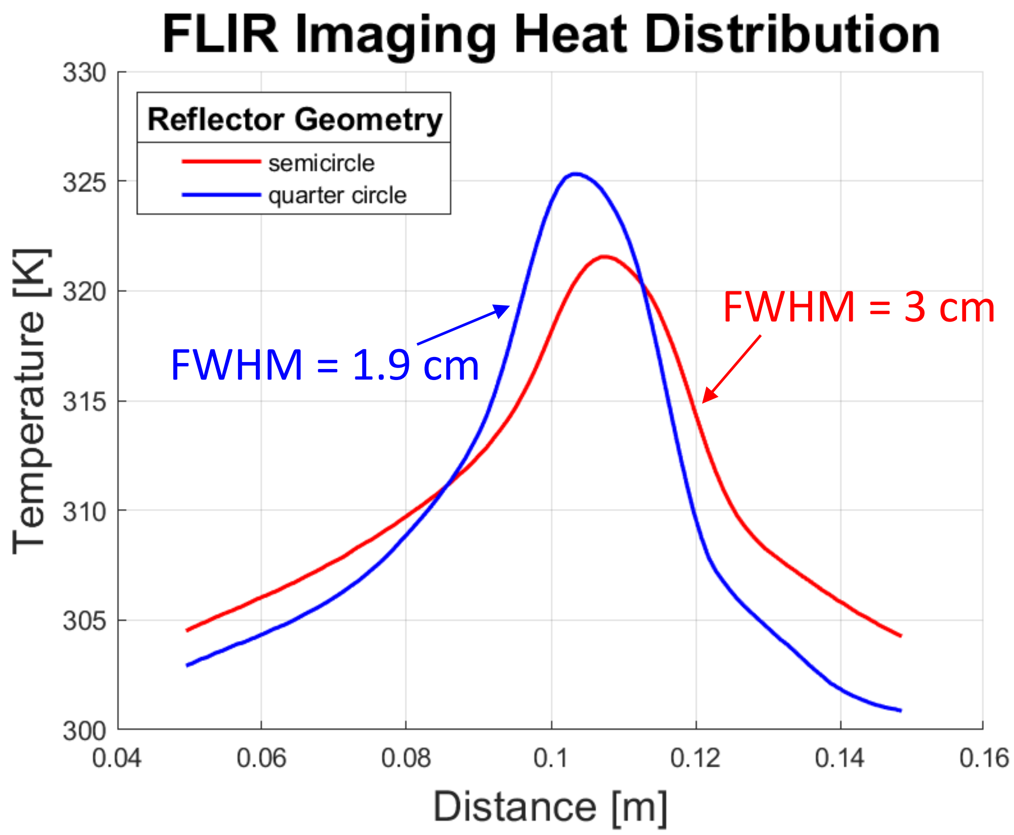


IR Image: Heat distribution pattern produced by TCS

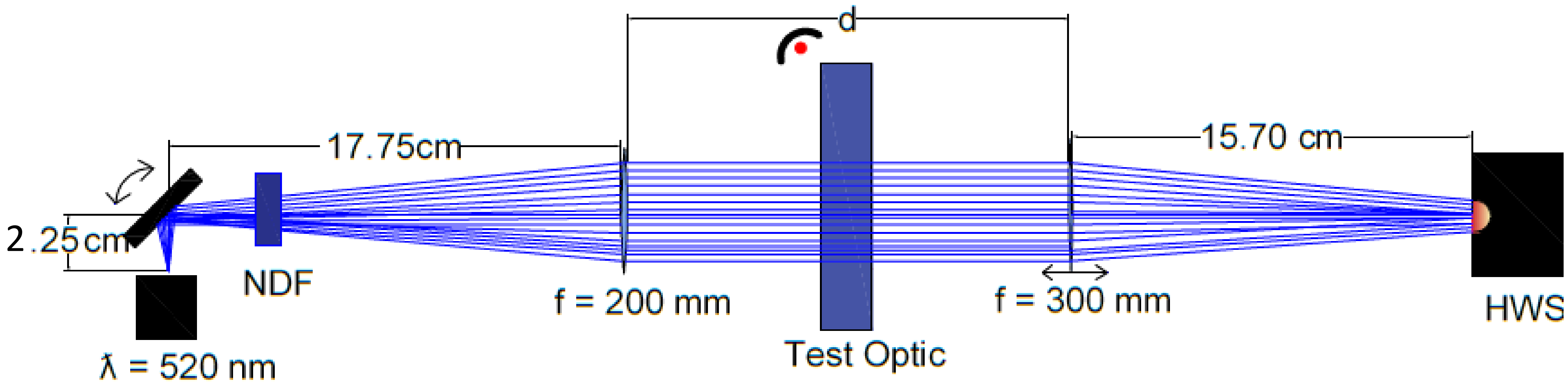
Reflector ROC (cm)	3.6	1.75
Delivery distance (cm)	10	5
Thermal Profile FWHM (cm)	2.85	1.9

Simulation vs Experiment Temperature Profile

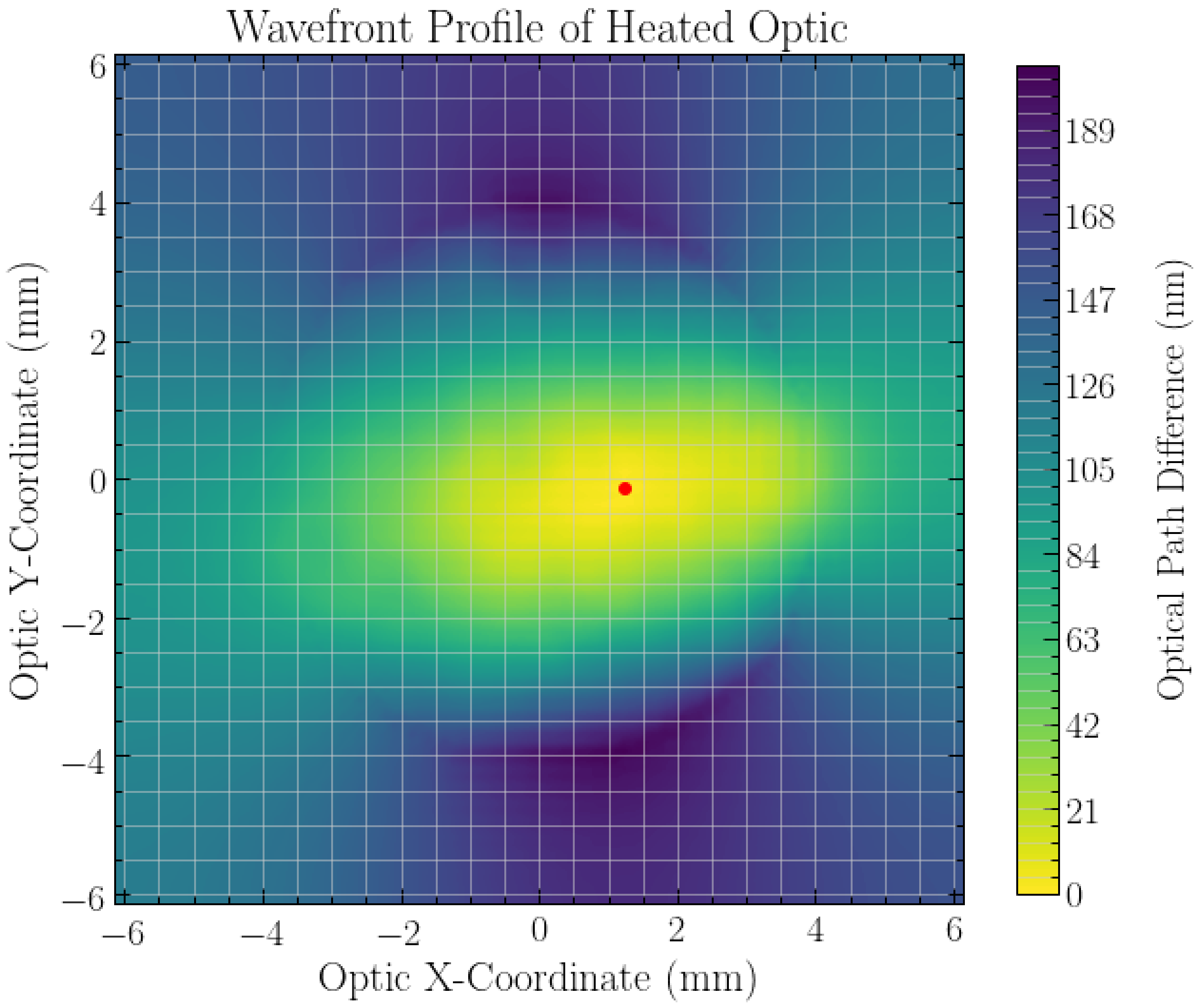




Experimental Setup



Hartmann Wavefront Sensor Measurement



Experimental Setup:

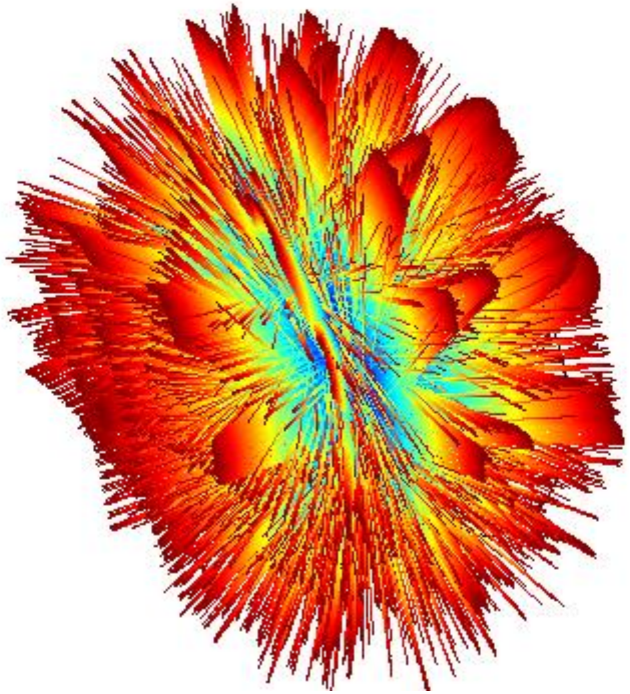
- ROC = 1.75 cm
- Radiated Power = 25 W
- Delivery distance = 6 cm

Conclusions and future work

- Obtained thermal profile can be used to actuate 7^{th} order modes
- Further parameter optimization is necessary for a better system
- LIGO noise requirements
- Vacuum compatibility considerations

Acknowledgements

I would like to thank my mentors: Jonathan Richardson, Aidan Brooks, and Rana Adhikari for their help and guidance through all parts of the project.



Thank you for your attention!

Questions?