LIGO

Modeling of Advanced LIGO with Melody

Amber Bullington
Stanford University

SWG-Optics Session

August 18, 2004

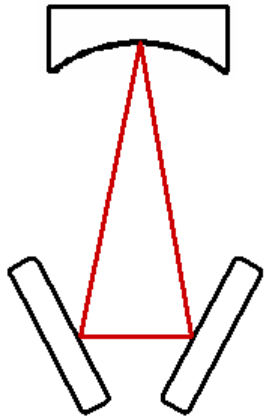
G040372-00-Z

Overview

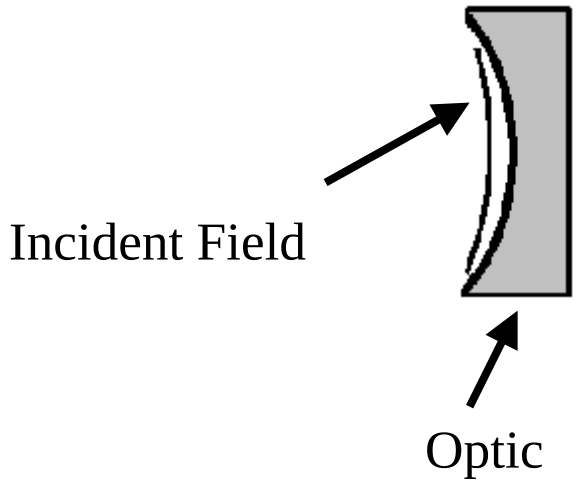
- Melody
  - » Simulate thermally loaded interferometer via modal expansion of the electric field
  - » Variables: Input power, Tilt, Material parameters
  - » Output: Mode profiles, Thermal distortions, Gain
- Advanced LIGO Mode Cleaner
  - » Updates to the model
  - » Simulations of the AdLIGO mode cleaner
- Inhomogeneous absorption
  - » Numerical model of absorption
  - » Study interferometer response to absorption centers

Mode Cleaner Model

- Proper mode cleaner representation
  - » Model a curved optic with an arbitrary incidence angle
  - » More general interferometer configurations

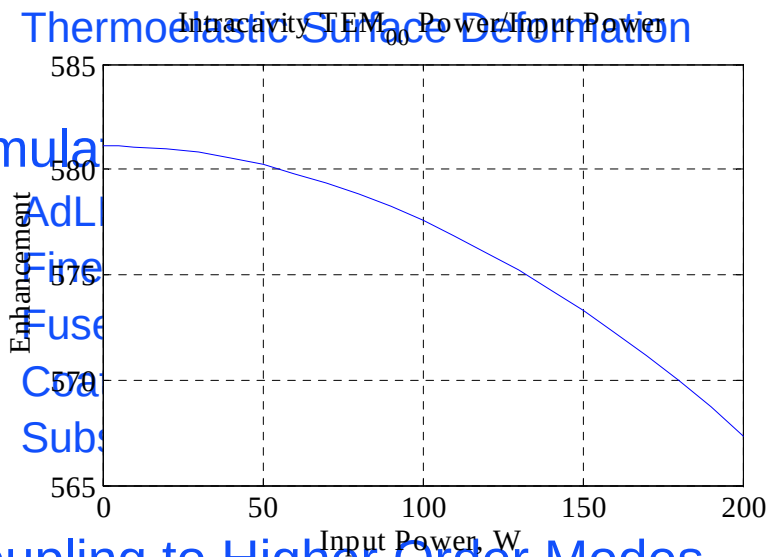


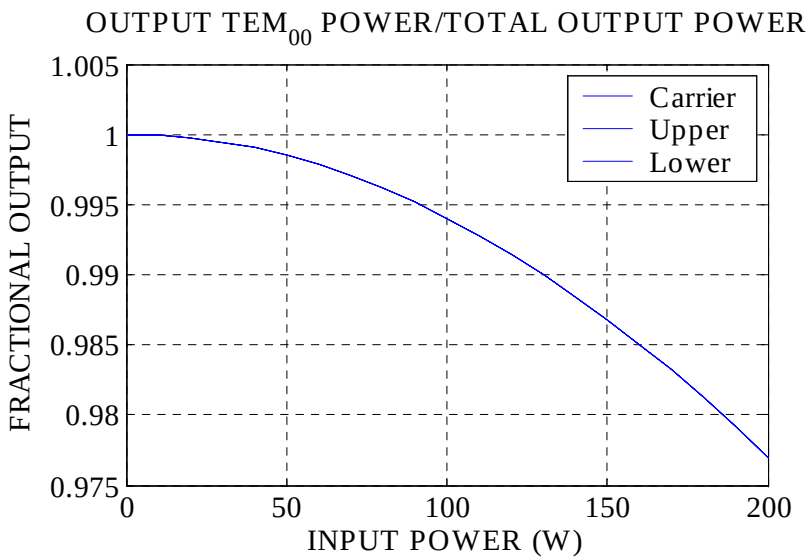
- Curvature mismatch
  - » Difference in curvature between incident field and optic
  - » Proper matching of field curvature with eigenmode curvature

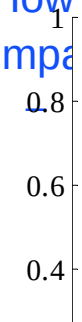


Thermal Loading I

- Thermal loading causes curvature mismatch
  - » Thermal Lensing
  - » Thermoelastic Surface Deformation
- Simula
  - » AdL
  - » Fine
  - » Fuse
  - » Coa
  - » Subs
- Coupling to Higher Order Modes
  - » How much?
  - » Impa

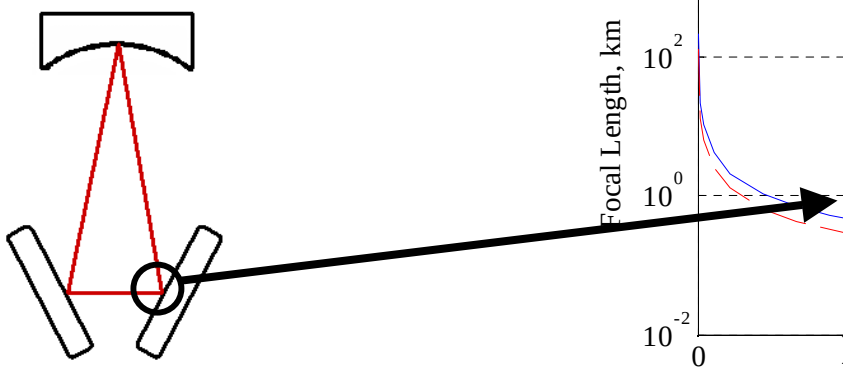


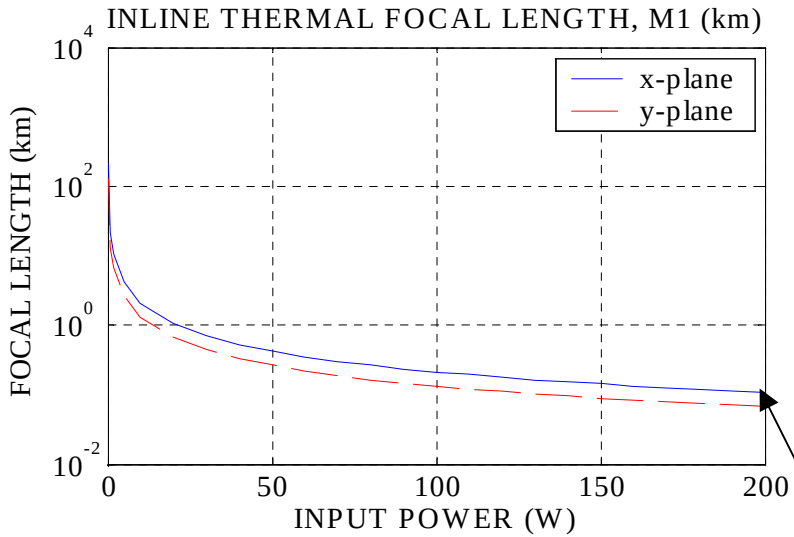




Thermal Loading II

- Astigmatic thermal lens
  - » Flat input/output optics
  - » Elliptical beam at non-normal incidence
- 200 W input power
  - » Flat Optic thermal lens
    - – X-plane = 108 m
    - – Y-plane = 67 m





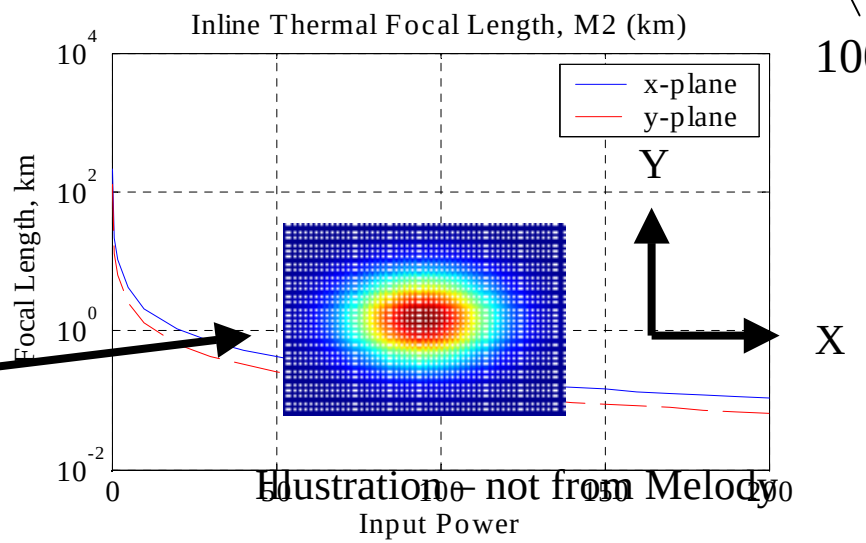
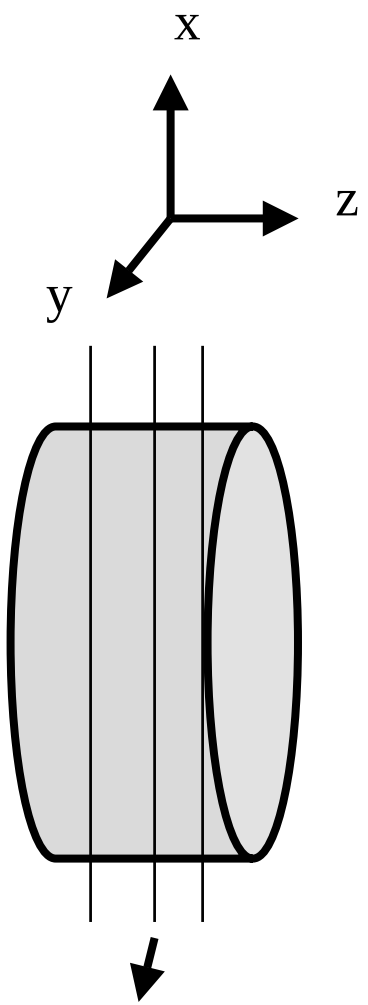


Illustration - not from Melody

Inhomogeneous Absorption

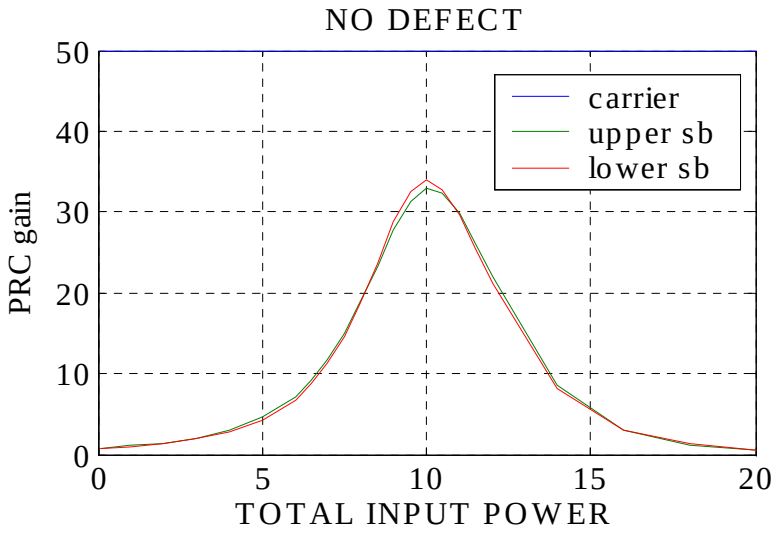
- Modified Femlab code by R. Lawrence ('Numerical Optic')
  - » Inhomogeneous absorption in coatings and substrate
  - » Thermal profiles for Melody
- Simulation features
  - » Specify a 3d array of absorption maps
  - » False map generators
    - – Single defect
    - – Various spatial frequencies with a striped or checkerboard pattern
- Preliminary Results
  - » ITM AR coating defect: spot with 2x absorption
  - » Impact on Power Recycling Gain
  - » Compare on center and off center cases
  - » Run with LIGO I parameters (bug in AdLIGO script)

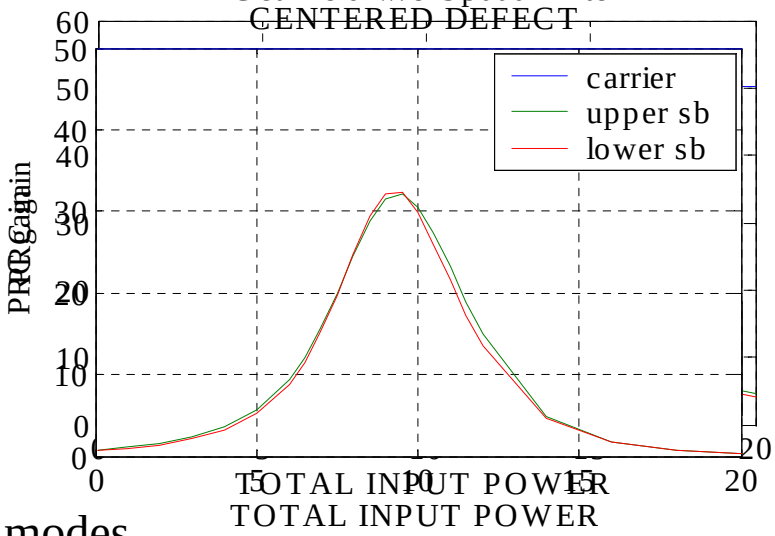


Slices through optic

Defect Simulation Parameters

- Compare response of sidebands in recycling cavity
  - » ‘Pseudolock’ for the carrier, note sideband behavior
  - » Variation in PRC gain, optimum operating point
- Parameters
  - » Defect size = waist/3
  - » Defect centered on optic or located at (x, y) = (waist/3, waist/3)
  - » Homogeneous coating absorption = 0.5 ppm
- Spatial Filter
  - » PRC gain variation for TEM_{00} mode only vs. all modes included in calculation





Fused Silica Case, 28 modes

Single Defect, Fused Silica

136 modes	SB gain decrease w/ spatial filter	SB gain decrease w/o spatial filter
Upper SB, Center defect	8.3%	6.3%
Lower SB, Center defect	9.1%	6.3%
Upper SB, Off-Center defect	17%	12%
Lower SB, Off-Center defect	7.1%	1.6% increase ?

- Center defect: 1 W decrease in optimum operating point
- Off-center defect: slight increase in optimum operating point for lower sideband

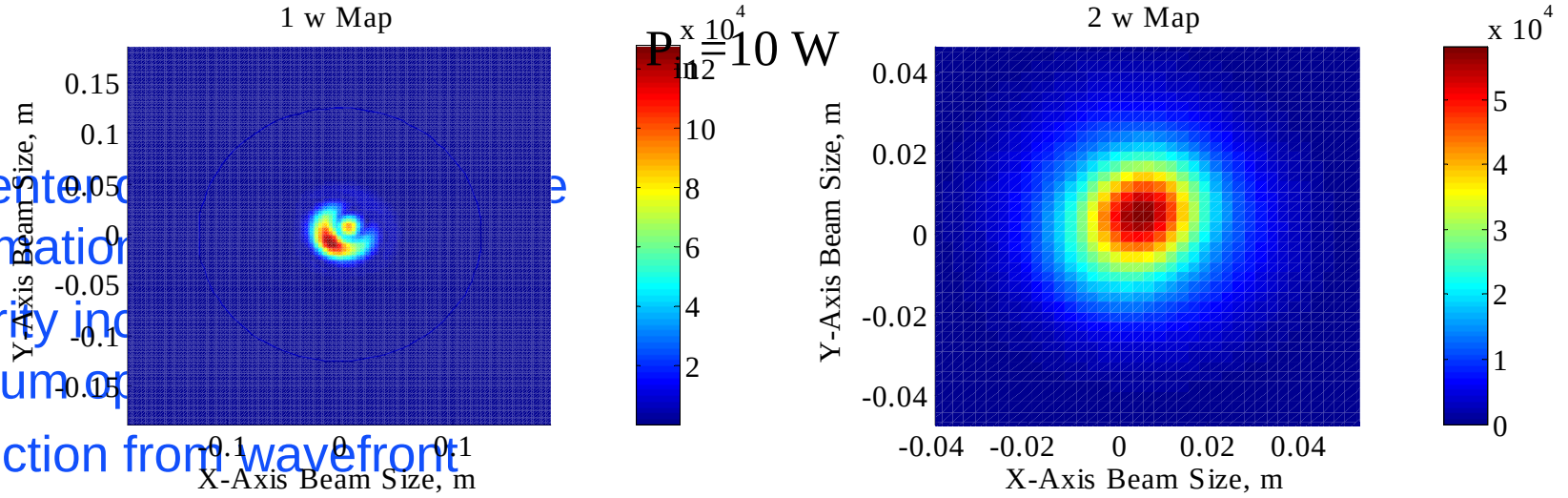
Single Defect, Sapphire

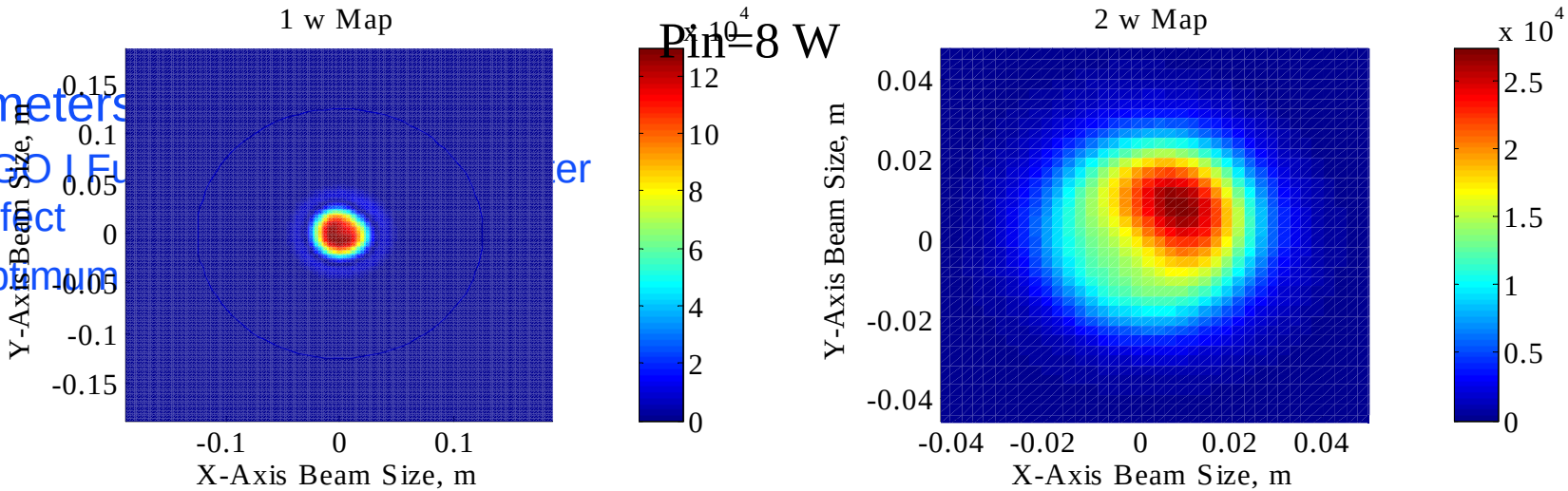
136 modes	SB gain decrease w/ spatial filter	SB gain decrease w/o spatial filter
Upper SB, Center defect	3.7%	2.1%
Lower SB, Center defect	2.9%	3.4% worse?
Upper SB, Off-Center defect	1.25%	.48%
Lower SB, Off-Center defect	1.6%	1.3%

- No significant shift in optimum operating point
- Overall, smaller changes than for fused silica

Mode Deformation, Off-Center Defect

- Off-center d… e deformation
- Severity inc… optimum op…
- Correction from wavefront sensing
- Parameters
  - » LIGO I Fu… …er defect
  - » Optimum





LIGO

Conclusion

- Thermally loaded mode cleaner has astigmatic thermal lens
- Fused Silica TMs more susceptible to inhomogeneous absorption
- Centered defect has larger impact on optimum operating point
- Continued development of absorption model, implementation with signal recycling