Beam Reshaping to Reduce Thermoelastic Noise

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Presentation to joint SWG, AIC, L80
@ LSC Meeting 8/16/00

~~[illegible]~~ [Research by Erica d'Ambrosio,
Richard O'Shaugnessy,
& Kip]

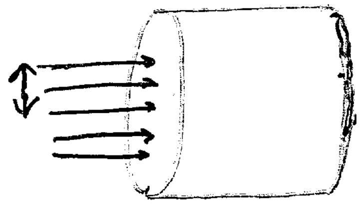
See also: Kip's presentation at March 2000
LSC Meeting

THERMOELASTIC NOISE

Erika d'Ambrosio
Richard O'Shaughnessy
Kip

Levin Thought Experiment

Oscillating Pressure r_o



$$P = \underbrace{P_o(r)}\cos(2\pi f t)$$

↑ $\propto$ Light beam energy flux

$$S_h^{\text{thermoelastic}}(f) \propto W_{diss} = \left\langle T \frac{dS}{dt} \right\rangle = \left\langle \int \frac{K_{th}}{T} (\nabla \delta T)^2 dvol \right\rangle$$

$$\propto \int (\nabla \cdot \Theta)^2 dvol$$

↑ Expansion due to static pressure $P_o(r)$

$$\propto \frac{1}{(r_o, \text{ beam radius})^3}$$ & depends on beam shape

↑ $\frac{1}{e}$ radius of energy flux on mirrors

LIGO-II Strategy

- Make r_o as large as possible (constrained by diffraction losses,...)

  $r_o = 3.8$ cm
  $W_o = 5.4$ cm
  (make larger?)

- Diffraction limited beam would have radius r_o = $b = \sqrt{\lambda L / 2\pi} = 2.6$ cm
- $r_o/b = 1.5$ ⇒ there is significant room to reshape
- Reshape beam holding diffraction losses fixed
  - We think $S_h^{\text{thermoelastic}}$ can be reduced by factor ~ 2

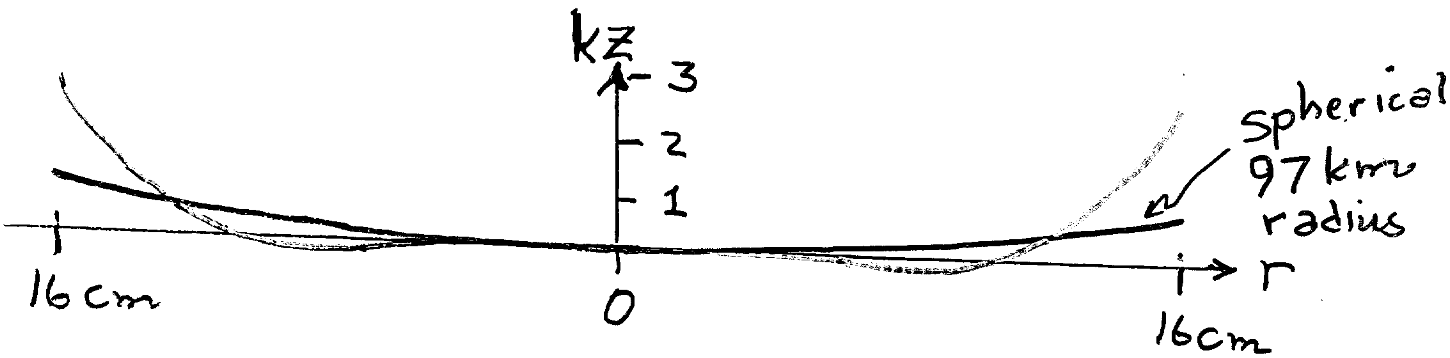
  ... possibly more

Two Ways to Reshape Beam:

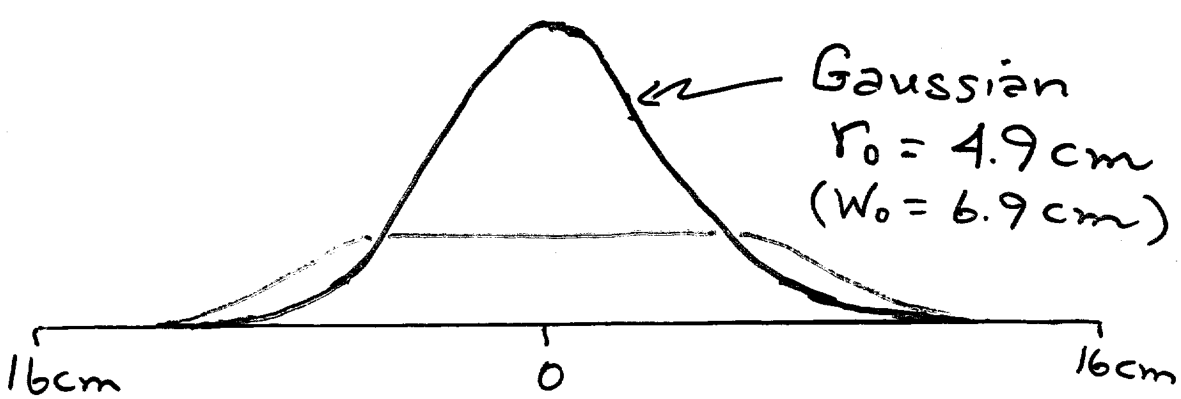
(1) Keep mirrors spherical
Excite several modes, incoherently (different λ)
... technically unpleasant?...

(2) Change mirror shapes
Example: mirror radius: 16 cm
naive diffraction losses: 21 ppm /bounce
identical mirrors

- Mirror Shapes



- Power Flux on Mirrors
(Fundamental Transverse Mode)



- O'Shangnessy: Flat topped $S_h \simeq \frac{1}{2} \times$ Gaussian S_h