

Parametric Instability pre-O4 at LIGO

How TCS saves the day

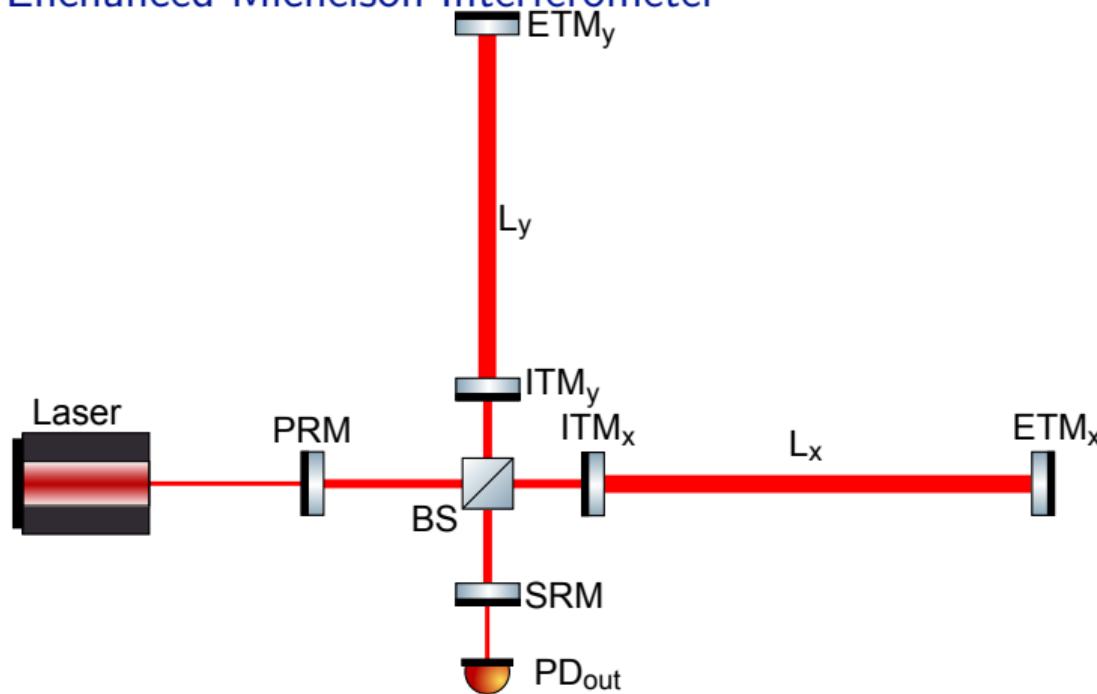
22 May 2023

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LIGO Livingston

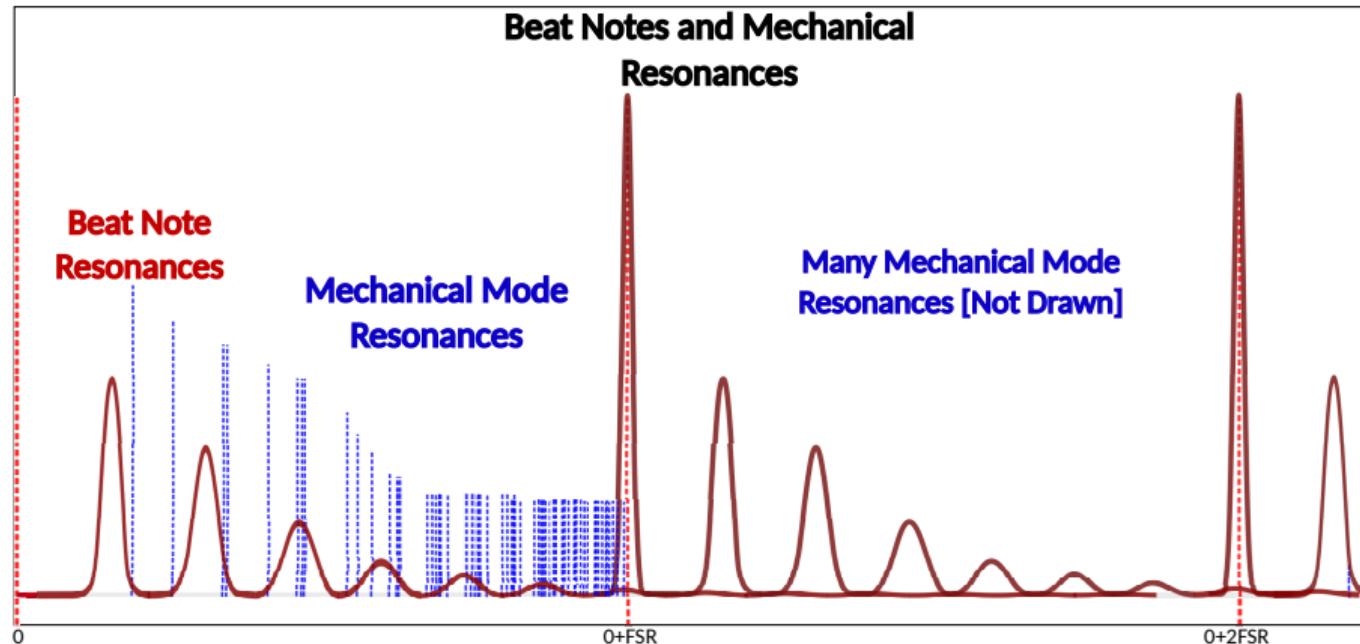
Overview

- Graphical overview of PI in LIGO cavities
- How PI changes with all Future Detector Proposals

Fabry-Perot Enhanced Michelson Interferometer



Optical Beat notes and Mechanical Modes



Parametric Instability

Parametric Instability Criterion, Danilishin *et al.*[1]:

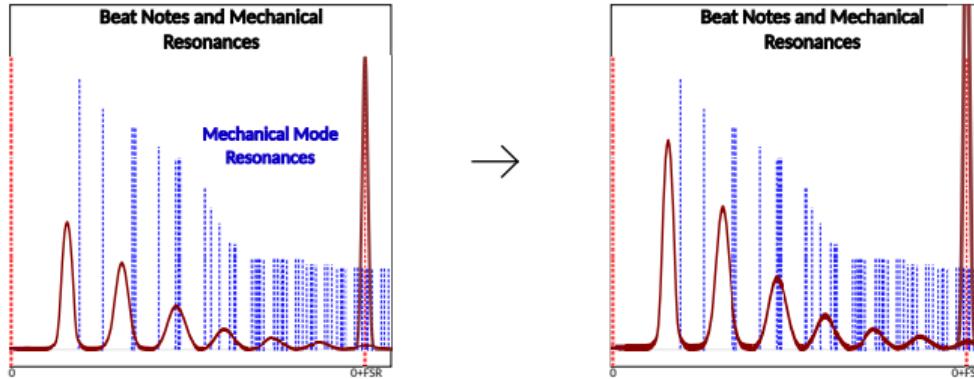
$$\frac{8 \Lambda_{01} \omega_1 P_{in}}{m \omega_m L^2 \gamma_m \gamma_0 \gamma_1} \left(\frac{\gamma_1^2}{\gamma_1^2 + 4\Delta_m^2} \right) \geq 1 \quad (1)$$

PI in action at LHO

Play with External Player

Alt. Link: [LHO aLog](#)

More Power

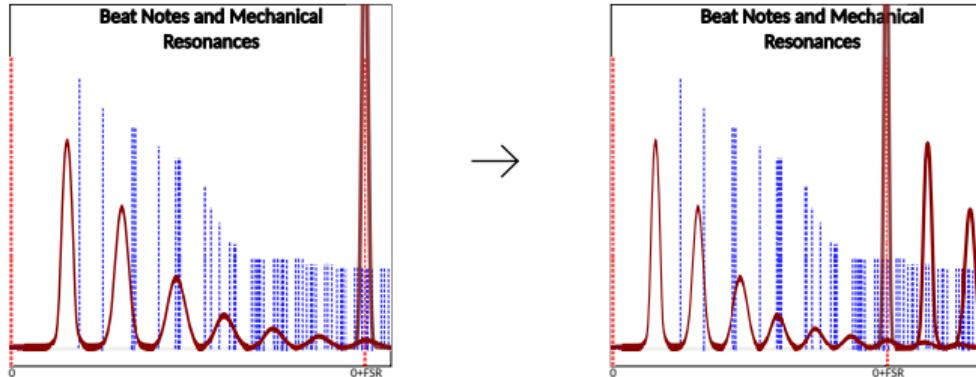


Effect on PI Gain

$$\frac{8 \Lambda_{01} \omega_1 P_{in}}{m \omega_m L^2 \gamma_m \gamma_0 \gamma_1} \left(\frac{\gamma_1^2}{\gamma_1^2 + 4\Delta_m^2} \right) \geq 1$$

Optical Mode Spacing Mechanical Mode Spacing

Longer Cavity Arms

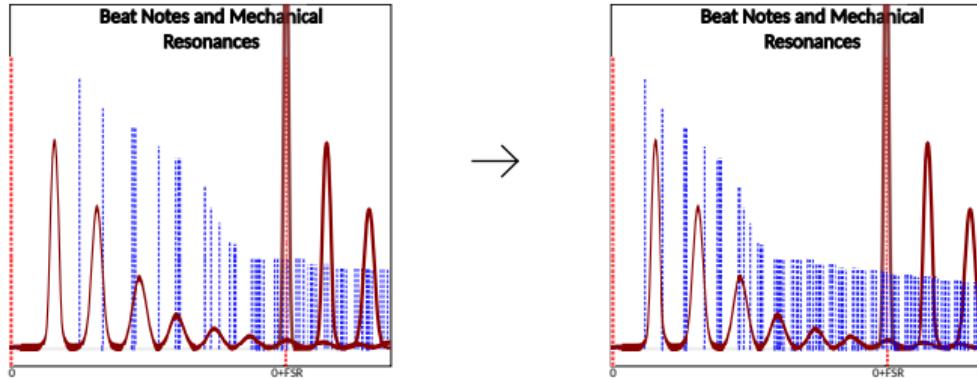


Effect on PI Gain

$$\frac{8 \Lambda_{01} \omega_1 P_{in}}{m \omega_m L^2 \gamma_m \gamma_0 \gamma_1} \left(\frac{\gamma_1^2}{\gamma_1^2 + 4\Delta_m^2} \right) \geq 1$$

Optical Mode Spacing Mechanical Mode Spacing

Bigger Test Masses



Effect on PI Gain

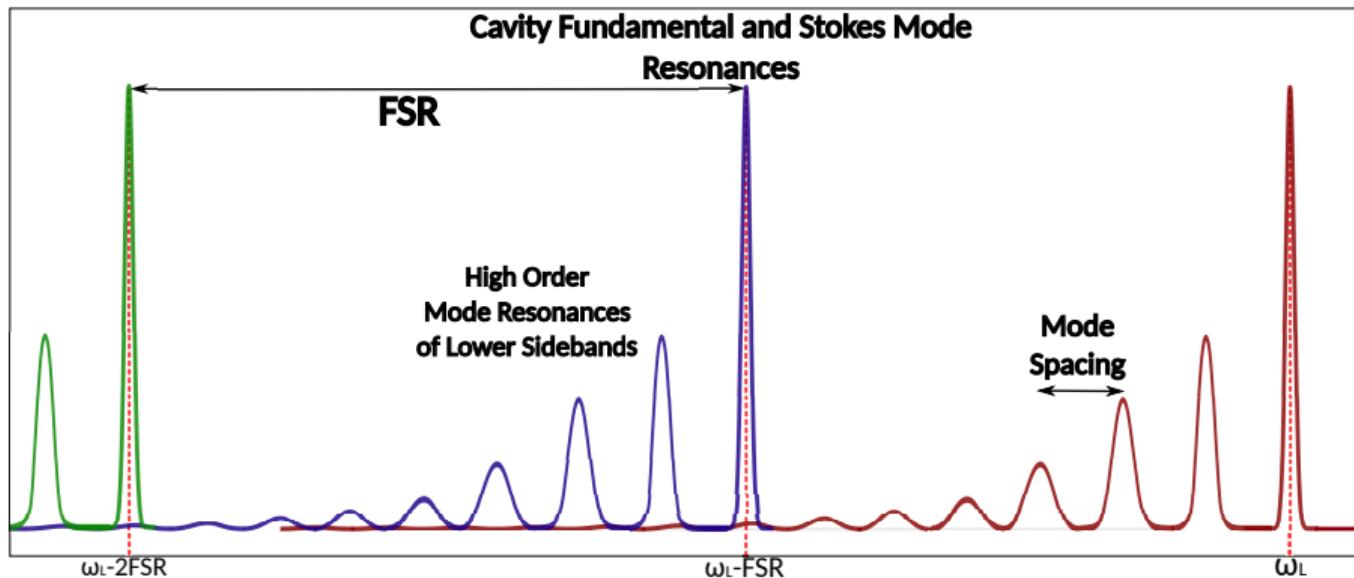
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Optical Mode Spacing Mechanical Mode Spacing

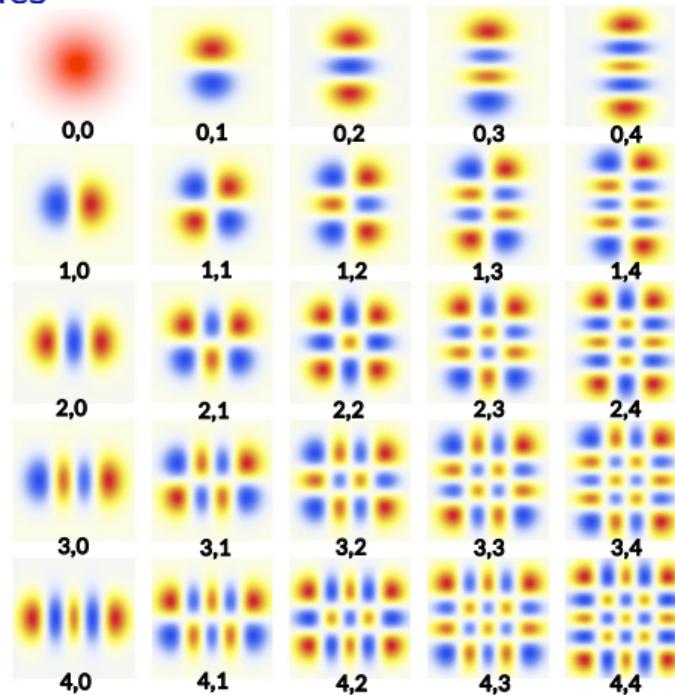
References I

- [1] Stefan L. Danilishin et al. "Time evolution of parametric instability in large-scale gravitational-wave interferometers". In: *Physical Review D* 90.11 (2014), p. 122008.

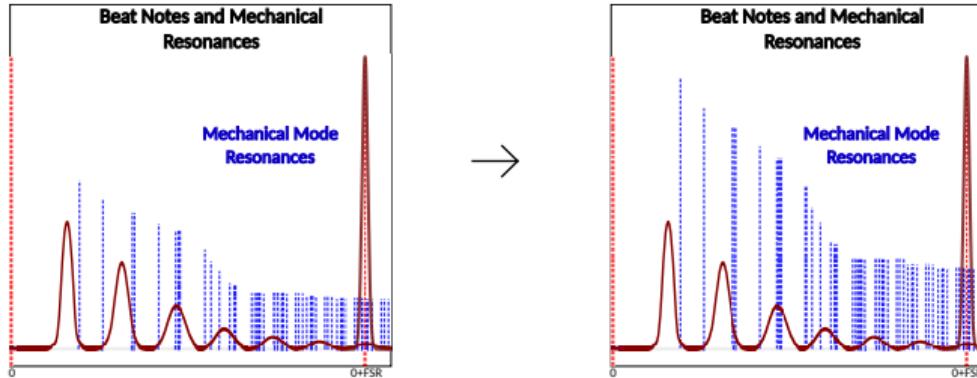
Optical Mode Structure of Fabry-Perot Cavity



Shapes of Optical Modes



Higher test mass Q-factors

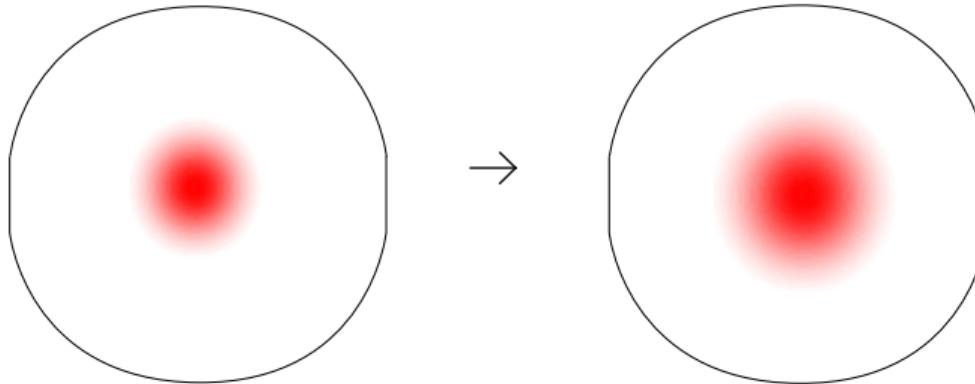


Effect on PI Gain

$$\frac{8 \Lambda_{01} \omega_1 P_{in}}{m \omega_m L^2 \gamma_m \gamma_0 \gamma_1} \left(\frac{\gamma_1^2}{\gamma_1^2 + 4\Delta_m^2} \right) \geq 1$$

Optical Mode Spacing Mechanical Mode Spacing

Larger Beam Sizes



Effect on PI Gain

$$\frac{8 \Lambda_{01} \omega_1 P_{in}}{m \omega_m L^2 \gamma_m \gamma_0 \gamma_1} \left(\frac{\gamma_1^2}{\gamma_1^2 + 4\Delta_m^2} \right) \geq 1$$

Optical Mode Spacing Mechanical Mode Spacing