Test Mass Butterfly Modes and Alignment

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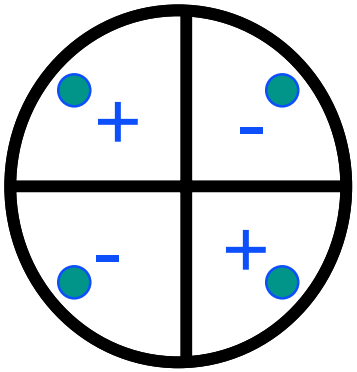
G020342-00-Z

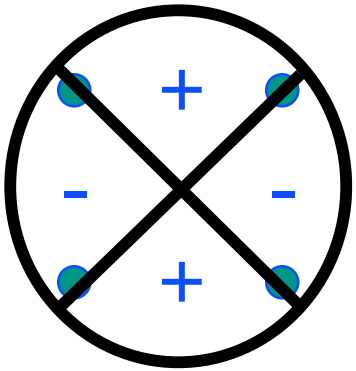
Introduction

- How can a vibrational mode of a test mass be used for alignment?
- What is the structure of a butterfly mode?
- How does the detected signal from the mode vary with changing the alignment of a resonant cavity?

The Butterfly Mode

- Two orientations of this mode exist
  - » Plus mode
  - » Cross mode
- The center of symmetry may be useful for centering a beam on a test mass

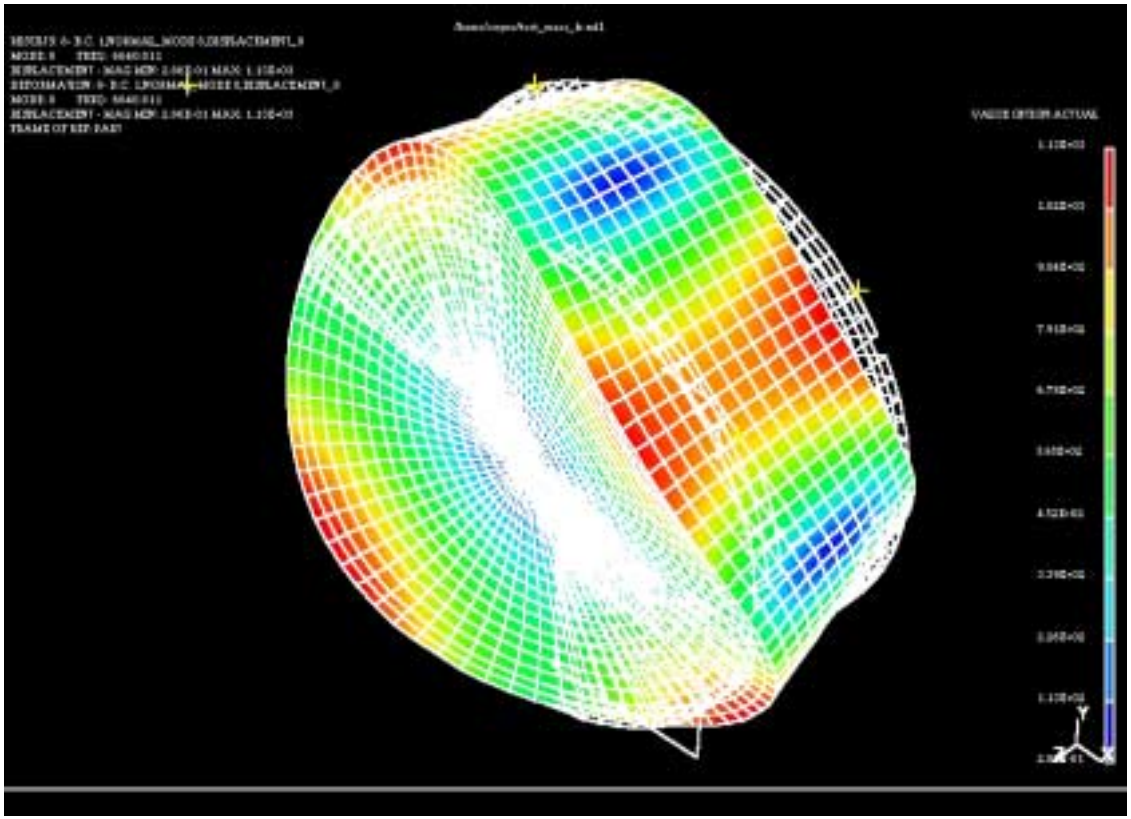




- Magnet

Simulation of Butterfly Modes

- Simulation by Dennis Coyne
- Calculated Frequency of vibration = 6640.811Hz
- Good Agreement with Measured Values
- No mode splitting predicted



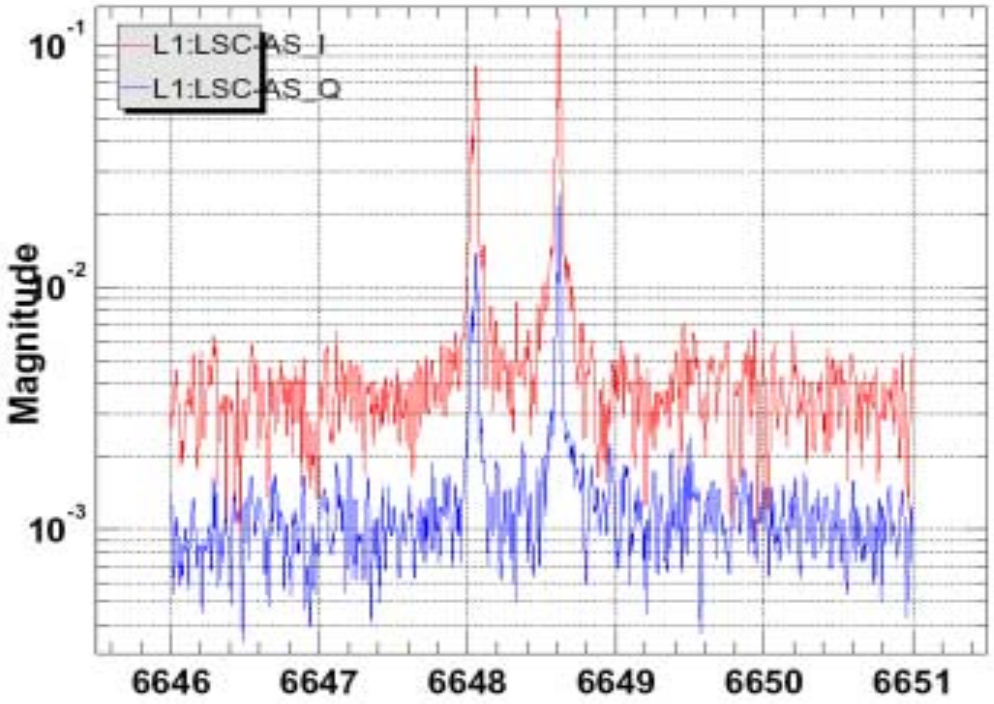
http://www.ligo.caltech.edu/~coyne/TM_modes/

Measuring Butterfly Mode Frequencies

- Drive the test mass with uniform noise
  - » Arbitrary Waveform Generator
  - » 6000Hz-7000Hz
  - » Amplitude ≈ 400 counts
- Lock an arm for the ETMs
  - » Observe butterfly signal in AS_I
  - » Turn on whitening filters AS1I, AS1Q on LSC panel
  - » Note filters FM5 and FM6 under SUS LSC
- Lock the Power Recycled Michelson for the ITMs
  - » Observe butterfly signal in REFL_I
  - » Turn on whitening filters AS1I,AS1Q,RFI

Frequencies of Vibration, ETMx

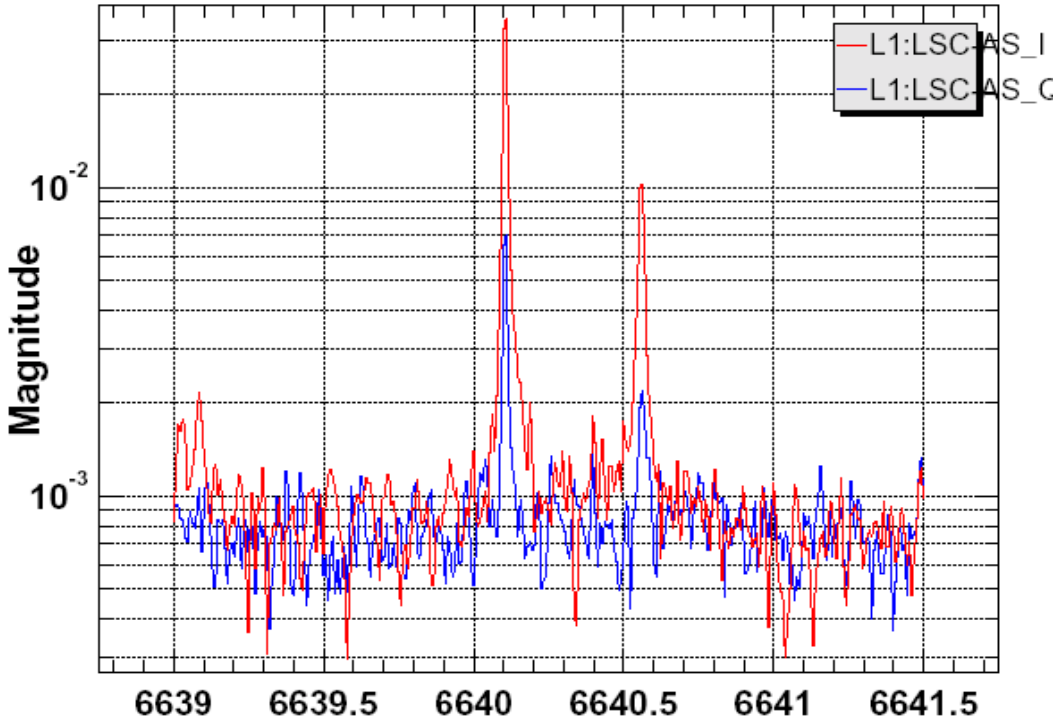
Amplitude Spectrum of Modes for ETMx



- Lower Mode (plus) = 6648.01Hz
- Upper Mode (cross) = 6648.56Hz

Frequencies of Vibration, ETMy

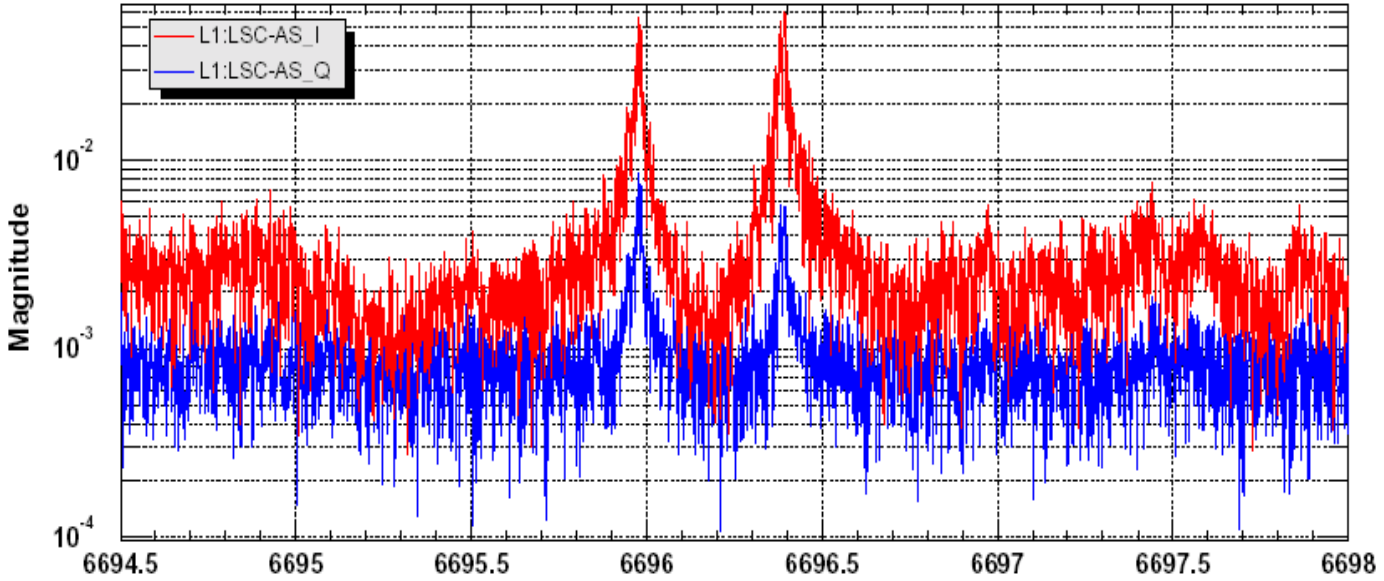
Amplitude Spectrum of Modes for ETMy



- Lower Mode (plus) = 6640.217Hz
- Upper Mode (cross) = 6640.665Hz

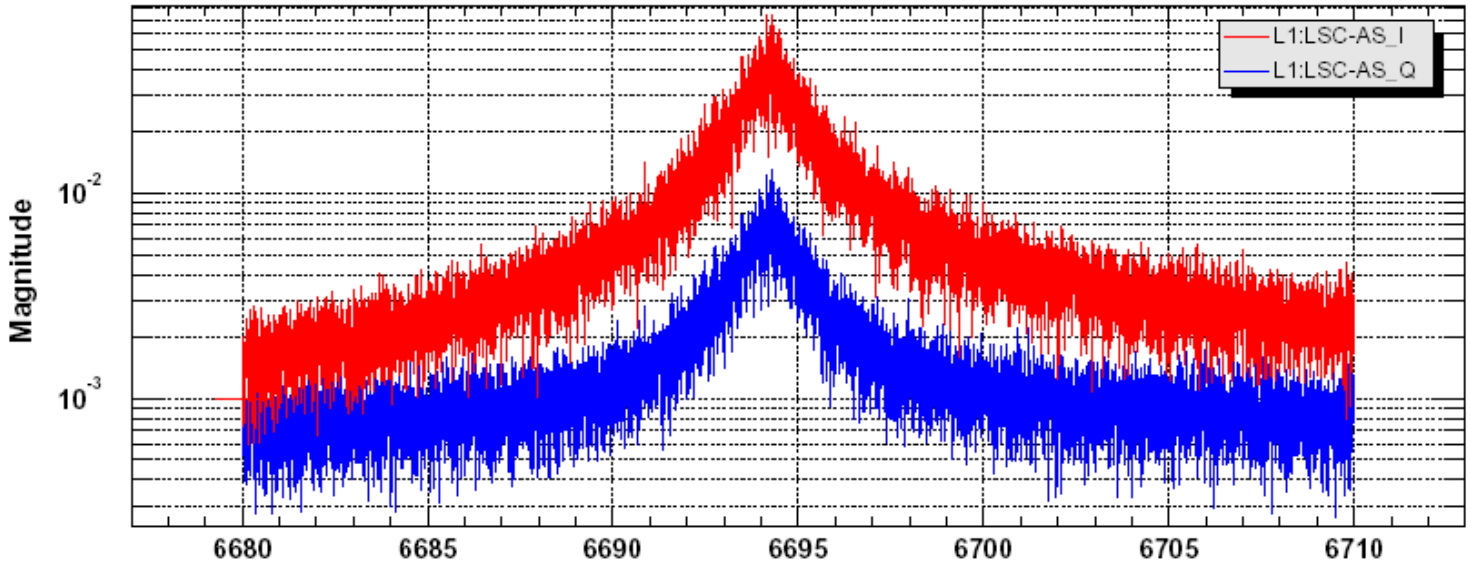
Frequencies of Vibration, ITMx

Amplitude Spectrum of Modes for ITMx



- Lower Mode = 6695.978Hz
- Upper Mode = 6696.391Hz

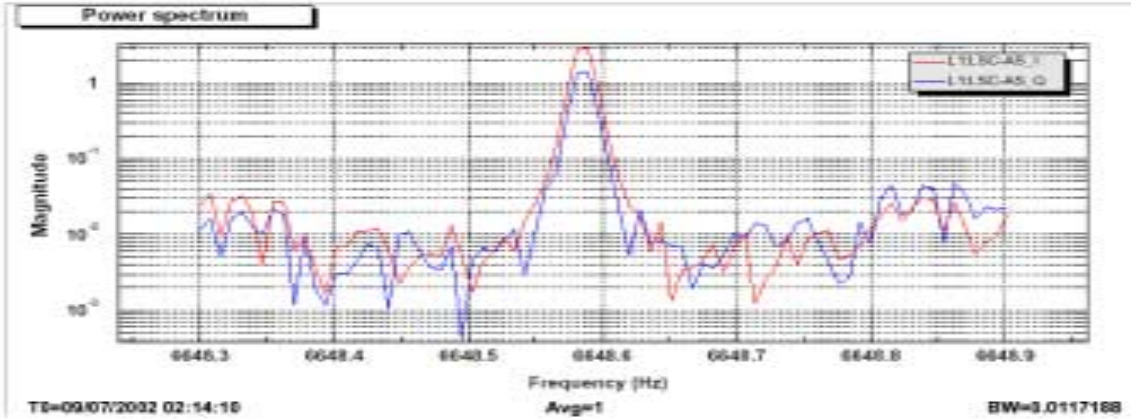
Frequencies of Vibration, ITMy



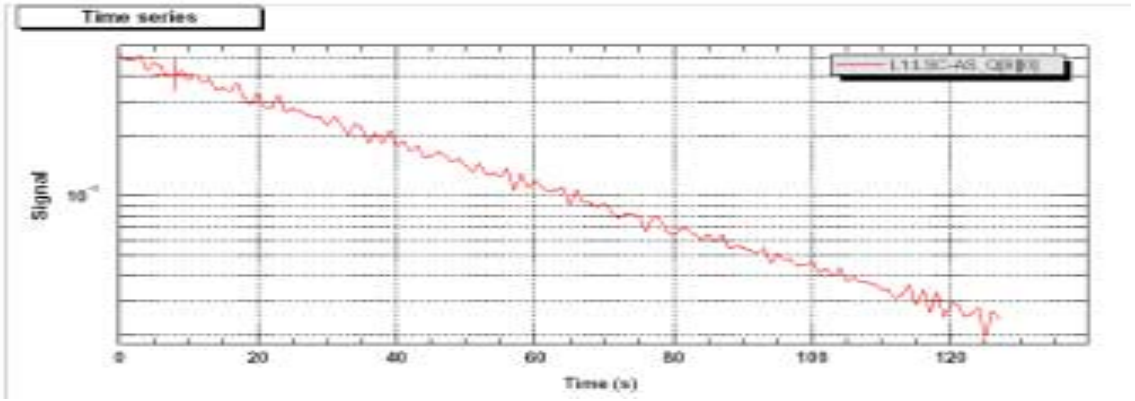
- Only one mode seen at 6694.2Hz
- Degenerate Modes?
- Sign of Suspension Problems or Damaged Magnet?
- Misidentified Mode?
  - » ITMx and ITMy frequencies only 2Hz apart!

Q Measurements

- Excite mode with sinusoidal drive
- Stop the excitation and observe the ring down
- More Q plots on 7/8/02 LLO detector group log entries



Decay of 6648.56Hz mode of ETMx



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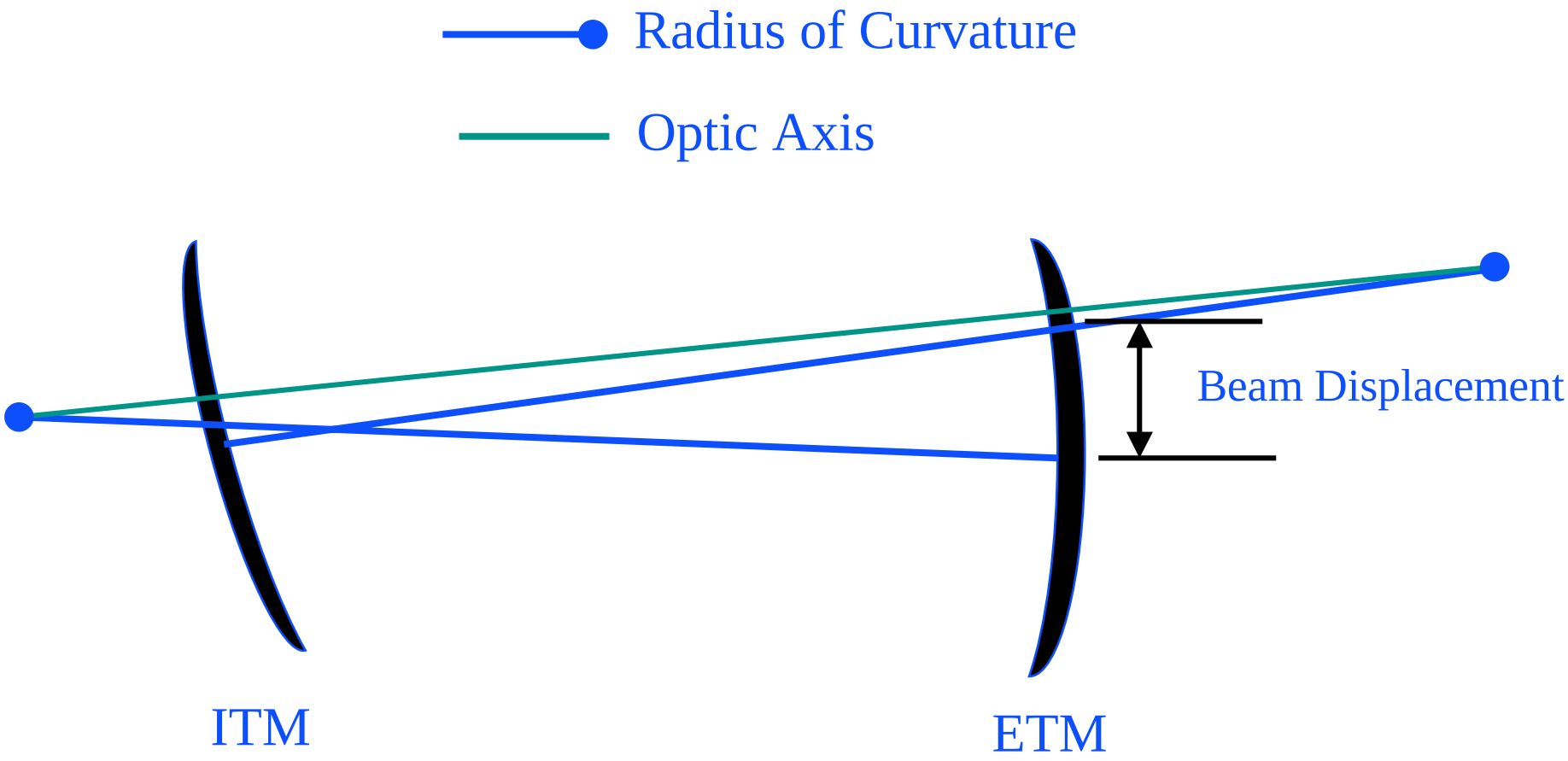
Summary of Frequencies

	Plus Mode	Plus Mode Q	Cross Mode	Cross Mode Q
ETMx	6648.01Hz	2.1×10^6	6648.58Hz	8.3×10^5
ETMy	6640.217Hz	2.3×10^6	6640.665Hz	8.8×10^5
ITMx	6695.978Hz	$\sim 10^5$	6696.391Hz	$\sim 10^5$
ITMy	NA	NA	6694.16Hz	$\sim 6 \times 10^3$

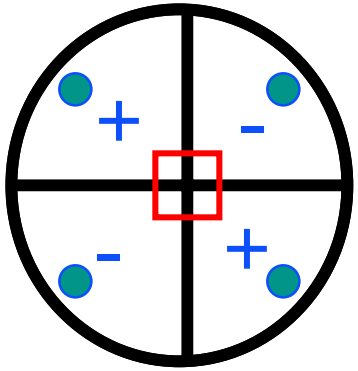
Determination of Mode Structure

- How can the position of the nodal lines be determined?
  - » Sinusoidal drive of desired mode
  - » Misalign resonant cavity by known amounts
    - – Misalign single arm for ETMs
    - – Misalign power recycled michelson for ITMs
  - » Measure signal amplitude from spectrum at different resonant configurations

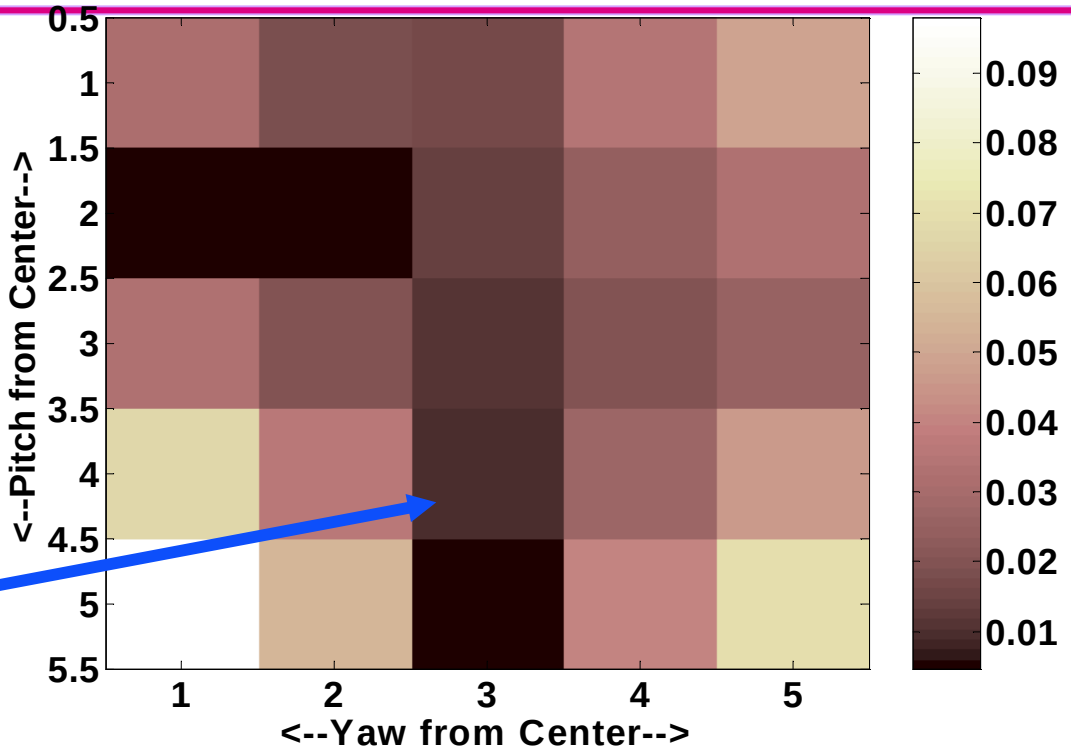
Cavity Misalignment



Mode Structure, ETMx

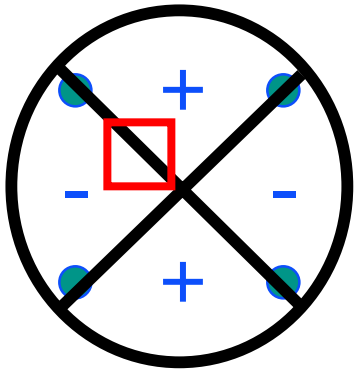


Evidence of Plus Structure

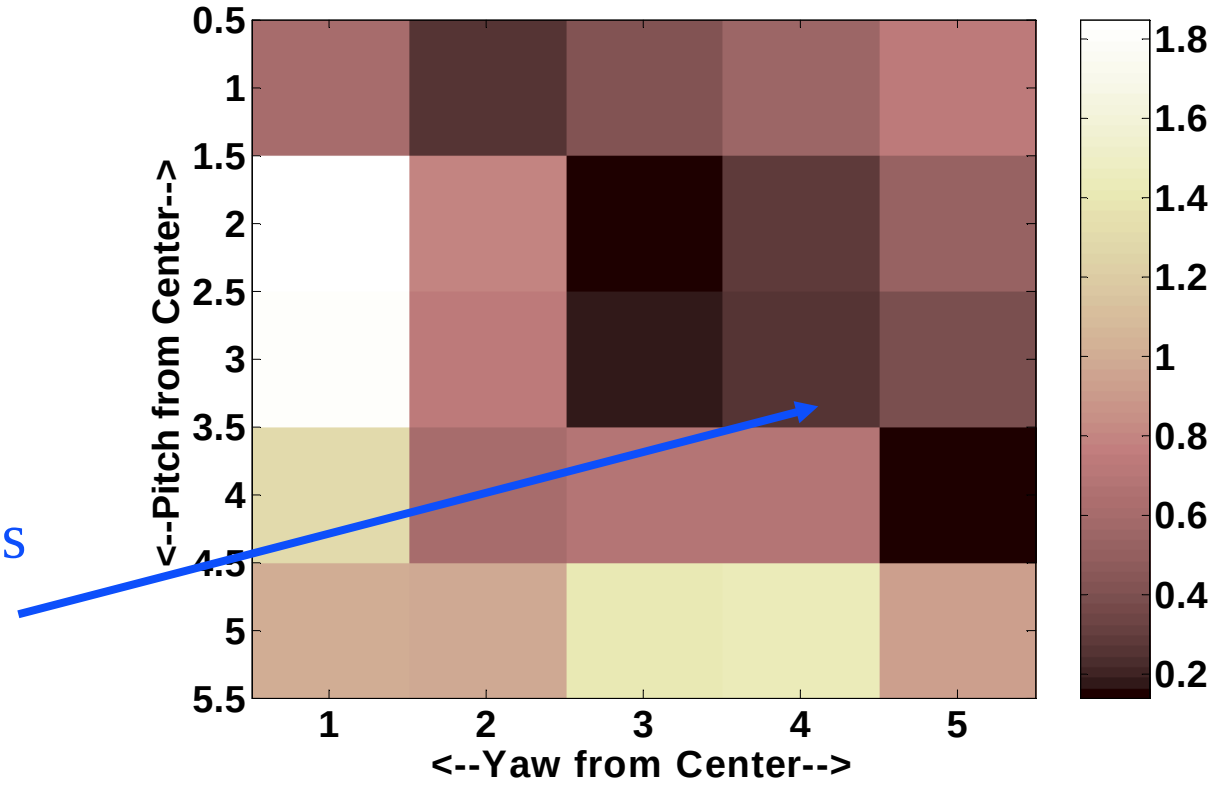


- ETMx map structure suggests lower mode at 6648.01Hz has “plus” structure
- Mapped with a single arm lock
- Map size = 23mm x 14mm

Mode Structure, ETMy



Evidence of Cross Structure

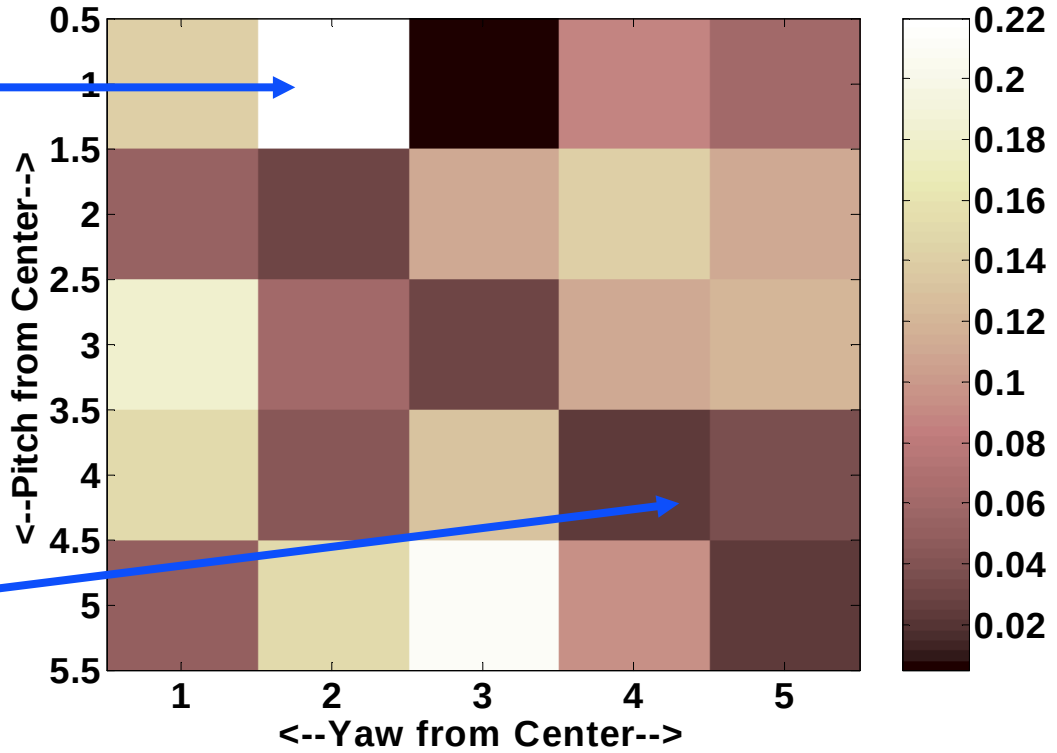


- ETMy map structure suggests upper mode at 6640.67Hz has “cross” structure
- Mapped with a single arm lock initially misaligned near upper left
- Map size = 12mm x 8mm

Mode Structure, ITMy

Anomaly

Cross Structure Evidence



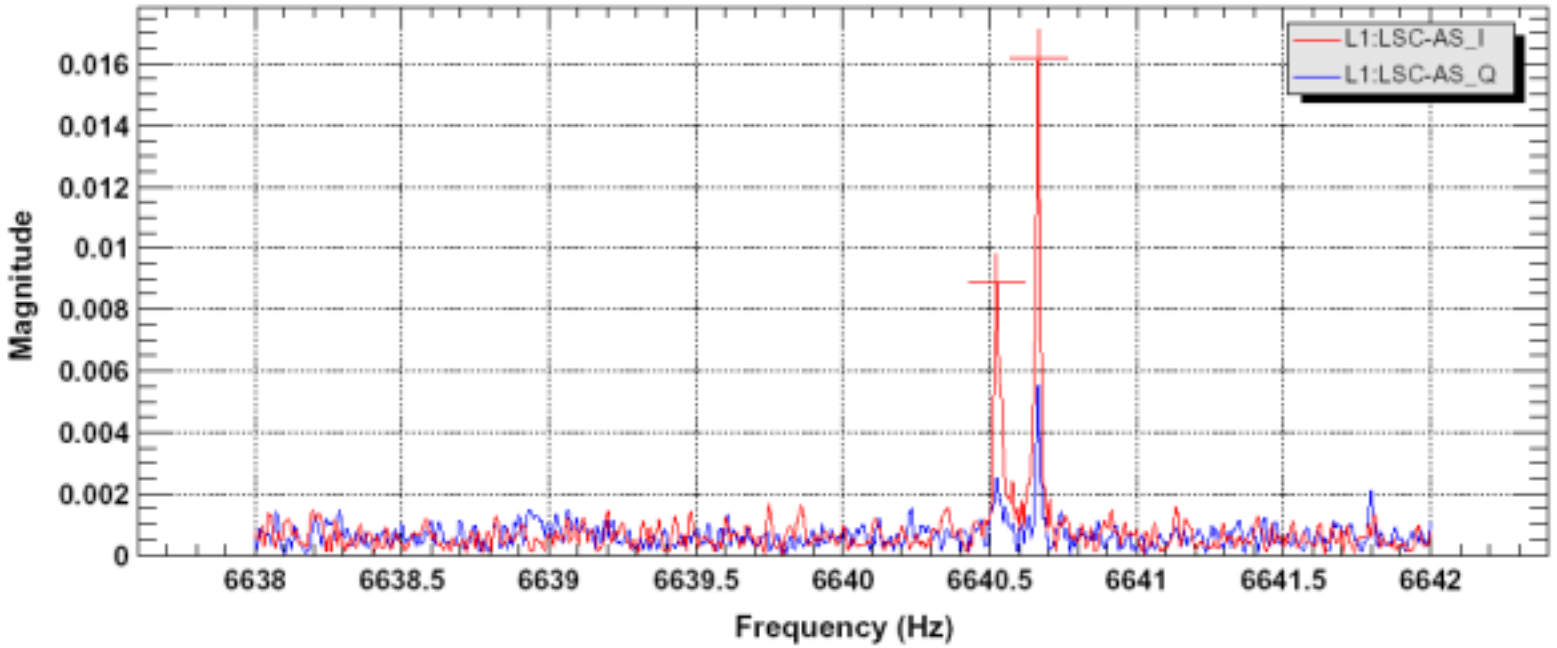
- ITMy map structure suggests mode at 6694.2Hz may be a cross mode
- Mapped using the Power Recycled Michelson

Alignment

- Butterfly mode was minimized by making slight changes in alignment
- Signal did not disappear entirely
- Altering the alignment of the fully locked interferometer
  - » Signal decreased with misalignment - wrong trend!
  - » Signal more susceptible to changes in power

Mode Coupling

- Driving one butterfly mode can excite the other mode



Sinusoidal drive of upper mode of ETMy excites lower mode

Conclusion

- What can be done in the future?
  - » Examine the phase of the detected signal w.r.t the drive signal
  - » Create a “phase map”
- Automated alignment with the butterfly modes?
  - » Modes ring up naturally when full interferometer acquires lock

Acknowledgements

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- Special thanks to the following people
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  - » Mark Coles
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