Parametric Instabilities in Advanced Gravitational Wave Detector

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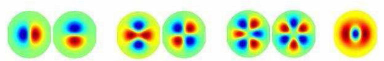
Introduction

- The level of parametric instability (PI) is critically determined by the resonant condition of the recycling cavities of the detectors
- The cases of parametric instability for power recycling interferometer and dual recycling interferometer were studied
- 5 to 30 unstable modes per test mass at full power operation
- Instability gain R varies from 3 to ~10^3
- To minimize the parametric instability the asymmetry of the interferometer should be > 5m

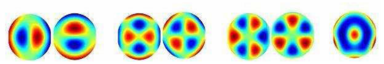
Analysis parameters

- Power recycling cavity (PRC) and signal recycling cavity (SRC)
  - T_{PRM}=2.3%, T_{SRM}=20%,
- Non-symmetric arm cavities
- Up to 8th order optical transverse modes considered
- Fused silica test masses
  - Test mass wedge and flats on the barrel considered
  - Optical coating considered
  - 5500 acoustic modes considered

Example of acoustic modes & transverse optical modes overlap



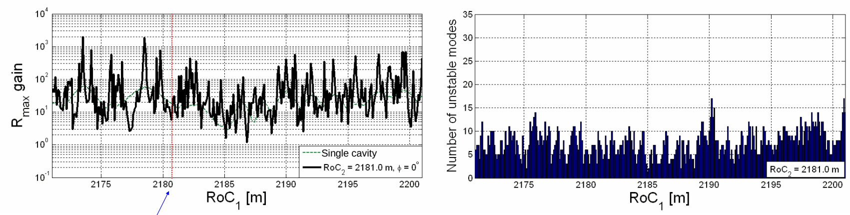
Acoustic modes



Optical modes

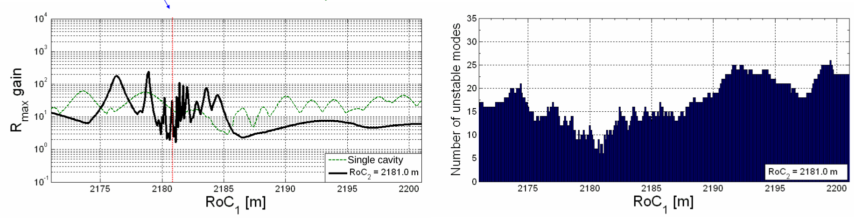
PI in dual recycling interferometer

Worst case: both cavities resonant for all transverse modes

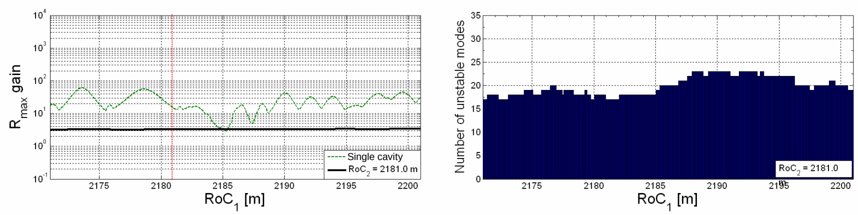


Symmetry limit

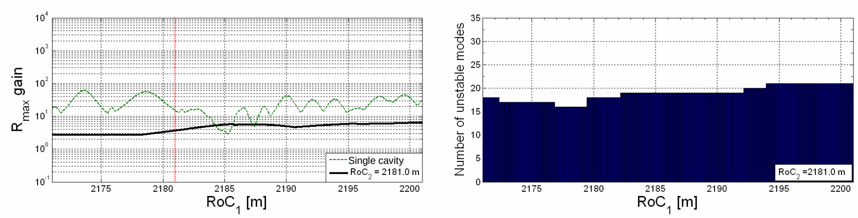
PRC resonant, SRC anti-resonant for all transverse modes



Best case: both cavities anti-resonant for all transverse modes

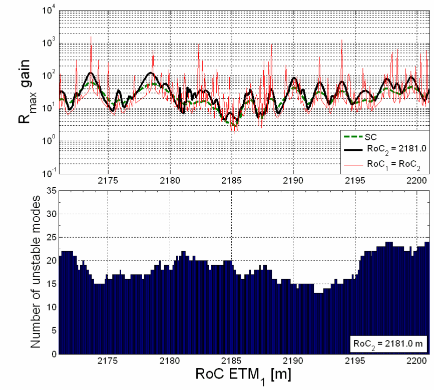


Detuning increase PI gain
PRC anti-resonant, SRC detuned 11° from anti-resonance for all transverse modes

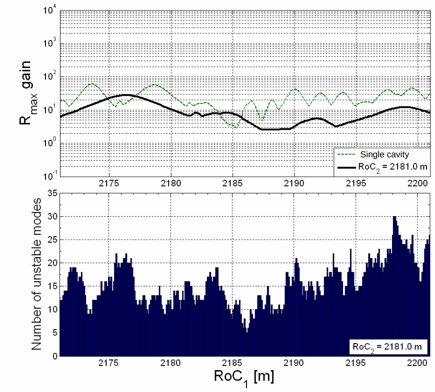


PI in power recycling interferometer

PRC resonant for all transverse modes: symmetry increase PI gain



PRC anti-resonant for all transverse mode



Conclusion

- PI occurs in all configurations
- PI suppression always required for full power operation
- Further modeling including Guoy phases for each transverse mode is needed to predict PI in real interferometers
- Important to consider effect of transient glitches in cavities