

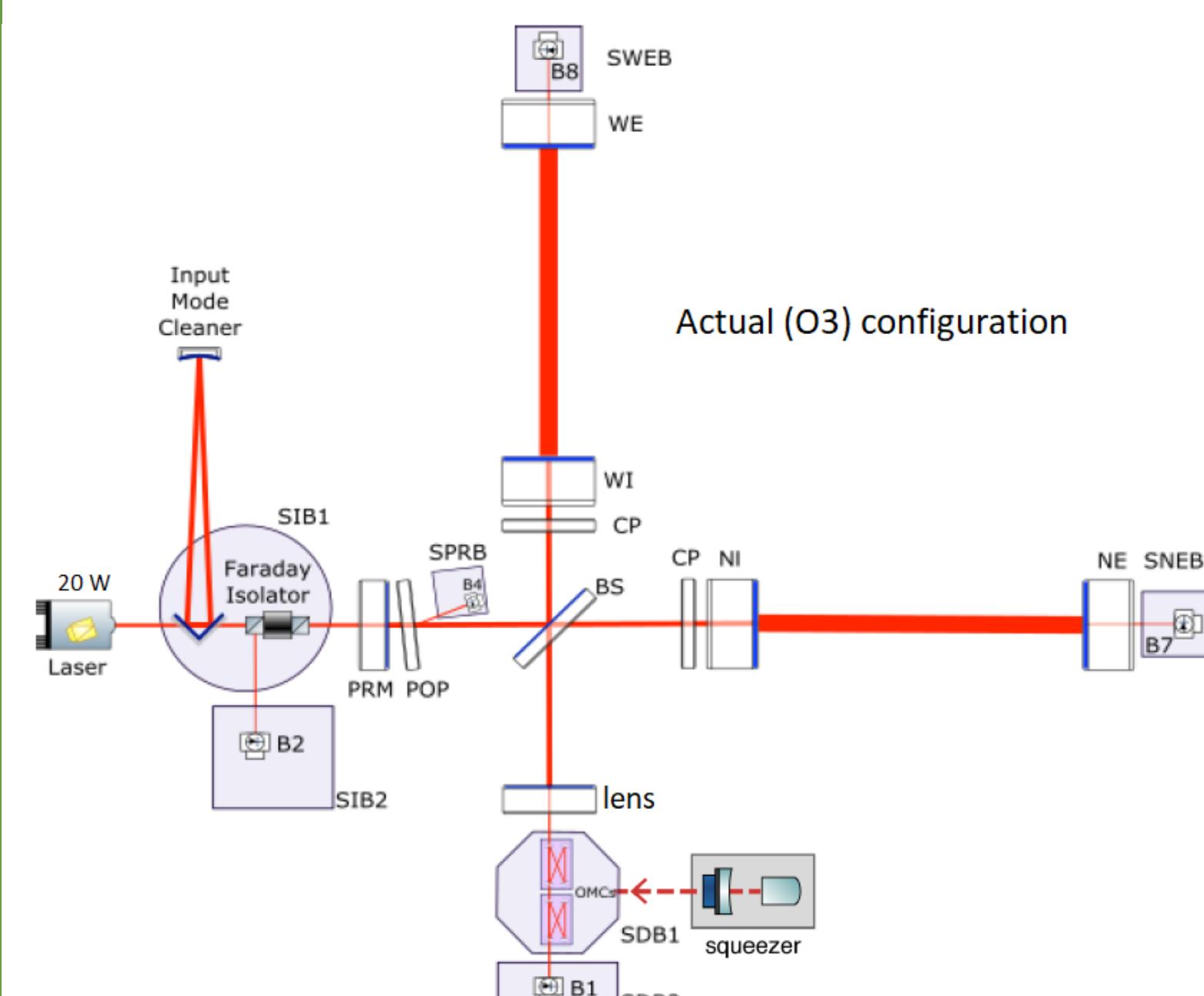


Parametric instability predictions for Advanced Virgo

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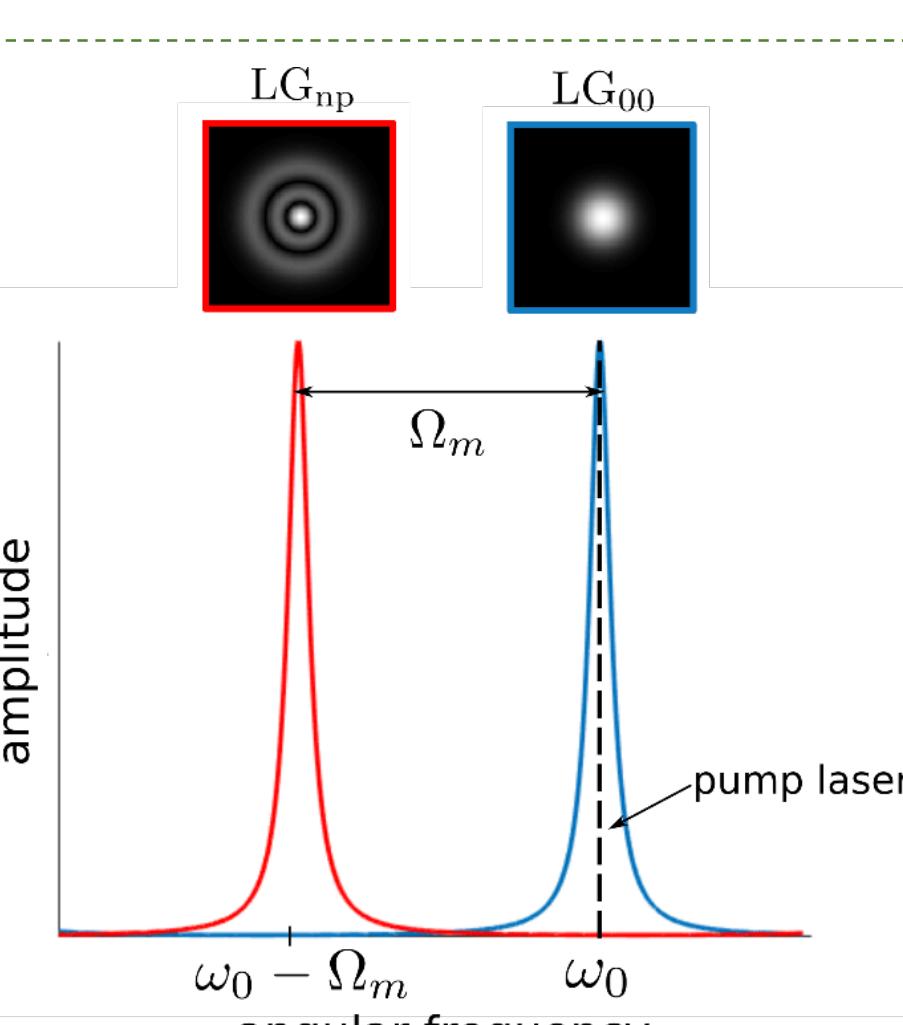
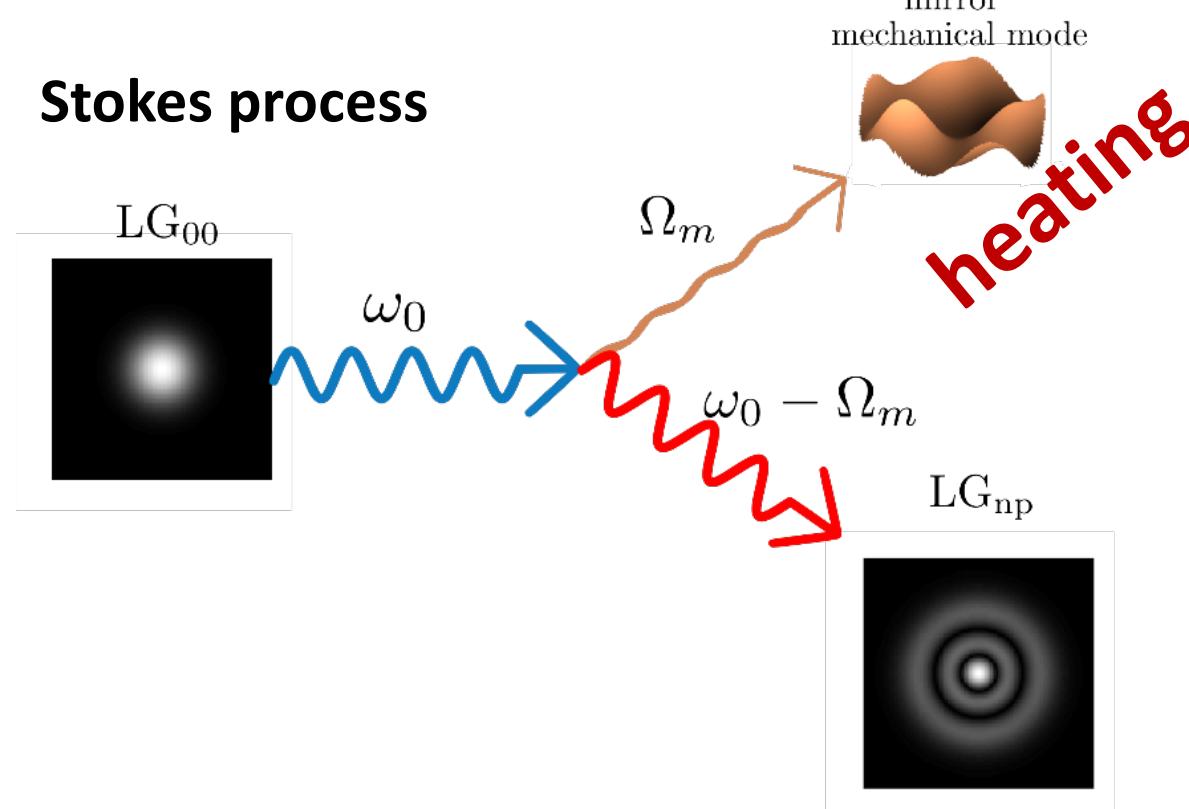
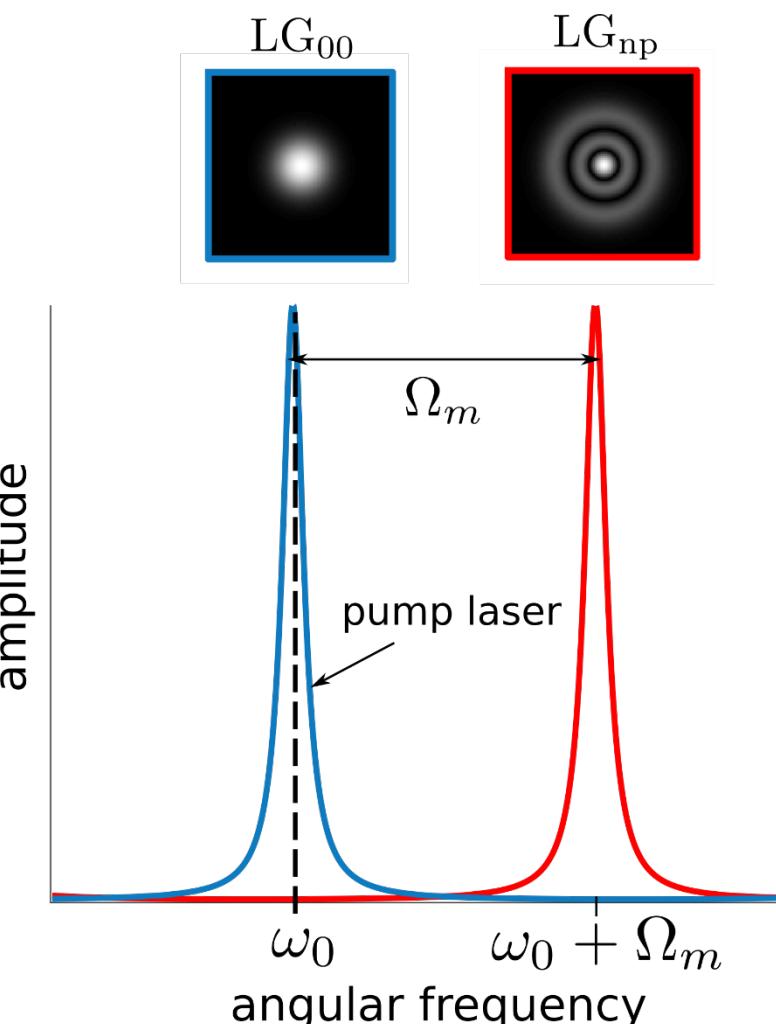
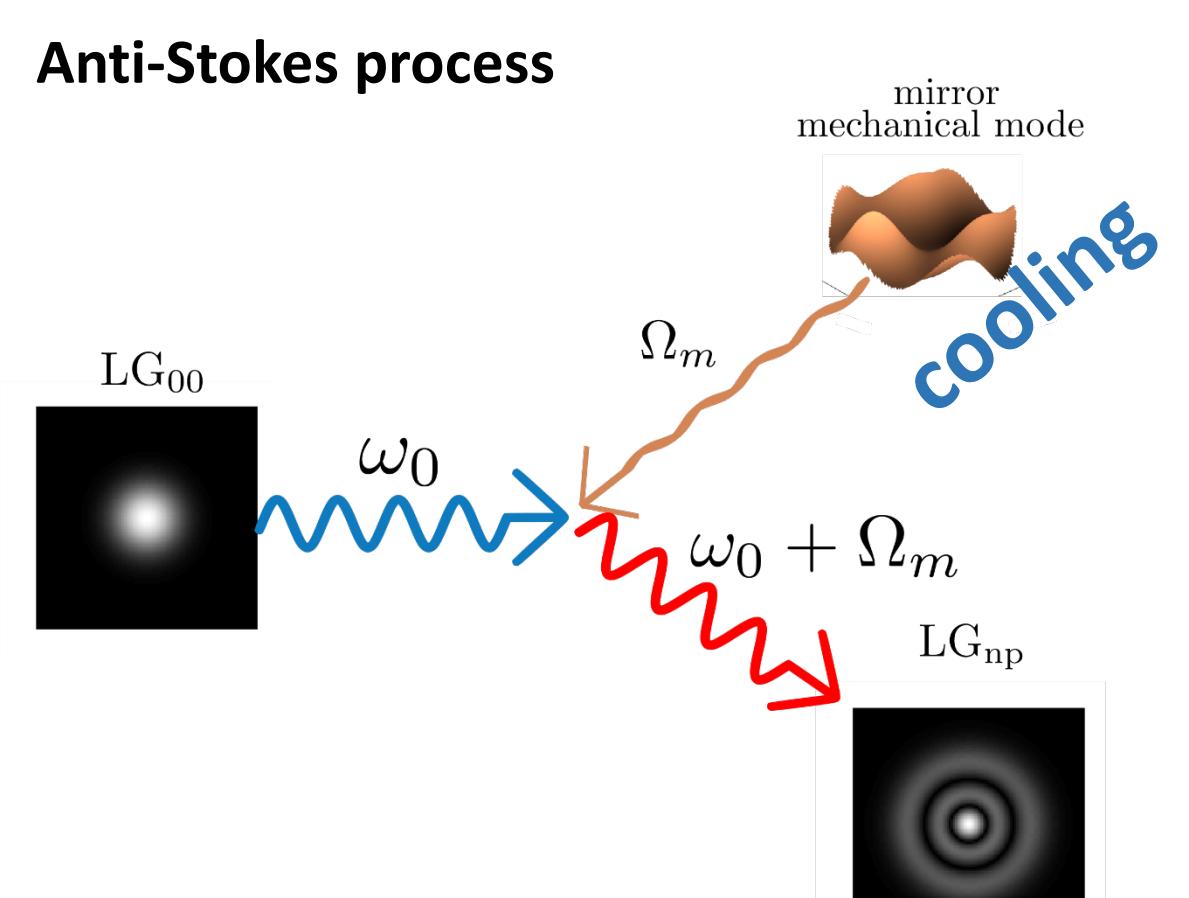
Virgo gravitational wave detector



Orders of magnitude

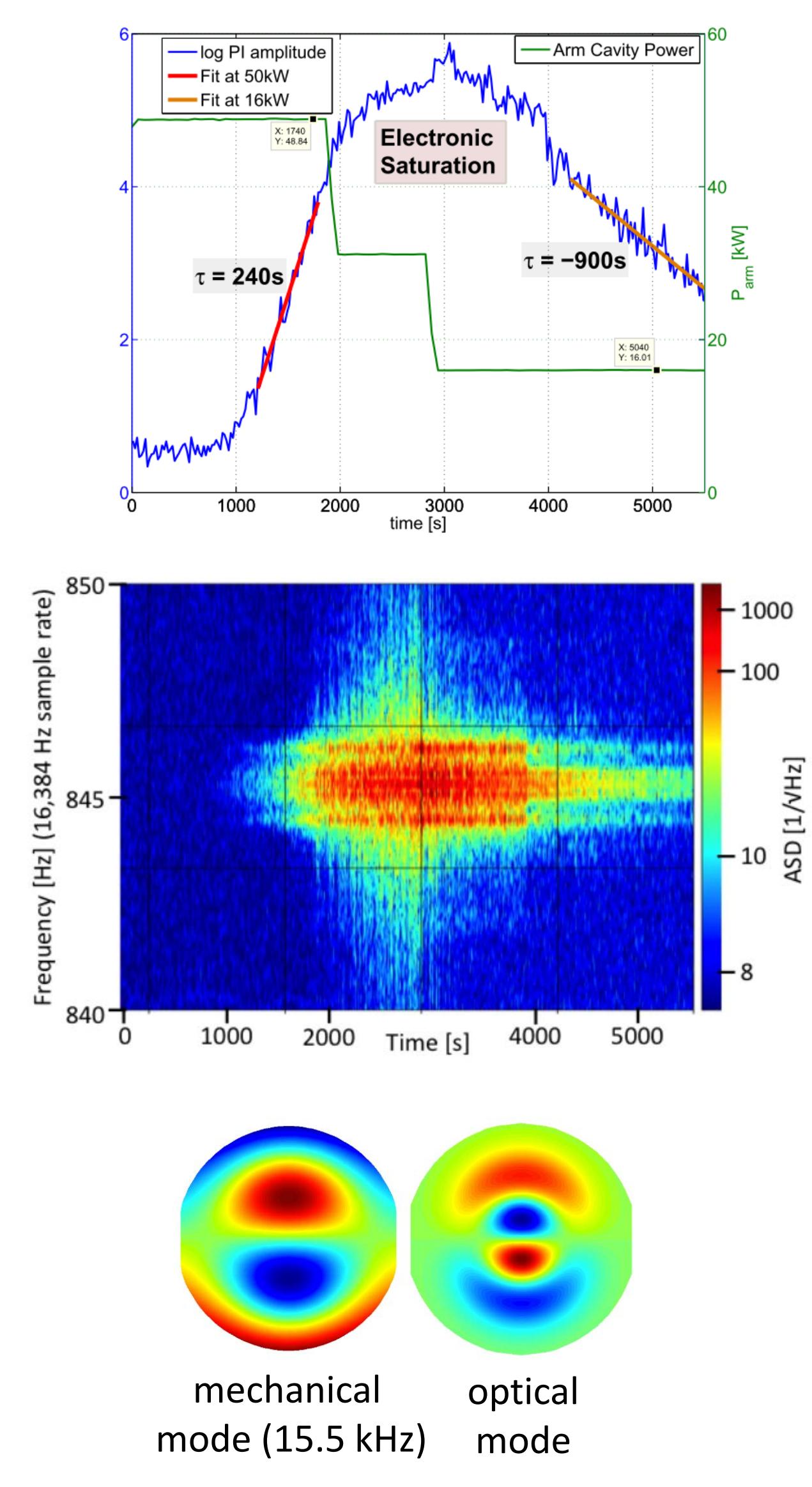
- Arm lengths : 3000m
- RoC NI & WI : 1424 m
- RoC NE & WE : 1695 m
- Transmittance NE & WE : 4 ppm
- Transmittance NI & WI : 13770 ppm
- Transmittance PRM : 48400 ppm
- Round trip loss : 55 ppm
- Cavity Finesse : 454
- Distance PR-cavities : 12 m
- Mirror mass : 42 kg
- Intracavity power : 100 kW for 20 W input
- Gouy phase of PR cavity : 1.8 mrad

Three mode instability in a single ended optical cavity



three mode instability

Observation in LIGO



Evans et al. Phys. Rev. Lett. 114, 161102

Parametric gain simulation methods

- Finesse (frequency domain interferometer software)
- Two photons formalism

Parametric gain

$$R_m = \frac{8\pi Q_m P_{\text{arm}}}{M\omega_m^2 c \lambda} \sum_{n=0}^{\infty} \Re[G_n] B_{m,n}^2$$

$$G_n = G_n^- - G_n^{+*}$$

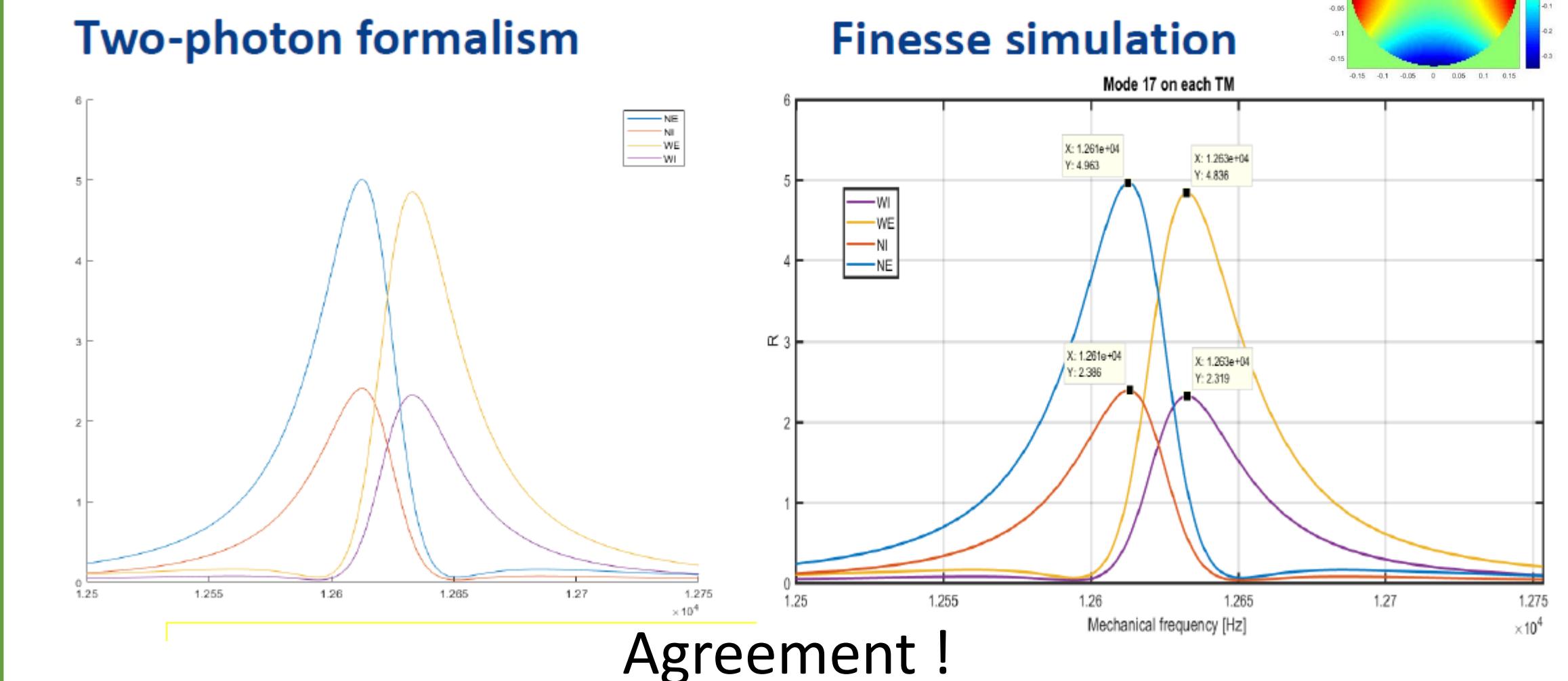
Stokes Anti-Stokes

Spatial overlap integral between the 3 modes

<http://www.gwoptics.org/finesse/>
Caves et al, Phys. Rev. A 31, 3068–3092 (1985).
Evans et al Phys. Lett. A, 374, 4, 2010

Comparison between methods

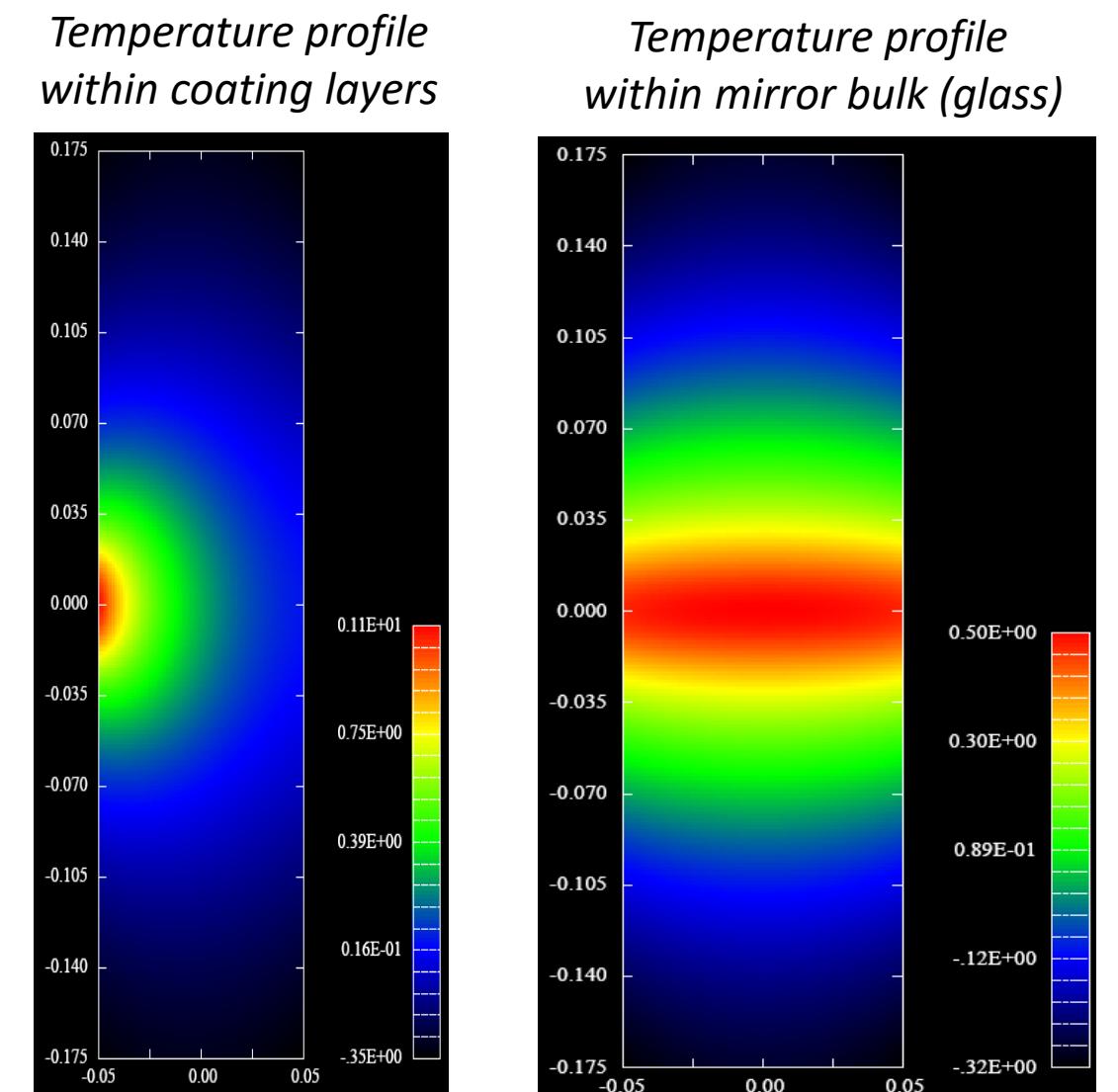
Two-photon formalism



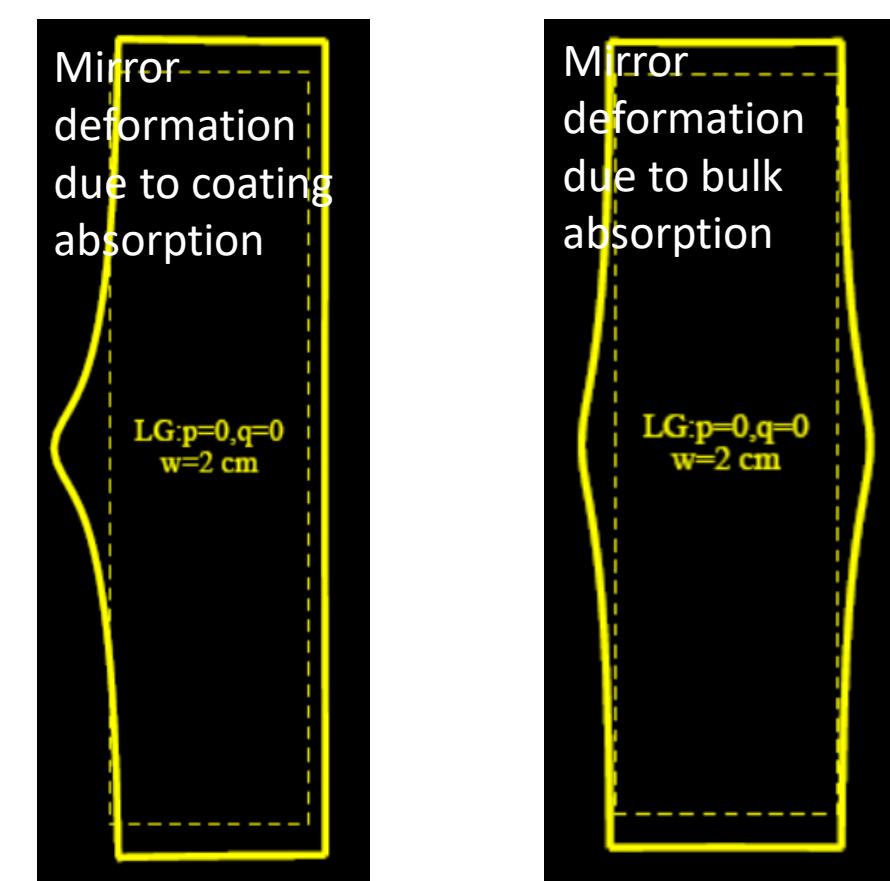
Finesse simulation

Thermal effects

Gaussian beam incident on input mirror with waist 2 cm

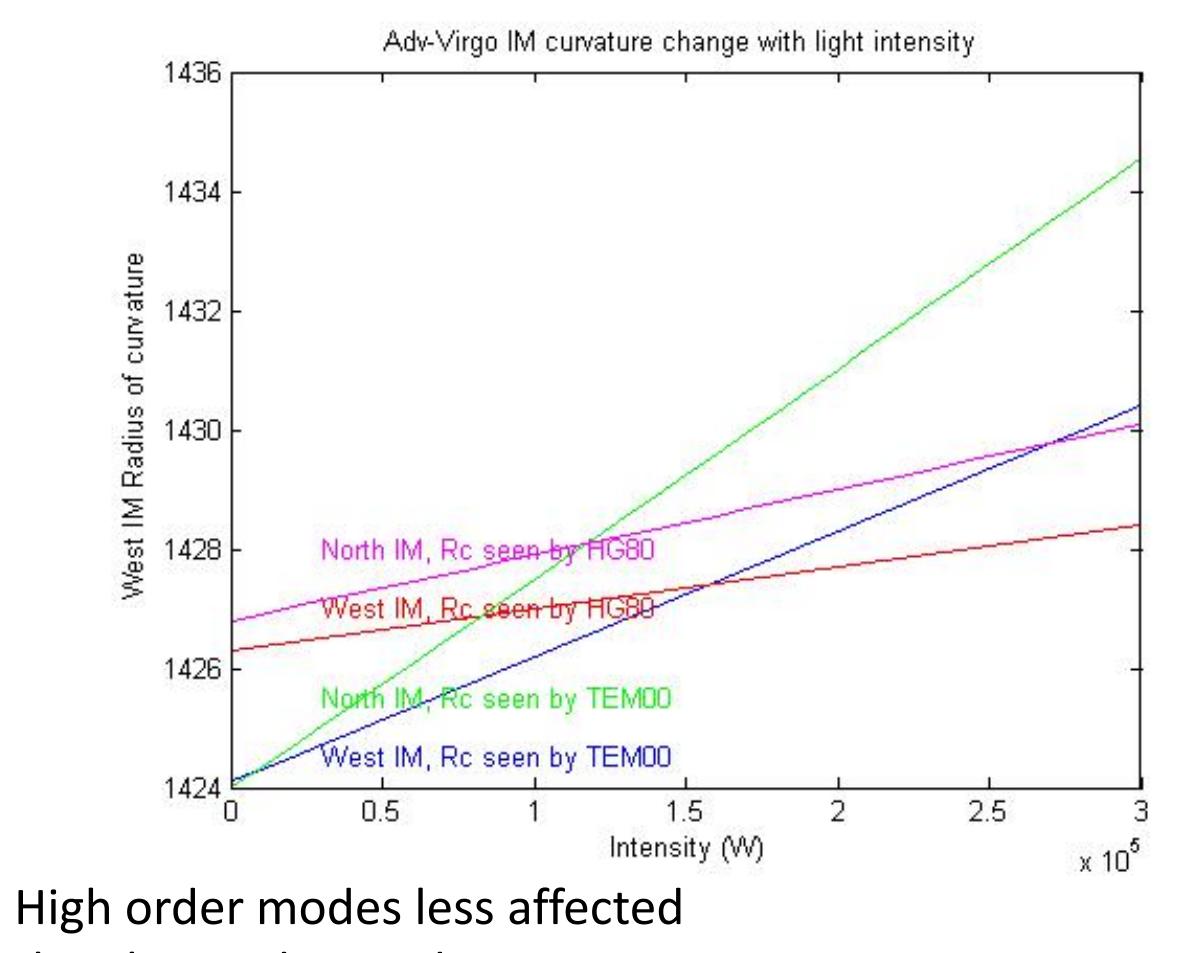


The mirror surface heating due to light absorption leads to a mirror surface deformation, and refractive index change.



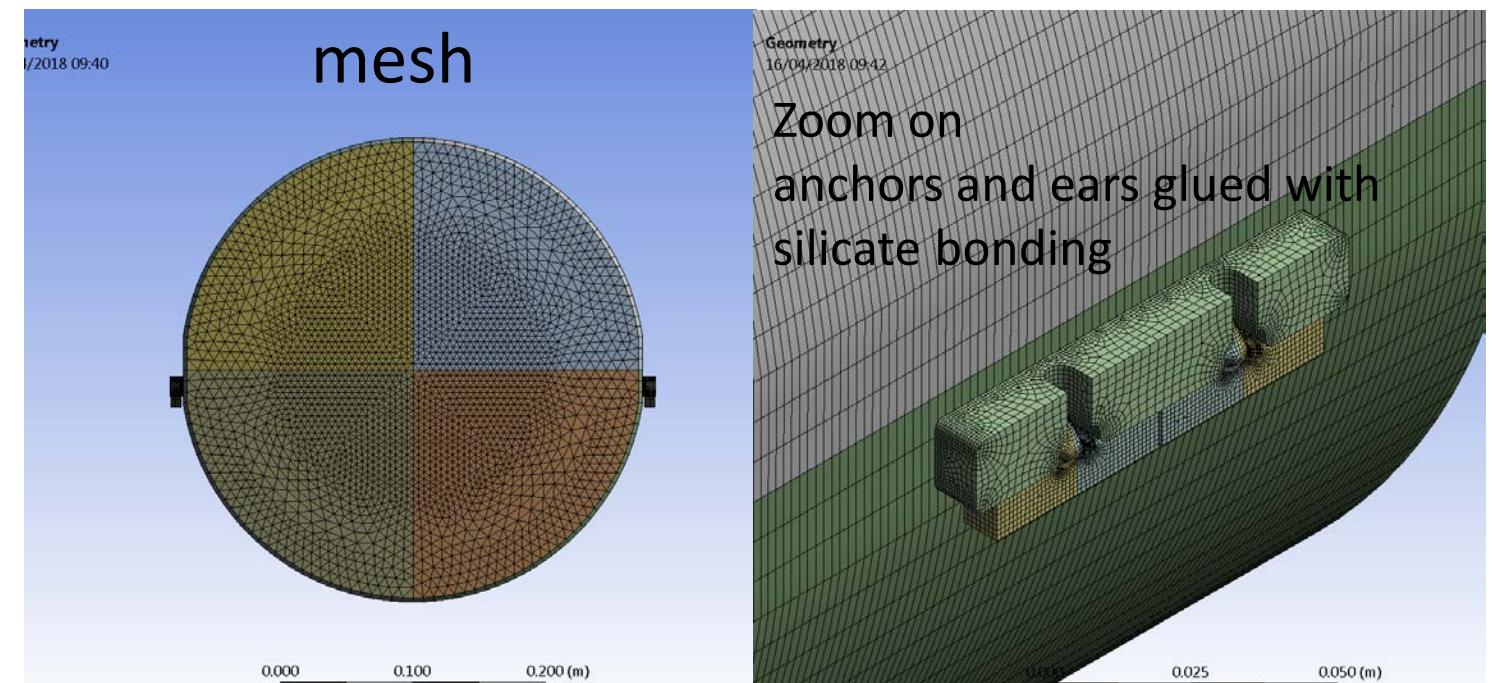
Ref. Vinet VIR-599

Radii of curvature vs intracavity power



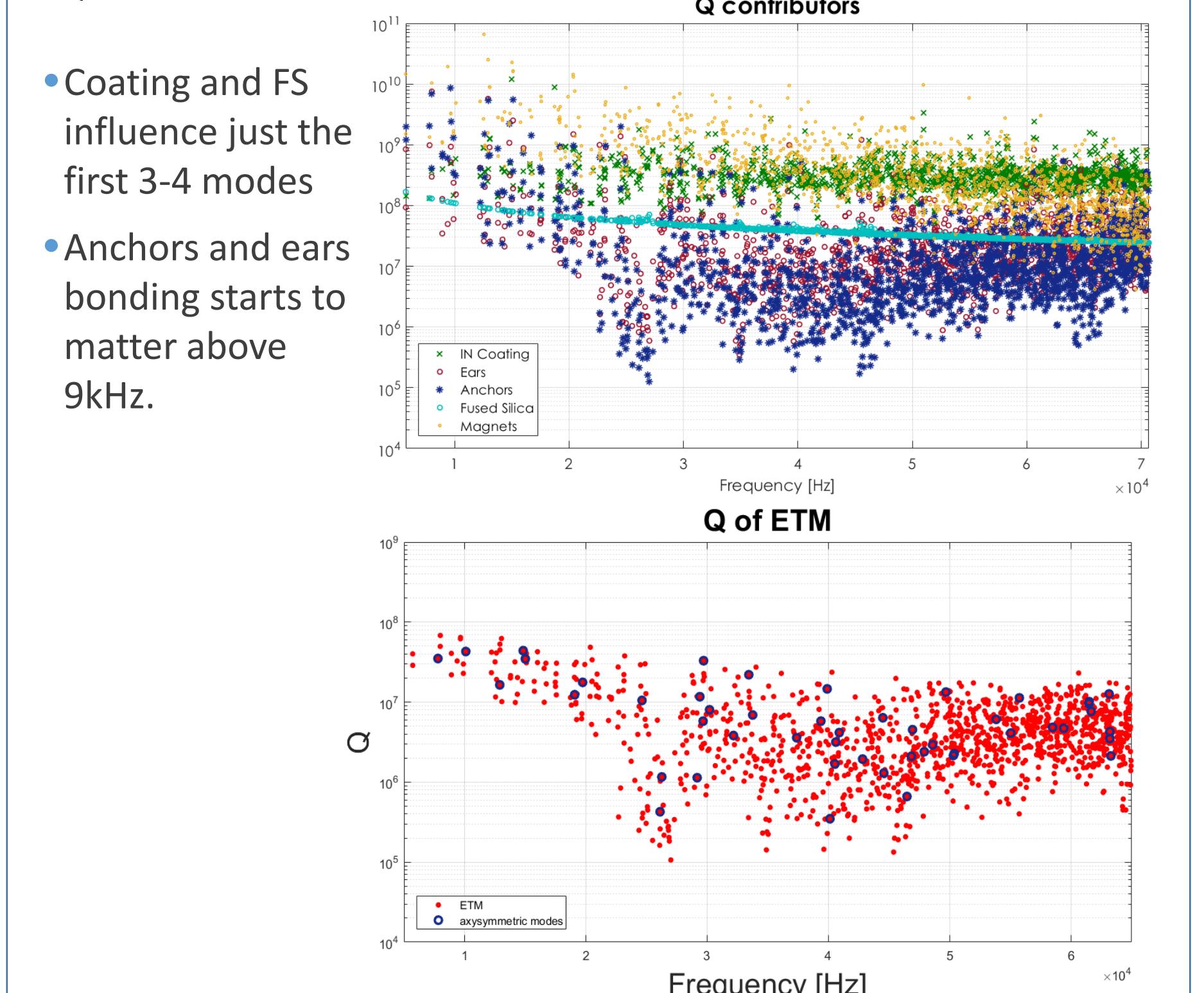
Mechanical mode FEM simulation

FEM with ANSYS



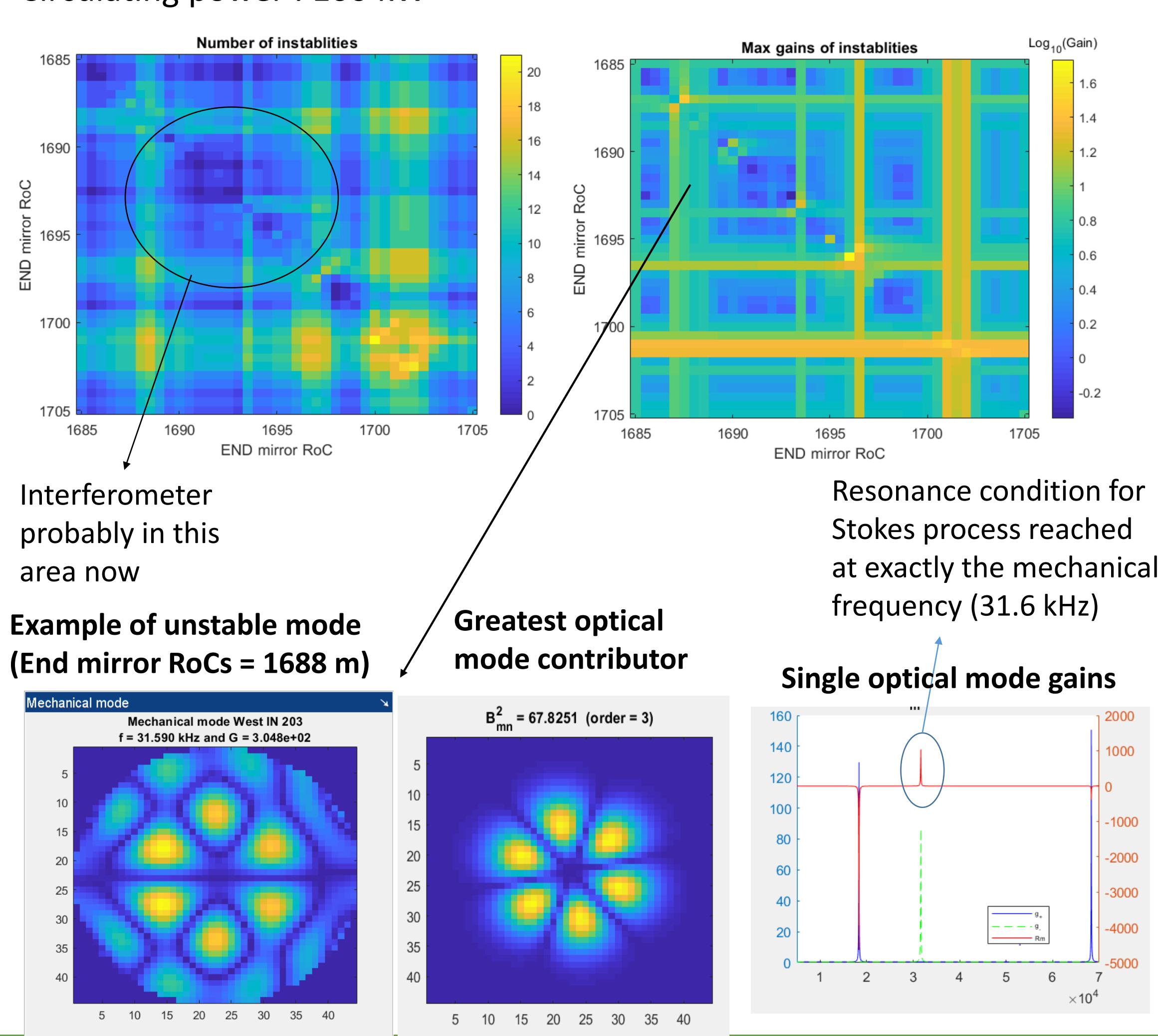
- Material properties are extracted from fits to measured frequencies
Young Modulus: 72.248 GPa
Poisson ratio: 0.16629
Density: 2201 kg/m³
- Compute mechanical Q, frequencies and modal maps

Q evaluation from FEM

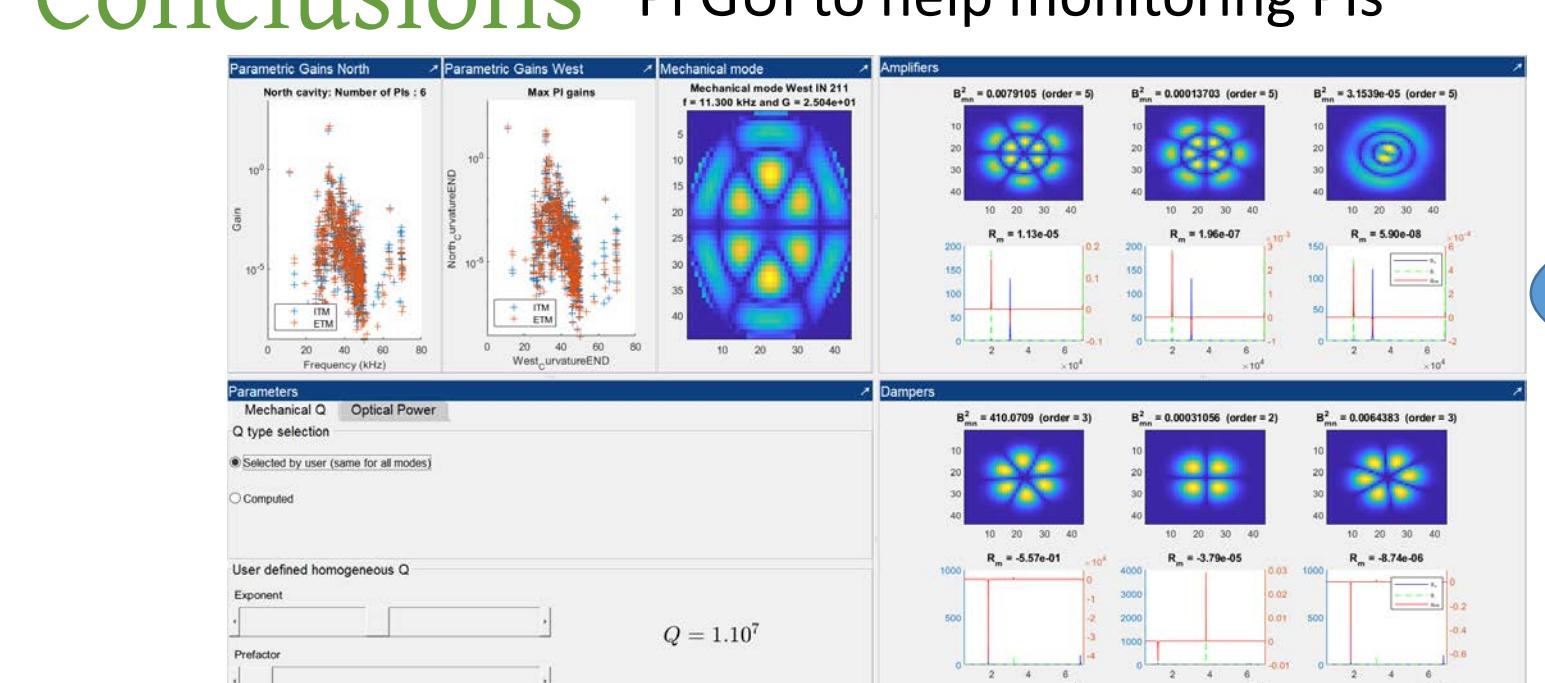


Example of predictions

Circulating power : 100 kW



Conclusions



Not many PIs expected for O3 at 100 kW

<https://github.com/ThibautJacqmin/ParametricInstability>

Mitigation strategies :

- End mirror RoC varying with ring heaters
- Passive dampers
- Active damping via radiation pressure