

Ring Dampers and Gold Barrel Coatings

-to control parametric instabilities

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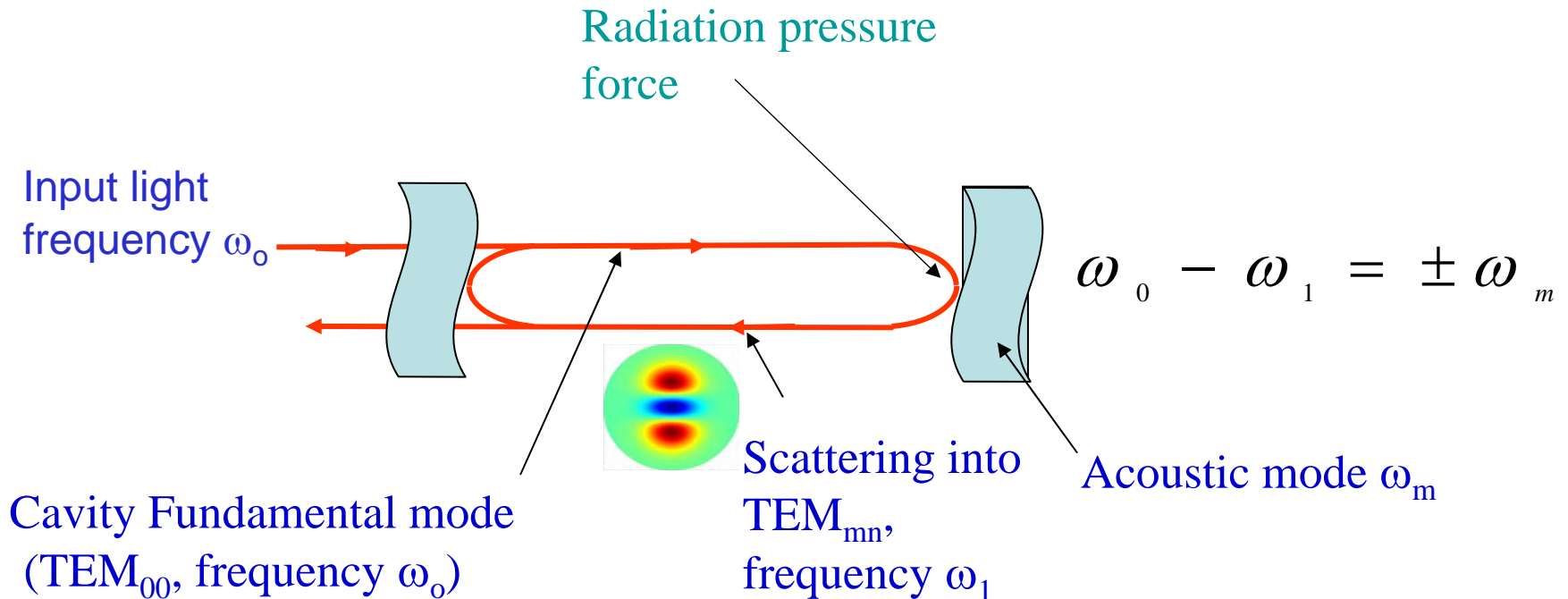
UWA Experimental Team:

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Current main focus:

Control of Parametric Instabilities

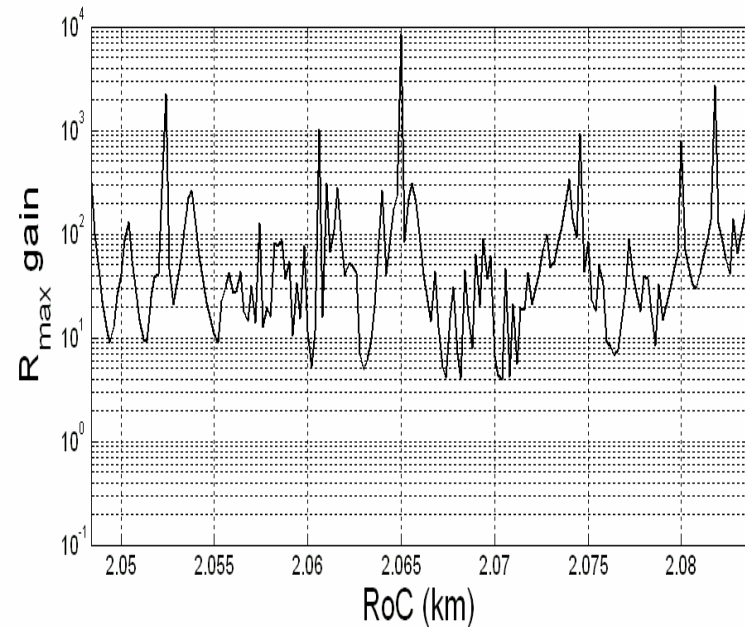
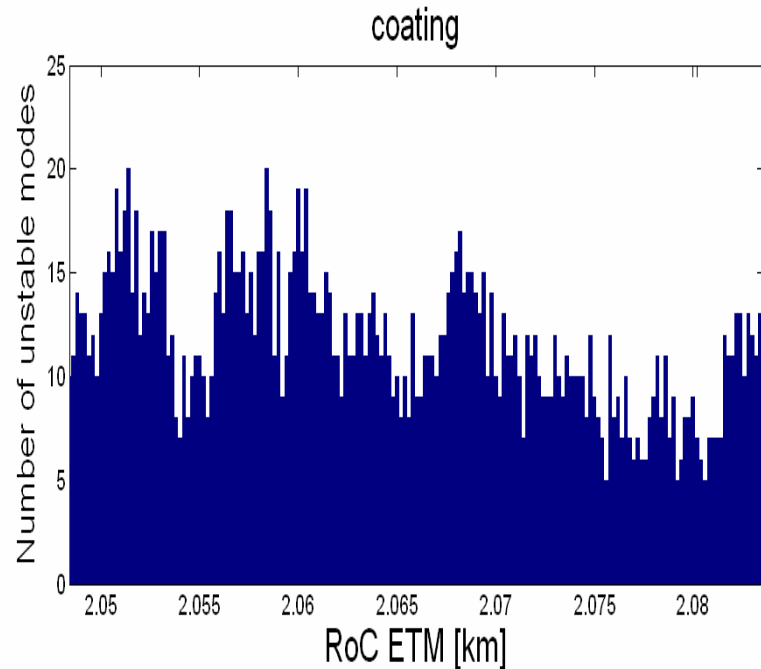
Parametric Instability



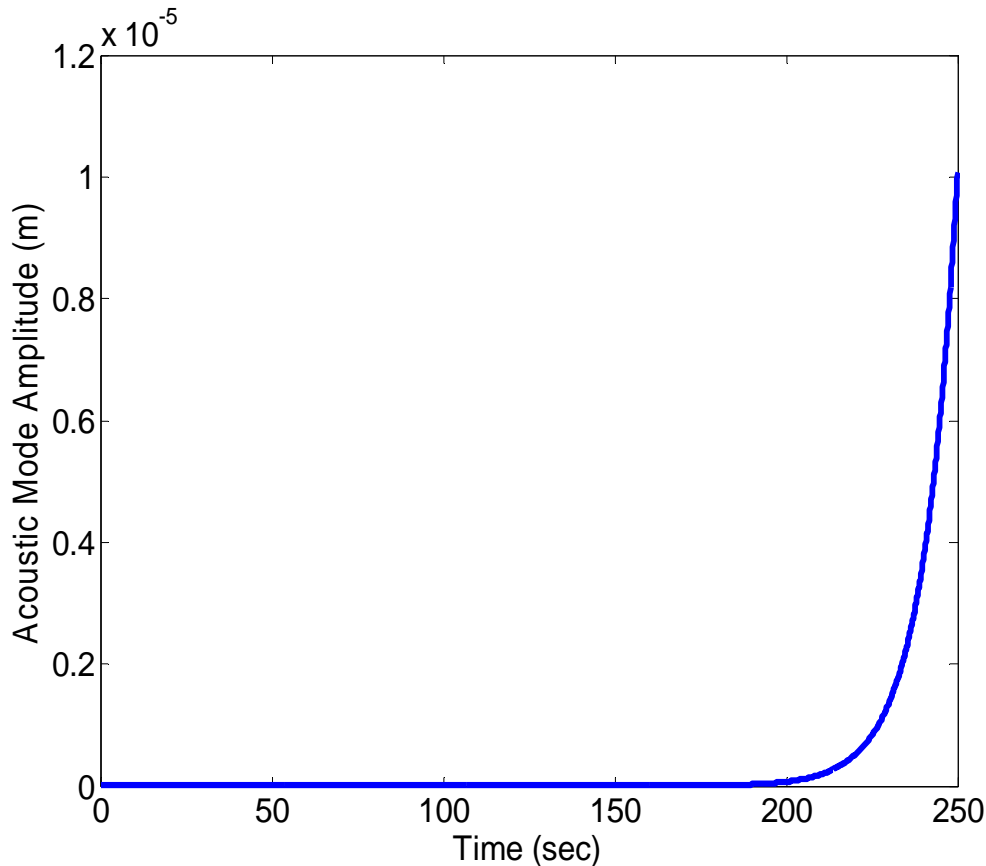
3-mode interaction requires **frequency matching** and **spatial overlap** of acoustic and optical modes

Current Status: Simulation

AdvLIGO predictions: 5-10 unstable modes per test mass; maximum PI gain of 10-100

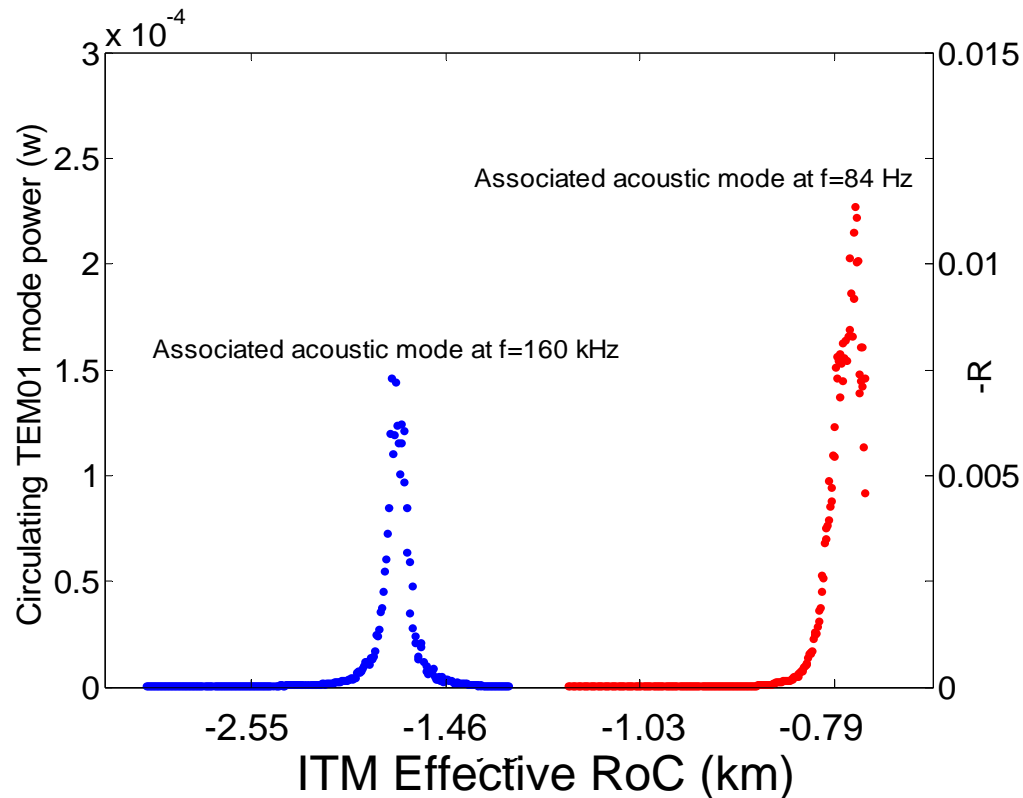


PI Effects: Time to break lock



- Time to reach vibration amplitude 10^{-6} m: ~230 seconds
- TL time constant: hours
- RoC: not constant

Current Status: Experiments with Sapphire Test Masses



- Measured power of the TEM01 mode as a function of the ITM RoC.

- Blue line: interactions with acoustic mode at frequency of ~ 160 kHz

- Red line: interactions with acoustic mode at frequency of ~ 84 kHz.

Simple spectrum because:

- single cavity
- small test mass
- low mode density

How to Control PI

When $R > 1$ the instability will occur

Reduce Q_m with minimum noise:
Ring damper

Parametric Gain:
$$R = \frac{8P_{in} Q_0 Q_1 Q_m}{L^2 \omega_0 \omega_m^2} \frac{\gamma B_1 / m_{eff}}{1 + (\Delta\omega / \delta_1)^2}$$

$Q_{0,1,m}$: Q-factors of the cavity modes, TEM_{00} and TEM_{mn} , and the acoustic mode respectively

Detuning by RoC

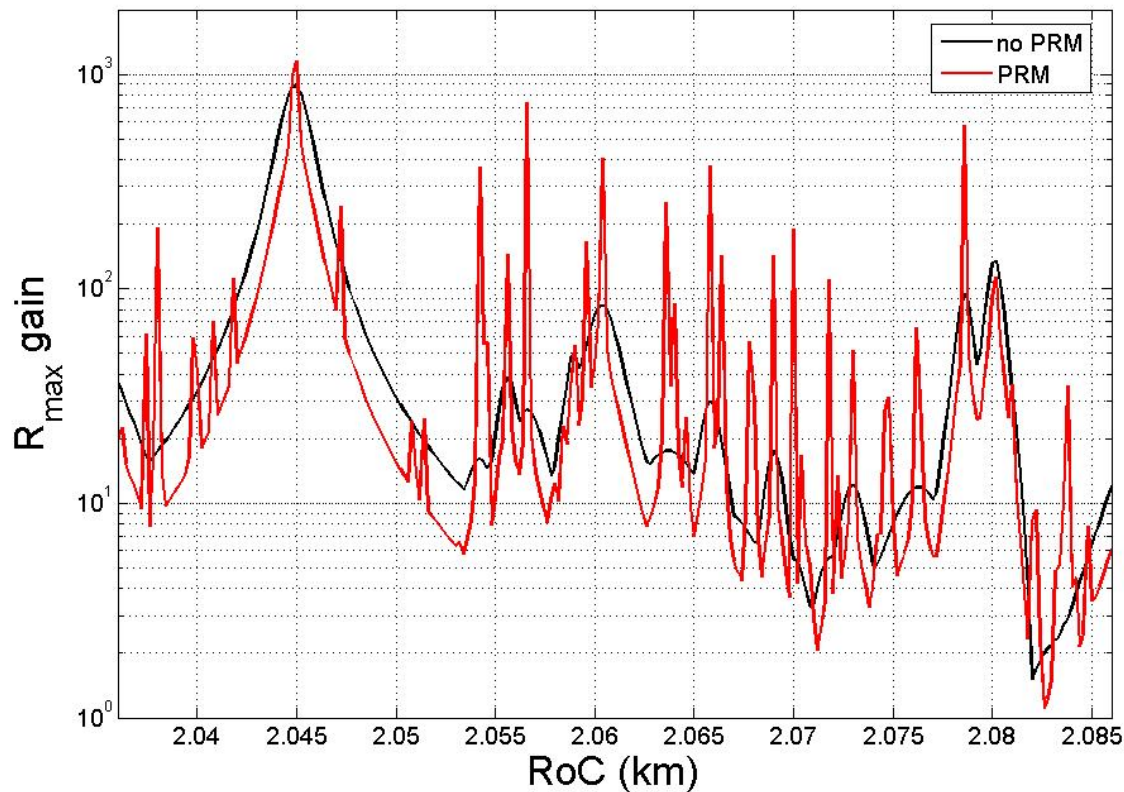
$$\Delta\omega = \omega_0 - \omega_1 - \omega_m$$

ω_0 : the frequency of the TEM_{00} mode

ω_1 : the frequency of the TEM_{mn} mode

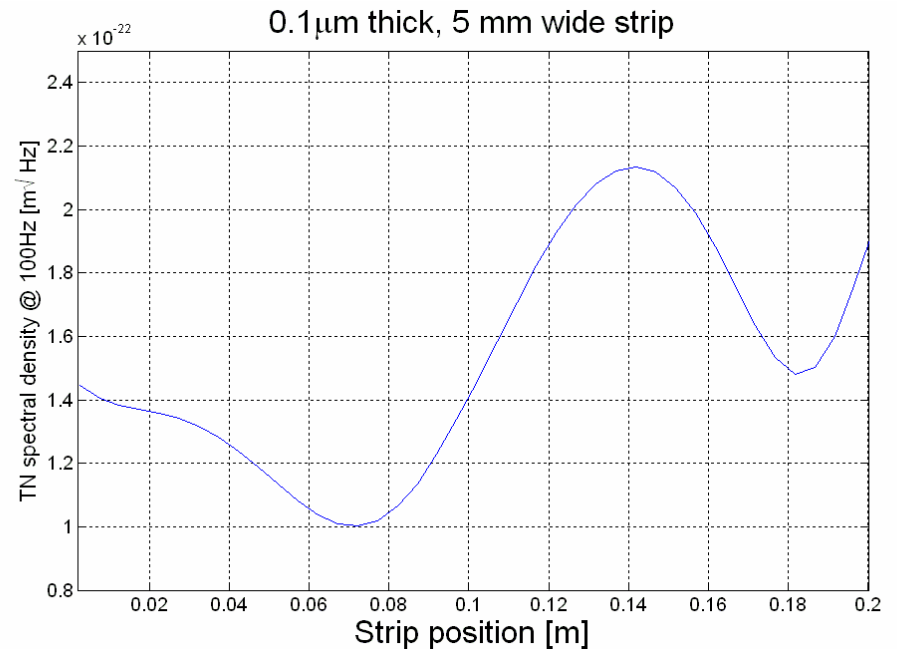
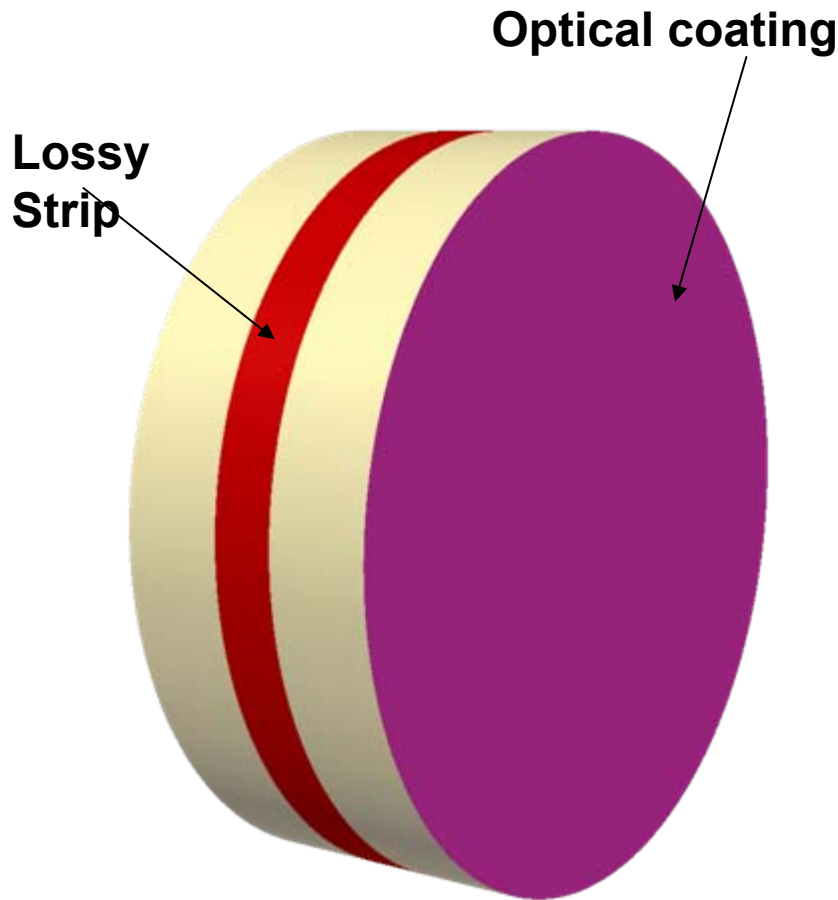
$$\delta_1 = \omega_1 / 2Q_1$$

Radius of Curvature Tuning



- Simple cavity: Black
- Marginally stable PR: Red
- Stable PR : PI gain curve will sit between these two curves

Ring dampers: Q reduction with minimum noise



Gold Strip: Thermal noise spectral density vs. position

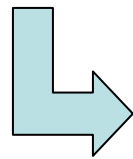
Modelling AdvLIGO Ring Damper and Barrel Coating

Modelling assumptions:

- Full AdvLIGO test mass with flats
- Best estimated of fused silica acoustic loss
- Best estimated of coating acoustic loss

Model Results:

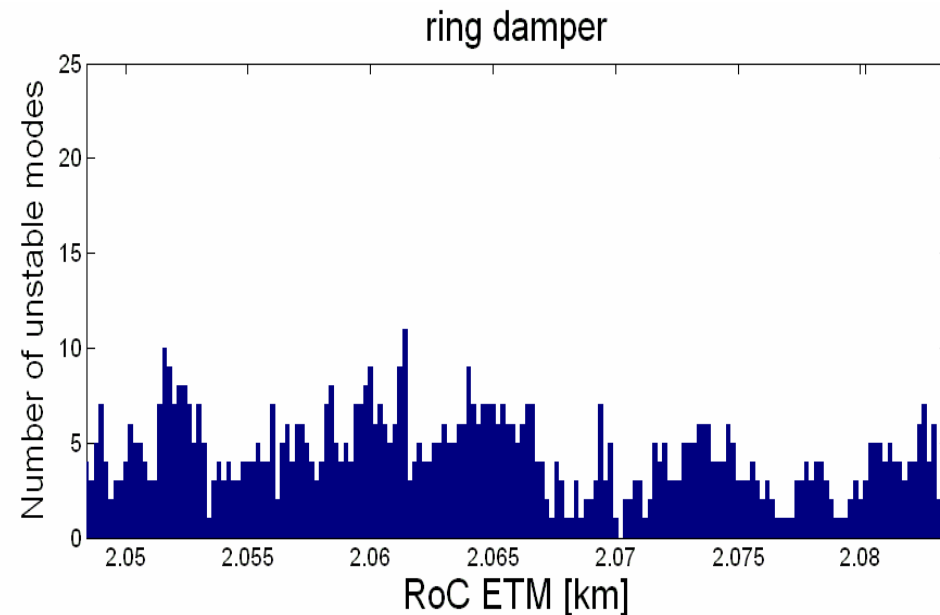
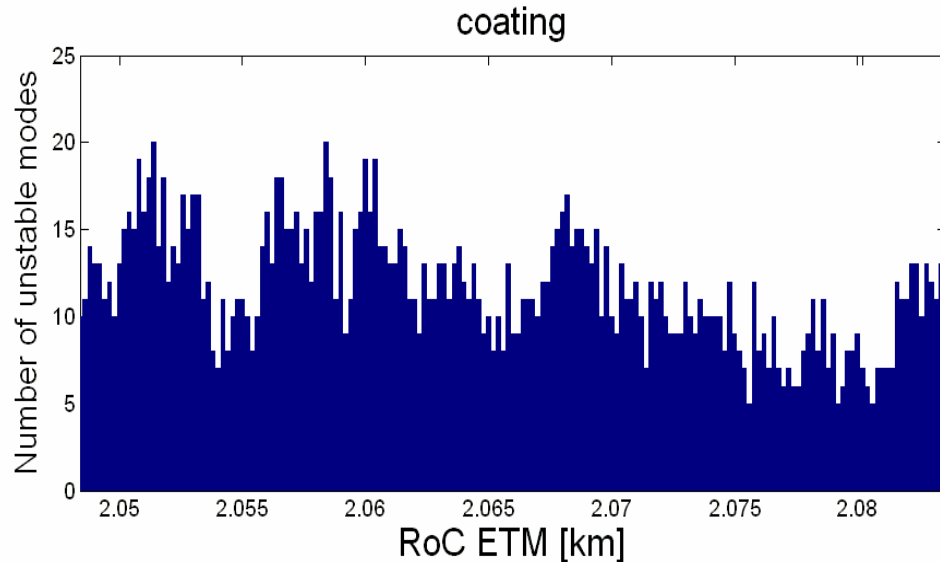
- Is the thermal noise penalty acceptable?
- Higher thermal noise



larger stability windows

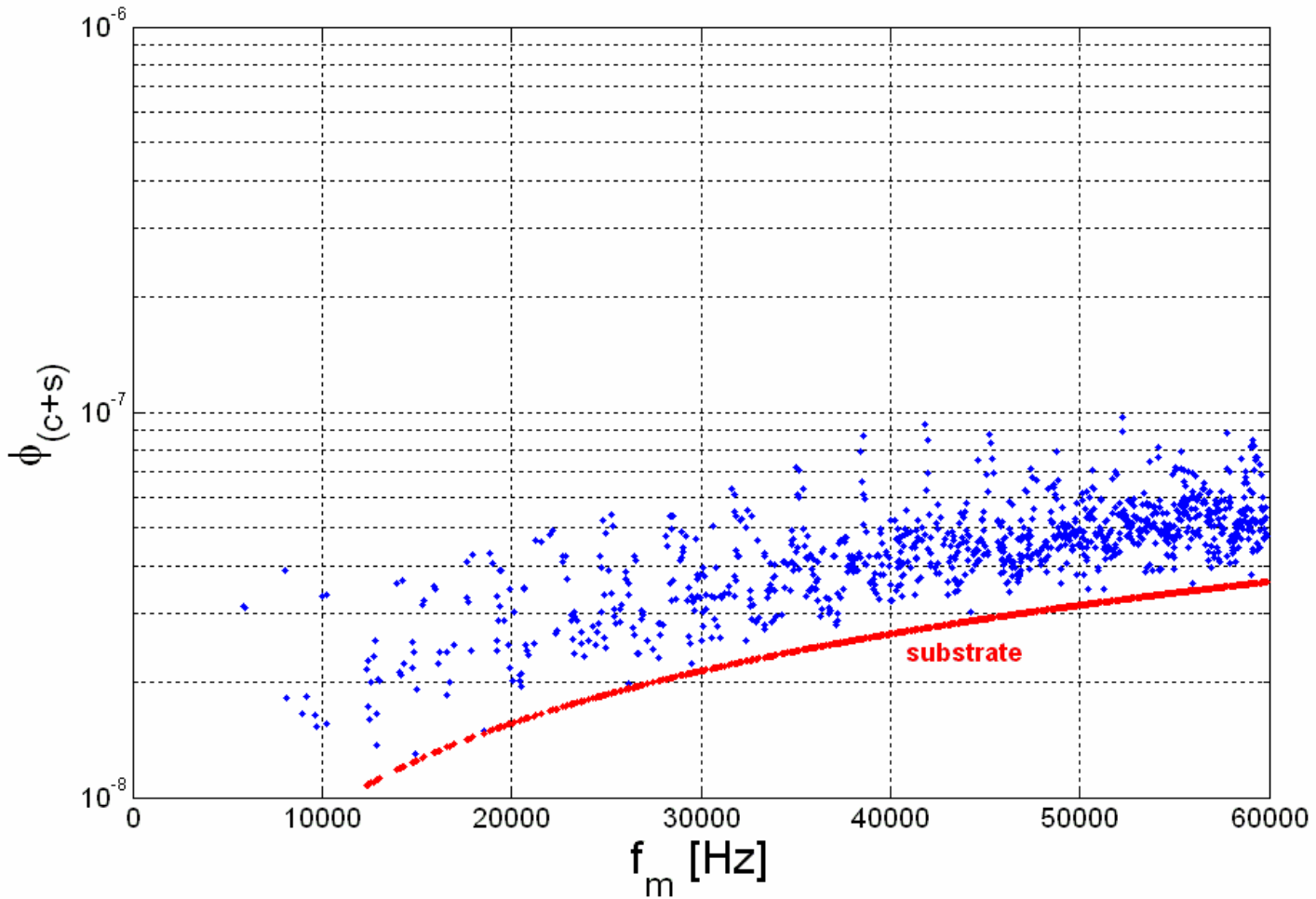
For minimal thermal noise other control schemes are needed

Number of unstable modes with and without ring damper



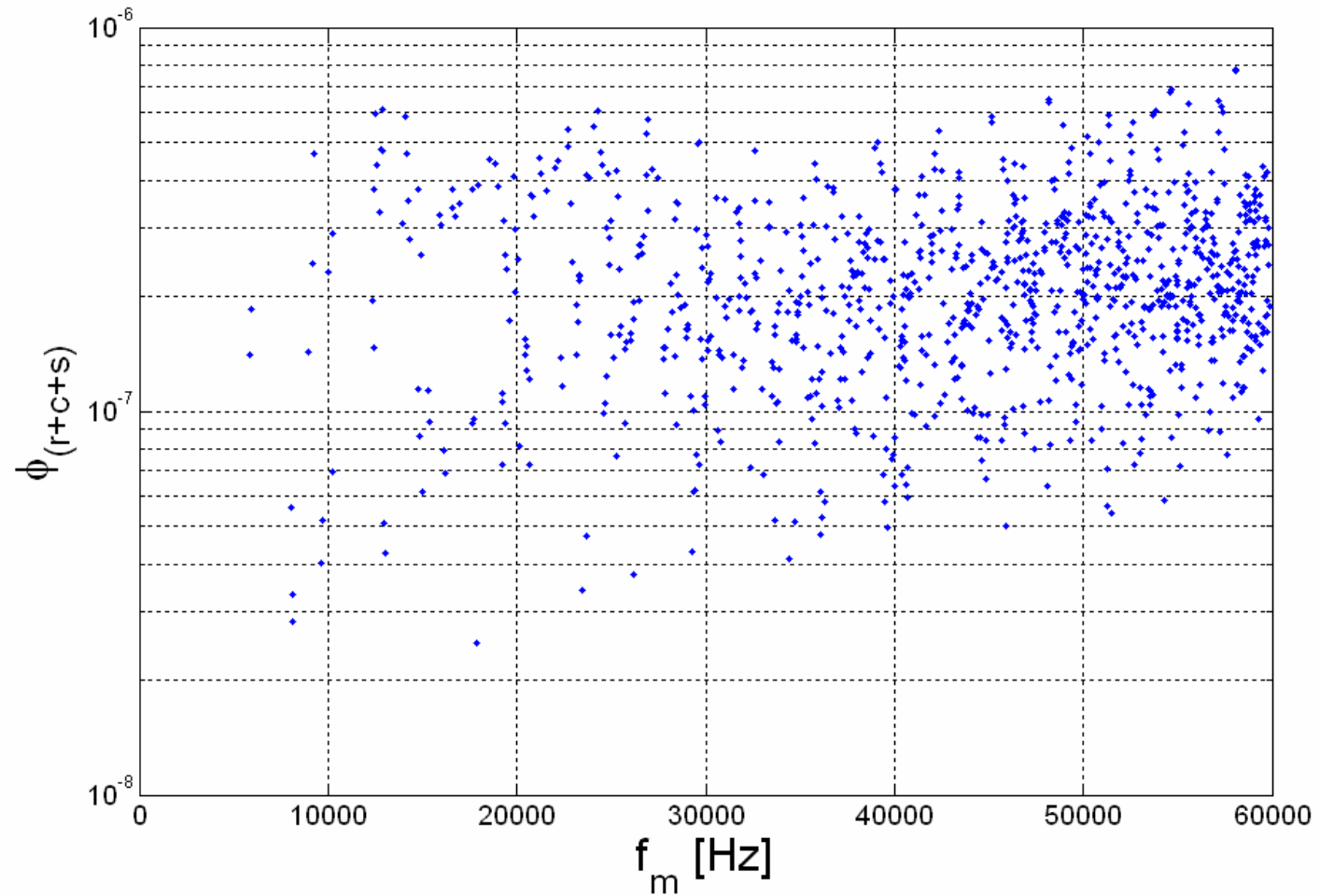
- Number of unstable modes reduced to mostly < 5

ETM optical coating



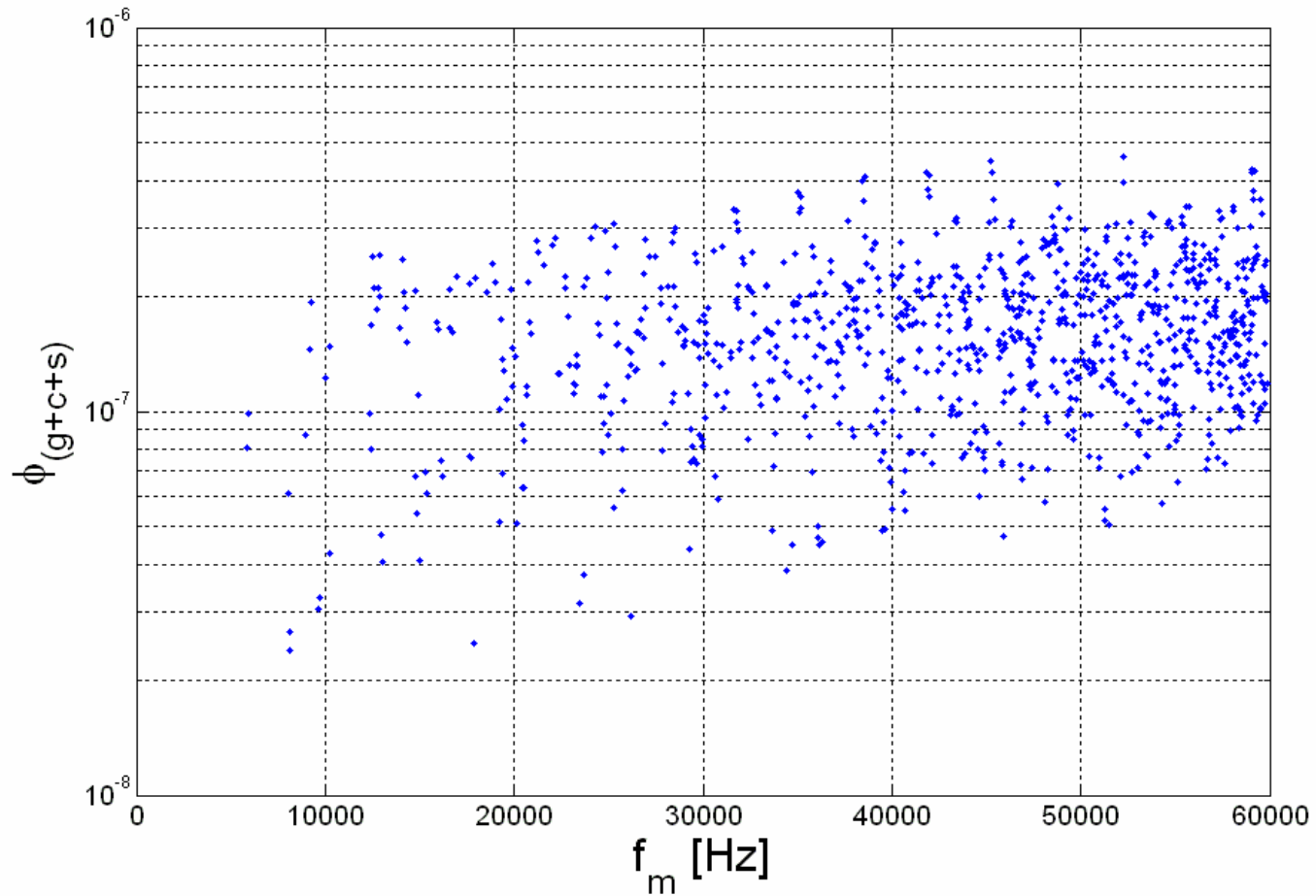
TN = 5.70e-21 (only optical coating)

20 μ m ring damper, $\varphi=5.5e-3$



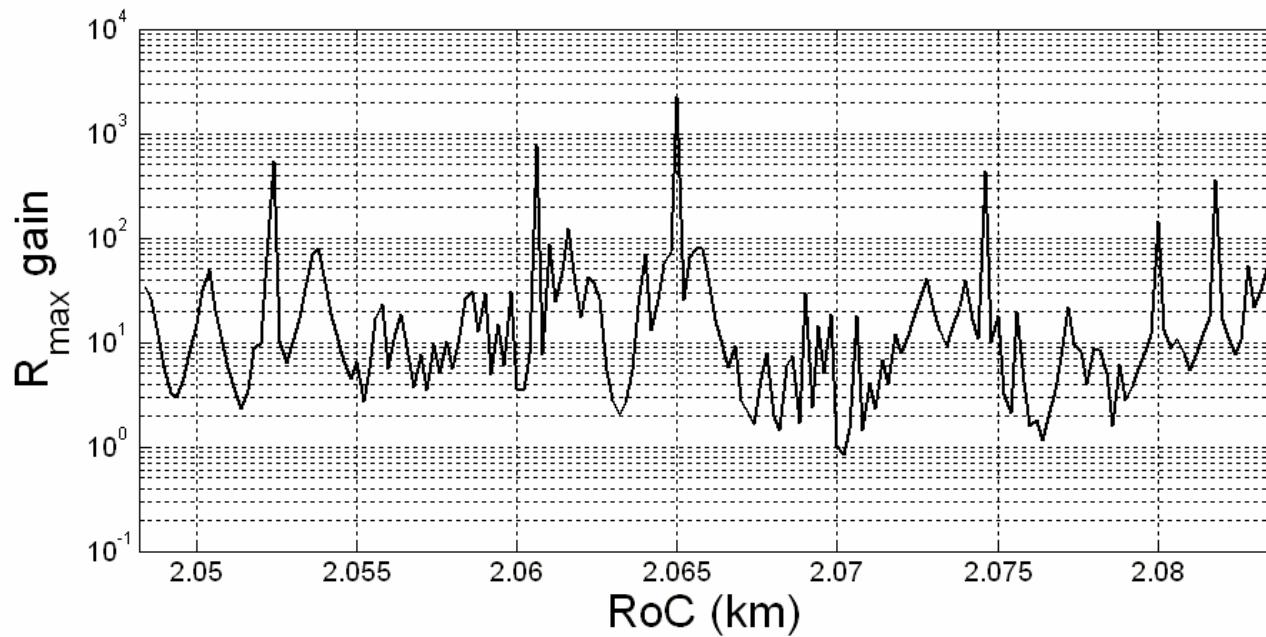
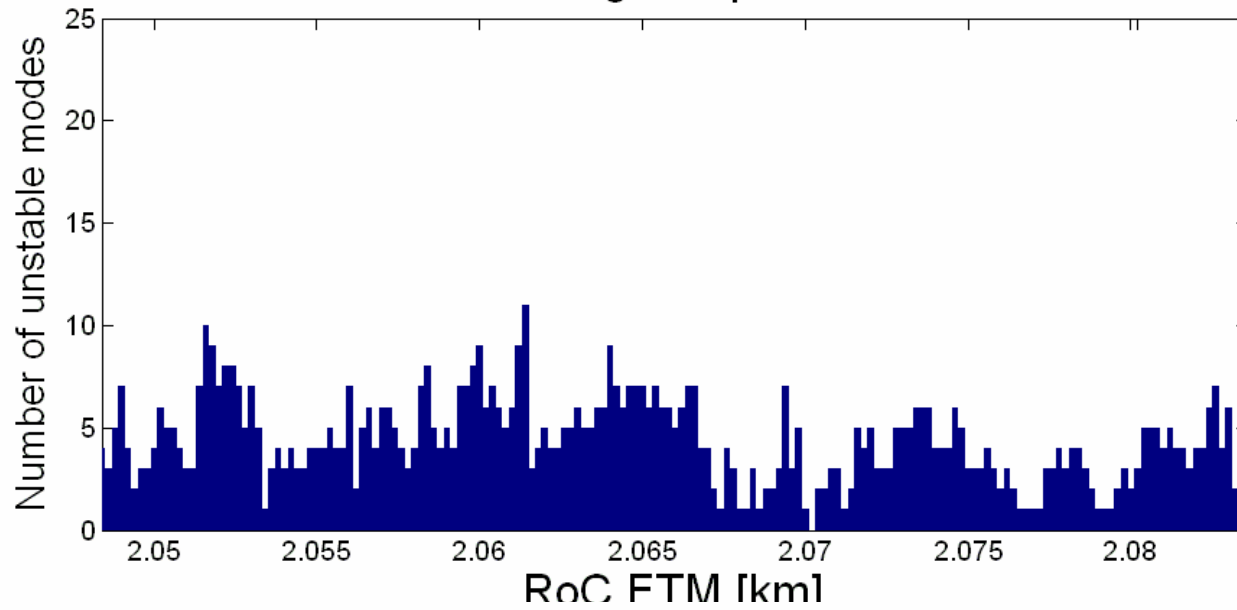
TN = 2.41e-21 (only ring damper)

1 μm barrel gold coating, $\varphi=0.01$

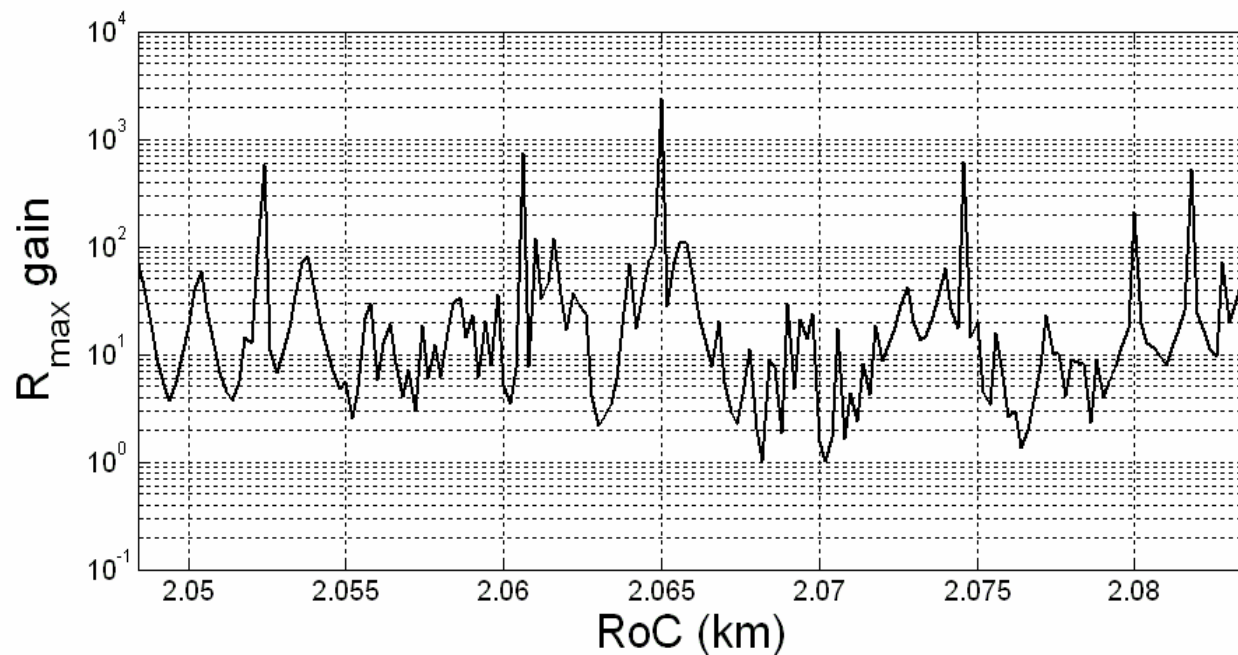
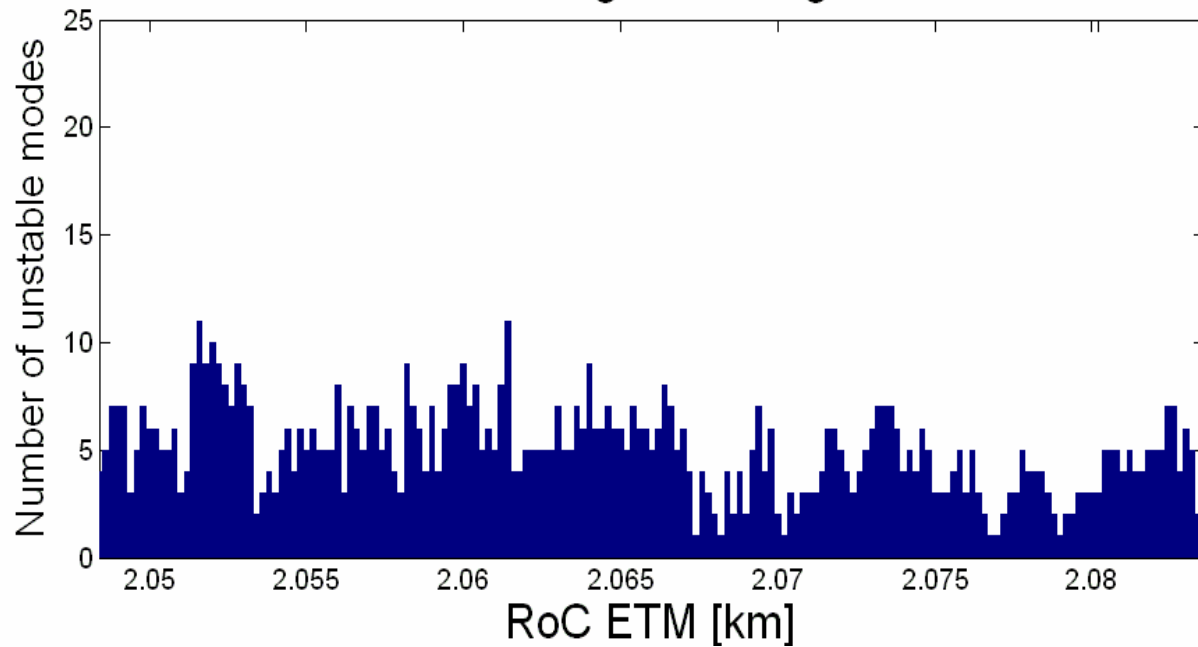


TN = 2.74e-21 (only gold coating)

ring damper



barrel gold coating



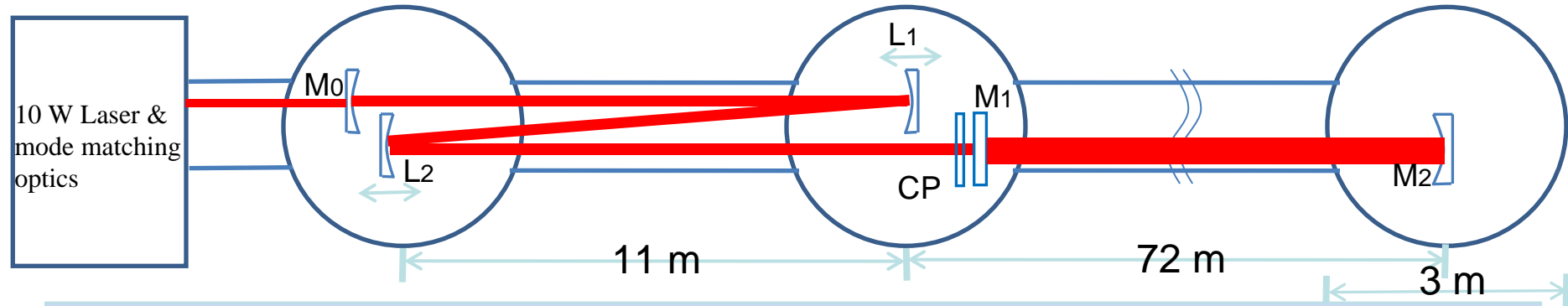
- In best case, a few modes with $R > 1$ per test mass
- Need other control at the same time

Other Control Schemes

- Optical feedback
- Feedback control using electrostatic actuation
- Tune stable recycling cavities

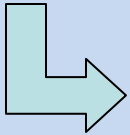
Proposed Gingin Experiment

Configuration using existing vacuum system:



PRC:

- Increase cavity the power and finesse
- Tune the high order mode Guoy phase



- Maximise the Parametric gain
- Study the control schemes
- Study the thermal aberration
- Study the ring damper

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