Mechanical Loss of Vacuum Compatible Epoxies for Tuned Mass Dampers

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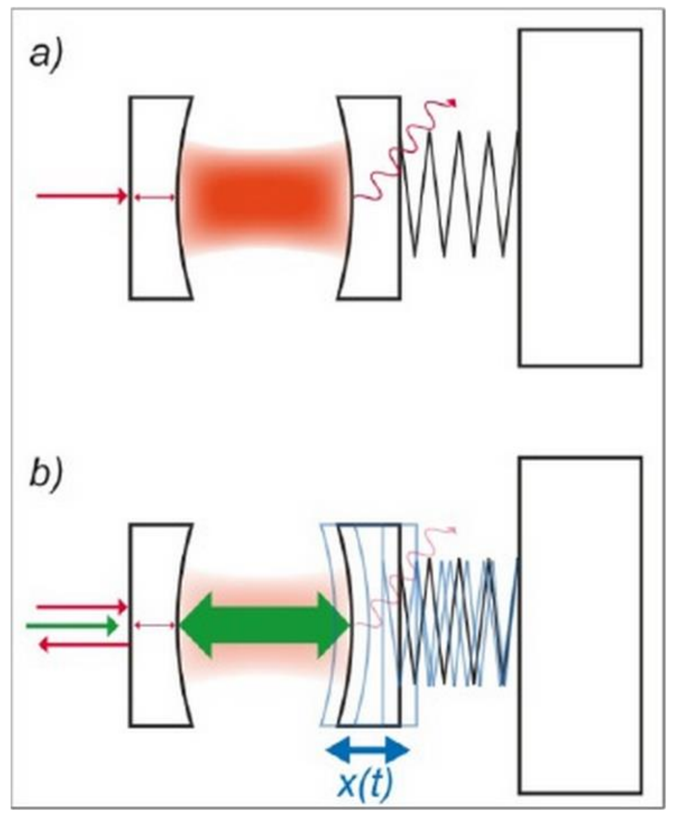
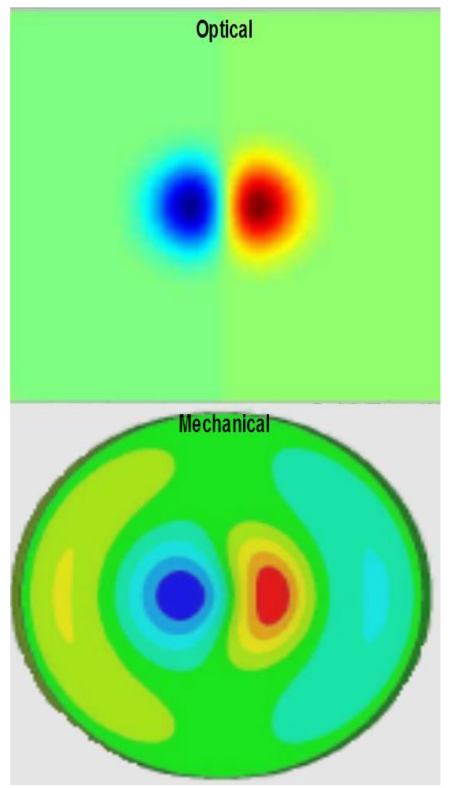
Parametric Instability

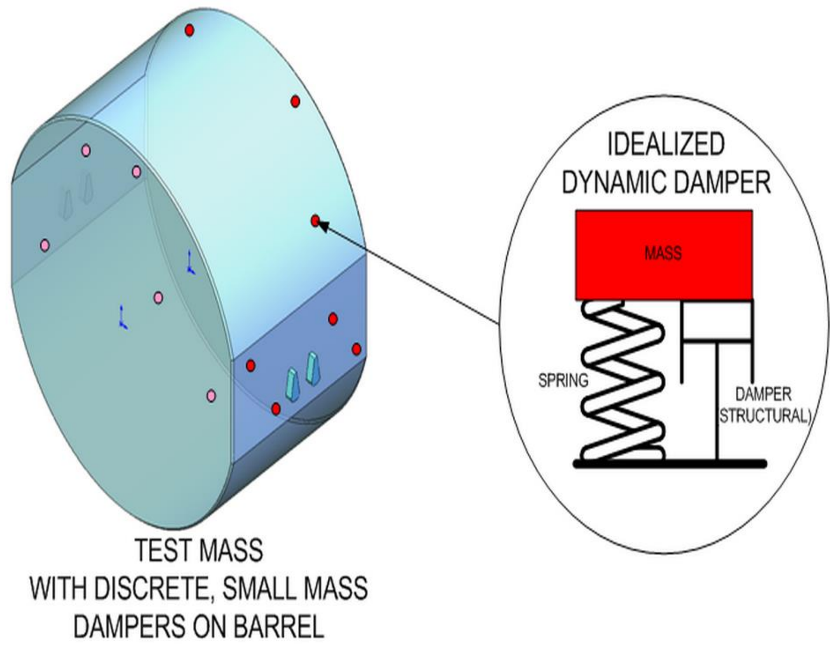
The higher optical power in the Fabry Perot cavities of Advanced LIGO potentially introduces the issue of parametric instability; the exchange of energy between the optical modes of the cavity and the acoustic modes of the mirrors. Energy transfer from the optical cavities to the mirrors could ring up the mirror's elastic modes, increase the rms motion, and potentially lead to control problems and lock loss.

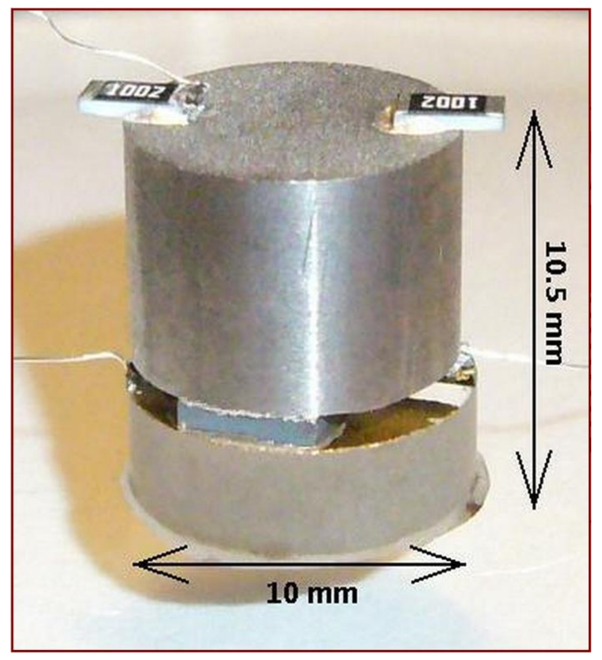




Epoxy Solution

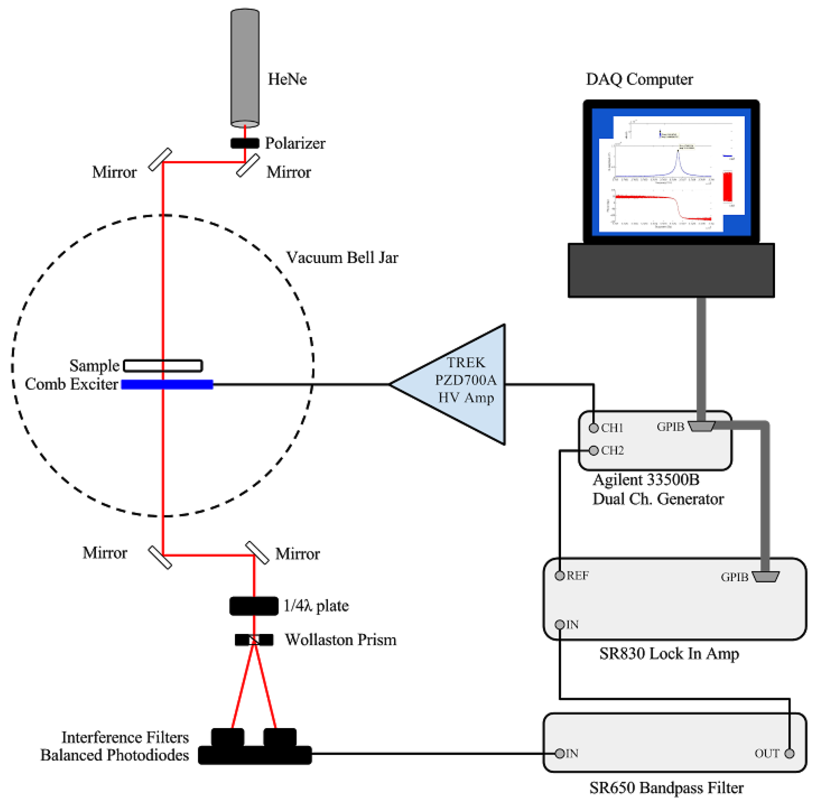
One possible solution is to damp the test mass modes with tuned mass dampers. There is a concern that damping the system would increase mechanical loss and result in higher thermal noise. However, the test mass modes are above 50kHz, while thermal noise is a concern around 100Hz. Parametric instability can be mitigated if a damping device that damps higher frequencies more than lower frequencies can be created. Because these dampers must be retrofitted onto the aLIGO mirrors, silicate bonding is not possible. At American University, we are measuring the mechanical loss of different epoxies in order to find a suitable candidate for attaching these dampers to the test masses.

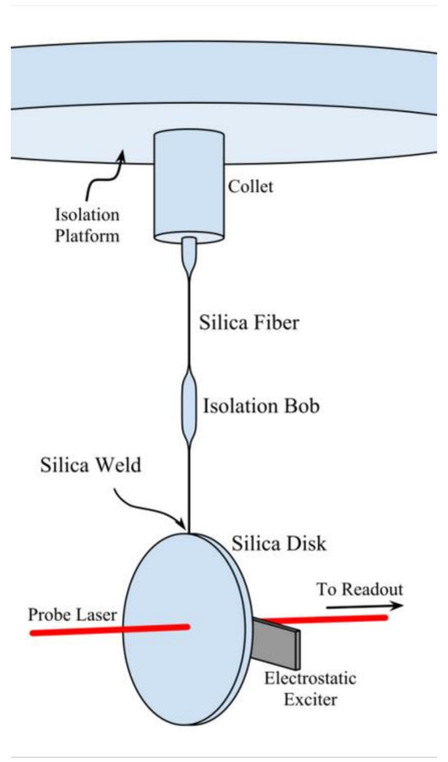




Technique

We find the modal Qs of different silica disks with different epoxies between the disks and a thin top wafer of silica. The position of the epoxies on the silica disks is determined via Finite Element Modeling (FEA).





Epoxies in Progress

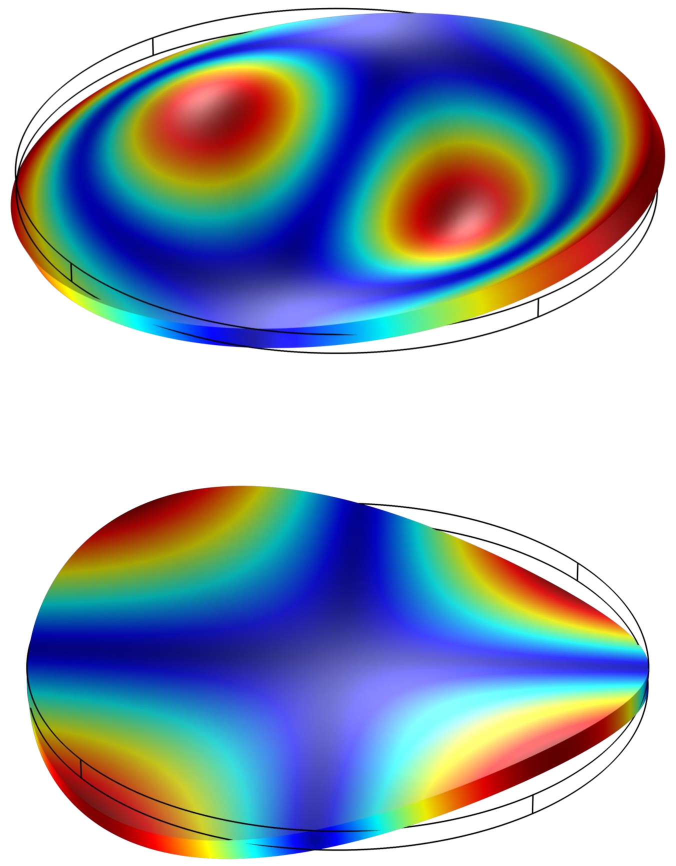
Name	Frequency	Quality Factor
Hysol EA 9313	2692 Hz	4.5x10^5
(centered)	6114 Hz	1.2x10^6
	6115 Hz	1.1x10^6
	9370 Hz	1.2x10^6
EP1730	2683 Hz	35,000
(off center)	4077 Hz	300
	9367 Hz	14,000

Current Status

An epoxy has not been chosen yet. With relatively high ϕs, Hysol Tra-Duct and Masterbond will likely be ruled out. Optocast and Epotek potentially have low enough thermal noise to be used.

Interpretation into Mechanical Loss

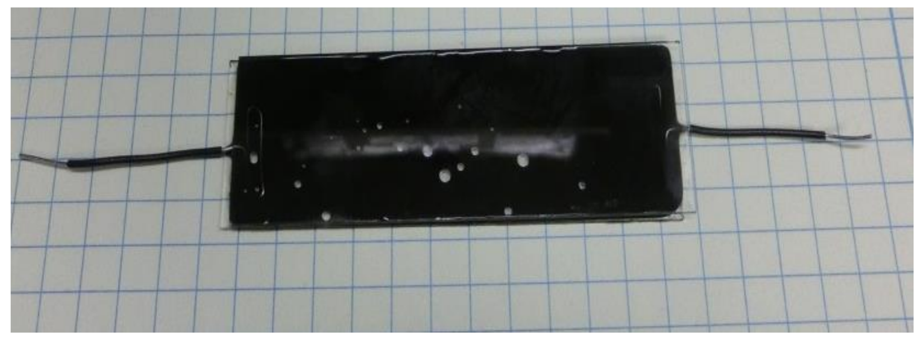
After obtaining the Qs of the silica disk with epoxy on them, we use the FEA program COMSOL to obtain our mechanical loss phis. The program takes into account the properties of the silica disk and wafer, the Young's modulus of the epoxy, the Qs of the different frequencies, and the bulk and shear properties to determine the phi. This is an ongoing progress, as we still need to find the thicknesses, Young's moduli and related parameters to some of the epoxies.



Epoxies analyzed with FEA

Name	Thickness	Young's Modulus	Viscosity	ϕ
Hysol Tra-Duct 2902	47 µm	4.8 Gpa	20 Pa s	$0.05 \leq \phi \leq 0.1$
EMI Optocast 3553LV	10 µm	3.4 Gpa	.5 Pa s	$0.01 \leq \phi \leq 0.05$
Masterbond EP30	10 µm	2.9 Gpa	.02 Pa s	$0.02 \leq \phi \leq 0.14$
Epotek 353ND	10 µm	3.7 Gpa	12.5 Pa s	$\phi \approx 0.03$

Future plans with Epotek 353ND



We are adding carbon to EpoTek in an attempt to make it conductive, and then re-test the new mixture for mechanical loss.