Overview of Research in the Optics Working Group

Gregory Harry, on behalf of the OWG
Massachusetts Institute of Technology

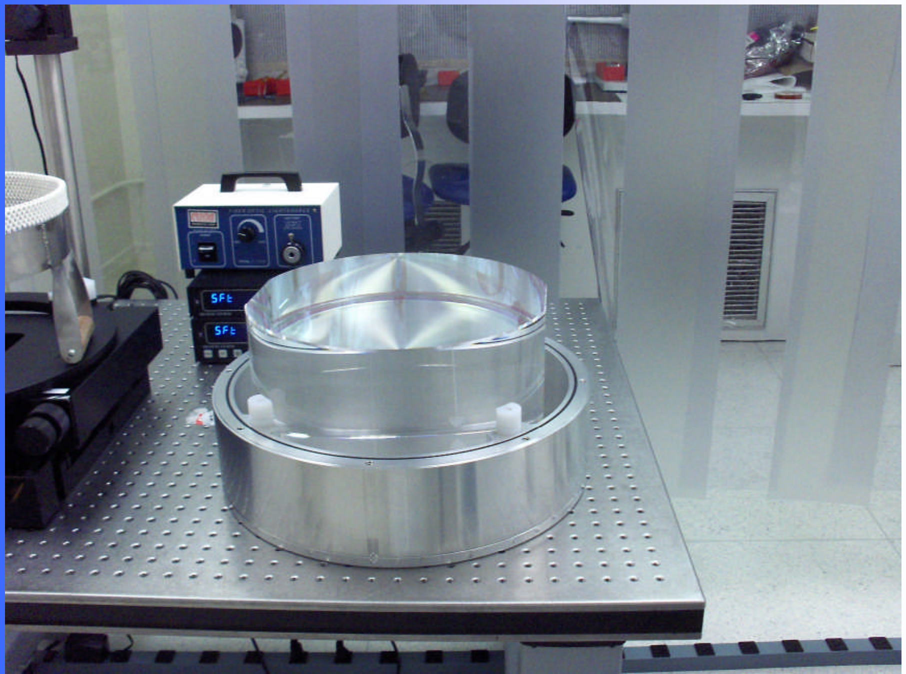
July 25, 2007
LSC Meeting – MIT

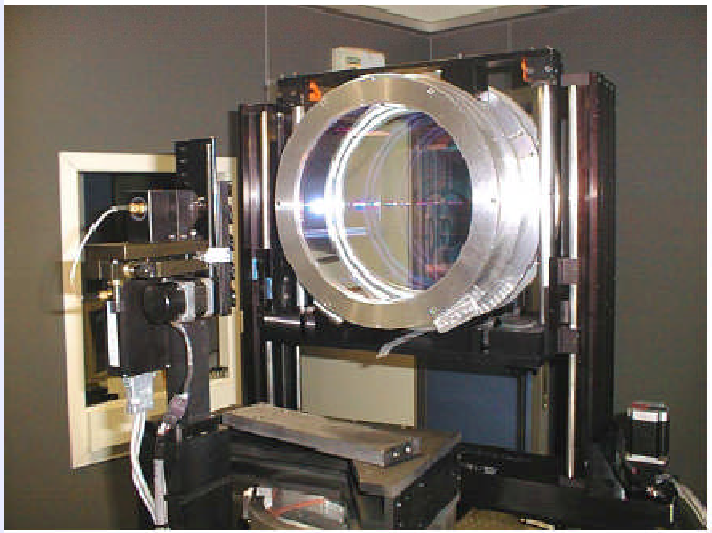
G070529-00-R

Outline

- LASTI Optic
- Coating Research
  - Mechanical loss mechanism at Glasgow
  - dn/dT at ERAU
  - Silica mechanical loss at HWS
  - Absorption at Stanford
- Auxiliary Optics
  - Mechanical loss of gold coating
  - Ring heater development
- Input Optics
- Gingin
  - 3 mode opto-acoustic parametric interaction

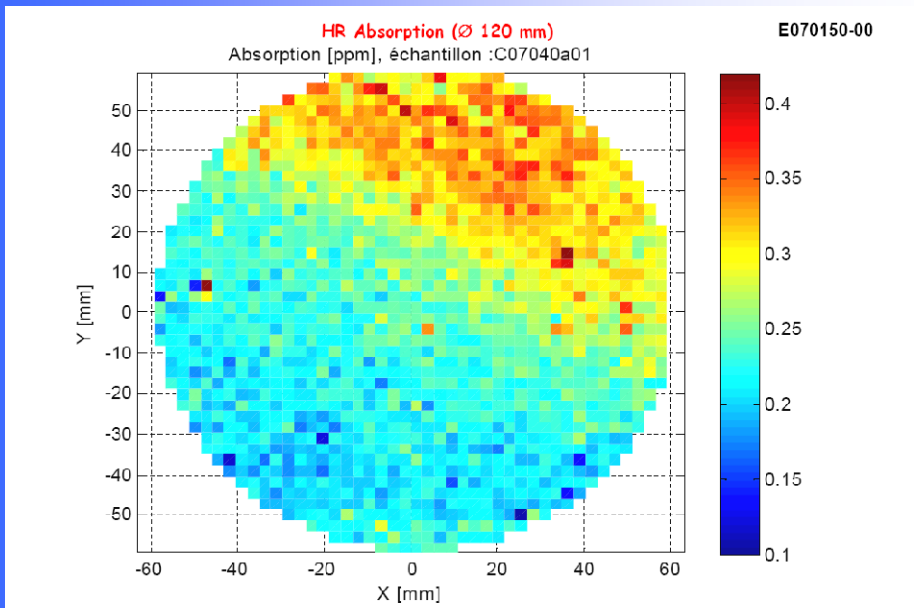
LASTI Optic



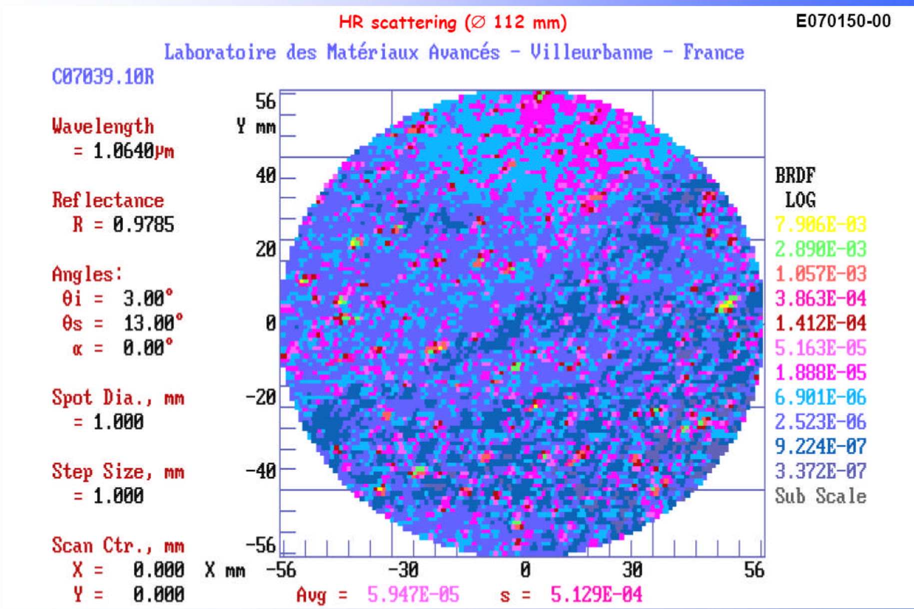


LASTI Optic Characterization

	Adv LIGO Req	LMA Measurement	CIT Measurement
Roughness	< 2 Å	1.03 Å	
Transmission	< 20 ppm	10.7 ppm	
Absorption	< 0.5 ppm	0.26 ppm	0.3 ppm
Scatter	< 15 ppm	24 ppm	15 ppm
		(but better closer to center)	(near center)



Absorption Map of LASTI Optic



Scatter Map of LASTI Optic

Coating Project

LIGO All-Hands Meeting, Jay Marx singled out coating research among all hardware (and software) projects as important in the coming five years.

NSF Review Panel stated that coating research needs to continue during Advanced LIGO construction and commissioning

Plan being developed within LIGO Lab to devote significantly more resources to coating research and development

Titania-doped tantala/silica samples distributed here at LSC for development work

Absorption measured - all meet 0.5 ppm spec, some < 0.3 ppm
Structure and impurities - X ray diffraction measurements
Effect of UV, high power
Charge buildup and time constant
dn/dT

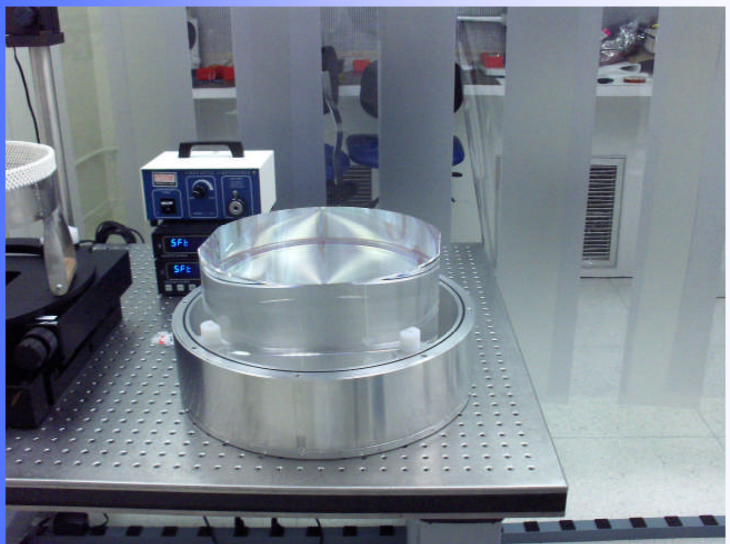
Coating Runs

CSIRO Coating Runs

- Gold Coating for Q tests
- Silica-Titania/Silica, 50% Silica
- Titania-Tantala/Silica, 40% Titania
- Titania-Tantala/Silica, 20% Titania

LMA Coating Runs

- LASTI Optic, Titania-Tantala/Silica
  - Layer thicknesses not optimized
- TNI Mirrors, Titania-Tantala/Silica
  - Layers optimized for minimum noise
- Silicon diving boards with Titania-Tantala/Silica



LASTI Optic at LMA

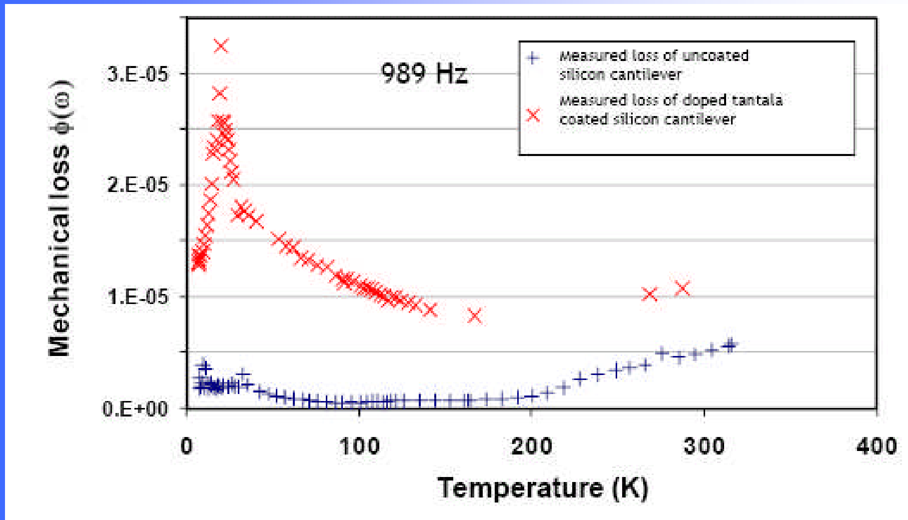
Coated Silicon Cantilever

Coating Loss vs Temperature at Glasgow

- Silicon loss decreases as temperature drops (unlike silica)
- Cantilevers etched from silicon wafers (by collaborators at Stanford)
- Thin sample allows coating mechanical loss to dominate
- Thick block at end is left for clamping
- Single layers coatings deposited by LMA

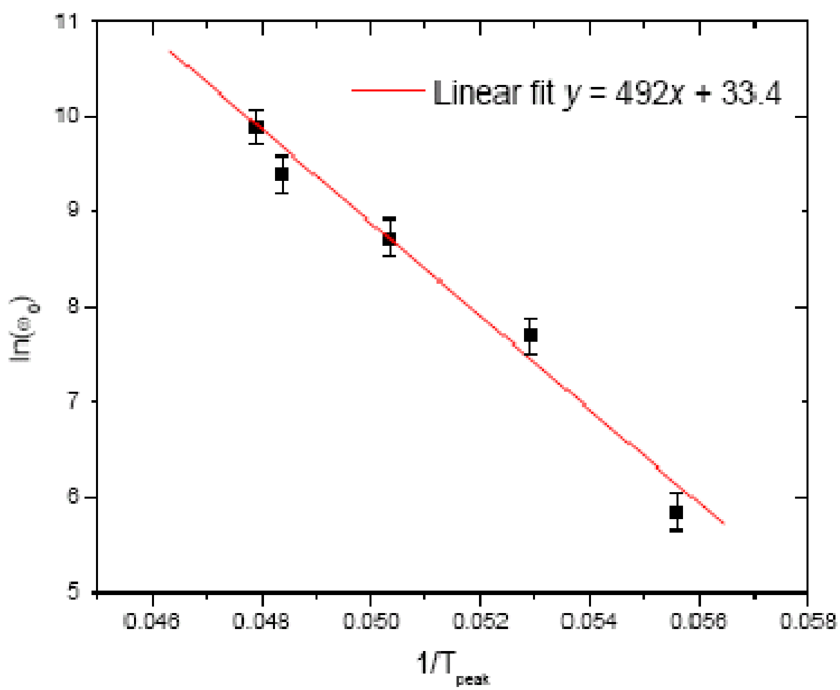
Coating Loss vs Temperature at Glasgow

Mechanical loss vs Temperature
Coated and Uncoated



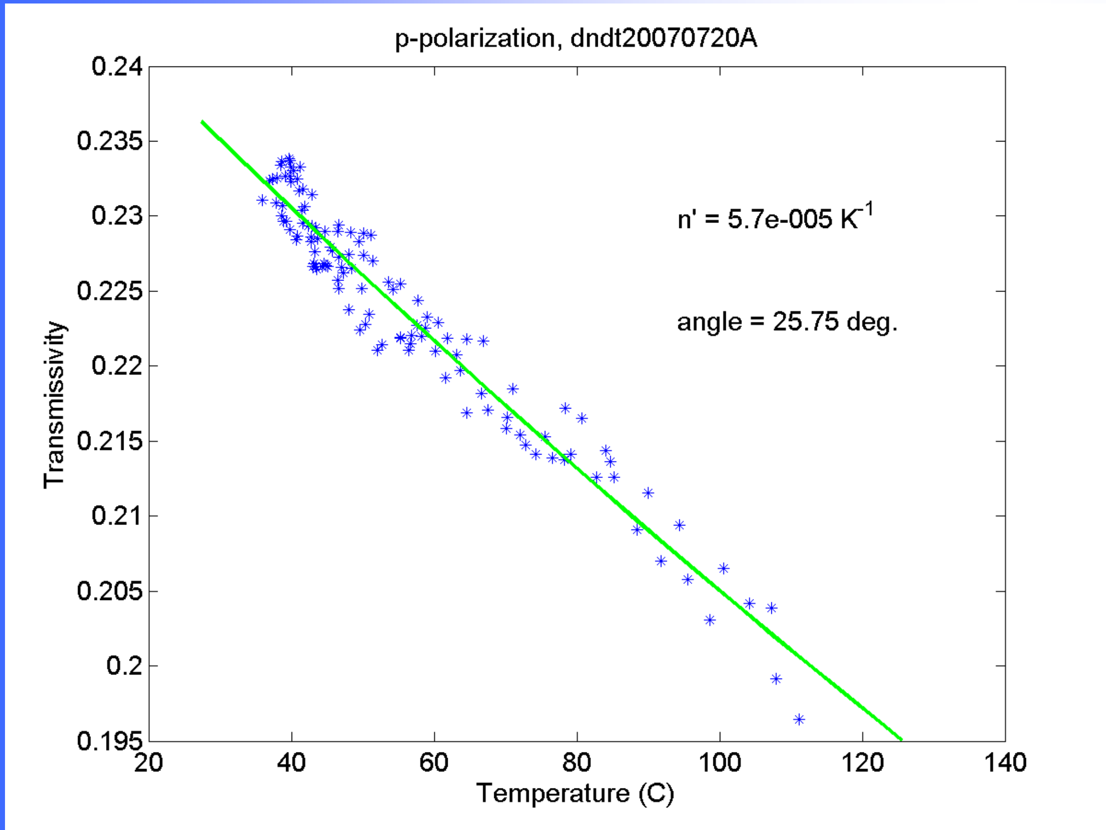
- Clear indication of added loss from coating
- Dissipation peak at about 19 K
  - Seen in all modes
  - 56 Hz - 1920 Hz

- Mechanical loss vs temperature and frequency
- Calculate activation energy of loss mechanism
- 42 +/- 2 meV

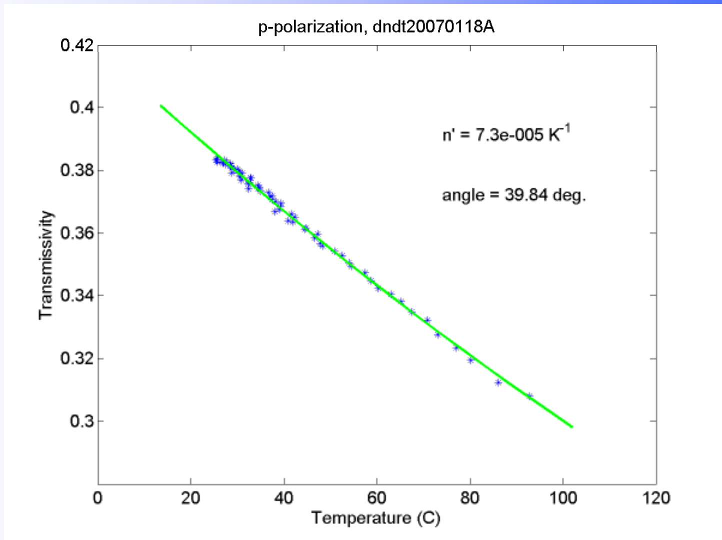


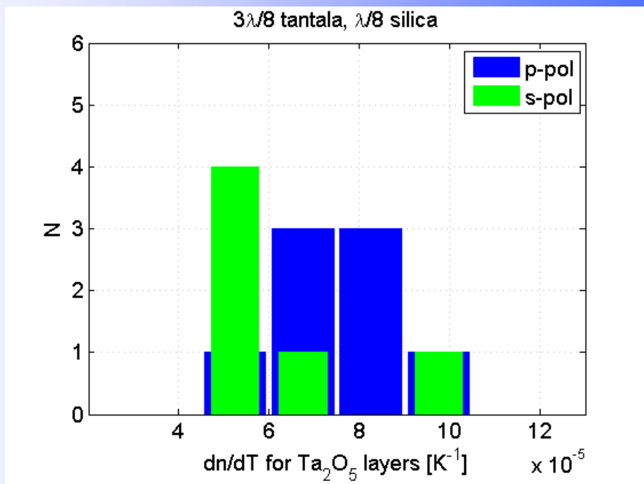
dn/dT Measurements at ERAU

1/8 Tantala - 3/8 Silica



3/8 Tantala - 1/8 Silica

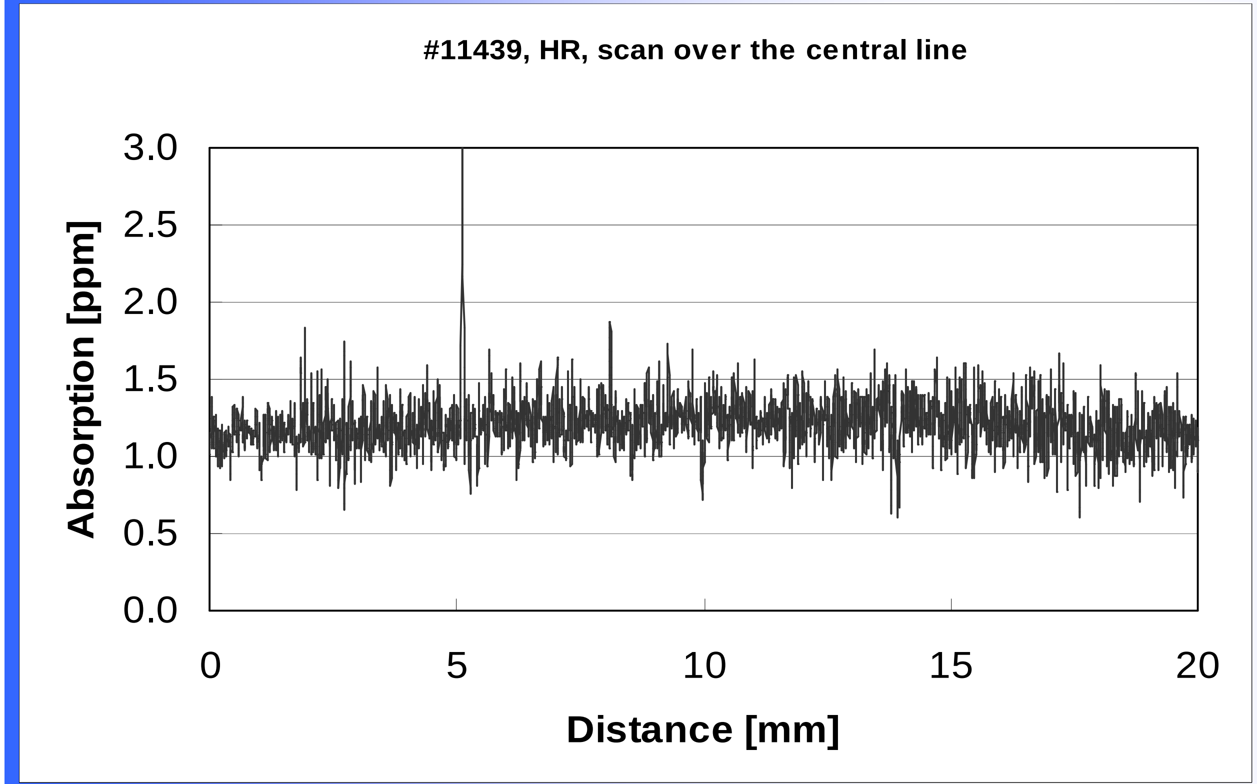


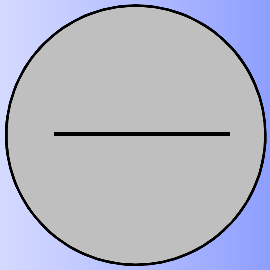


- Consistent with previous measurements with more tantala
- Still rather high spread
- Planning to do at 1.064 μm with titania-doped tantala/silica very soon

Coating Absorption Work at Stanford

- 40% TiO_2 - Ta_2O_5/SiO_2 CSIRO sample
- $\alpha_{average}$ = 1.25 ppm (layers not optimized for absorption)



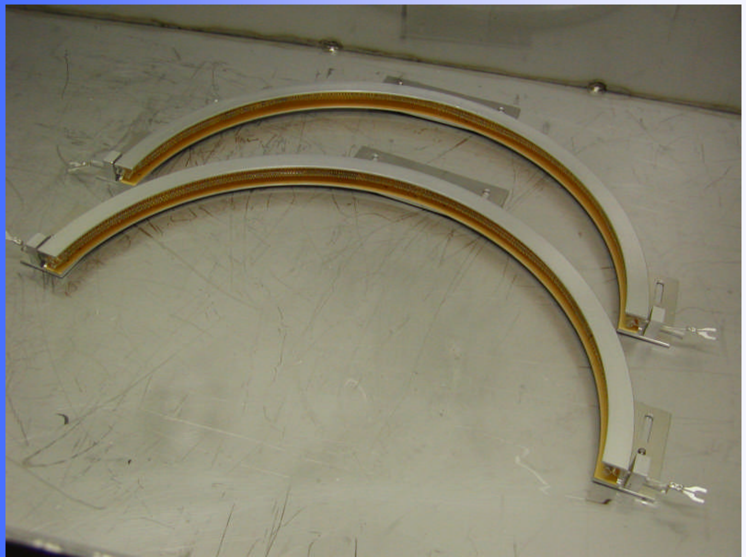


Transversal scan over the surface along the central line (20 mm length)

Also continuing work on sapphire absorption

Auxiliary Optics
Ring Heater

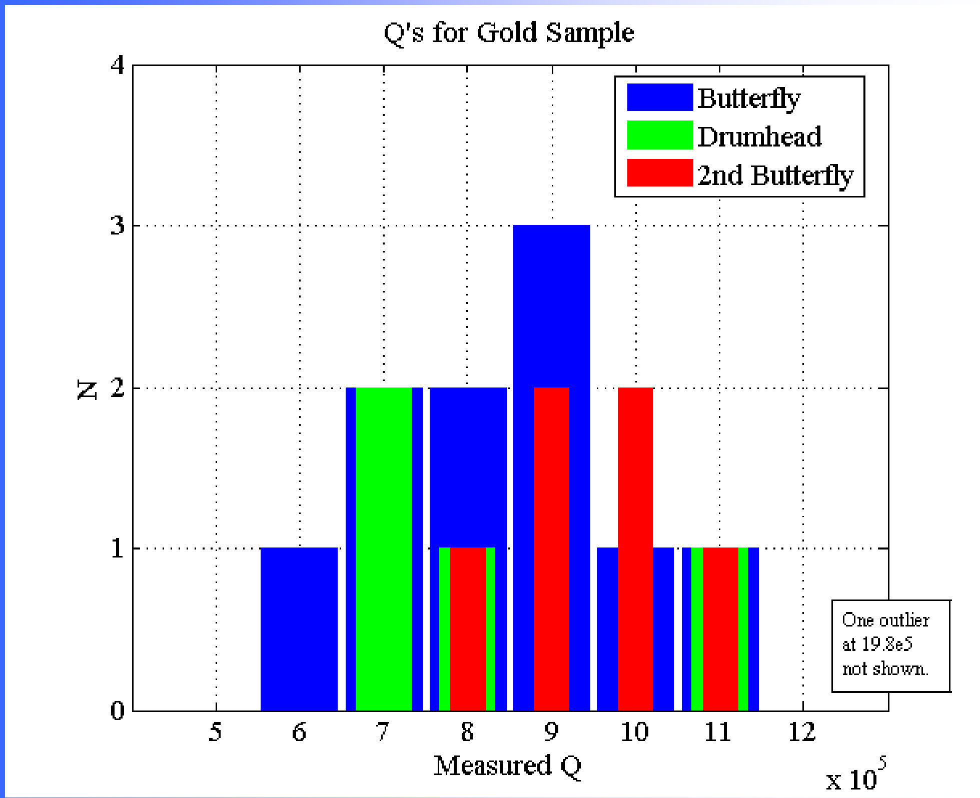
Advanced LIGO Ring Heater



- Preliminary design prototype of Advanced LIGO ring heater complete
- For Advanced LIGO thermal compensation
  - Also considering adding gold coating to core optics' barrel

- Advanced LIGO photon calibrator has passed conceptual design review
  - In preliminary design phase

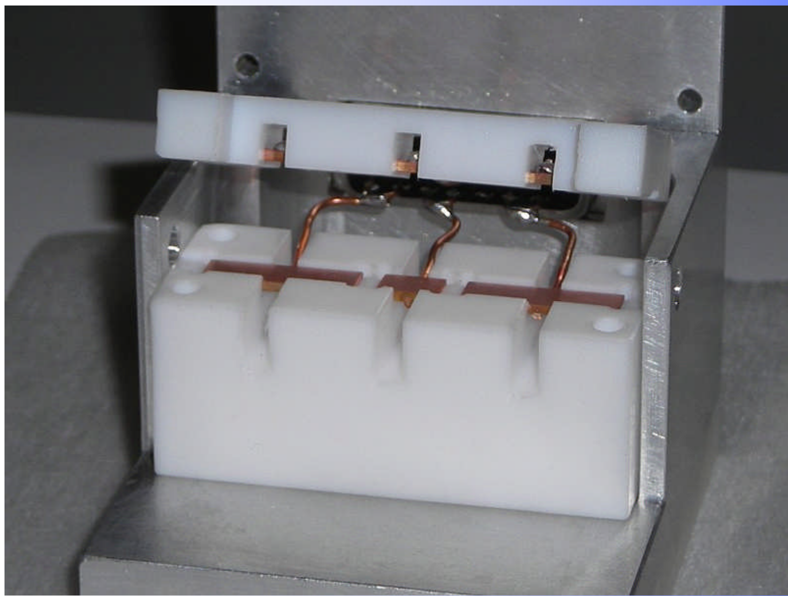
Mechanical Loss of Gold Coating at ERAU

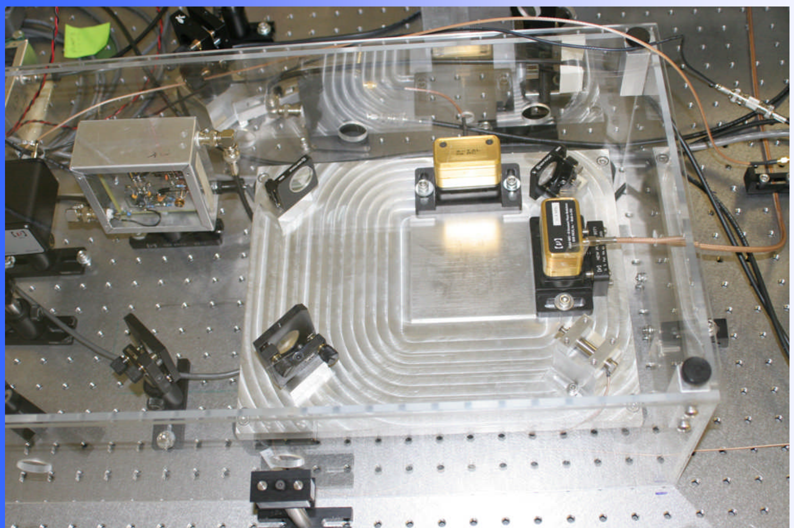


- 100 nm thick coating
- ϕ_{gold} = 9.1 +/- 0.1 X 10^{-3}
- Unclear why such large spread (Gain drift in readout?)
  - MZ has one path through welded area of glass
  - MZ has one path through curved part of viewport
- Will examine the effects on thermal noise, parametric instability, and charging
  - FEA code by Dennis Coyne for TN and PI
  - Can not use analytical code that assumes free boundary conditions on barrel

Input Optics

- Enhanced LIGO electro-optic modulator
    - Single crystal
    - Three separate electrodes
    - Three modulation frequencies



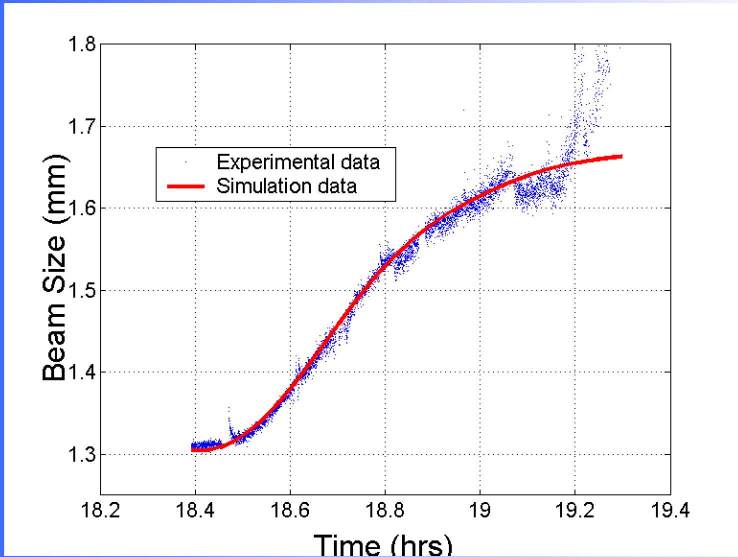


- Advanced LIGO modulation
- Mach-Zehnder Modulator
    - Avoids sidebands on sidebands

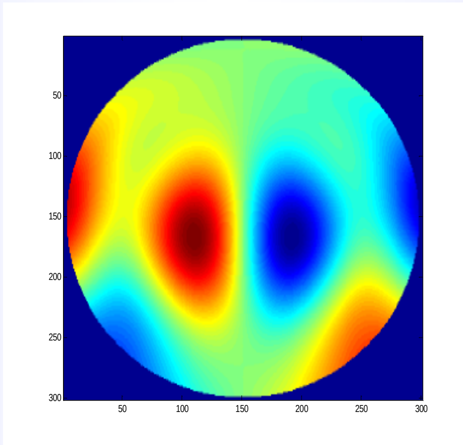
Gingin

Observation of 3-mode Opto-acoustic Parametric Interaction

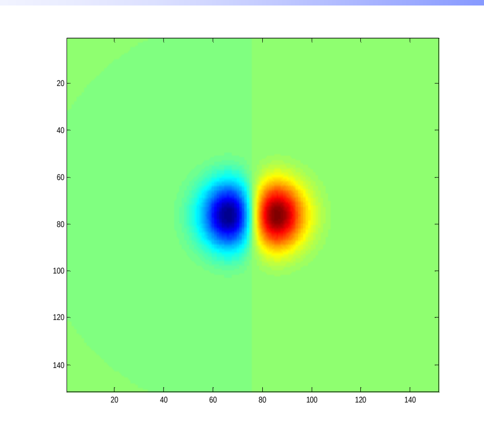
- Acoustic mode excited electrostatically
- Observe higher order optical mode as frequency is thermally tuned



Thermal Tuning of High Order Optical Frequencies

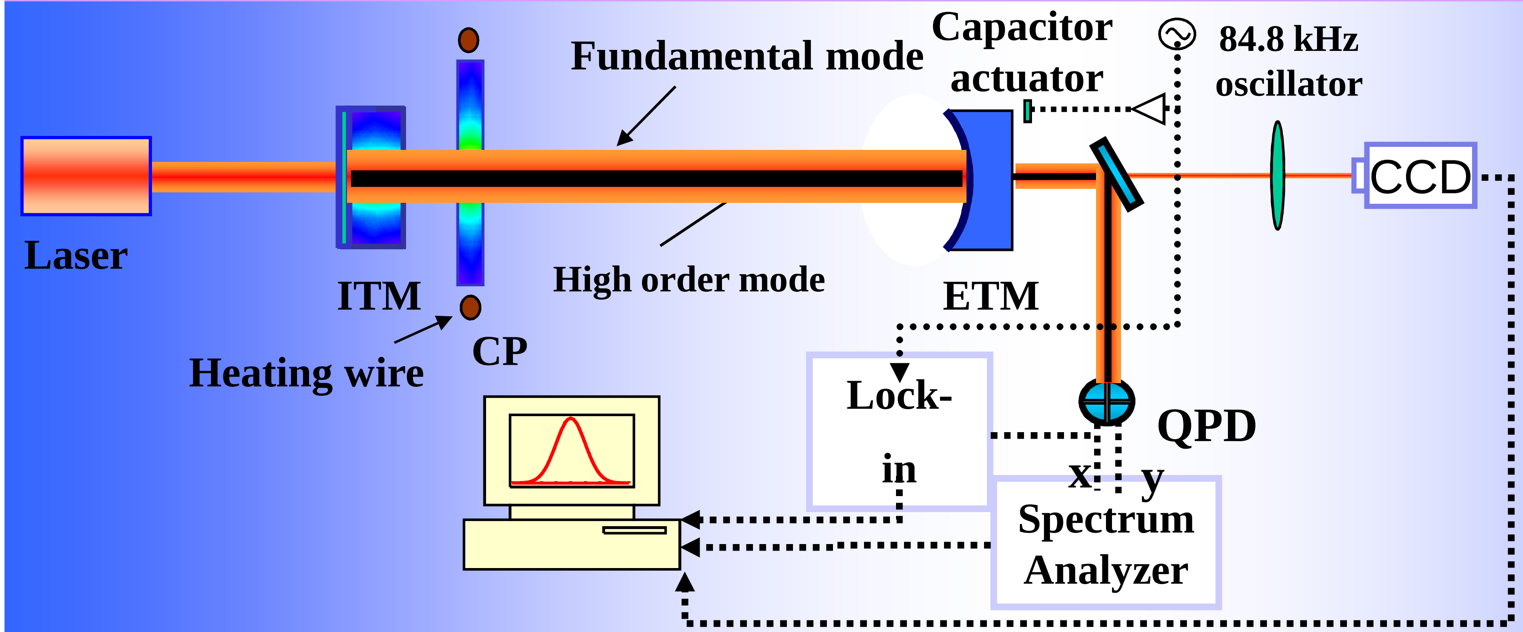


Mechanical Mode 84.8 kHz



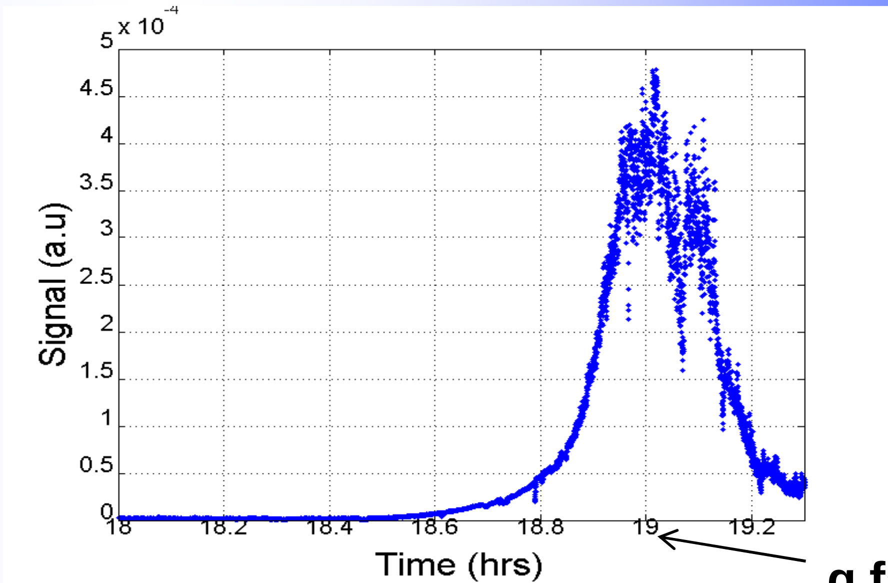
First Order Optical Mode

Gingin



Experimental Setup

Amplitude of optical modes beating signal at 84.8 kHz vs. time of heating (RoC change)



g factor ~ 0.98

Steve's Slide