



LIGO and Industry

Capability/Product	Company
Ultra-high Vacuum Technology	CB&I
Passive Seismic Isolation	Hytec Inc.
Active Seismic Isolation	Barry Controls, TMC Inc.
Precision Optical Polish	CSIRO, WP, Goodrich
Precision Optical Metrology	Veeco
Large, Low Absorption Sapphire	CSI
High performance optical coatings	REO, MLD, SMA/Lyon
Highly Stable Infrared Laser	LWE
Low Noise Analog to Digital Converter	FDI



Ultra-High Vacuum (UHV)

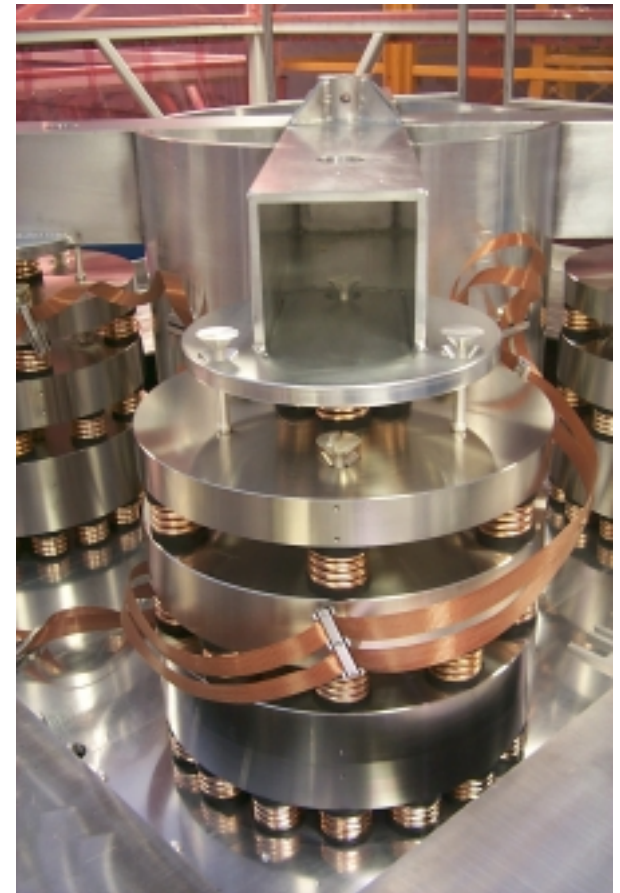
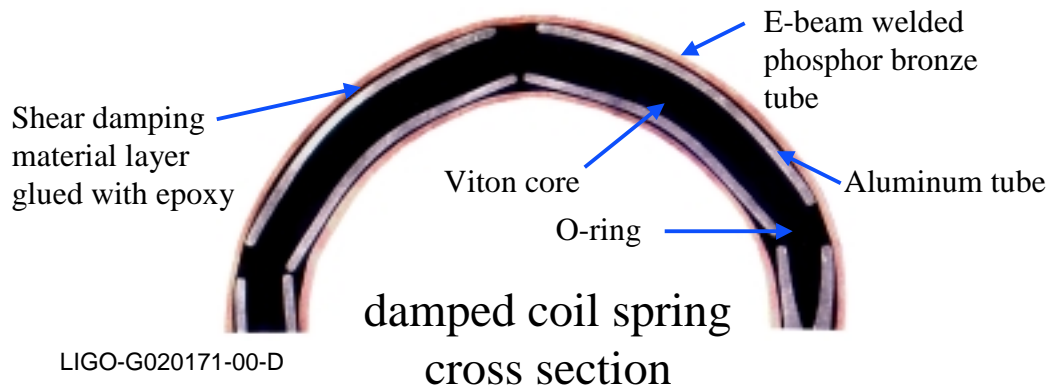
- Vacuum system research developed in LIGO laboratories transferred to Chicago Bridge and Iron Co.
 - » The development of economical low outgassing stainless steel
 - » Low outgassing and reliable welding techniques
 - » Low cost environmentally friendly cleaning techniques and test methods
 - » Low cost techniques to search for leaks in large vacuum systems.





Passive Seismic Isolation Stack

- Enabling isolation R&D performed within LIGO
- Stack designs and prototype development transferred to Hytech Inc., a Los Alamos, NM based design/engineering Co.
 - » Low creep and high isolation factor designs above 10 Hz
 - » High frequency parasitic modes of the internal stack members to not compromise isolation
 - » Vacuum compatible design
 - » Design is being considered by other projects



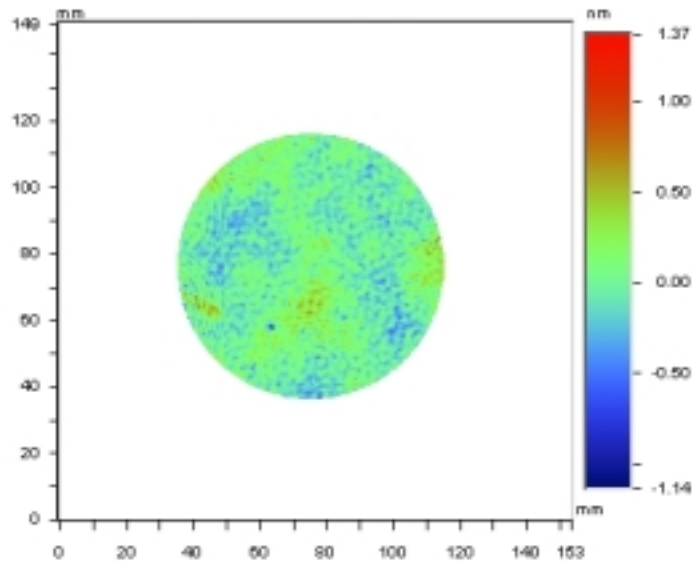
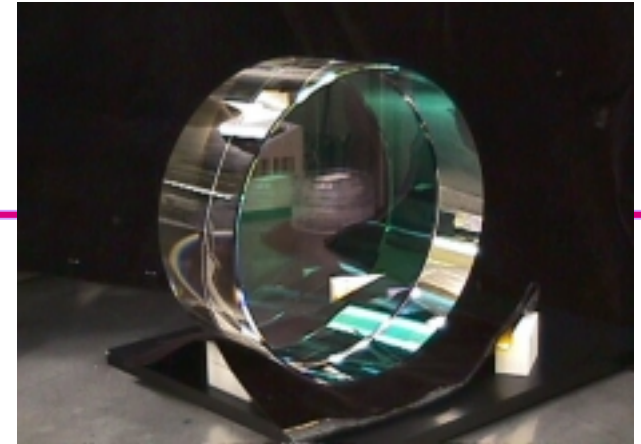
Active Seismic Isolation

- LIGO helped Barry Controls improve on their 6 degree-of-freedom, active isolation systems by evaluating pre-production units in the MIT/PNI experiment
 - » ~30x reduction in rms motion in the 1-30 Hz band
- Stacis units are now sold commercially by TMC Inc.
 - » Installed in the 40m Experiment





Precision Polishing



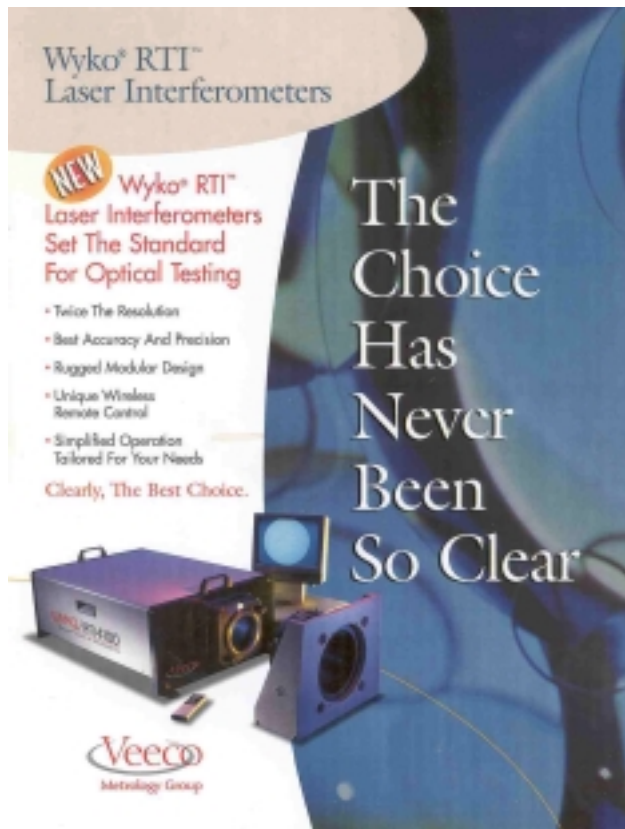
Date: 10/16/2000
Time: 16:25:23
Wavelength: 1.064 um
Pupil: 100.0 %
PV: 2.5067 nm
RMS: 0.1639 nm

X Center: 283.00
Y Center: 244.00
Radius: 150.00 pix
Terms: Tilt Power Astig
Filters: None
Masks: Analysis Mask

- Polished Fused Silica
 - » CSIRO (Australia): 0.16 nm rms/80mm = $\lambda/6500$ at 1064nm
 - » Wave Precision (formerly General Optics) and Goodrich (formerly Hughes/Danbury): $\lambda/1500$
- Sapphire Inhomogeneity compensation:
 - » Exploring ion beam etch: CSIRO
 - » Computer controlled polishing: Goodrich
- Demonstrated sapphire surface polish to 0.6 nm rms/80mm:
 - » CSIRO



Precision Surface Metrology



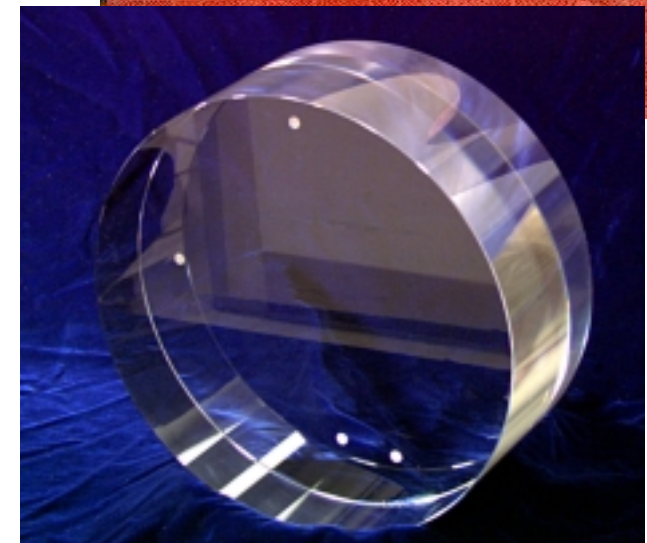
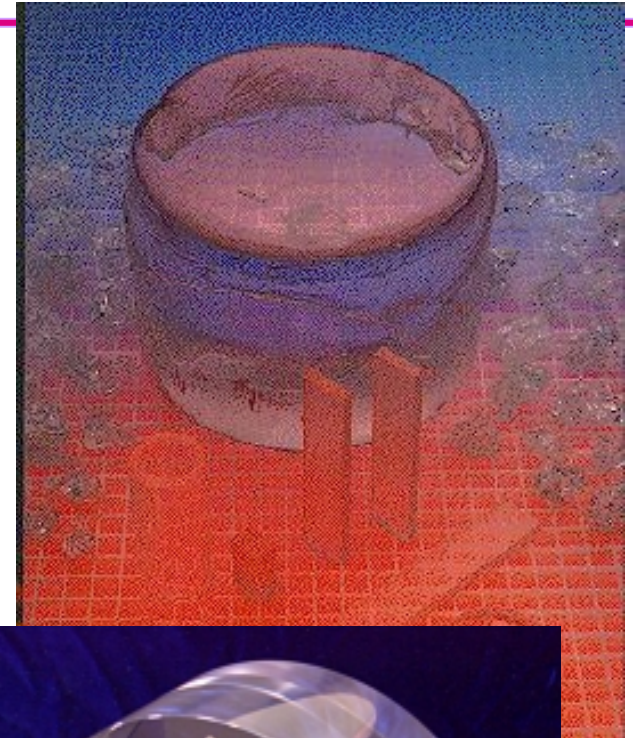
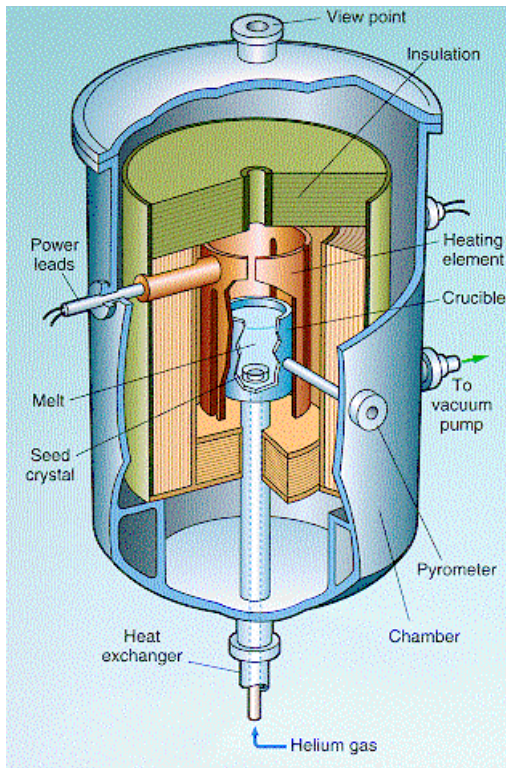
- Veeco Metrology Group

- Features from a Custom Fizeau Interferometer made for LIGO are now incorporated in the new RTI interferometer
- Optical surfaces measured with repeatability of $<0.2\text{nm rms}$

Large Sapphire Optics

- Crystal Systems

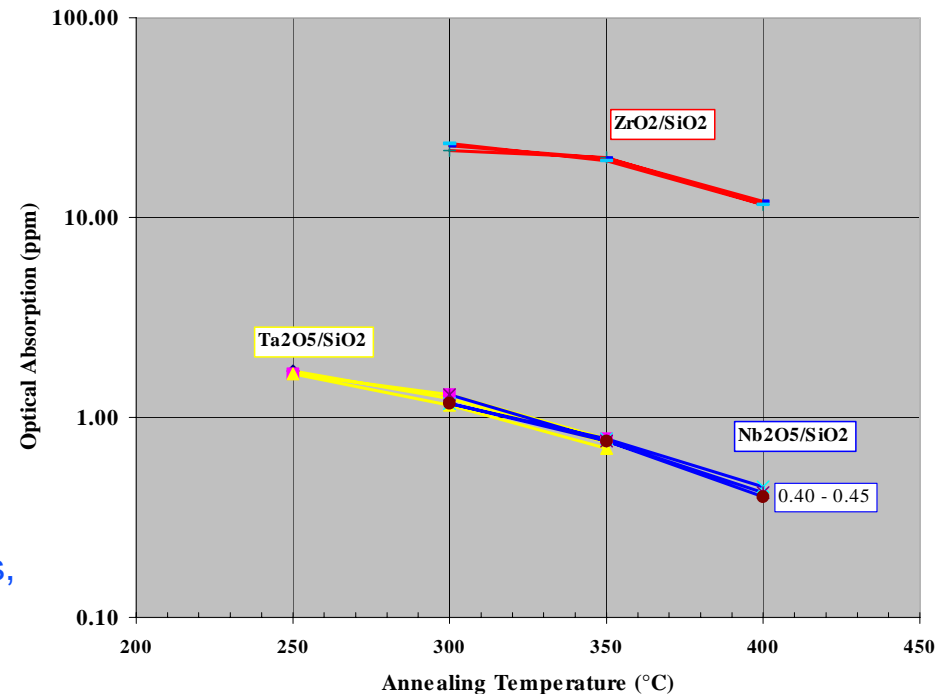
- Heat exchanger growth method
- Optical Quality Sapphire
- 380 mm Boule grown in LIGO supplied crucible
- Program to lower absorption at 1064 nm to ~10ppm/cm





High Performance Optical Coatings

- REO (Colorado) produced all of the coatings for the Initial LIGO Core Optics
 - » Low absorption (< 5ppm) and low scattering coatings over 10 cm.
 - » Improved their yield for smaller telecommunications products
- Sub-ppm losses (~0.5 ppm) observed in coatings from both MLD (Oregon) and from SMA (Lyon, France)
 - » Metrology performed by the LIGO Scientific Collaboration
 - » Meets Adv LIGO Requirements with an active thermal compensation system
 - » If we can achieve ~0.2 ppm (sapphire) or ~0.05 ppm (fused silica), & achieve our in-depth absorption goals, then an active thermal compensation may not be needed
- MLD is pursuing a series of coating runs targeting optical losses
 - » Spinoff of fathers of the field of low-loss coatings
 - » Could modify for Adv LIGO-sized substrates, not trivial





Highly Stable Infrared Laser

- LIGO contracted Lightwave Electronics, Inc. for a 10-W single-mode, single-frequency Nd:YAG laser
 - » Frequency and amplitude stability of Lightwave's NPRO line of lasers with a factor of 15-fold increase in output power
 - » Added to product line as the Lightwave 6000 laser
- Follow-on contract for further enhancements:
 - » development of a new optical technique, which involves the use of a nonlinear optical parametric oscillator, for which Lightwave has filed a patent
 - » offers broadband suppression of intensity noise of 20-30 dB over the frequency range DC to -1 MHz



Power Stability	< 1% RIN pk-pk, < 24 hrs. < 1% RIN rms, 1 Hz – 3 MHz < -163 dB/Hz, > 10MHz (2dB of shot noise limit for 10mA of photodetected current)
Frequency Stability	< 50MHz / hr, < 1GHz / month Linewidth < 5 kHz over 1 msec