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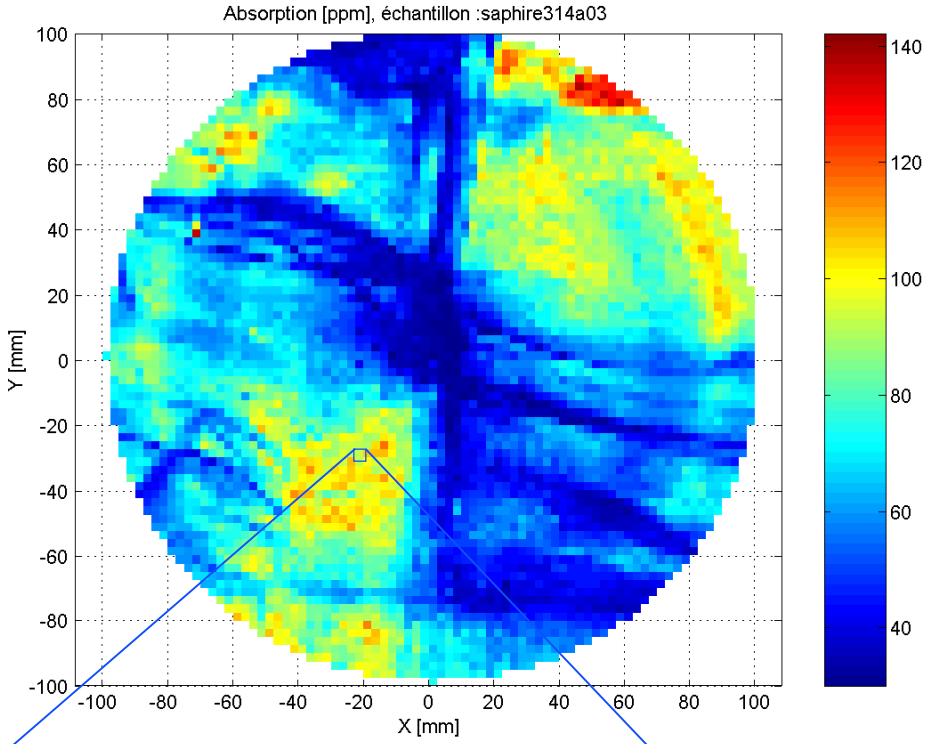
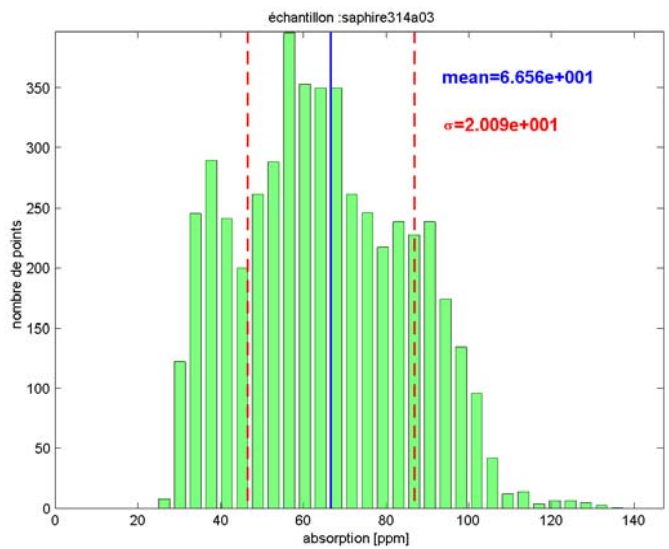
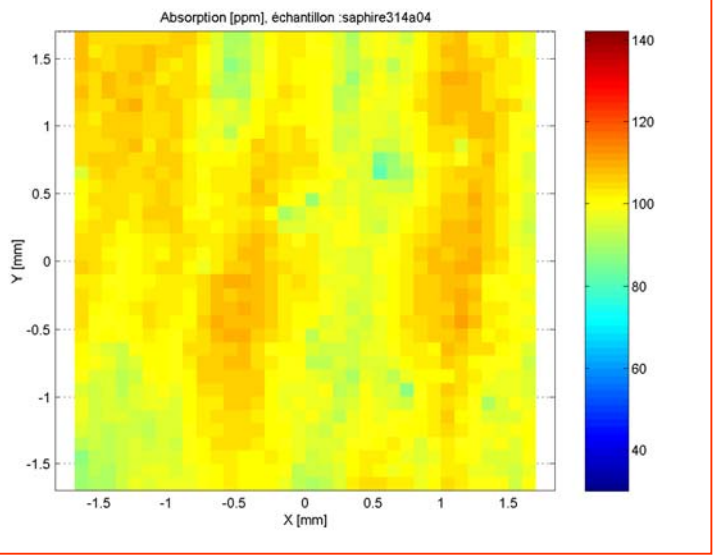
Main Efforts of the Core Optics WG

- **Sapphire test mass R&D**
  - » Focus has moved to characteristics of AdLIGO-sized substrates
  - » Beginning to understand asymptotic limits of performance ?
- **Fused silica test mass R&D**
  - » Interest has rekindled based on recent high Q results
  - » Detailed R&D plan formulated for advancing FS to AdLIGO readiness
- **Coating R&D**
  - » Probably the most serious technical risk facing AdLIGO optics
    - – Mechanical loss is high: if no improvement, sensitivity decreases by 30%
    - – Low optical loss must be preserved…
    - – Second round coating R&D program initiated
- **New Test Mass Down-select date – March-April 2004**

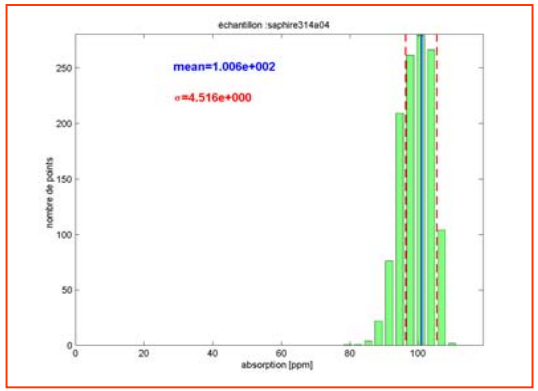


Mean absorption: **67 ppm.cm^{-1}**
ϕ 200 mm scan
2.5 mm steps





Mean absorption: **101 ppm.cm^{-1}**
3.5x3.5 mm² **zoom**
0.1 mm steps



Absorption map at
Z = -63 mm

J. M. Mackowsky,
SMA-Virgo

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Identification of Trace Elements in Sapphire

S. McGuire (SUBR), G. Lamaze and E. Mackey (NIST)

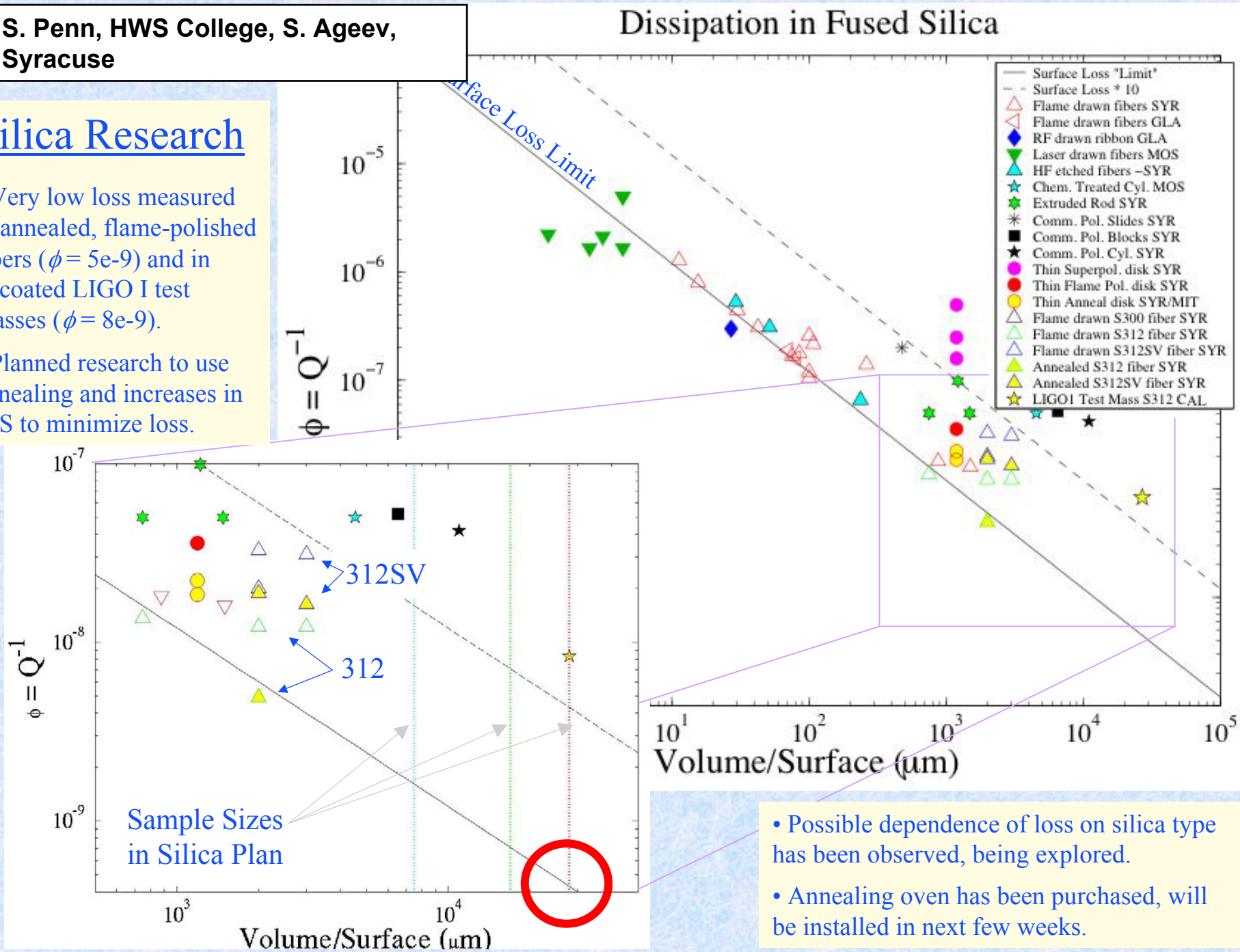
- Instrumental Neutron Activation Analysis (INAA) to assess correlations between 1064 nm absorption and presence of impurity states
- No smoking gun…

Element	Low Loss	High Loss	SRM 1575a	Certified Value
Sc	0.06 ± 0.02 ppb	0.20 ± 0.04 ppb	10.8 ± 0.8 ppb	10.1 ± 0.3 ppb
Cr	9 ± 2 ppb	8 ± 1 ppb	0.36 ±0.03 ppm	0.3 - 0.5 ppm range
Fe*	≤ 1 ppm	≤ 1 ppm	45 ± 2 ppm	46 ± 2 ppm
Co	≤ 1 ppb	1.2 ± 0.4 ppb	68 ± 3 ppb	61 ± 2 ppb
Zn	30 ± 3 ppb	40 ± 4 ppb	39 ± 2 ppm	38 ± 2 ppm
Sb	≤ 2 ppb	≤ 2 ppb	10 ± 3 ppb	not certified
La	7 ± 0.4 ppb	4 ± 0.4 ppb	53 ± 7 ppb	not certified

S. Penn, HWS College, S. Ageev, Syracuse

Silica Research

- Very low loss measured in annealed, flame-polished fibers (ϕ = 5e-9) and in uncoated LIGO I test masses (ϕ = 8e-9).
- Planned research to use annealing and increases in V/S to minimize loss.



- Possible dependence of loss on silica type has been observed, being explored.
- Annealing oven has been purchased, will be installed in next few weeks.

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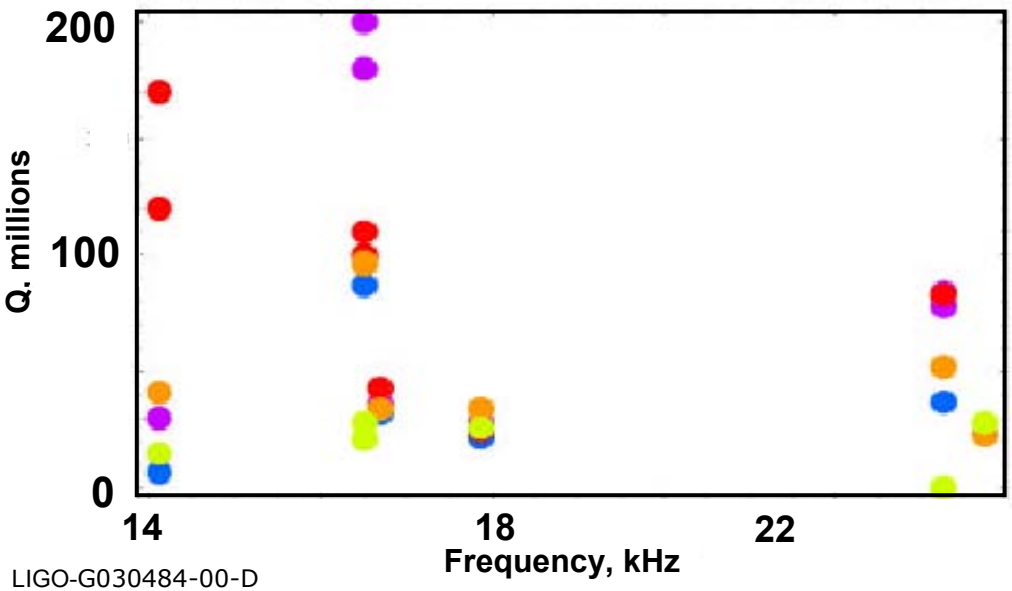
Mechanical Loss in Large Substrates - Sapphire

P. Willems and D. Busby, LIGO- T030087-00-R

- Qs in excess of 2×10^8 !!!
- frequency dependence measured; Q decreases with increasing frequency
- FE model → good agreement with measured Qs, frequency dependence
  poor barrel polish contributes to loss



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Coating Mechanical Loss

S. Vyatchanin , MSU; Peter Sneddon, U. Glasgow

- Both *thermoelastic loss*** and *loss resulting from residual dissipation* are of significance for coating thermal noise (increasing the overall thermal noise level by a few 10s of percent).
- Analysis of SiO_2/Ta_2O_5, SiO_2/Al_2O_3 and Al_2O_3/Ta_2O_5 coatings suggests that Ta_2O_5 has greater residual loss than SiO_2 and Al_2O_3
  - SiO_2 and Al_2O_3 have frequency-dependent loss
- For a silica substrate:
  - a SiO_2/Ta_2O_5 coating has the lowest thermoelastic noise and the lowest total thermal noise, though is still dominated by the loss in the Ta_2O_5.

** V. Braginsky, et al., Phys. Lett. A 312 244

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Coating Mechanical Loss (cont'd)

Peter Sneddon, U. Glasgow

- For a sapphire substrate:
  - a SiO_2/Al_2O_3 coating has the lowest overall thermal noise. However, this can only be reduced by a factor of ~ 2 before the thermoelastic floor is reached.
  - an Al_2O_3/Ta_2O_5 coating has a lower thermoelastic noise floor and could have a lower total thermal noise if the residual loss in the Ta_2O_5 can be reduced.
- ***Suggests the way forward is to reduce the loss of the Ta_2O_5, or find an alternate high-index material with a lower mechanical loss and similar thermoelastic properties. This should reduce the total coating thermal noise for both silica and sapphire mirrors.***

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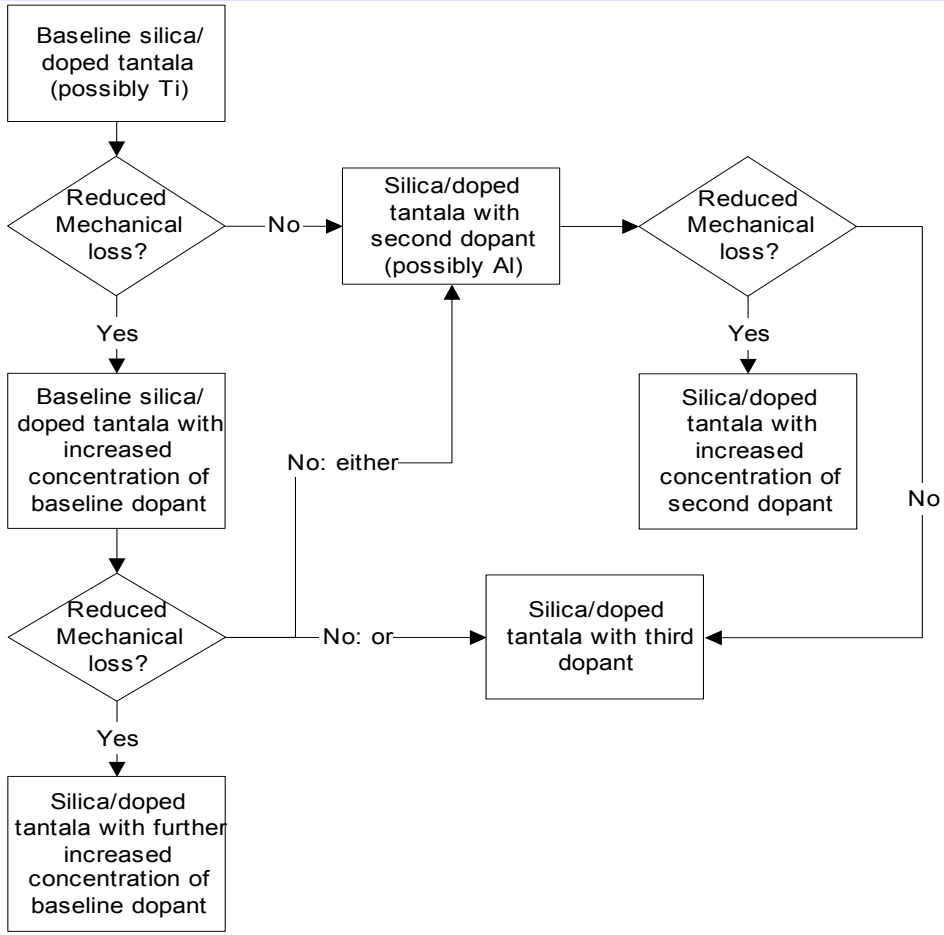
Coating Mechanical Loss

G. Harry, et al., LIGO-C030187-00-R

Advanced LIGO Coating Development Plan

- outlines research program for participant vendors
- RFP sent to coating vendors
- 5 companies responded positively
- committee formed to evaluate proposals
- met in early August
- CSIRO, SMA-Virgo selected for coating R&D contracts



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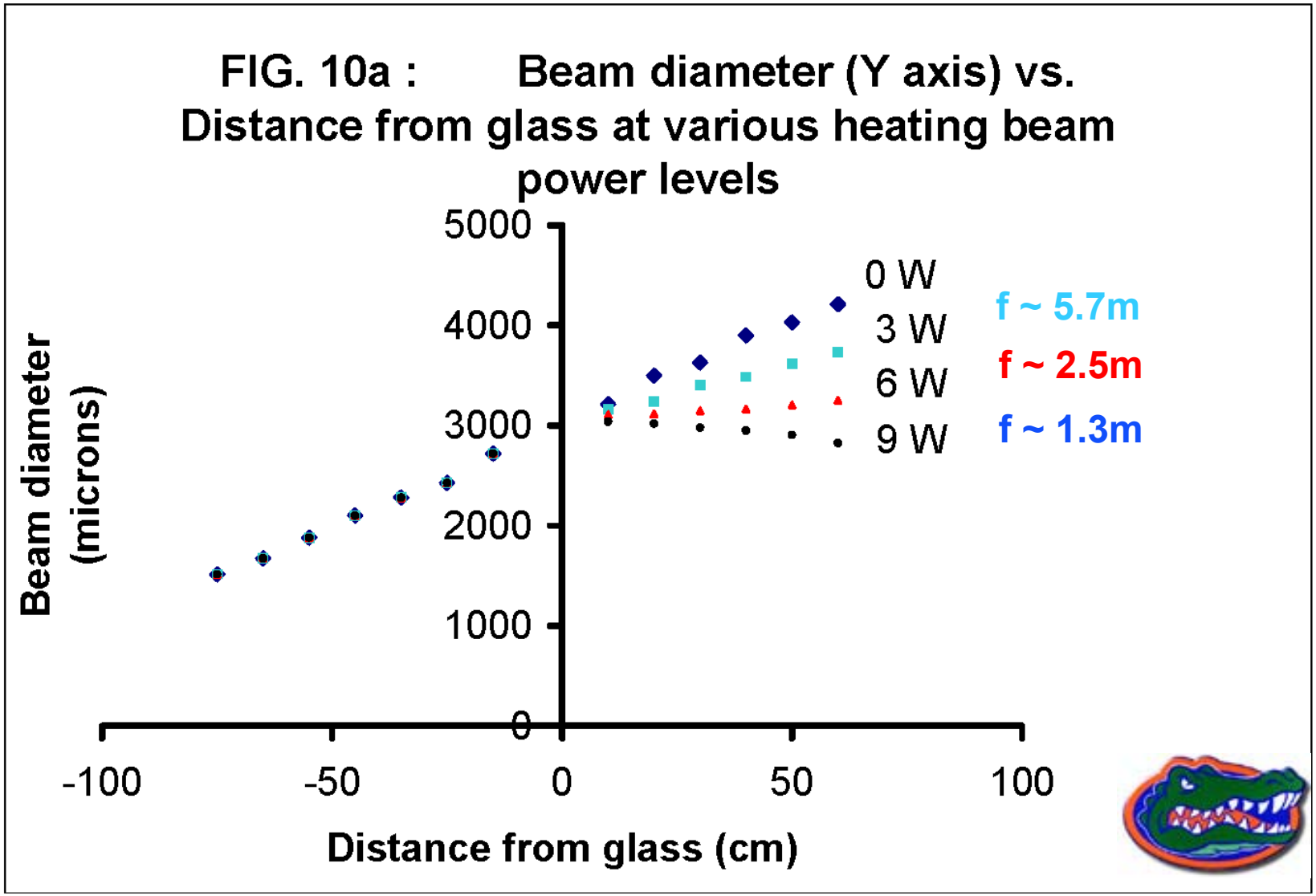
Adaptive Mode matching



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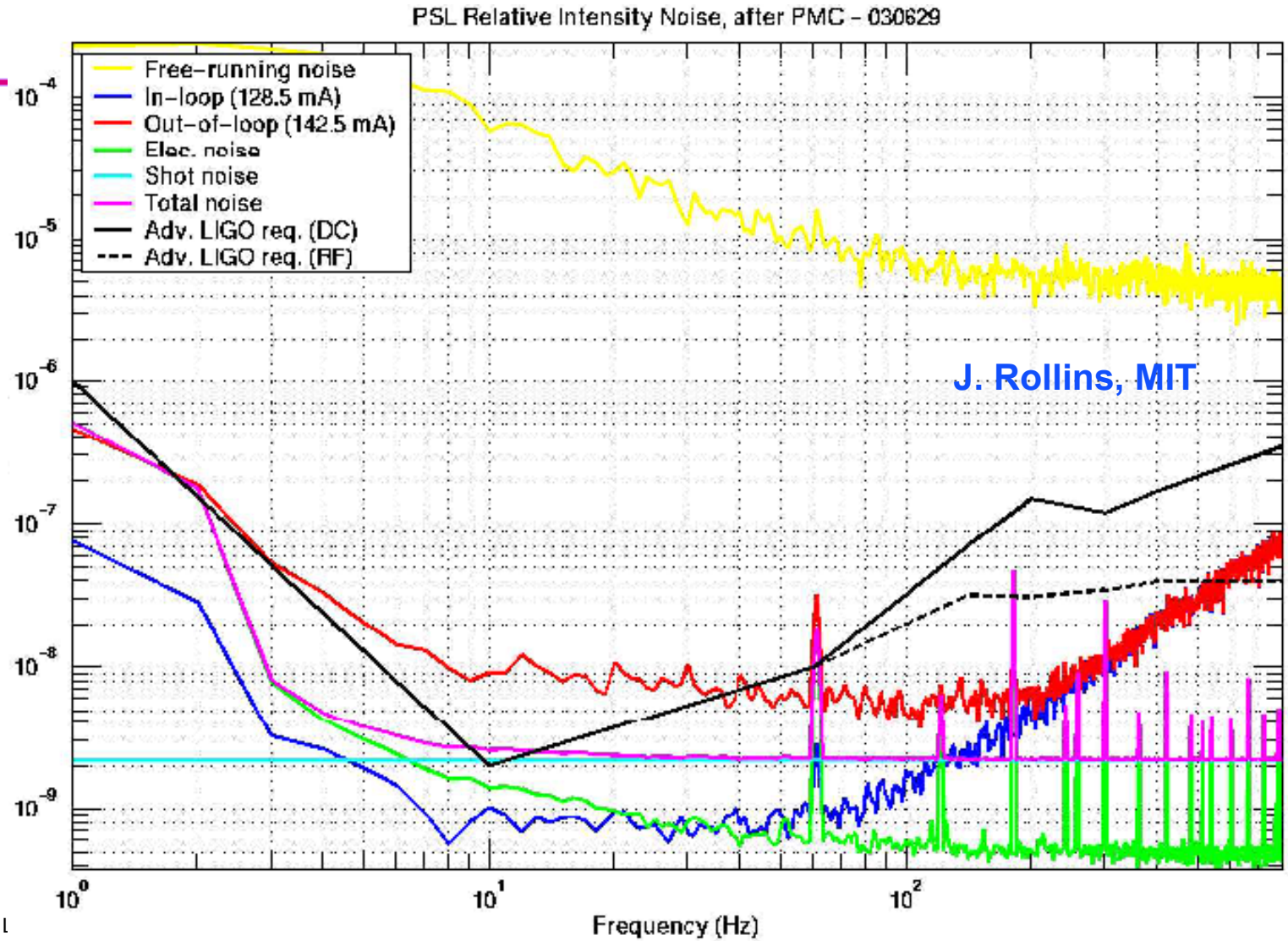
Advanced LIGO Intensity Stabilization



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Sapphire Test Mass Requirements Redux

Legend: √ = 'good' (√) = 'close' ? = 'jury still out'

Mass	40 kg √
Physical dimension	31.4 cm x 13 cm √
Optical homogeneity	< 10 nm rms √**
Microroughness	< 0.1 nm rms (√)
Internal scatter	< 10 ppm/cm ?
Absorption	10 - 40 ppm/cm* (√)
Thermal noise	Q > 2 x 10^8 √
Birefringence	< 0.1 rad ?
Polish	< 0.9 nm rms (√)

** engineered solution

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Fused Silica Requirements Redux

Mass	40 kg √
Physical dimension	34 cm x 20 cm √
Optical homogeneity	< 10 nm rms √
Microroughness	< 0.1 nm rms (√)
Internal scatter	< 10 ppm/cm ?
Absorption	0.5 – 1.0 ppm/cm (√)
Thermal noise	Q > 1 x 10^8 ?
Birefringence	< 0.1 rad √
Polish	< 1.2 nm rms √