Coating Loss Measurements on Thin Fused Silica Substrates

LIGO-G020119-00-Z

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Outline

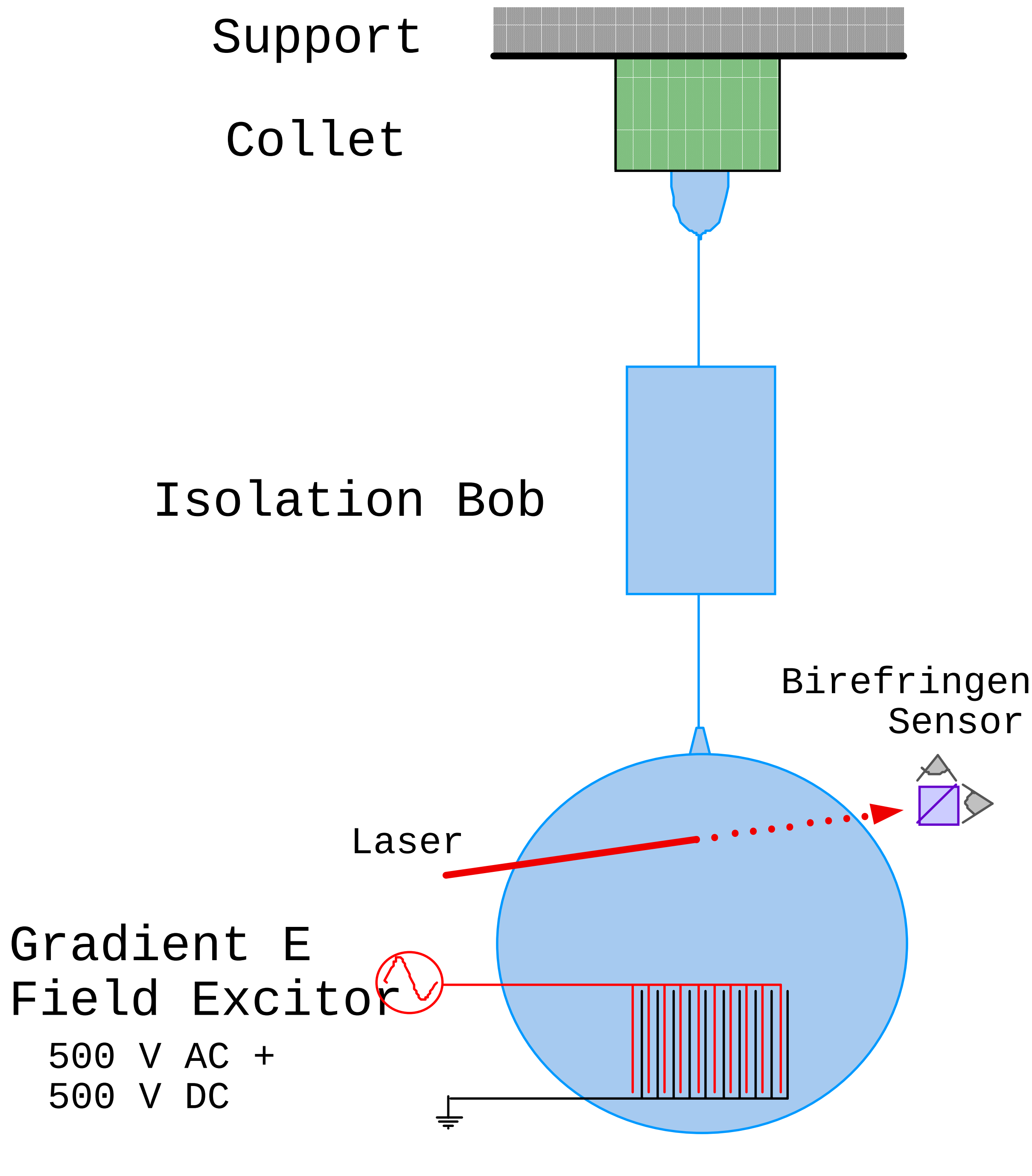
- Goals of Coating Loss Experiment
- Plan for Coating Measurements on Thin Substrates
- Thin Substrate Experimental Set-up & Sources of Loss
- Modifications for Future Coatings Work

Review of Coating Program

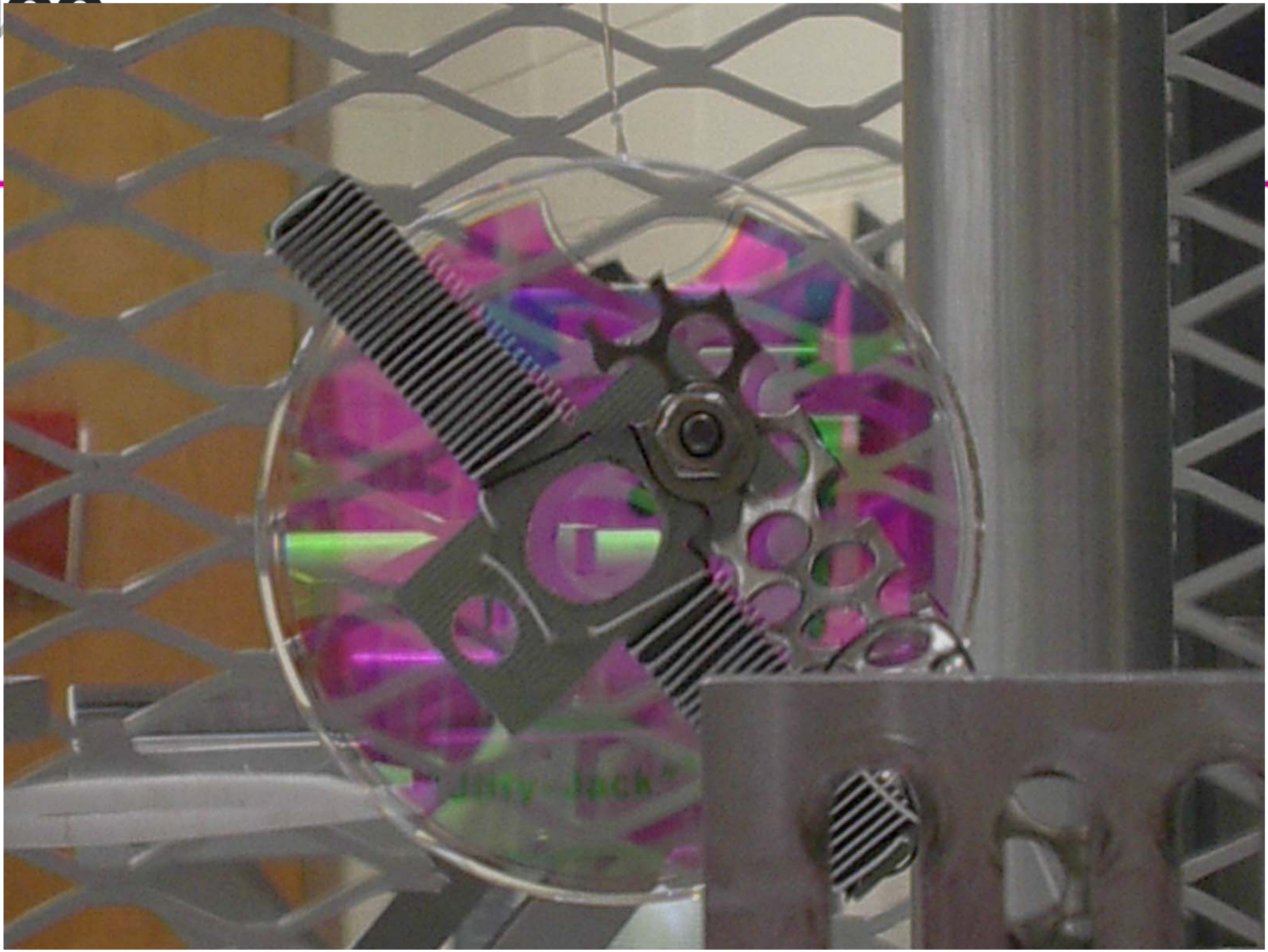
- Levin (1998) showed coatings could be a limiting source of loss.
- Preliminary measurements at Glasgow and Syracuse indicated
  $\phi_{\text{coating}} \approx 2.5 \times 10^{-4} \Rightarrow$ Test Mass Q's $\approx 10^{7}$
- Advanced LIGO requires $\phi_{\text{coating}} \approx 10^{-5}$ for Sapphire masses and 200 Mpc range.
- Coating program initiated:
  - » Thin Substrates with birefringent readout (Syracuse & MIT)
  - » Thick Substrates with interferometric readout (Glasgow & Stanford)

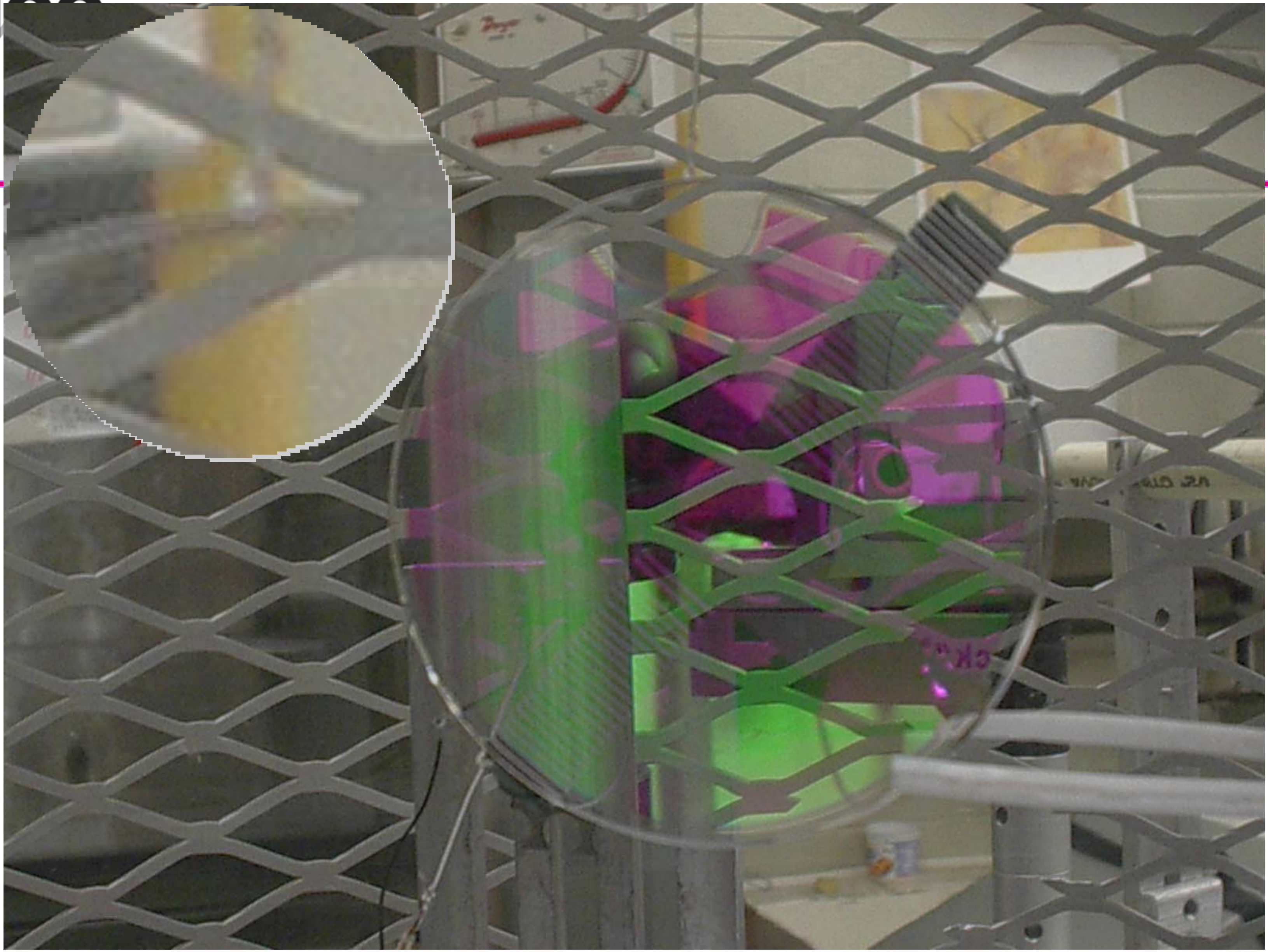
Thin Substrate Measurements

- Uncoated, Super-polished Disks
  (Mindrum & Wave Precision), Q = 6–20 million
- Annealed, Uncoated, Superpolished Disks, Q≈ 45 million
- Coated Disk, 2-layers, ($\lambda/4$ Ta_2O_5, $\lambda/4$ SiO_2) Q≈ 9 million
- Coated Disk, 30-layers, ($\lambda/4$ Ta_2O_5, $\lambda/4$ SiO_2) Q≈ 500,000
- Coated Disk, 30-layers, ($3\lambda/8$ Ta_2O_5, $\lambda/8$ SiO_2) Q≈ 400,000
- Coated Disk, 60-layers, ($\lambda/8$ Ta_2O_5, $\lambda/8$ SiO_2) Q≈ 500,000


Support
Collet
Isolation Bob
Birefringen
Sensor
Laser
Gradient E
Field Excitor
500 V AC +
500 V DC


"Jiffy-Jack"

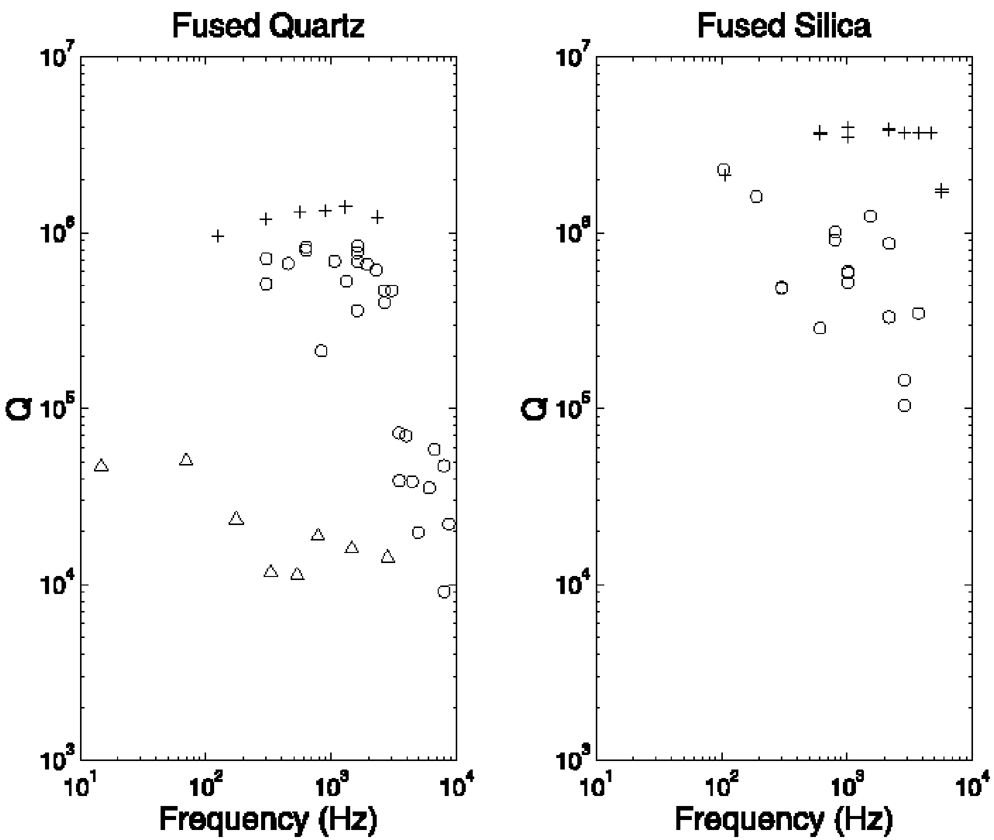




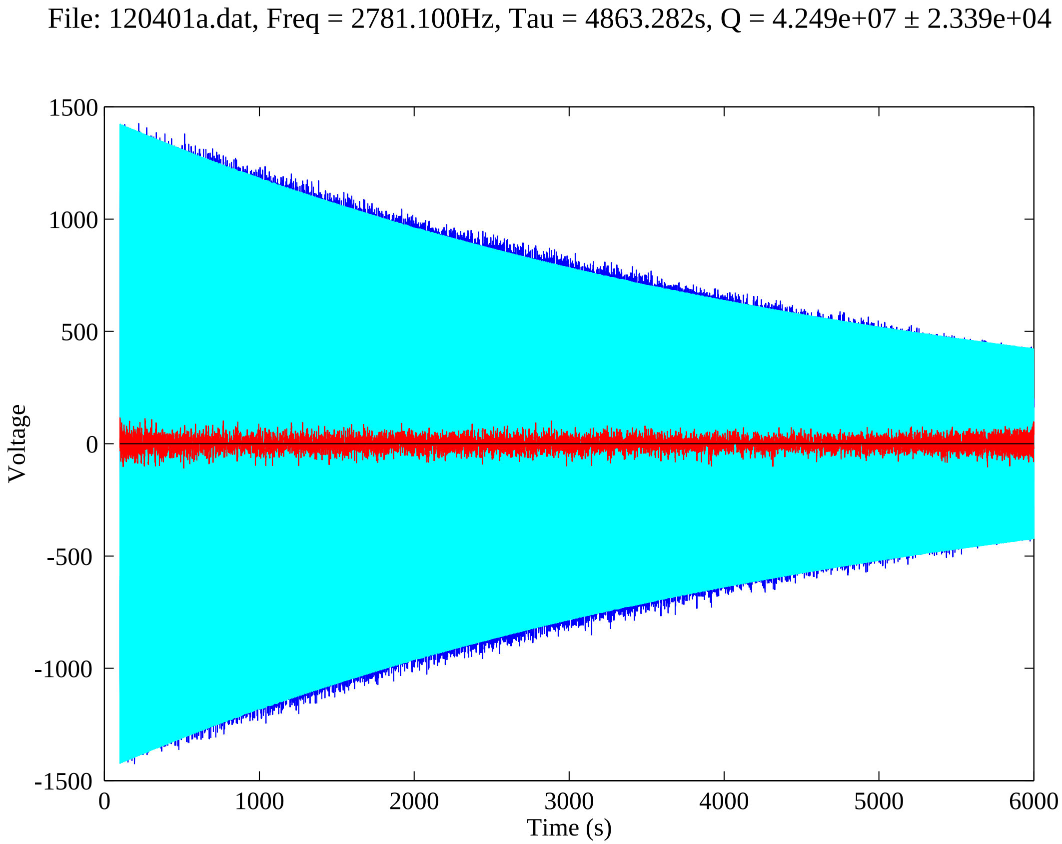
Benefits of the Thin Disk Method

- Geometry enhances ΔQ due to coatings (factor 40)
- Suspension methods (welding, collet & bob) are low loss
- Tiny ($\approx$ 100 μm) welds do not disturb coatings ($\Delta T \approx 0$)
- In-air feedback allows for mode identification
- Birefringence Readout has high SNR & clean analysis
- Excellent Agreement of Results between labs

Effect of the Isolation Bob

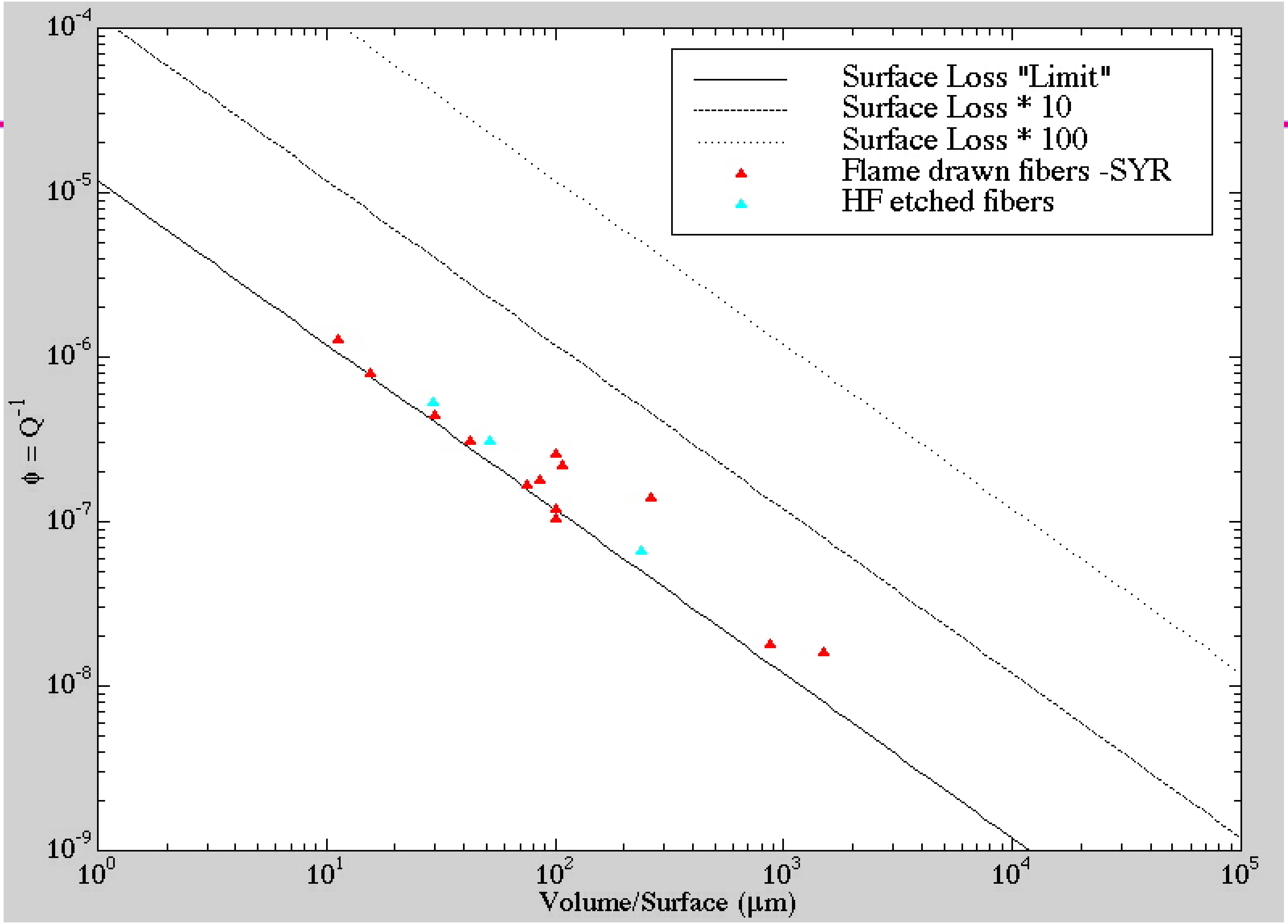


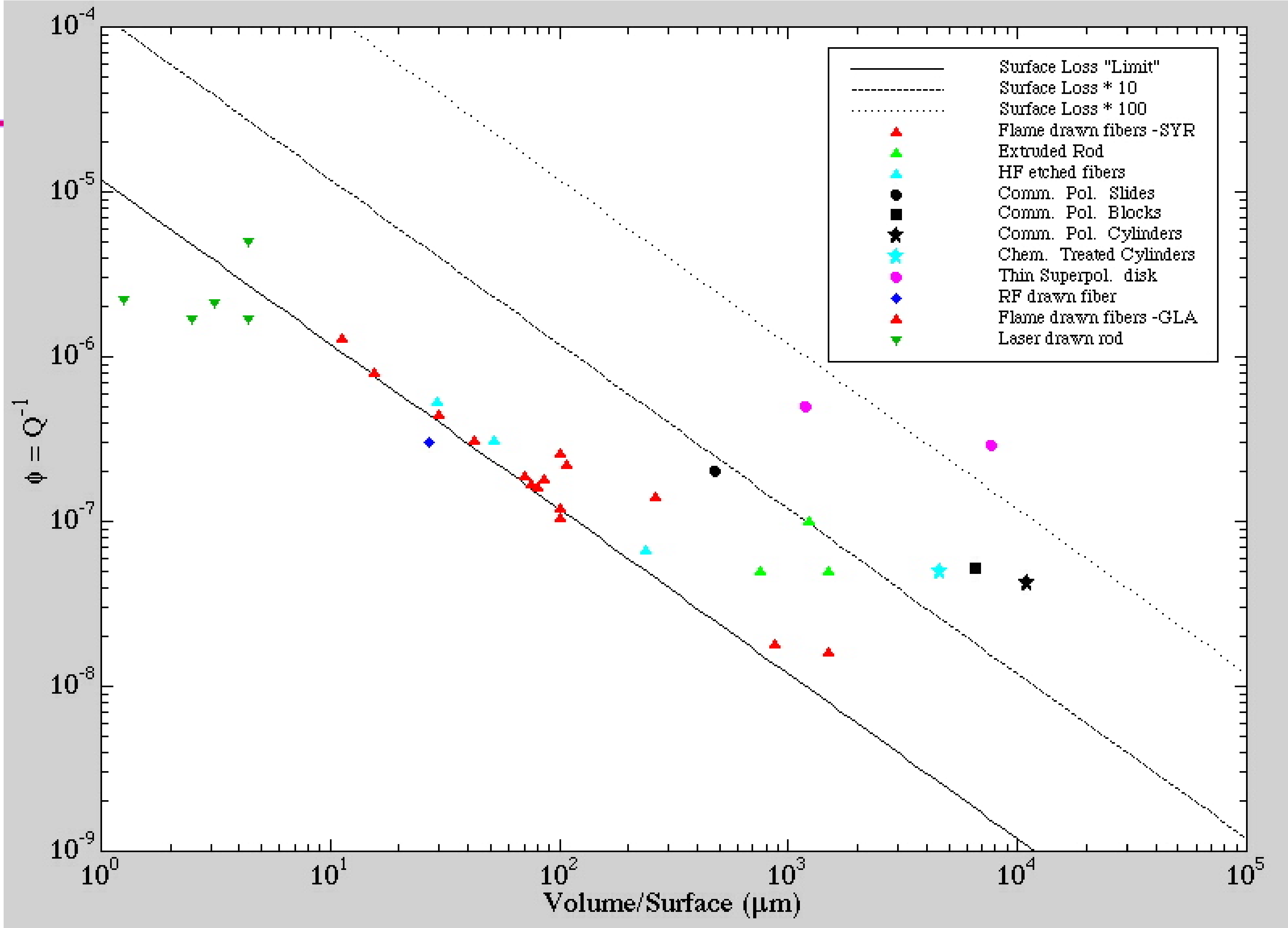
Annealed, Uncoated Disk



Thin Disk Method for Sapphire?

- Benefits of low cost, fast turn-around, and low noise measurements.
- Problems with attachment
  - » Bonding not preferable due to loss
  - » Is welding sapphire possible? Even if possible, amorphous weld would likely have higher loss.
  - » Develop a TAMA-like suspension using pins holding the sample edges


Surface Loss "Limit"
Surface Loss * 10
Surface Loss * 100
Flame drawn fibers -SYR
HF etched fibers
$\phi = Q^{-1}$
Volume/Surface (μm)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}


Surface Loss "Limit"
Surface Loss * 10
Surface Loss * 100
Flame drawn fibers -SYR
Extruded Rod
HF etched fibers
Comm. Pol. Slides
Comm. Pol. Blocks
Comm. Pol. Cylinders
Chem. Treated Cylinders
Thin Superpol. disk
RF drawn fiber
Flame drawn fibers -GLA
Laser drawn rod
$\phi = Q^{-1}$
Volume/Surface (μm)
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10^{-8}
10^{-9}
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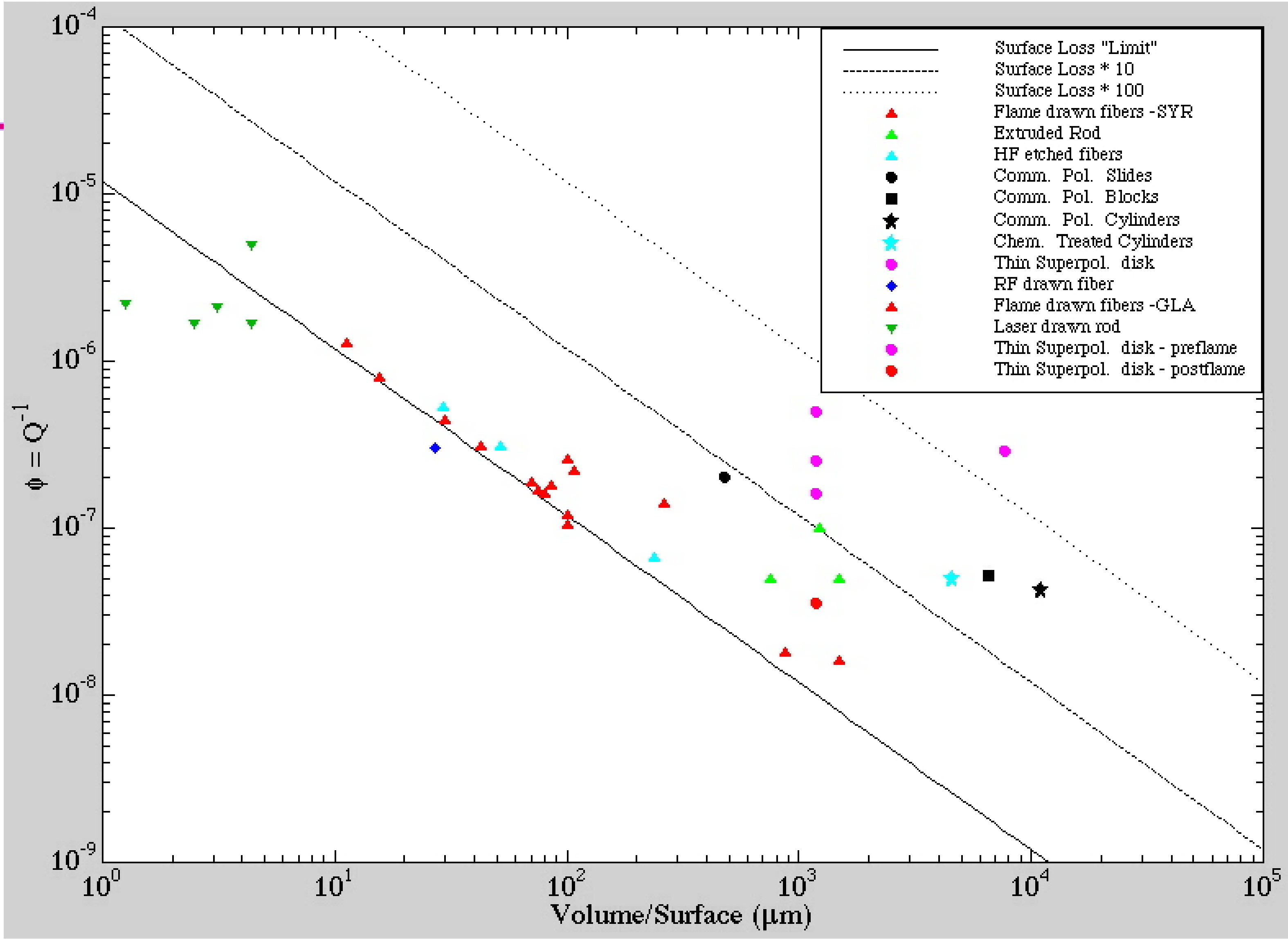
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}



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Comm. Pol. Cylinders
Chem. Treated Cylinders
Thin Superpol. disk
RF drawn fiber
Flame drawn fibers -GLA
Laser drawn rod
Thin Superpol. disk - preflame
Thin Superpol. disk - postflame
$\phi = Q^{-1}$
Volume/Surface (μm)
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}