Investigating Surface Loss in Fused Silica

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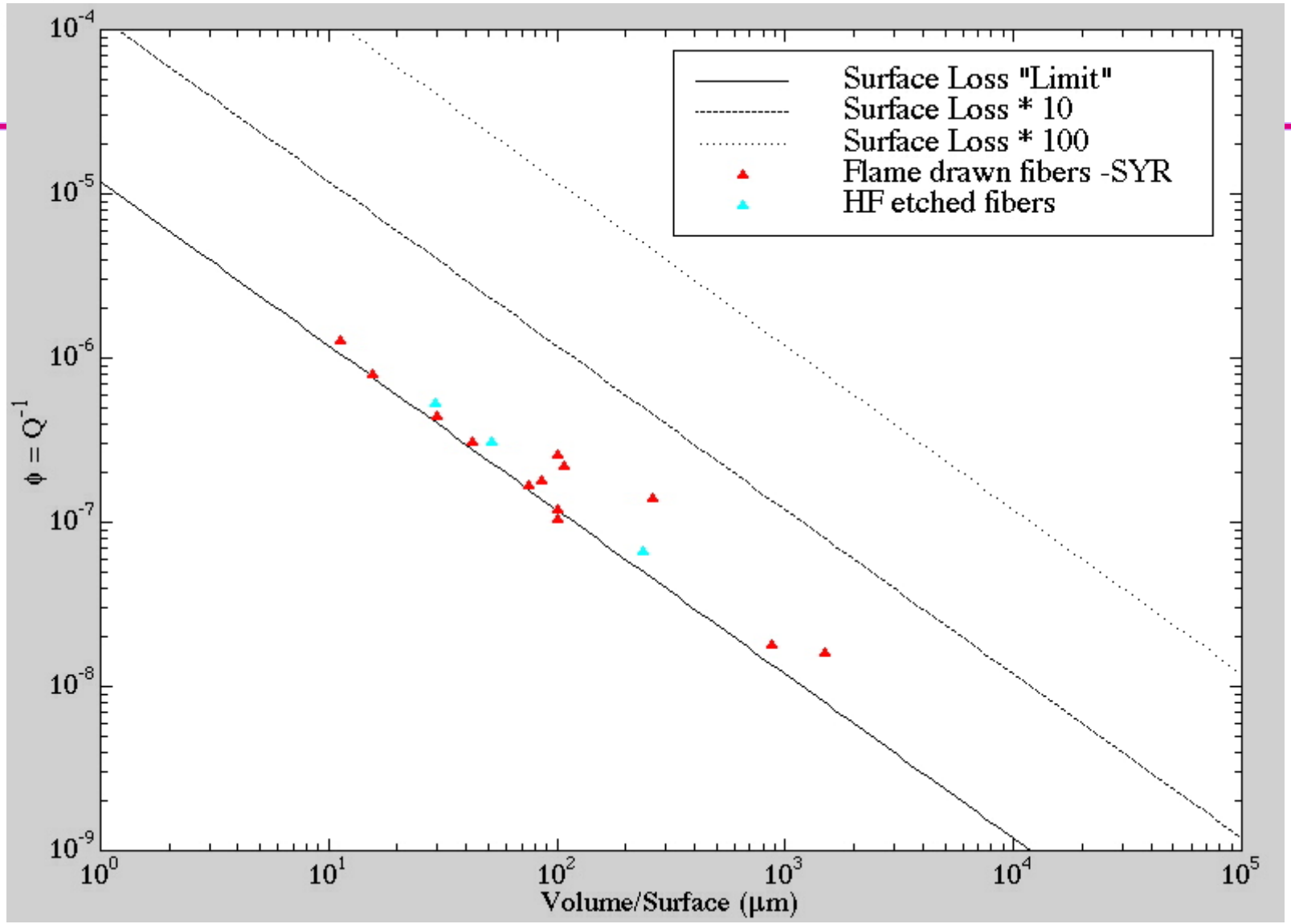
LIGO-G010133-00-Z

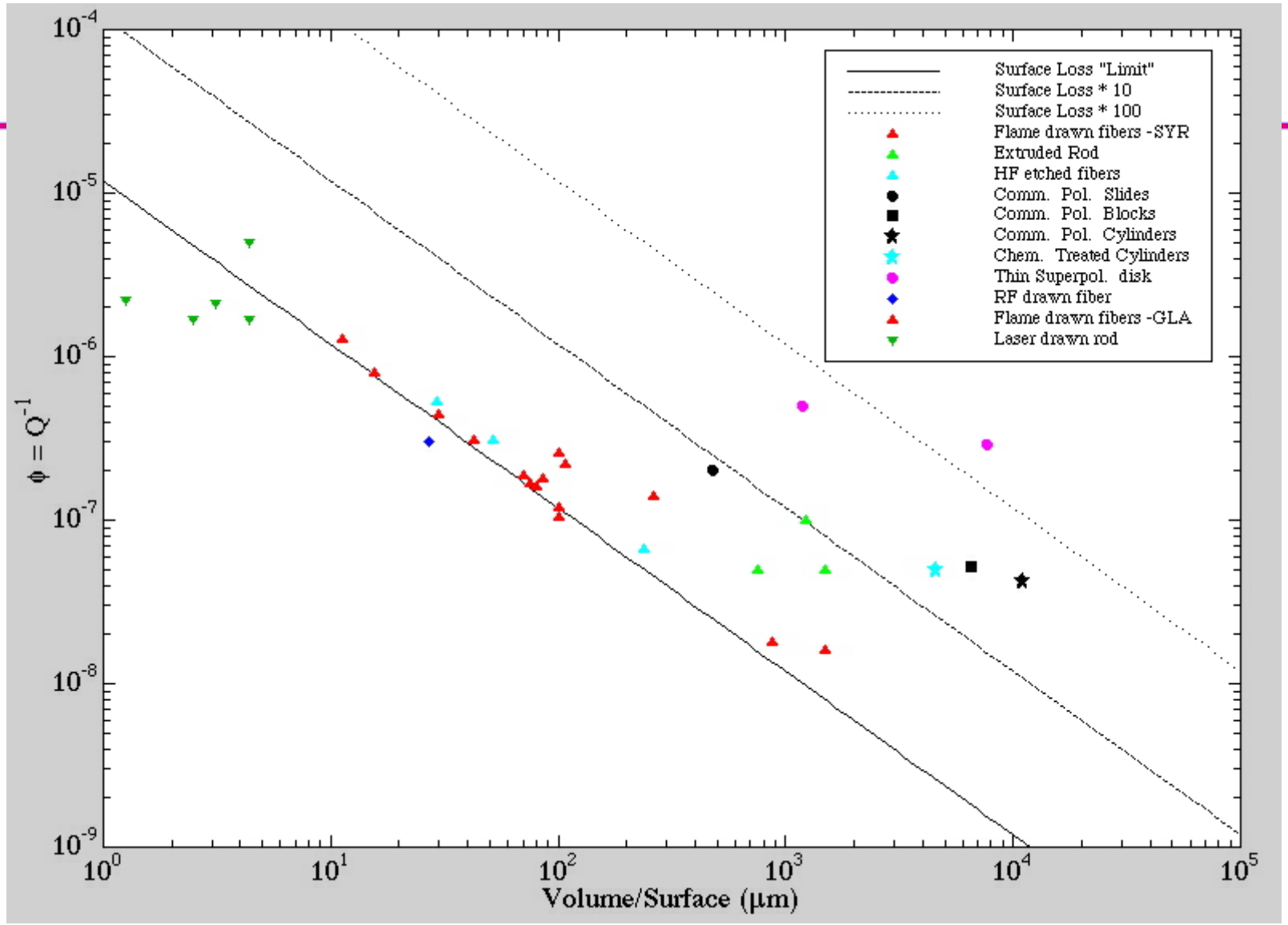
Synopsis

- Identifying a surface-dependent loss in fused silica and understanding the loss for different surface preparations.
- Reducing surface loss. “Can we repair the surface?”
- Proposal for experiment to explore laser polishing of optics.
- Measurements of loss in Silicate Bonds

When we last talked …

- Q measurements on flame polished fibers show strong surface dependence.
- Q = 66 million measured in 6 mm flame polished fiber.
- Catalogue of known fused silica Q's suggests similar surface dependence for other surface types.


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}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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
$\phi = Q^{-1}$
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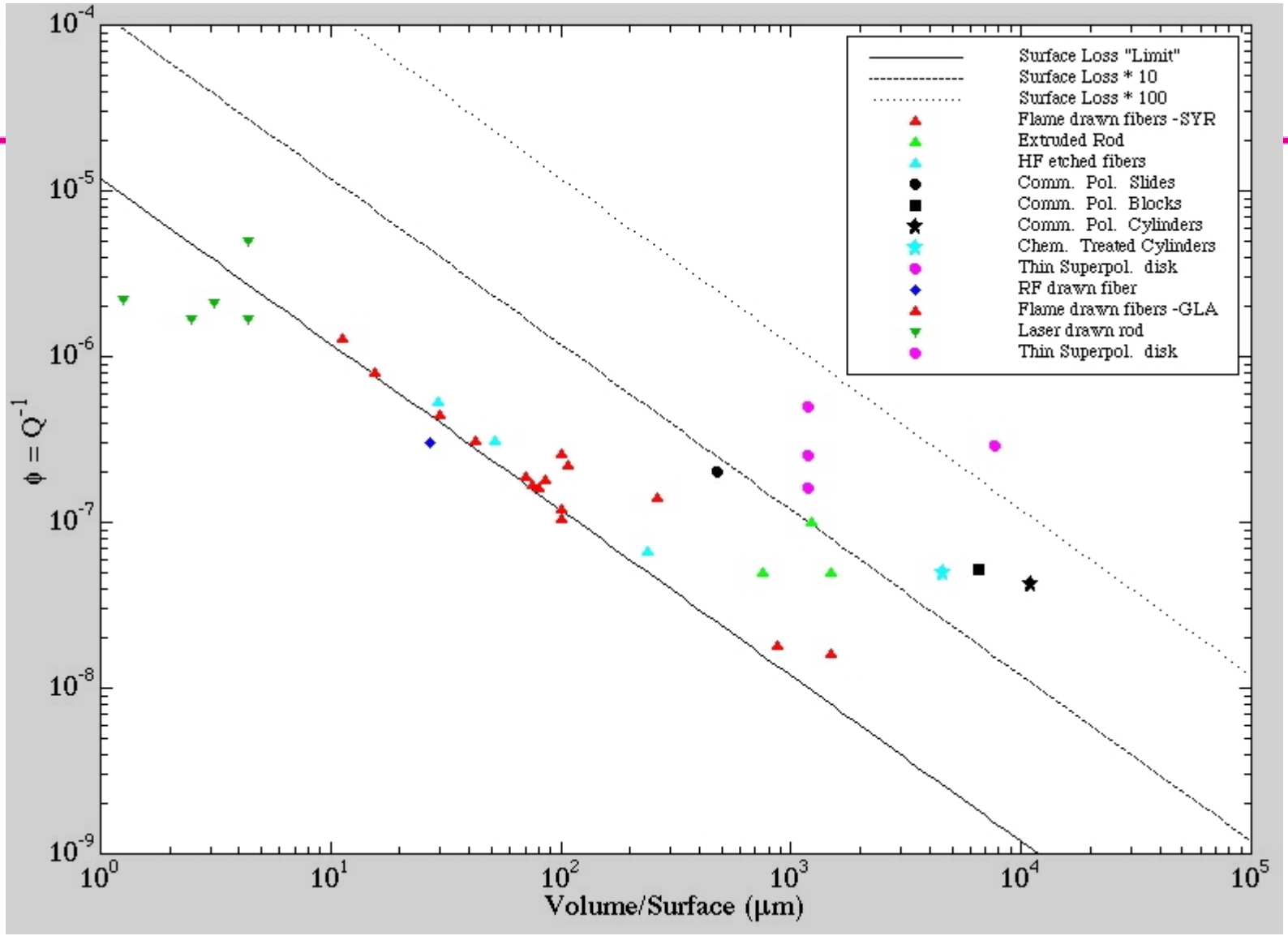
Surface Damage and Repair

- Polish-induced surface damage
  - Water and/or slurry absorption
  - Microcracking
- Flame polishing repair of superpolished sample
  - Improve the mechanical Q
  - Destroy the optical quality
- Can we improve the Q and maintain the optical properties of a superpolished sample?

Q of Superpolished/Flame-Polished Disk

- Superpolished Disk.
  - Fused silica (II ?) thin disk (3”OD x 0.1”) with superpolished faces.
  - Standard Syracuse resonant Q ringdown. (Double-bob suspension. Electrostatic comb excitor, birefringent sensor)
  - Q = 6 million (f = 4.5 kHz, drumhead)
  - Q = 4 million (f = 3 kHz, butterfly)
- Flame-Polished Disk
  - H-O torch used to flame polish the faces. Flame heats 1 cm OD regions to transition temperature. Final surface “mottled” into flame-sized regions
  - Subsurface defects seen during flame polishing.
  - Q = 28 million (both modes)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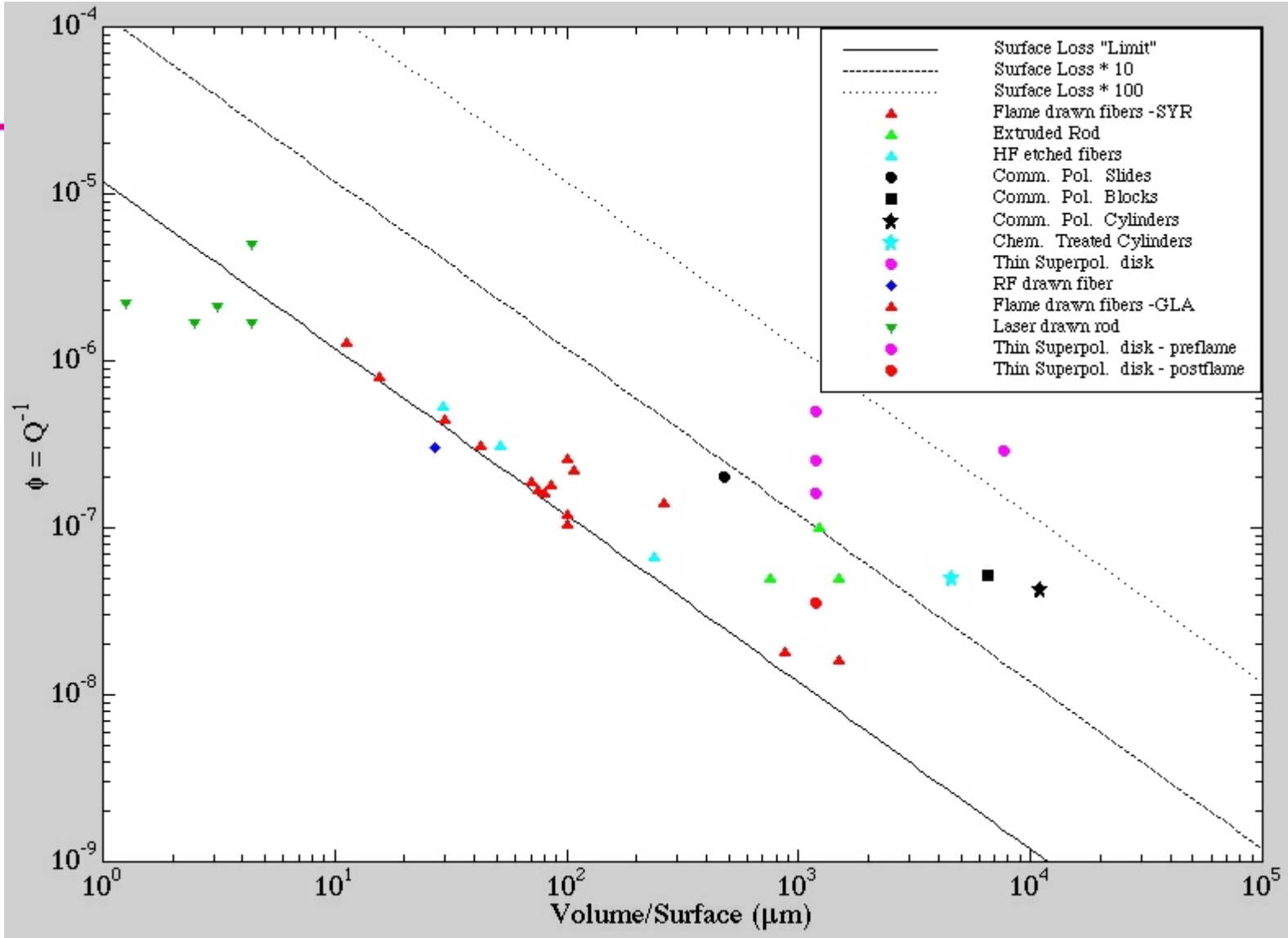
Volume/Surface (μm)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RF drawn fiber
Flame drawn fibers -GLA
Laser drawn rod
Thin Superpol. disk - preflame
Thin Superpol. disk - postflame
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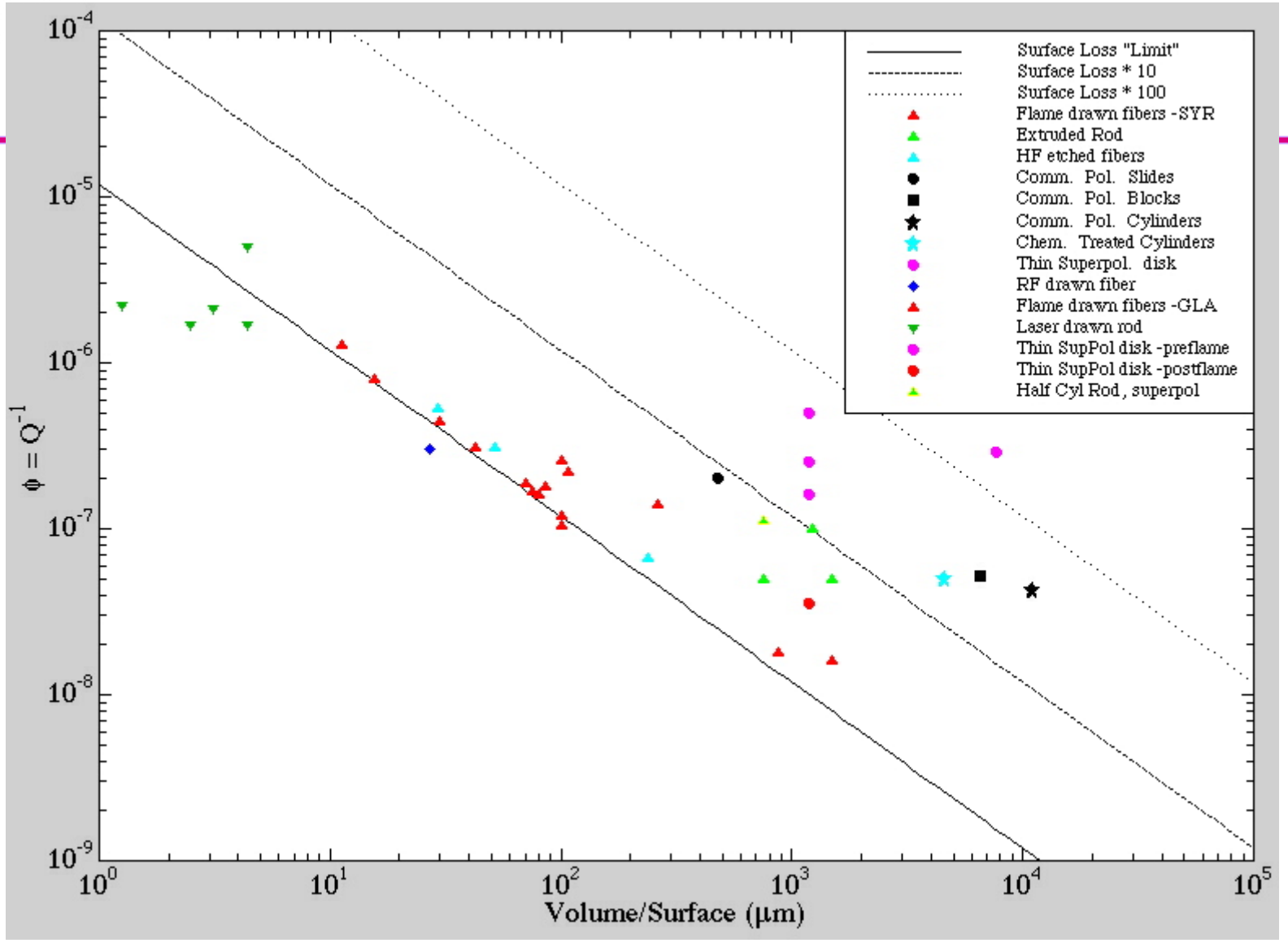
Laser Polishing

- A focused CO2 laser can heat a small region on the surface to the glass transition temperature without ablation.
- The diameter and depth of the heated region can be tuned to optimize repair of defects (few micron) but maintain the flatness and roughness of the optic (< 0.1 micron). Beam is rastered to polish entire surface.
- Collaborative effort by Syracuse, Florida, and MIT.

Q of Silicate Bonds (Glasgow-Syracuse Collaboration)

- Unbonded sample.
  - Fused silica half cylinders (10cm x 0.5 cm OD) extruded rod with superpolished flat.
  - Standard Syracuse resonant Q ringdown. (Double-bob suspension. Electrostatic comb excitor, shadow sensor)
  - Q (f = 1.3 kHz) ≈ 9 million for the two fundamental modes.
- Bonded sample.
  - Two half cylinders bonded along superpolished flat and offset 1 cm
  - Two fundamental modes measured
  - Q(f = 2455 Hz) = 2×10^5 Q(f=2303 Hz) = 3×10^5
- FEA modeling required to extract Φ_{bond}.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Thin SupPol disk -postflame
Half Cyl Rod, superpol
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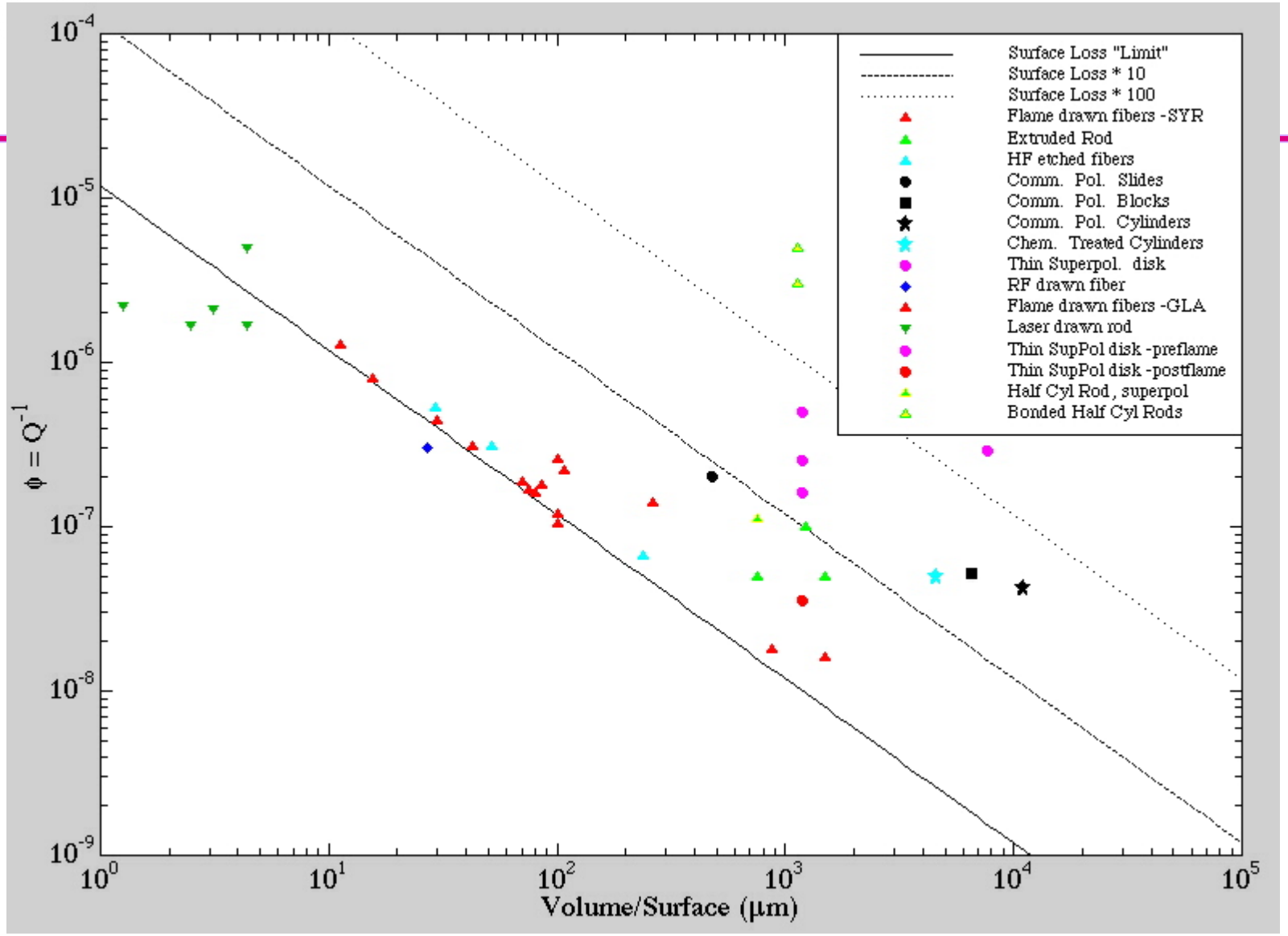
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