



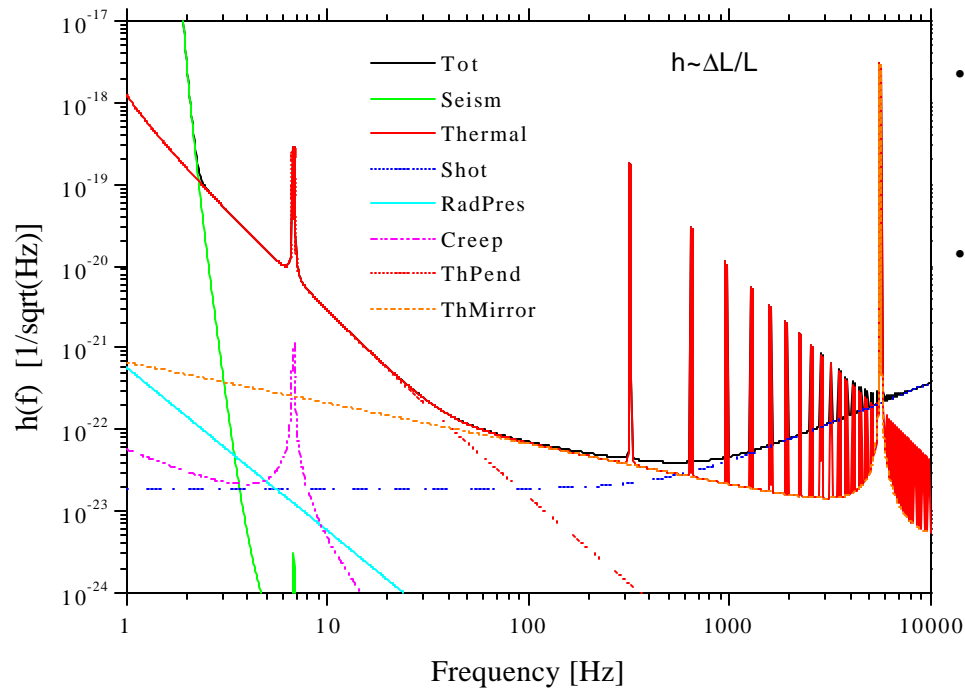
Monolithic Suspension for Virgo

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for the Perugia Virgo Group



The Virgo Sensitivity Curve



- The pendulum thermal noise is dominant between 3 and 50 hz
- C85 shows the best thermal noise value for metal wire suspension



Pendulum Thermal Noise

3 Contributions to the thermal noise

- Clamping losses
 - Can be reduced by using special clamps with high clamping pressure
 - “Spacers” on the wire-mirror contact point
- Ideal solution:
 - Monolithic wires

- Material internal loss angle

$$f_w = f_0 + \Delta \frac{\frac{f}{f_0}}{1 + (\frac{f}{f_0})^2}$$

- Geometrical dilution factor

$$Q_{pend} = \frac{1}{f_w} \frac{2L}{r^2} \sqrt{\frac{M g}{p n E}}$$

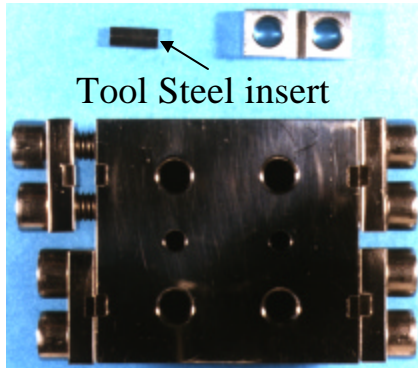
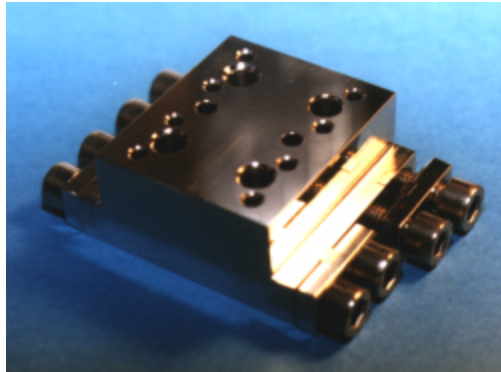
$$X^2(\omega) \approx 4k_B T \frac{g}{\omega^5} \left[\frac{1}{L^2} \sqrt{\frac{Eg}{4pNm}} + q_g^2 \frac{E}{mL} \right] \frac{f_{mat}}{T_b C_s}$$

Breaking strength

f_{mat}
 $T_b C_s$



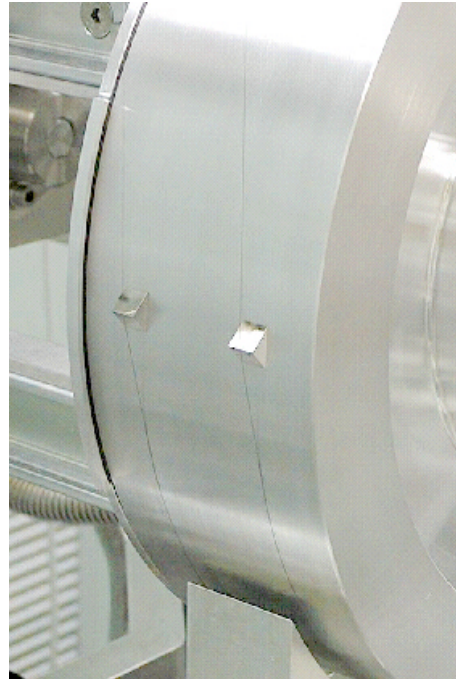
Top View



Tool Steel insert

Bottom View

Clamps & Spacers

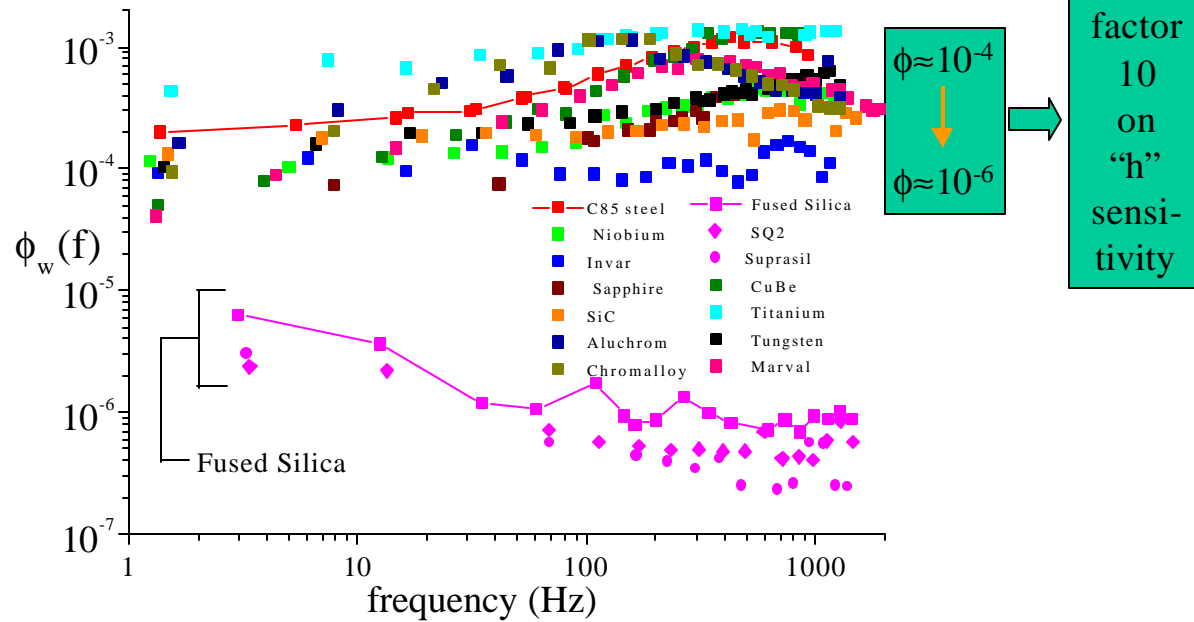


- High pressure Clamps and Spacers are used to reduce the friction (stick and slip process) between wire and clamping devices or mirror
- Monolithic solution will eradicate the problem!
- Silicate bonding will be used to connect the wires to the mirror



Measured Losses of Materials

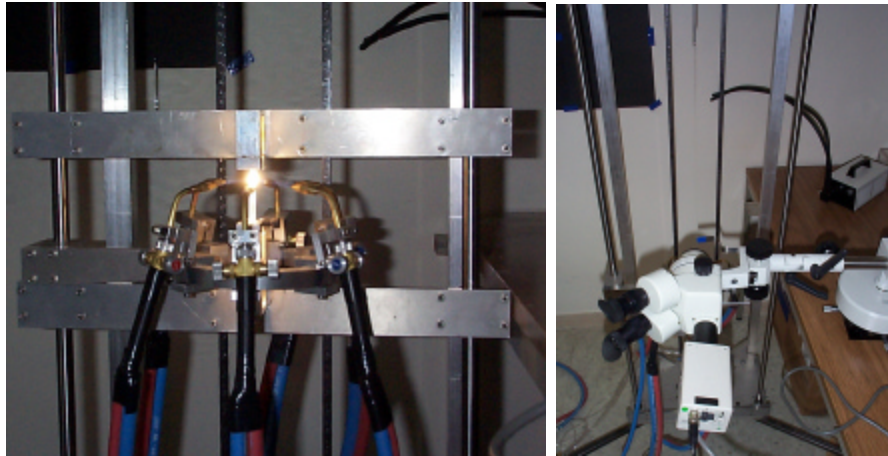
- All metals (and sapphire) have a similar loss





Fused Silica Vs C85 Breaking Strength: Production facility

- Fused Silica breaking strength is strongly dependent on the production and handling procedures
 - Impurities inserted in the production procedure can decrease the breaking strength down to few hundreds of MPa.
 - For this reason we abandoned the induction oven wire production facility
 - A new facility to produce fused silica wires has been realized using a H_2-O_2 flame





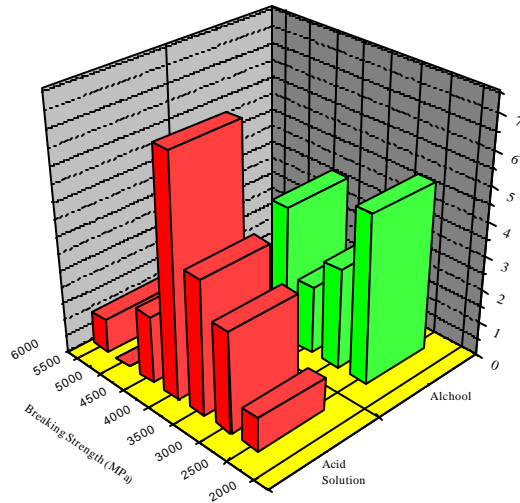
Fused Silica Vs C85 Breaking Strength: Handling

- Fused silica fibers are very sensitive to surface scratches caused by contact with metal or other hard materials.
- In this case the Griffith's law relate the scratch size to the breaking strength
- In literature humidity plays a role in the aging of the fiber, but for the moment we haven't conclusive data.
 - A 200 μm diameter fused silica fiber has been loaded for more than one year with 5.5 kg in a very humid environment.
 - Failure has occurred after the last strong earthquake in Perugia.

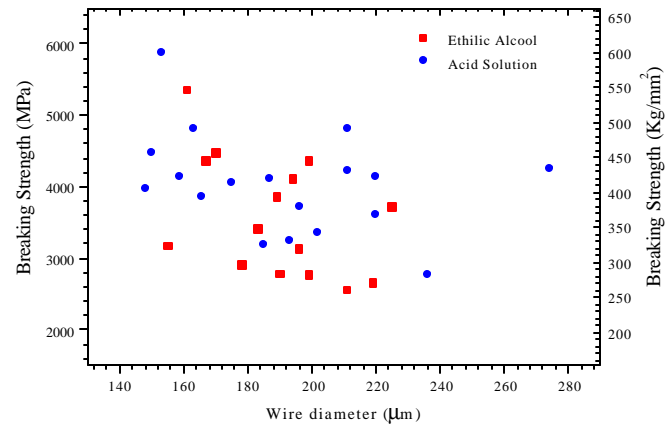


Fused Silica Vs C85 Breaking Strength: Results

- The C85 steel shows an high breaking strength ($T_b \sim 2.74\text{GPa}$) and a good “confidence factor” ($C_s \sim 0.65$). For this reason C85 has been selected as reference solution for the Virgo mirror suspension wires
- Synthetic Fused Silica shows a similar breaking strength if well produced and carefully handled, but the “confidence factor C_s ” is still lower because of a large dispersion of the measured breaking strength values and handling problems.



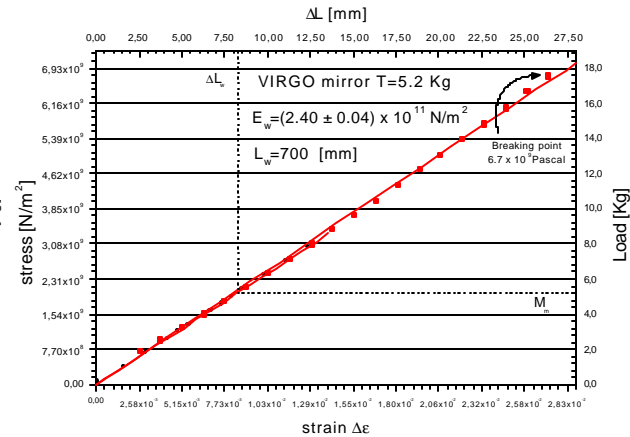
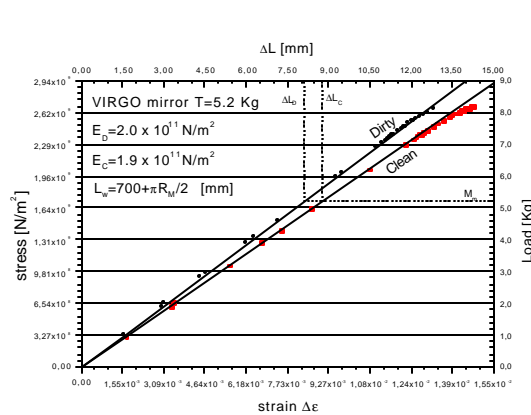
C85 Steel (Mpa)	F.S. Alcohol cleaning (Mpa)	F.S. Acid solution cleaning (Mpa)
2743±64	3577±827	4031±711





Fused silica fibers plasticity

- Fused silica fibers are brittle and don't show any plasticity behaviour





Next Steps

- Increase the Confidence Factor C_s by reducing the breaking strength dispersion
- Learn how to “glue” the wires to the mirror through the silicate bonding
- Prepare a full scale prototype of the Virgo last stage suspension
- If everything will works correctly:



The expected Virgo sensitivity with fused silica fibers

