Development of CO_2 Laser Pulled Fibres and Welding

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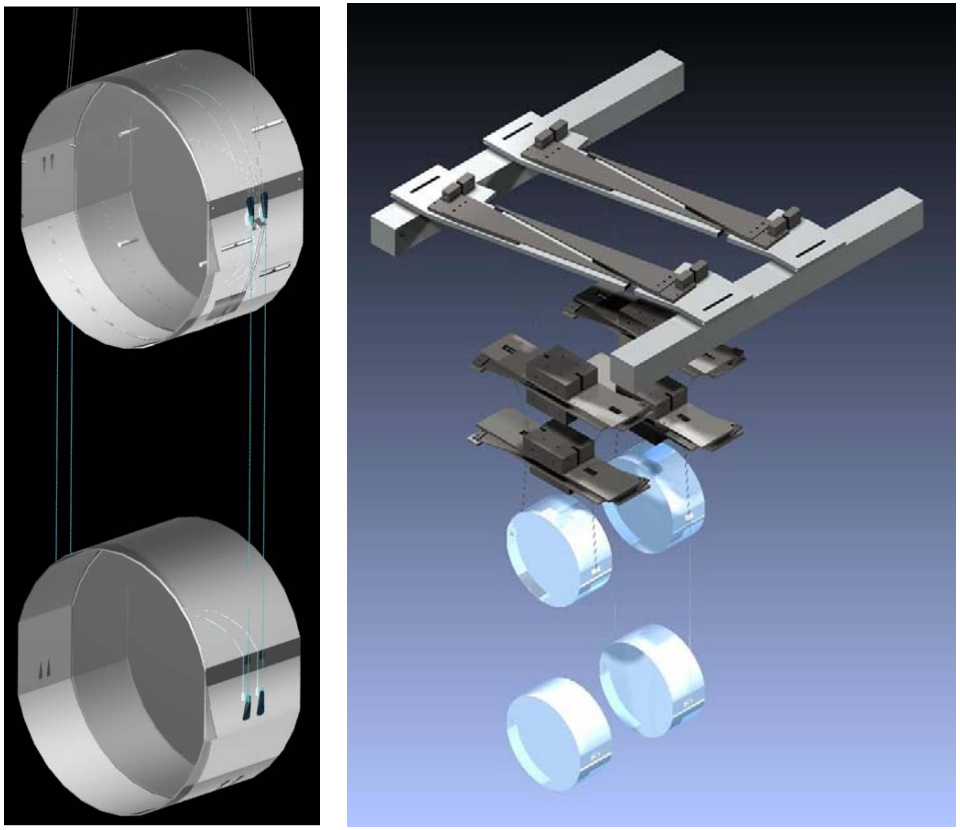
Monolithic stage of Adv. LIGO suspensions

- This talk will cover aspects of production and testing of suspension elements suitable for Advanced LIGO.
- The criteria that must be met by suspension fibres are:
  - Strength (x3 safety margin)
  - Thermal noise performance
- Current baseline are 600 x 1.13 x 0.13mm ribbon fibres.
- To meet these criteria we require
  - Breaking stress > 2.4 GPa
  - Intrinsic loss $<3 \times 10^{-11}/t$, where t is the thickness of the ribbon



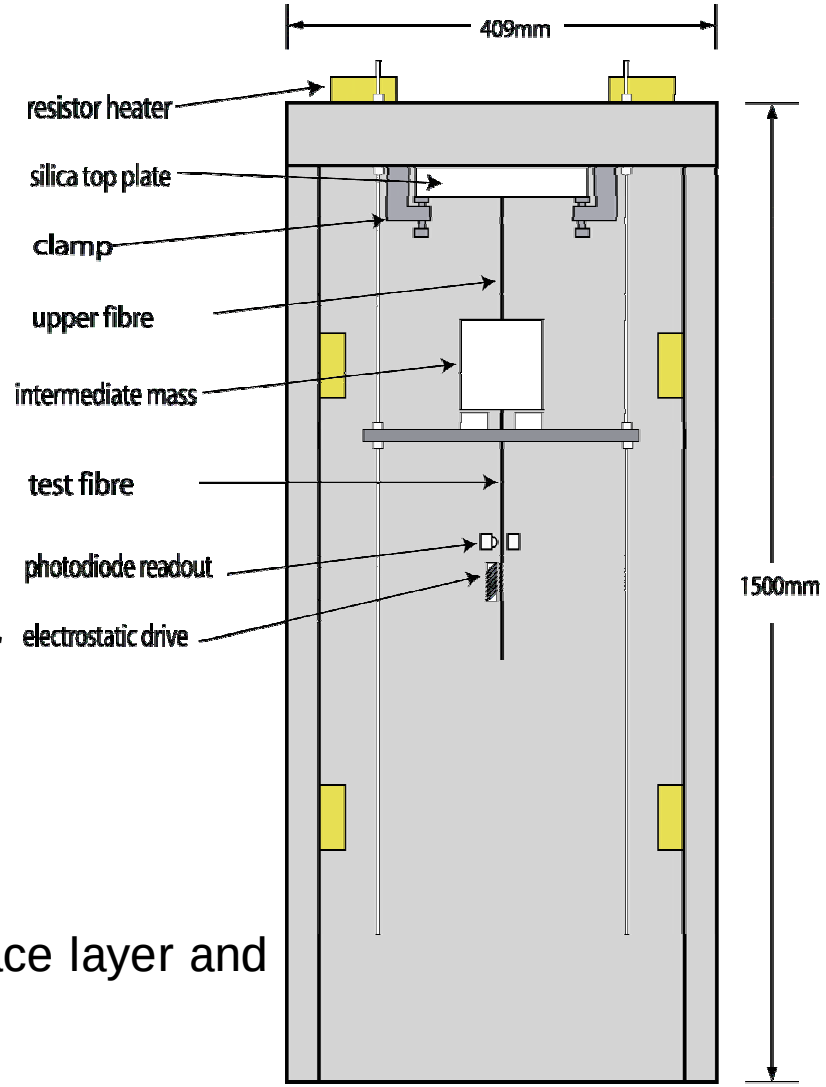
Mechanical Loss in Flame Pulled Ribbons

- Loss of cantilever bending modes measured for two Suprasil 3 ribbons
- Fibres were produced in a hydrogen-oxygen flame
- Fit measured loss using model that takes into account the distribution of energy:

$$\phi \cong 6\frac{h}{t}\phi_{surface} + \phi_{bulk} + \phi_{thermoelastic}$$

Surface loss term

where h is the thickness of the lossy surface layer and t is the ribbon thickness



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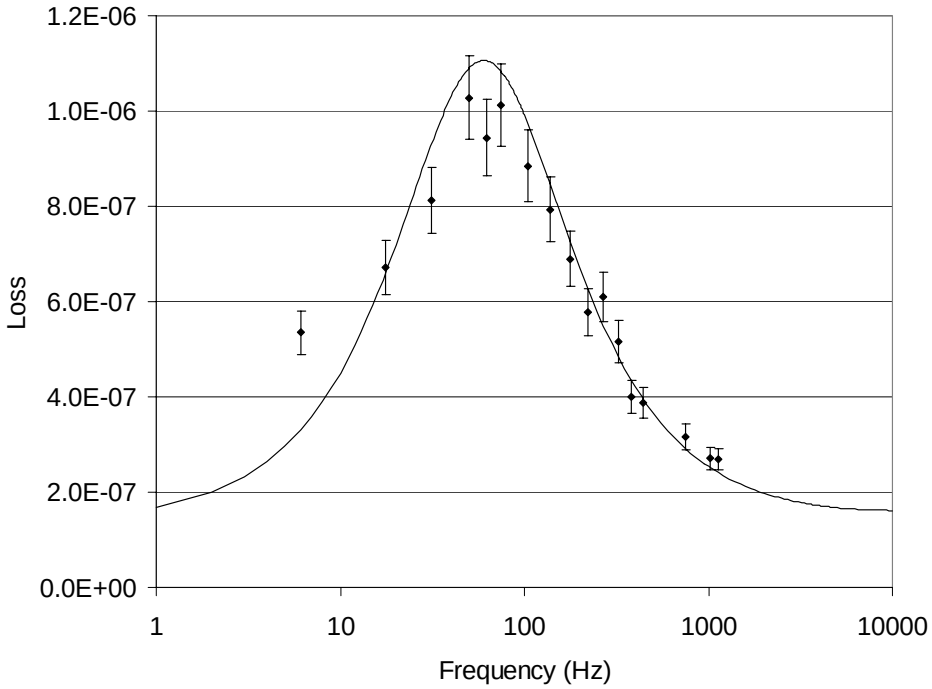
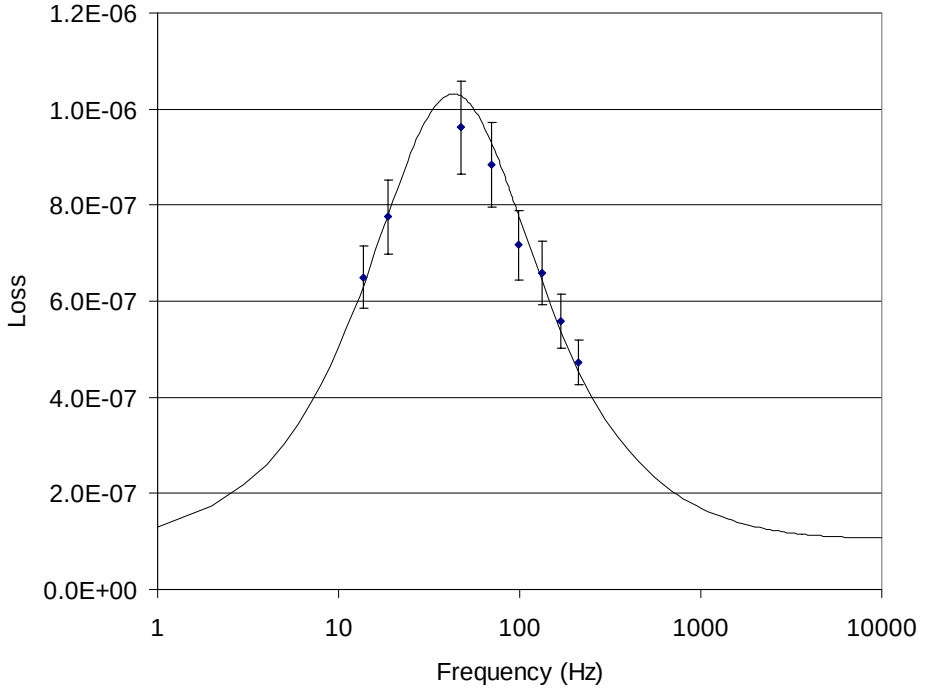
Mechanical Loss in Flame Pulled Ribbons



First fibre



Second fibre

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Mechanical Loss in Flame Pulled Ribbons

- Loss measurements by A.Heptonstall et al.(Phys Lett A, in press) are consistent with a surface loss term of:

$$h\phi_{\text{surface}} = (3 \pm 1) \times 10^{-12}\,\text{m}$$

- This compares favourably with measurements on cylindrical fibres of similar material. Data compiled by S.Penn et al.(Phys Lett A, 2006) allows us to calculate a value for Suprasil 2 of:

$$h\phi_{surface} = (6.0 \pm 0.4) \times 10^{-12}\,\text{m}$$

- This also compares well with measurements by A.Grettarson et al. (Rev. Sci. Intrum., 1999)

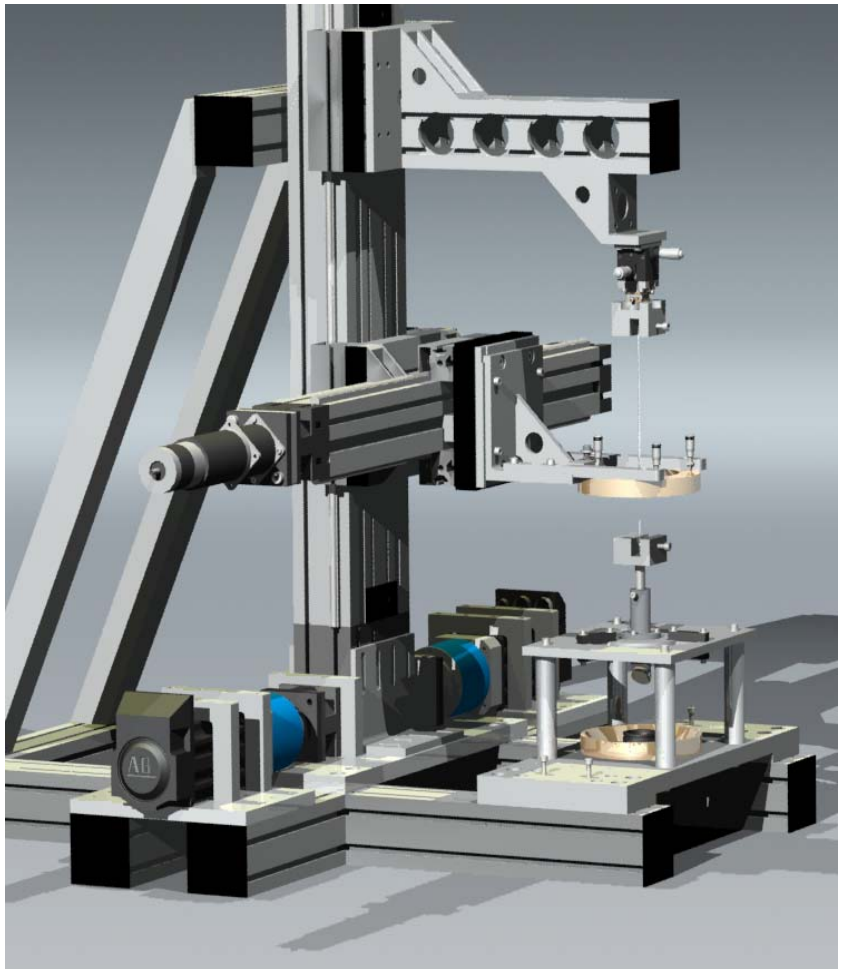
$$h\phi_{surface} = 5.9 \times 10^{-12}\,\text{m}$$

- Perhaps most importantly, this is below the value used to calculate the thermal noise performance in the Suspension conceptual design document:

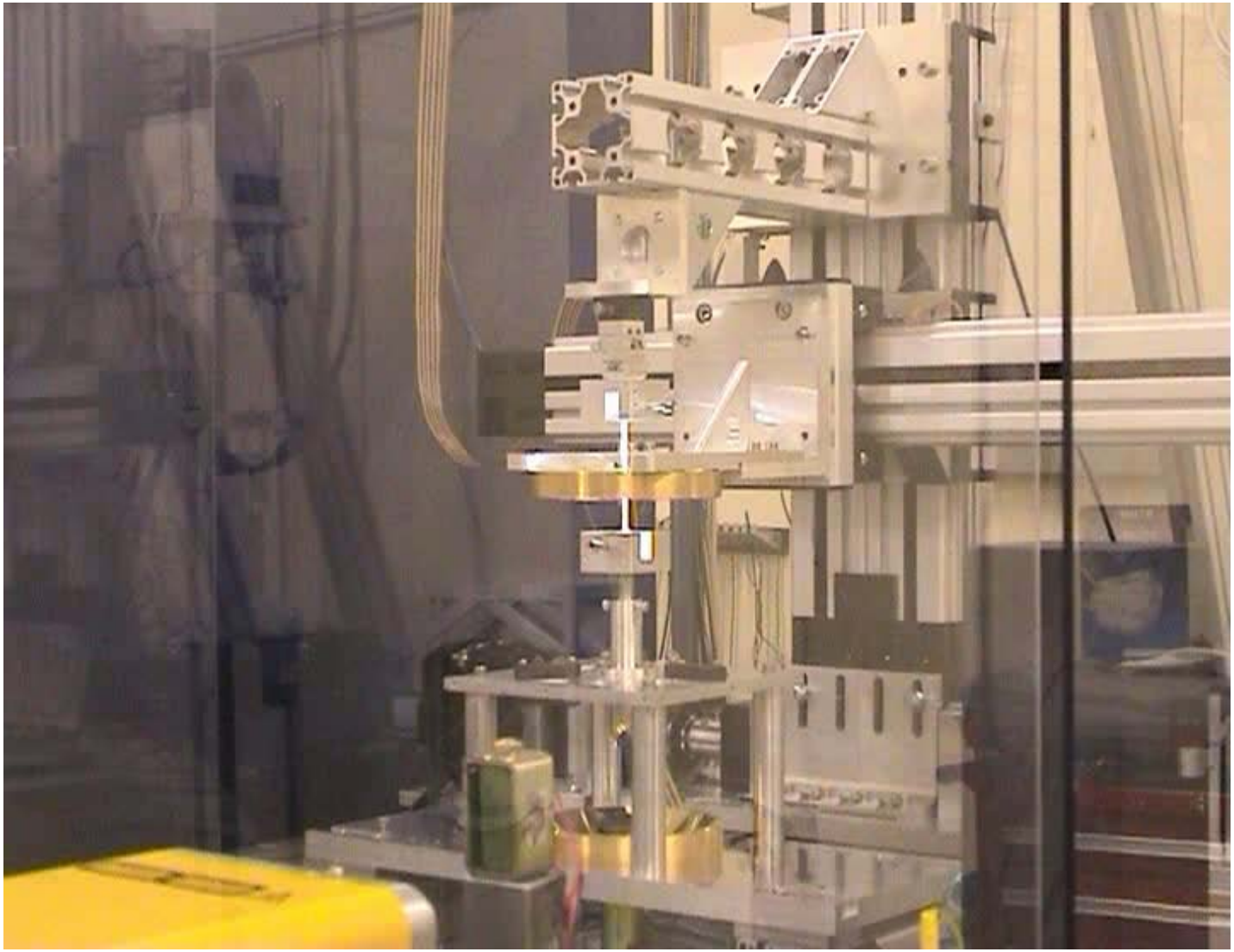
$$\phi_{\text{intrinsic}} = \left(3 \times 10^{-11}\right)/\text{t} = \left(6h\phi_{\text{surface}}\right)/\text{t} \quad \Longrightarrow \quad h\phi_{surface} = 5 \times 10^{-12}\,\text{m}$$

Improving the fibre pulling system

- Advanced LIGO suspensions require ±1.9% tolerance on fibre dimensions.
- This is a slight increase on the ±2.1% achieved in the GEO600 suspensions.
- Repeatability and tolerance in flame pulling machine is limited by gas regulation and slack in mechanical parts.
- In order to improve on this, a new system has been designed using a CO_2 laser, higher precision drive and magnetic linear encoder.
- The machine will also be capable of welding ribbon fibres.



Current machine status



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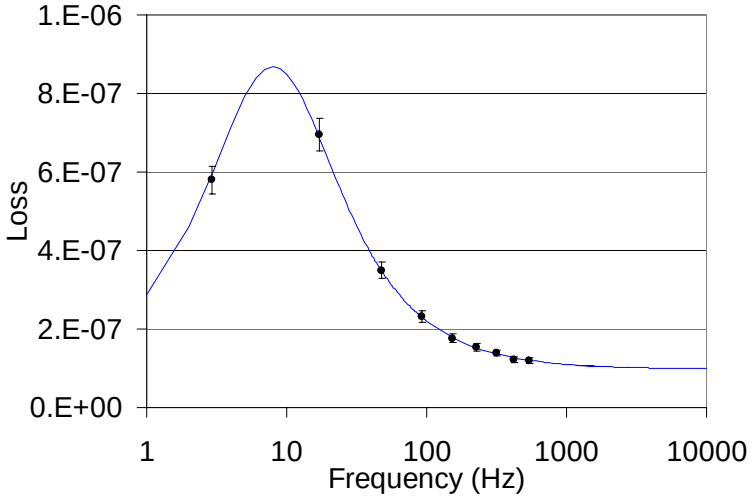
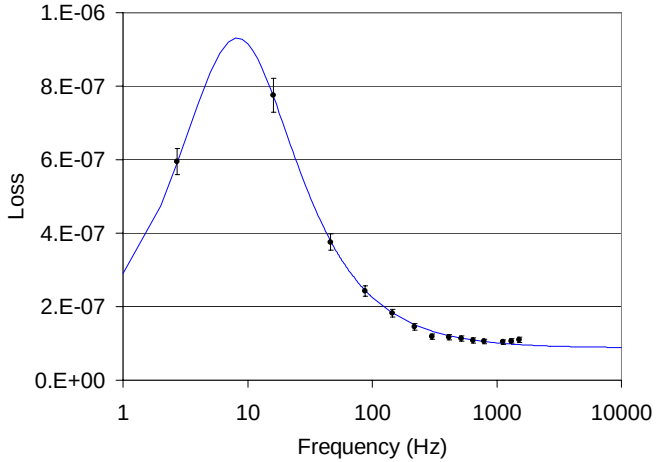
Mechanical loss in CO_2 laser pulled fibres





- Four Suprasil 300 fibres of diameter ~470μm were measured
- Initial analysis of losses shows a surface loss consistent with:

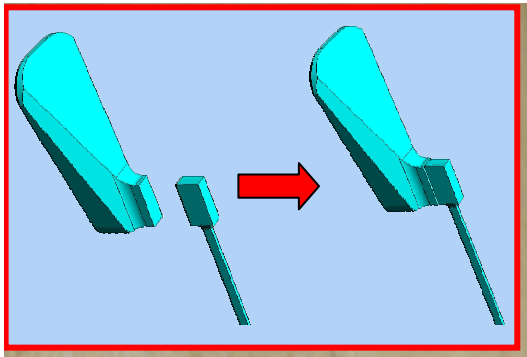
$$h\phi_{surface} = 4.7\times10^{-12}\,\mathrm{m}$$

- From Penn et al we can calculate values:

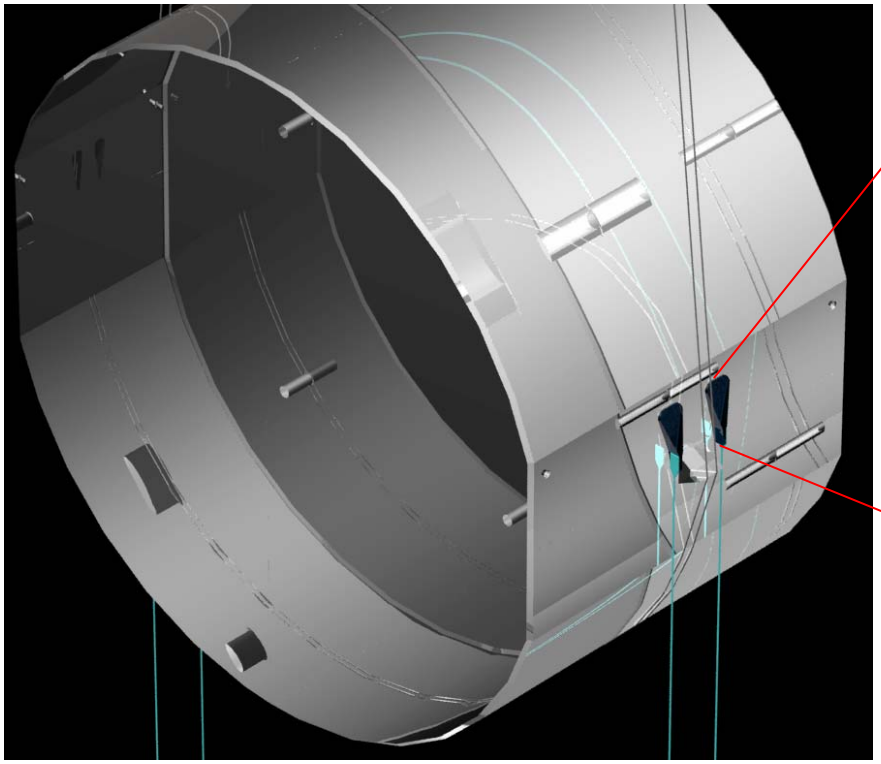
for suprasil 2 $\quad h\phi_{surface} = 6.05\times10^{-12}\,\mathrm{m}$

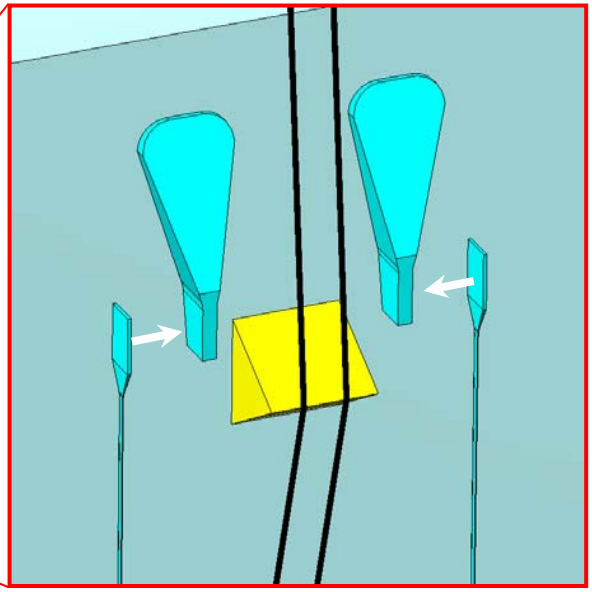
for suprasil 312 $\quad h\phi_{surface} = 3.25\times10^{-12}\,\mathrm{m}$

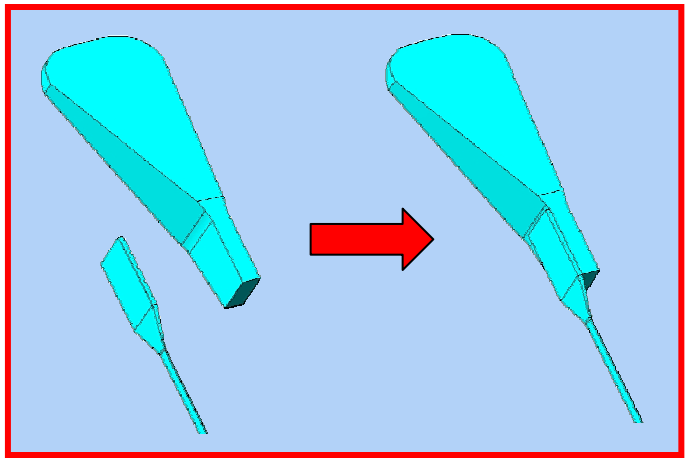
- Suprasil 300 is not necessarily expected to be similar to 312 or 311 as it has a different manufacturing process and a lower OH content



Improved ear design







- Reduces stress in ear
- Improves access for welding
- Increases the overlap area for weld

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Future work

- Work on stable pulling of ribbons using laser
  - We believe this is closely tied to laser stability, which we are currently investigating.
- Characterisation of strength and loss of CO_2 pulled ribbons.
- Continued tests of welding for attaching fibres
  - Parts for test new welding approach have only recently completed manufacture.
  - Completion of machine for welding.
- Ordering of new design of ear is currently taking place
  - Strength testing of ears and welds.
  - Bonded area will be very similar to previous design and no issues are foreseen with this.