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Static Fatigue in Fused Silica Fibres

Fused silica fibres used in current ground-based gravitational wave detectors, such as Advanced LIGO, sustain loads of 40 kg with stresses reaching up to ~780 MPa in their thinnest regions. Reducing fibre diameter and increasing stress improves suspension thermal noise performance by improving damping dilution. In addition, the resonant modes are shifted to more favourable frequency ranges within the detection band by raising the violin mode and lowering the bounce and roll mode frequencies. Future detectors, such as Cosmic Explorer and Einstein Telescope HF, aim to operate at higher stresses, however, fibre lifetime under a static load is limited by failure due to surface or volumetric defects.

Hang times of fibres under a constant stress have been previously measured in air indicating lower lifetimes due to stress-enhanced reactions with atmospheric moisture. Preliminary tests done at the Institute for Gravitational Research, Glasgow show that fibres held at 4.4 GPa lasted only 22 seconds in air but exceeded 77 days when loaded in vacuum. Since the fibres support expensive optics which are not easily replaceable, accurately estimating fibre lifetime under vacuum at operational stress levels is essential for defining safe design stresses while optimizing thermal noise performance.

Since direct testing at design stress would require multi-year experiments, we test fibres at higher stresses with reasonably small lifetimes and extrapolate to operational values using empirical models based on crack propagation mechanics. Additionally, we will use spectrometry to determine the vacuum exposure time required for moisture outgassing before it is safe to load the fibres.

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