Contribution ID: **54** Type: **Talk**

ET-FIBER: Monocrystalline Silicon Fibre Development for Cryogenic Test Mass Suspensions

Tuesday 7 October 2025 09:30 (15 minutes)

The ET-FIBER project is a collaborative R&D initiative, focused on developing monocrystalline silicon fibres for suspending a 100 kg test mass in the E-TEST prototype. E-TEST serves as a critical cryogenic prototype for the Einstein Telescope , operates a large monocrystalline silicon mirror cooled radiatively to 20–25 K, while achieving low seismic noise below 10 Hz through advanced vibration isolation. In this context, ET-FIBER aims to design, manufacture, and characterise silicon fibres capable of supporting these large test masses under cryogenic conditions, while meeting the stringent mechanical and thermal noise requirements of next-generation detectors.

While second-generation detectors like Advanced LIGO and Virgo employ fused silica fibres for suspension, their mechanical and thermal properties degrade at cryogenic temperatures. Silicon, in contrast, offers low mechanical loss and excellent thermal conductivity at low temperatures, making it a strong candidate for third-generation cryogenic suspensions. However, working with crystalline materials presents unique challenges. The mechanical loss in such materials is anisotropic and depends on crystal orientation, defect density, and impurity levels. Furthermore, welding or bonding techniques required to attach fibres to the test mass can disrupt the crystal structure, introducing additional dissipation mechanisms and compromising performance. Unlike amorphous materials such as fused silica, monocrystalline silicon lacks isotropy, making it more sensitive to geometrical and fabrication-induced imperfections.

ET-FIBER addresses several unresolved questions critical to silicon fibre technology. These include determining the breaking strength and yield thresholds of monocrystalline silicon fibres under cryogenic conditions, identifying optimal manufacturing techniques for producing ultra-pure, defect-free fibres, and understanding the mechanical and thermal behaviour of different fibre geometries. Additionally, the project explores how internal friction and surface losses contribute to overall thermal noise, and how these losses scale with diameter, surface finish, and bonding interfaces. Thermal conductivity is a key parameter in fibre design, as fibre diameter directly influences heat extraction from the test mass. Therefore, careful optimisation of fibre geometry is necessary to balance thermal transport with mechanical stability. This includes a detailed examination of variations in mechanical loss with temperature and crystal orientation, further highlighting the influence of crystalline anisotropy.

Through a combination of theoretical modelling, material characterisation, and experimental testing, we aim to provide a comprehensive understanding of silicon fibre performance under cryogenic conditions. By enabling the systematic development and evaluation of monocrystalline silicon fibres, ET-FIBER supports the Einstein Telescope's technical roadmap. The outcomes of this work will help define suspension design parameters, manufacturing protocols, and mechanical loss budgets for cryogenic test masses. By integrating fibre R&D into the E-TEST platform, ET-FIBER ensures that critical performance characteristics can be tested under realistic operational conditions, paving the way for reliable, low-noise silicon suspensions in future gravitational wave observatories.

Author: Mr MAGAIN, Gilles (University of Liege)

Co-authors: SPENCER, Andrew; TRAVASSO, Flavio; Prof. COLLETTE, Christophe (University of Liege); ZEOLI, Morgane (Université Catholique de Louvain-la-Neuve); SINGH, Hemendra

Presenters: Prof. COLLETTE, Christophe (University of Liege); Mr MAGAIN, Gilles (University of Liege)

Session Classification: MAD25: Session 2. Suspensions