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Cryogenic Evaluation of Materials for Vibration Isolation in Next-Generation Gravitational Wave Detectors

Laser Interferometer Gravitational Wave Observatories are instruments designed to detect gravitational waves. The detections made by LIGO confirmed the last remaining prediction of General Relativity and ushered in a new era of gravitational wave astrophysics. In order to improve sensitivity by an additional factor of two and to halve the low-frequency cutoff to 10 Hz, an upgrade to the LIGO observatory, called "LIGO Voyager,"is planned. This new interferometer is designed to operate at a temperature of 123 K, due to silicon's near-zero thermal expansion coefficient at that temperature. Other observatories currently in development, such as the Einstein Telescope (ET) and the Cosmic Explorer (CE), also plan to operate at cryogenic temperatures. In this context, it is necessary to adapt components for operation under cryogenic conditions, such as vibration isolation systems and, more specifically, their springs. Currently, there are candidate materials for the manufacture of these springs, which exhibit mechanical quality factors (Qm) suitable for this type of application. These materials include: stainless steel, niobium, tungsten, CuAl (6%), molybdenum, aluminum 5052 (similar to aluminum 5056), and maraging steel (already used in current interferometers). To carry out measurements under temperature conditions similar to those in detector operation, an experimental setup was developed to expose the material samples to a temperature of 77 K. This made it possible to observe the deflection of metals and alloys under both ambient and cryogenic conditions. As a material is cooled, its Young's modulus tends to increase; from a practical standpoint, this means that k, which represents the elastic constant in Hooke's law, also increases. For stainless steel, for instance, it was demonstrated that the cryogenic condition increased the spring constant by 1.40×10^2 N/m.

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