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Growth of monocrystalline silicon fibers for mirror suspension in gravitational-wave detectors

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Monocrystalline silicon fibers are a promising candidate to be used in gravitational-wave detectors for suspension of silicon test masses. High thermal conductivity and mechanical quality factor Q, very low thermal expansion coefficient, large strength-to-weight factor and compatibility with test masses enable stable support of heavy silicon mirrors and effective extraction of laser beam heat deposited therein. In addition, excellent material properties of silicon at cryogenic temperatures perfectly fit requirements of future third generation gravitational-wave detectors, such as the Einstein Telescope (ET), which will operate at cryogenic temperatures in order to reduce thermal noise and increase the detection-sensitivity at intermediate frequencies. As-grown monocrystalline silicon fibers have a particular interest for suspension application since they are both in bulk and surface free from cracks and defects (e.g. dislocations) that ensures high tensile strength.
In the frame of our research, we investigated crucible-free crystal growth methods for fabrication of fibers that can be suitable for application as mirror suspensions in ET. As the result, two growth set-ups, float zone (FZ) and pedestal, were developed and successfully utilized for fabrication of thin silicon fibers with monocrystalline structure and circular cross section. After thorough step-to-step process adjustment, the growth conditions were significantly improved, ensuring the stable and reproducible growth of 0.5 m to 1.0 m long silicon fibers, by both pedestal and FZ techniques, with uniform diameter along the entire length of the crystal, measured to be 3.0 mm, with maximum deviation of less than 0.1 mm. The structural analysis of as-grown fibers shows that the developed technique ensures the growth of dislocation-free monocrystalline silicon, which is highly preferable for mirror suspensions

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