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Fabrication considerations of large-scale scale silicon mirrors for future cryogenic gravitational wave detectors

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Cryogenic gravitational wave detectors are planned to be significantly more sensitive than current room temperature detectors. Cryogenic detection relies on materials that have low mechanical loss and Brownian noise at low temperatures, ruling out the use of the fused silica mirrors currently used. Silicon is proposed as a cryogenic mirror substrate due to its excellent mechanical loss and thermal properties. There are three predominant methods of creating silicon substrates: float-zone silicon, Czochralski silicon, and quasi-monocrystalline silicon. Currently, single-crystalline silicon produced with the float-zone method meets both the low optical absorption and low mechanical loss requirements of these detectors, however, it is limited in the diameters that can be produced. The planned ~50cm, 200kg mass gravitational-wave detection mirrors cannot be achieved with this form of silicon creation. Czochralski silicon does not meet the required low absorption, and may also not meet the diameter requirements, although magnetically-stabilised Czochralski silicon shows some promise. We are studying quasi-monocrystalline silicon, which is made via directional solidification and does have the capacity to meet the desired mirror size requirements. Here we present initial measurements of the optical absorption and mechanical loss of this material.

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