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Recent advancements in substrate-transferred crystalline coatings

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Owing to their high optical quality and low elastic losses, substrate-transferred crystalline coatings are currently redefining the performance metrics of a range of precision metrology applications including both room temperature and cryogenic mHz-linewidth lasers for optical clocks, stabilized frequency combs for microwave generation, and ultrastable resonators for fundamental physics experiments. These novel coatings are generated by transferring separately grown single-crystal GaAs/AlGaAs heterostructures to arbitrary optical substrates such as fused silica, sapphire, and silicon (among others). With continuous refinement in epitaxial growth and layer transfer, we have realized significant improvements in the near-IR optical performance of these mirrors. For center wavelengths spanning 1000 to 1600 nm, we have reduced the scatter + absorption losses to < 3 parts per million (ppm), enabling a cavity finesse exceeding 600,000 (equivalent to a reflectance > 99.9995%) at 1550 nm. We have now put a strong focus on the development of large area (> 25-mm diameter) and low defect density crystalline coatings, targeting applications in next-generation interferometric gravitational-wave detectors. To date, our direct-bonding process has been demonstrated to a maximum diameter of 200 mm, limited by the size of commercially available GaAs wafers. Given the present capabilities of industrial crystal growers, GaAs boules can now be grown to ~40 cm in diameter. To demonstrate the high quality of the epitaxial growth we have successfully verified that the uniformity of production-grade molecular beam epitaxy systems is sufficient to meet the stringent specifications for these large optics. In this direction we have performed uniformity tests of the material layer thickness (and thus optical transmission), as well as absorption and scatter loss measurements over areas with a diameter of up to 500 mm. These experiments show a clear and promising path towards low-noise crystalline coatings relevant to existing and future gravitational-wave observatories.

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