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## REFERENCE

1. G.D. Cole et al. *Appl. Phys. Lett.* **122**, 110502 (2023).

The complete author list for the paper covered by this summary is online at [optica-opn.org/optics-in-2023](https://optica-opn.org/optics-in-2023).

# Ultralow-Noise Coatings for Gravitational-Wave Detectors

Large-area, low-noise, substrate-transferred GaAs/AlGaAs crystalline coatings represent an exciting alternative to traditional ion-beam sputtered (IBS) coatings, currently a key limitation to improvements in advanced gravitational-wave (GW) detectors such as LIGO and Virgo. Implementing AlGaAs-based crystalline coatings will give GW observatories significantly enhanced sensitivity and thus greater detection rates and astrophysical reach.

It's estimated, for example, that the large reduction in coating thermal noise enabled by crystalline coatings could improve the detection rate of the binary neutron star mergers by some five times and the detection rate of binary black-hole mergers by three times relative to systems employing IBS mirrors.<sup>1</sup> Moreover, given the low thermal noise of AlGaAs at room temperature, future GW detectors could realize these significant sensitivity gains while avoiding the expense and complexity of cryogenic operation.

However, the development of large-area AlGaAs coatings presents unique challenges.

In a recent study,<sup>1</sup> we described how those challenges are being met, summarizing the current status of development efforts relevant to large-area substrate-transferred crystalline coatings and covering characterization efforts focused on understanding novel noise processes as well as optical metrology on 10-cm-diameter mirrors.

The study explored options to expand the maximum coating diameter to 20 cm and beyond, forging a path to produce low-noise mirrors amenable to next-generation GW observatories. The work also included a detailed discussion on the unique requirements for these novel semiconductor-based coatings and outlined potential experimental testbeds for large-area prototype mirrors. Monocrystalline AlGaAs-based coatings exhibit promising optomechanical properties for enhanced sensitivity in GW detection and demand further investigation. Experimental efforts have confirmed the enhanced properties of these coatings for the currently manufactured 10-cm-diameter mirrors, with the simultaneous achievement of excellent optical and mechanical properties, including parts-per-million levels of scatter and absorption coupled with an approximately tenfold reduction in elastic loss.<sup>1</sup>

As discussed in our study, the cost and timeline to realize dedicated large-diameter production capabilities for the roughly 30-cm-scale required for next-generation terrestrial GW facilities are comparable to those for the development of other important subsystems, such as seismic isolation and quantum squeezing. The latter is an appropriate comparison, given that coating thermal noise is the limiting noise source in the most sensitive frequency band of these systems. The low-noise coatings we are developing also offer potential budgetary savings in future detectors by eliminating the need for cryogenic operation. We thus see a bright future ahead for the development of high-performance crystalline coatings for advanced astronomical applications. **OPN**



Prototype semiconductor supermirror (GaAs/AlGaAs direct-bonded to fused silica).

### Complete Author List of Summarized Paper

Following is the complete author list and affiliations for G.D. Cole et al., "Substrate-transferred GaAs/AlGaAs crystalline coatings for gravitational-wave detectors," Appl. Phys. Lett. **122**, 110502 (2023).

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