Materials for Advanced Detectors 2025

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Optical Simulations of Ion Implanted Layers for Advanced Gravitational-Wave Detection

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Thermal noise originating from mirror coatings remains a key limitation to the sensitivity of gravitational-wave detectors, particularly within their most sensitive frequency range. As next-generation detectors, such as the Einstein Telescope and LIGO Voyager, move toward cryogenic temperatures to mitigate this noise source, conventional coating materials like Ta\textsubscript{2}O\textsubscript{5} and SiO\textsubscript{2} prove insufficient due to their high mechanical losses at low temperatures. Promising alternatives, including amorphous silicon (a-Si) and silicon nitride (SiN), offer improved thermal noise performance; however, the substantial optical absorption of a-Si hinders its practical application. To overcome this, we introduce a novel strategy: fabricating highly reflective structures directly within crystalline silicon (c-Si) mirror substrates using ion implantation, a well-established technique in the semiconductor industry that has not been explored in this context. This method enables the integration of SiO\textsubscript{2} and SiN layers at precisely controlled depths, while maintaining the advantageous optical properties of high-purity c-Si. We present the first successful demonstration of such a multilayer structure, exhibiting no visible surface degradation. While the presentation by Luca Massaro concentrates on the implantation schedules and mechanical properties of the layers, the present work reports the optical analysis of single and double silica (SiO\textsubscript{2}) layers implanted in a c-Si substrate, as well as single and double silicon nitride layers (SiN) implanted in a similar substrate.

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