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Advancing Gravitational-Wave Detection Through Ion Implantation for Low Thermal Noise Coatings

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Coating thermal noise limits the sensitivity of gravitational-wave detectors in the most sensitive frequency band. As third-generation detectors, like the Einstein Telescope or LIGO Voyager, advance toward cryogenic interferometers to reduce thermal noise, current coating materials such as Ta_2O_5 and SiO_2 become inadequate due to their high mechanical loss at low temperatures. Alternative materials, like amorphous silicon (a-Si) and silicon nitride (SiN), are promising due to low thermal noise, but the high optical absorption of a-Si is a limiting factor. We propose a paradigm-shifting approach: forming highly reflective structures directly inside the crystalline silicon (c-Si) mirror substrates via ion implantation. This technique, widely adopted in the semiconductor industry, is unexplored in this context. Ion implantation has the potential to achieve significantly lower optical absorption compared to a-Si by preserving the optical properties of high-purity c-Si layers. Using a dedicated ion implanter, we created buried SiO_2 and SiN layers at controlled depths inside c-Si substrates. We report the first successful fabrication of a multilayer structure exhibiting no visible surface damage. Simulations of the implantation schedule are compared with Rutherford Backscattering Spectrometry (RBS) measurements. Furthermore, preliminary optical analysis and mechanical loss results are presented. Ongoing development of SiN-implanted structures may be a way to meet—and exceed—the demanding requirements of third-generation observatories. While the presentation by Ismail El Ouedghiri concentrates on the optical properties, this presentation focuses on the implantation schedules and mechanical properties of the layers.

Author: MASSARO, Luca

Presenter: MASSARO, Luca

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