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

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The forthcoming era of gravitational wave detectors, exemplified by the Einstein Telescope, demands unprecedented levels of sensitivity. Central to this progress is the deployment of cryogenic low-frequency interferometers, hinging on silicon as the mirror substrate material. A critical hurdle lies in mitigating coating thermal noise, a main limiting factor to detector precision. This project follows a new approach, using ion implantation to produce novel mirror coatings. Unlike traditional deposition methods, ion implantation creates coating layers inside the material instead of on the surface, potentially preserving the low noise characteristics of the crystalline silicon substrate. By implanting nitrogen ions into crystalline silicon, we aim to create low-index layers of silicon nitride (SiN) amidst the crystalline silicon, aiming to optimize the balance between optical absorption and thermal noise. Additionally, ion implantation promises to circumvent size limitations inherent in crystalline coatings, opening the door to larger mirrors needed for future gravitational wave detectors. The culmination of this endeavor lies in thermal noise tests conducted in the ETpathfinder facility. Here, the implanted mirror will be integrated and rigorously evaluated, providing a demonstration of the anticipated advancements. In conclusion, this project embarks on a transformative journey, leveraging ion implantation to revolutionize mirror coatings for gravitational wave detectors. Through extensive simulations, precise implantation, and comprehensive characterization, we aspire to refine the state-of-the-art in this critical facet of gravitational wave research.

Presenters: WOEHLER, Janis (Maastricht University); MASSARO, Luca (Maastricht University)

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