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High Power is Nothing Without Control: Tackling Thermal Aberrations in Future GW Detectors

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Almost all future plans for gravitational wave detectors foresee operation at increasingly higher power levels to reduce shot noise, making residual aberrations from thermal effects more critical, potentially becoming a limiting factor despite the effectiveness of current correction methods.
Since the beginning of the Virgo project, we made significant strides in mitigating thermally-induced aberrations, which pose a key challenge for maintaining interferometric stability and sensitivity. These aberrations, primarily caused by thermal effects in the optics, affect the main laser beam and degrade detector performance. By analyzing the techniques employed to correct these aberrations during O4 and the long commissioning experience, we can identify potential critical elements for future operations.
To address these challenges, we are actively refining thermal compensation systems, improving real-time monitoring and control of non-axisymmetric or non-spherical residual aberrations, and developing more advanced adaptive optics. These innovations aim to enhance the detector's resilience to thermal disturbances, ensuring that future runs, such as O5 and beyond, operate at peak sensitivity. We present the landscape of hints gathered from current experience that point to possible future issues, providing a picture of the status of developing solutions.

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