# Testing novel high-reflectivity mirror technologies from room-temperature to 4 K

**M. Kempkes, T. Legero, U. Sterr, D. Nicolodi**
Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
email: mona.kempkes@ptb.de

Coating thermal noise in high-reflectivity mirror coatings constrains the stability of state-of-the-art optical resonators and hence limits the performance of many precision laser experiments. To get beyond this limitation highly reflective coatings with significantly lower mechanical losses than traditional $Ta_2O_5/SiO_2$ dielectric coatings are needed. However, only a few promising alternatives have been developed so far.

Crystalline AlGaAs/GaAs multilayer coatings seemed to be a suitable candidate [1] and optical resonators equipped with these coatings demonstrated a performance near the predicted thermal noise floor at room-temperature [2]. Yet, two experiments at 124 K and 4-16 K recently revealed a hitherto unknown noise source which limits the frequency stability far above the expected thermal noise floor at cryogenic temperatures [3, 4]. This not yet identified noise exceeds the thermal noise reduction expected from the low mechanical losses and challenges the potential use of crystalline coatings in next generation cryogenic gravitational wave detectors.

Furthermore, photo-birefringence with very different behavior between room-temperature and cryogenic experiments has been observed in AlGaAs/GaAs multilayer coatings. Thus, one of the most promising mirror coating candidates for ultra-stable optical resonators with fractional frequency stabilities beyond the $10^{-17}$ level still holds unresolved issues.

We will present a low-vibration closed-cycle cryostat setup for the characterization of mirror coatings performance and direct Brownian thermal noise measurements from room-temperature to 4 K. Using a high-finesse optical resonator as well as multiple techniques to circumvent technical noise sources related to vibration and temperature fluctuations this facility will enable analyzing the optical behavior of AlGaAs/GaAs multilayer coatings across a broad temperature range, which in turn helps understanding the source of the observed excess noise and possibly identifying suppression or mitigation strategies.

The same system will also offer the possibility to verify thermal noise estimates and ruling out yet unknown noise sources in other novel high-reflectivity mirror designs such as nanostructured meta-etalons [5, 6] and amorphous-Si multilayer coatings [7] over a temperature range relevant for applications in ultra-stable optical resonators and in next generation gravitational wave detectors.

## References

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