Cryogenic Vacuum Constraints to Mitigate Frost Formation on the Optics of Future Gravitational Wave Detectors

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The use of cryogenic mirrors in future gravitational wave detectors has been individuated as a viable solution to reduce thermal noise and obtain the desired detection sensitivity at low frequency. Operating at temperatures down to ~10 K presents several extraordinary challenges, one being the cryogenic vacuum system hosting the cold mirrors. Gases composing the residual vacuum will tend to cryosorb on the mirror surface and build up a contaminant ice layer ("frost"). This can severely perturb or even prevent detection. Then, to preserve the unquestionable improvements expected by cooling down the mirrors at cryogenic temperatures, a series of necessary solutions need to be adopted.

Here we will analyze the consequences of hosting a cryogenically cooled mirror in a vacuum system. By introducing a simple way to estimate the ice growth on the mirrors, we will give the limits for an acceptable operating pressure to avoid frost formation in a given period of continuous data taking. Frost formation, however, cannot be totally avoided and an active solution to remove the growing frost adlayer would be desirable. Among the potential mitigation methods to cure such a phenomenon, we will consider electron stimulated desorption as a possible way to desorb the ice layer from mirrors. Such defrost method will clearly cause electrostatic charging, which has been already shown to affect gravitational wave detection on running interferometers. Here we will give an experimental proof of principle on how electrons can not only induce ice desorption but also mitigate charging issues by properly tuning their kinetic energy.