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C2Or3C-03: Cryopump concept development for the cryogenic mirror region of the Einstein Telescope – the future gravitational wave observatory

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The Einstein Telescope (ET), as the planned third-generation, underground gravitational-wave observatory for Europe, will increase the sensitivity compared to the current advanced detectors (Virgo, LIGO, KAGRA) and expand the frequency band to lower frequencies. Proposed as an equilateral triangle with 10 km long vacuum pipe arms, the Einstein Telescope will consist of three laser interferometers for high (HF) and low frequencies (LF) each.
The main optics of ET-LF will be cooled to cryogenic temperatures below 20 K and the whole system, consisting of the beam pipes, the suspension towers and the cryostat containing the mirror, requires high to ultra-high vacuum conditions. Residual gas has to be reduced as much as possible to avoid e.g. thermal or optical noise and due to the fact that gases like water will be adsorbed as frost on the cryogenic mirror surface and thus degrade its optical performance.
In order to fulfill the vacuum related requirements and to consider thermal radiation aspects from the warm interferometer to the cryogenic mirror, the use of tailor-made in-situ cryopumps is envisaged. Simulations at KIT, performed with the in-house Test Particle Monte Carlo code ProVac3D and a simplified model of the system, considered the main gas sources from the neighbouring systems (coming from the outgassing steel surface along the entire beam pipe, the warm tower with the mirror marionette, and the adjacent tower) and the sinks by pumping stations distributed along the pipe arms, the cryogenic pump section close to the mirror and the cryogenic mirror environment. These simulations showed different needs for the pumping of hydrogen (to lower the residual pressures) or heavier species like water (to lower the frost formation on the cryogenic mirror surface) –depending on the position in the interferometer related to the mirror. With these findings, the development of a pumping concept was worked out.
In parallel, the outgassing rates of the inner walls of the beam pipe tubes, influencing strongly the vacuum pumping demands, have been investigated experimentally with a dedicated outgassing facility at KIT in order to support the decision process for different material options.
This paper describes the developed pumping concepts, utilizing cryogenic pumps integrated into the beam pipe tubes of 1 m diameter, with their individual objectives regarding pumped species and needed temperatures. Also the open decision between cryocondensation at 3.7 K or physisorption on a sorbent at higher temperatures like 10 K for hydrogen pumping is discussed.
Besides the assessment of resulting thermal radiation on the mirror, the expected heat loads on the cryopumps, to be managed by the cryoplant of ET, are assessed.
Finally, the key parameter of frost formation on the cryogenic mirror, important for long operational phases without pause and maintenance, is derived from the predicted residual pressure of sticky gases like water.

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