Vacuum Technology
Room 205 ABCD W - Session VT2-MoA

Vacuum for Fusion and Large Systems II

Moderators: Freek Molkenboer, TNO Science and Industry, the Netherlands, **Marcy Stutzman**, Jefferson Lab

4:00pm **VT2-MoA-11 The Einstein Telescope Beam Pipe Vacuum System: The Pilot Sector***, **Ivo Wevers**, Giuseppe Bregliozzi, Paolo Chiggiato, Manjunath Dakshinamurthy, Ana Teresa Perez Fontenla,* CERN, Switzerland*; Purnalingam Revathi,* university of Antwerp, Belgium*; Carlo Scarcia,* CERN, Switzerland **INVITED**

Gravitational waves were first detected in 2015 by LIGO, which has since measured several other events in collaboration with VIRGO. These groundbreaking discoveries have driven the development of next-generation gravitational wave observatories, including the Cosmic Explorer (CE) in the U.S. and the Einstein Telescope (ET) in Europe.

A key factor in enhancing detection performance is the length of the Fabry-Perot cavities, where high-power laser beams are stored in an ultrahigh vacuum. Both CE and ET require over 100 km of vacuum pipes, each approximately 1 meter in diameter. If built using the same materials and design as LIGO and VIRGO, these vacuum systems could account for an important fraction of the total budget for the new facilities. To reduce the cost impact of the vacuum system, unconventional materials, less expensive pipe manufacturing and different surface treatments were investigated.

Mild steels and ferritic stainless steels have emerged as promising, cost-efficient alternatives due to their inherently lower residual gas content. However, material selection must also consider availability, formability, weldability, strength, ductility, corrosion resistance in addition to cost. Based on these criteria, ferritic stainless steel AISI 441 (EN 1.4509) has been identified as the most suitable material for ET's beam pipe vacuum system.

To validate this approach, a 40-meter-long pilot beam pipe is being constructed at CERN. This test sector will assess the vacuum layout, material performance, vibration transmission and operational strategies needed to achieve ultrahigh vacuum (UHV) in a dust-controlled environment at a lower cost. The results will play a crucial role in shaping the final design of the next-generation gravitational wave detectors.

4:45pm **VT2-MoA-14 Comparative Water and Hydrogen Outgassing Behavior of Bare vs. Magnetite-Coated AISI 1020 Low-Carbon Steel***, **Aiman Al-Allaq**,* ODU - Jefferson Lab*; Md Abdullah Al Mamun, Matthew Poelker,* Jefferson Lab*; Abdelmageed Elmustafa,* ODU

Building on our previous work on low-carbon steel's outgassing characteristics, this study presents a systematic comparison between bare and magnetite-coated AISI 1020 steel vacuum chambers. Room temperature pump-down curves for both chambers follow power-law behavior ($P \propto t^{-\alpha}$) with α values near 1.1, indicating diffusion-limited desorption. The magnetite coating initially provides 5.3× lower water outgassing rates (1.88×10^{-11} vs. 9.88×10^{-11} Torr·L/s·cm^2), but this advantage reverses after thermal treatment, with bare steel outperforming magnetite by 3.3× after 80°C and 1.4× after 150°C baking. More significantly, hydrogen outgassing measurements show bare steel achieving rates as low as 9.6×10^{-16} Torr·L/s·cm^2 compared to 2.4×10^{-14} Torr·L/s·cm^2 for magnetite-coated steel after intensive thermal conditioning. Comprehensive characterization through Sips isotherm modeling reveals higher binding energies for magnetite (1.12-1.24 eV) versus bare steel (0.9-0.97 eV), while Arrhenius analysis shows similar activation energies (0.33-0.68 eV). RGA measurements confirm hydrogen dominance (>99%) in the residual gas composition. These findings enhance our understanding of the fundamental outgassing mechanisms in low-carbon steel and provide quantitative data essential for vacuum system design.

5:15pm **VT2-MoA-16 VTD Business Meeting***,*

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