Thursday Morning, November 12, 2026

Vacuum Technology
Room 321 - Session VT2-ThM

Engineering for Big Vacuum Systems

Moderators: Klaus Bergner, VACOM, **Giulia Lanza**, SLAC National Accelerator Laboratory

11:00am **VT2-ThM-13 Recent Results and Paths Forward Towards the Development of a Continuous Cryogenic Pumping and Impurity Removal System for Fusion Devices***, **Trey Gebhart***[1]*, Nirajan Adhikari,* Oak Ridge National Laboratory

Future deuterium-tritium fueled fusion power plants must breed tritium and sustain a burning plasma using a semi-closed loop fuel cycle. The DT fusion fuel cycle is an important aspect of any fusion energy configuration whose purpose is to provide fuel to the plasma, pump and separate machine exhaust products, and recover fuel from breeding and plasma exhaust products. The current method of separation requires a large building for palladium membranes and cryogenic distillation columns. The concept of directly recirculating the exhaust gas, bypassing the tritium plant, to make fuel pellets was proposed in the 1990s and later termed Direct Internal Recycling (DIR). The residual fusion fuel in the machine exhaust stream is separated locally and diverted directly to the fueling systems, bypassing isotopic separation and other processing equipment, and therefore significantly reducing the required size of the tritium plant, reducing plant tritium inventory, and thus increasing the economic viability of fusion as an energy source.

One concept for DIR consists of a series of cryogenic pumps to separate the impurities from the machine exhaust gas by utilizing the different triple point temperatures of exhaust constituents. Pumps for this concept are being developed at Oak Ridge National Laboratory. In this concept, the plasma exhaust gases are initially passed through an impurity trap operating at ~25-30 K to desublimate impurities such as hydrocarbons, argon, oxygen, and nitrogen. The resulting process stream will consist of deuterium, tritium, and helium. The process stream is then pumped by a continuous cryopump known as a "snail pump". This pump is a steady state continuous cryopump that desubliminates all remaining exhaust gas constituents while allowing helium, a byproduct of the fusion reaction, to pass through. The helium is pumped to the tritium plant for processing while the desublimated material is continuously scraped off, heated until sublimation, and transported to the fueling system. The resulting clean DT stream is then sent directly to the fueling systems. This contribution outlines the overall design of the system, along with the most recent modeling and experimental results from this potential fusion pumping system. The R&D paths forward required for deployment in the fusion environment will also be presented.

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11:15am **VT2-ThM-14 SPARC Tokamak Vacuum Pumping System Commissioning and Status***, **Matt Fillion**, Oliver Mulvany, Evelyn Richards, Alana Guilbault, Carl Avola, Emily Marget, Chris O'Connor,* Commonwealth Fusion Systems*; Shaun Hughes,* Commonwealth Fusion Systems, UK*; Chris Tesluk, Eric Dombrowski, Cory Crowley, Heena Mutha,* Commonwealth Fusion Systems

The SPARC tokamak is a compact, high-field, deuterium-tritium fueled magnetic confinement device, aimed at demonstrating net energy gain. The SPARC vacuum pumping systems (VACP) comprises three subsystems: the cryostat pumping system provides vacuum insulation of cryogenic components, the leak detection system provides interspace pumping of vulnerable double-walled vacuum components, and the torus pumping system is an integral part of the D-T fuel cycle to enable plasma operations.

Each VACP subsystem is being commissioned to demonstrate plant readiness for plasma operations. This talk will provide an update on SPARC vacuum pumping systems assembly and commissioning activities, and coming steps. We will discuss the plant-side integrated commissioning and characterization of the vacuum pumping systems; e.g., system base pressures and vacuum quality. Additionally, we will demonstrate the system's ability to receive hydrogen isotope gas loads via a temporary test stand, verify its exhaust paths, and validate fault responses.

11:30am **VT2-ThM-15 Scalable Strategies for Large Ultra-High-Vacuum Systems***, **Melina Fuentes-Garcia**,* California Institute of Technology

The Laser Interferometer Gravitational-Wave Observatory (LIGO) detects gravitational waves by measuring distortions in spacetime as they pass through a set of 4km-long interferometer arms. To achieve the required sensitivity, the interferometer must operate under ultra-high-vacuum (UHV) to minimize phase noise associated with scattering from residual gas species in the beamtube arms. Water vapor, a dominant gas species, has a strong binding energy to stainless steel, and when a beamtube is exposed to atmospheric air during venting, a bakeout is typically required to accelerate desorption and restore UHV conditions. For LIGO, and other large-scale systems, bakeout is not feasible due to the significant cost. Presented here are two complementary studies motivated by this challenge. The first examines backfilling of a UHV chamber, made of a section of initial LIGO beamtube, with ultra-high-purity dry air to suppress re-adsorption of water vapor, with the potential of avoiding a bakeout entirely. The second investigates an alternative bakeout method and alternate beamtube material for third generation gravitational wave detectors, such as Cosmic Explorer. It utilizes a movable induction heater to drive off water vapor from a mild steel beamtube. While this effort is intended to inform design on future detectors, in particular beamtube material selection and bakeout technique, it draws on experimentation and modeling closely related to that of the first study. Together, these investigations point toward practical strategies that can be applied to large scale UHV systems.

11:45am **VT2-ThM-16 Engineering Aspects of a-C Coating Systems Targeting Low Secondary Electron Yield***, **Abhilash S Reghu**, Byron Golden, Jessica Brown, Sumanta Nayak, Susheng Xin, Kenneth Decker, Charles Hetzel,* Brookhaven National Laboratory

The amorphous carbon (a-C) coating campaign for the Electron–Ion Collider (EIC) beamline at Brookhaven National Laboratory is advancing rapidly. A prototype system successfully established the coating process, paving the way for the design and construction of a 12-meter full-scale production coating machine, which is currently undergoing testing. Once validated, more coating machines will be deployed to expand the facility and complete the campaign on schedule. This paper presents the essential features and engineering considerations of the coating systems and discusses key lessons learned during commissioning, testing, and operation, with a focus on strategies for achieving low secondary electron yield.

12:00pm **VT2-ThM-17 The Vacuum System Design for the Extreme Photonics Applications Centre (EPAC)***, **Keith Middleman**,* Science & Technology Facilities Council - STFC, UK

The EPAC facility currently under construction at the STFC Rutherford Appleton Laboratory is a new UK national facility that provides a unique opportunity to develop laser driven accelerator research, enabling a plasma wakefield accelerator facility with multi-GeV electron beams and spatially coherent x-ray and gamma-ray beams for cutting-edge experiments in plasma physics, laboratory astrophysics and condensed matter and material science.

This paper describes the design of the vacuum systems for Experimental Area 1 of the EPAC facility where high intensity lasers interact with a high density of gas molecules to ignite a plasma. The EPAC facility will run in the High Vacuum (HV) range with a typical operating pressure of 10^{-6} – 10^{-7} mbar. However, at the interaction point where the plasma is ignited there will be a gas injection nozzle that will provide the required gas density. It is anticipated that the expected gas pressure at the interaction point could be in the range of 10^{0} – 10^{2} mbar.

The vacuum design is presented showing what has been done to minimise the spread of the localised high-pressure gas from the target location into the laser delivery beamline. This is essential to avoid laser breakdown and non-linear effects occurring before the laser reaches its peak intensity at the focus. The differential pumping configuration will be explained and there will be an overview of the gas dynamics work done across the pressure regimes from transitional flow to molecular flow.

The outcome of this work is a vacuum system capable of the demands put upon it from localised gas densities to the performance of the laser optics in delivering the required laser intensities. It is anticipated that this new UK user facility will open in late 2026.

[1] **JVST Highlighted Talk**

Author Index

Bold page numbers indicate presenter

— A —
Adhikari, Nirajan: VT2-ThM-13, 1
Avola, Carl: VT2-ThM-14, 1
— B —
Brown, Jessica: VT2-ThM-16, 1
— C —
Crowley, Cory: VT2-ThM-14, 1
— D —
Decker, Kenneth: VT2-ThM-16, 1
Dombrowski, Eric: VT2-ThM-14, 1
— F —
Fillion, Matt: VT2-ThM-14, **1**
Fuentes-Garcia, Melina: VT2-ThM-15, **1**
— G —
Gebhart, Trey: VT2-ThM-13, **1**
Golden, Byron: VT2-ThM-16, 1
Guilbault, Alana: VT2-ThM-14, 1
— H —
Hetzel, Charles: VT2-ThM-16, 1
Hughes, Shaun: VT2-ThM-14, 1
— M —
Marget, Emily: VT2-ThM-14, 1
Middleman, Keith: VT2-ThM-17, **1**
Mulvany, Oliver: VT2-ThM-14, 1
Mutha, Heena: VT2-ThM-14, 1
— N —
Nayak, Sumanta: VT2-ThM-16, 1
— O —
O'Connor, Chris: VT2-ThM-14, 1
— R —
Reghu, Abhilash S: VT2-ThM-16, **1**
Richards, Evelyn: VT2-ThM-14, 1
— T —
Tesluk, Chris: VT2-ThM-14, 1
— X —
Xin, Susheng: VT2-ThM-16, 1