Vacuum Technology Division
Room A213 - Session VT-MoA

Gas Dynamics, Surface Science for Accelerators, and Ultra-Clean Vacuum Systems

Moderators: Jason Carter, Argonne National Laboratory, James Fedchak, National Institute of Sandards and Technology (NIST)

1:40pm **VT-MoA1 Advancement in Transient Flow Simulations: Applications to Channel and Porous Media Conductance Modeling***, **Irina Graur Martin**,* Aix Marseille University, France **INVITED**

The gas flow through long channels of various and variable cross-sections is a practical problem in the MEMS and vacuum technology applications. As examples of such kind of flows the leakage through compressor valves and the flows in the micro bearing may be given. Among these applications, the gas flows through the low permeable membranes, which are also the flows at microscale, present also a great interest, especially in vacuum technology for filtering, separation process, protection and flow control. Recently some advancement in the transient flow simulation, based on the gas kinetic theory, was proposed in [1], [2]. Using this approach, the determination of the micro tube conductance is realized in [3]. The very similar approach is also proposed recently to characterize the permeability of the porous media like the low porous membranes [4]. Different examples of application of the proposed methodology will be shown for various type of porous media et different gases under isothermal and non-isothermal conditions.

References:

[1] F.Sharipov, I.Graur, General approach to transient flows of rarefied gases through long capillaries, Vacuum, v100, pp.22-25, 2014

[2] Graur, M.T. Ho, Rarefied gas flow through a long rectangular channel of variable cross-section, Vacuum, 101, 328-332, 2014.

[3] M. Rojas-Cardenas, E. Silva, M.-T. Ho, C. J. Deschamps, I. Graur, Time-dependent methodology for non-stationary mass flow rate measurements in a long micro-tube: Experimental and numerical analysis at arbitrary rarefaction conditions, I. Microfluid Nanofluid (2017) 21: 86.

[4] M.V. Johansson, F. Testa, I. Zaier, P. Perrier, J.P. Bonnet, P. Moulin, I. Graur, Mass flow rate and permeability measurements in microporous media, v 158, Vacuum, 2018, pp. 75-85

2:20pm **VT-MoA3 A Multiphysics Simulation Tool for Storage Ring Vacuum System Design and Optimization***, **Nicholas Goldring**, Z. Wu, D.L. Bruhwiler, B. Nash,* RadiaSoft LLC*; J. Carter, J.E. Lerch, K.J. Suthar,* Argonne National Laboratory*; R. Nagler,* RadiaSoft LLC*; P. Den Hartog,* Argonne National Laboratory

Fourth generation storage ring light sources are creating orders-of-magnitude brighter x-rays by reducing horizontal emittance via multi-bend achromats. This requires the bending magnet pole tips to be closer to the electron beam axis, which in turn requires smaller vacuum chambers. The resultant design challenges are dictated by complex and coupled physical phenomena including electromagnetic wake fields, high thermal stresses and photon stimulated desorption. To better analyze and optimize next-generation vacuum systems, the authors are developing and benchmarking a suite of COMSOL Multiphysics models, which include the production, propagation, and surface interactions of synchrotron x-rays, as well as the resulting physical phenomena specified above. These coupled physics models are benchmarked against the open source codes SynRad and MolFlow. Finally, the models are embedded within a browser-based GUI, enabling scientists and engineers to execute simulations in the cloud.

2:40pm **VT-MoA4 Vacuum System Design and Modeling for the Jefferson Lab Electron Ion Collider Interaction Region***, **Marcy Stutzman**,* Jefferson Lab

Jefferson Lab and Brookhaven National Lab are both pursuing designs to build an electron ion collider in the United States following the 2015 US Nuclear Science Advisory Committee recommendations for such a facility. The design of the Jefferson Lab Electron Ion Collider (JLEIC) interaction region (IR) requires vacuum in the UHV regime to reduce background rates sufficiently in the detectors. Additionally, though the final bending magnets are far upstream from the IR in the electron line, the interaction between residual gas and the electron beam will produce synchrotron radiation and subsequent elevated gas load in the interaction region. Preliminary designs of the vacuum system for the JLEIC interaction region and the cryogenic final focusing quadrupoles will be presented using the Molflow+ software. Synchrotron radiation due to the finite beam envelope traveling through the quadrupoles will be also modelled using Molflow's complementary program SynRad. However, since the primary synchrotron radiation in this system may be from the beam-gas interactions in the long straight section upstream of the IR, synchrotron radiation distributions and their effect on the gas load will also be studied using an existing 2D radiation prediction code and GEANT4 beam-gas interaction cross section calculations.

3:00pm **VT-MoA5 Photocathode Growth and Diagnostic Systems for LCLS-II***, **Xianghong Liu**, T. Vecchione, B. Dunham,* SLAC National Accelerator Laboratory

We have designed and manufactured a multisource physical vapor deposition system for producing photocathodes to be used in the LCLS-II, a hard X-ray free electron laser accelerator facility at SLAC. The photocathodes currently produced are thin film Cs_2Te, but the system has the capability to integrate up to four independent sources permitting the future growth of ternary and quaternary compounds. The deposition system has a load-lock which permits photocathodes to be transferred into and out of the system without breaking vacuum. The geometry of the photocathode substrate is adopted from INFN, so photocathodes can be exchanged between systems and institutions that share the same design using a vacuum suitcase. We have also designed a diagnostic system for characterizing photocathode performance and are in the process of manufacturing this system. The system is capable of measuring the quantum efficiency and transverse momentum distributions of photoemitted electrons. The wavelength dependence of these measurements can be recorded as a function of temperature down to below 10 K. We will present the designs of these systems and report on their operational status and early results.

3:20pm **VT-MoA6 Characterization of NbTiN Thin Film Structures***, **David Beverstock**, A.-M. Valente-Feliciano,* Jefferson Lab*; V.N. Smolyaninova,* Towson University*; M.J. Kelley,* The College of William and Mary

Approaching the bulk Nb material RF performance limits has urged development of alternative superconducting materials for superconducting radio frequency (SRF) accelerator cavities for further performance enhancement. A promising theory has predicted that thin film structures of superconductor-insulator-superconductor (SIS) [1] can delay magnetic flux penetration in accelerator cavities to higher fields. A candidate superconductor for the SIS structures is NbTiN. A few key aspects of SIS structures development are high quality individual layers, sharp interfaces and optimum thickness for first flux penetration (H_{fp}) delay. High quality monocrystalline NbTiN films are deposited by reactive DC magnetron sputtering. In a parallel development, interface quality was assessed by depositing bilayers of 3 nm NbTiN with ~1 nm AlN repeated up to 16 times with no increase in roughness of the structure. The stacked layers form a metamaterial, which could exhibit T_c greater than bulk NbTiN [2]. This contribution presents the characterization of the surface, material and superconductivity of NbTiN with concentration on the H_{fp} enhancement for 200 to 5 nm films and multilayer nanostructures.

References:

[1] Gurevich, Alex. "Maximum screening fields of superconducting multilayer structures." *AIP Advances 5.1* (2015): 017112.

[2] Smolyaninova, Vera N., et al. "Enhanced superconductivity in aluminum-based hyperbolic metamaterials." *Scientific reports 6* (2016): 34140.

Acknowledgements:

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4:00pm **VT-MoA8 Future Laser Interferometer Gravitational Wave Observatories and their Vacuum Requirements***, **Chandra Romel**,* California Institute of Technology*; R.F.M. Weiss,* Massachusetts Institute of Technology*; M. Zucker,* California Institute of Technology*; H.F. Dylla,* American Institute of Physics **INVITED**

The Laser Interferometer Gravitational Wave Observatory (LIGO) comprises a pair of large facility observatories in Washington and Louisiana dedicated to gravitational wave (GW) astronomy and astrophysics, funded by the U.S. National Science Foundation. A century after Einstein predicted the existence of gravitational waves, LIGO detected these ripples in the fabric of spacetime resulting from two massive binary black holes colliding almost 1.3 billion years away, birthing a new era of GW astronomy. For this achievement LIGO founders were awarded the 2017 Nobel Prize in Physics. Since the first detection in 2015, over a dozen black hole mergers have been recorded, in addition to neutron star collisions, marking a significant breakthrough for multi-messenger astronomy. Concepts of third generation GW instruments are undergoing research and development, with the promise to expand humanity's ability to listen to the cosmic symphony of gravitational waves out to the very edge of the universe.

An NSF workshop was held at the LIGO Livingston site in January to explore potential novel vacuum system solutions for 3G observatories. Cost effective solutions are required for the design, construction and operation of these large vacuum systems, proposed to be a factor of ten larger than the current systems in the U.S. (LIGO), Europe (Virgo) and Japan (KAGRA). Technologies developed and employed in the existing GW observatories have been shown to meet stringent requirements of vacuum integrity, low hydrogen and heavy molecule outgassing, minimal particulate generation, low vibration, and stray light optical absorbance for successful operation. However, extrapolating costs from current lengths to 40km/arm of vacuum beamtube indicates the need to investigate a wide range of technologies and materials that could significantly lower the final cost of 3G observatories such as the Cosmic Explorer in the U.S. and the Einstein Telescope in the E.U. Two classes of solutions for the vacuum enclosures were examined: 1) the first design concept is an extrapolation of the single-wall vacuum pipe in the present generation of detectors; 2) the second design concept involves double-walled or nested vacuum pipes that would separate the atmospheric load from the stringent UHV properties needed for the inner wall. Pumping solutions and surface treatments were examined for both concept designs with an emphasis on potential hardware and treatments that could lower total costs but still meet the stringent vacuum requirements.

4:40pm **VT-MoA10 Status Update on the New Space Calibration Facility at TNO***, **Freek Molkenboer**, R. Jansen, F.P.G. Driessen, T.S. Luijkx,* TNO, The Netherlands

In 2018 TNO started with the conceptual design of a new Space calibration facility, called CSI. The CSI will be used for the performance verification and calibration of optical earth observation instruments on satellites. At the end of 2018, Angelantoni Test Technologies (ATT) from Italy was awarded a contract after completion of the European tendering procedure as the supplier of the Thermal Vacuum Chamber (TVC) and in January 2019 Symétrie, located in France was awarded a contract after completion of the European tendering procedure as the supplier for the hexapod on a rotation table that will be placed inside the vacuum chamber.

The TVC will be a vertically placed stainless steel cylinder with a diameter of 2.75 meter and a height of 2.5 meter. The chamber and thermal shrouds are sliced diagonally, resulting in a wedge shaped bottom half and top half, this reduces the total height (room and top half of the chamber) required for opening the chamber and loading a space instrument.

The thermal shroud of the TVC will be able to create an environment between 193K and 353K. Two thermal plates will be present to cool part(s) of the instrument down to 100K if required. The vacuum system consists of two turbomolecular pumps and two cryopumps to reach the ultimate pressure of 10e-7 mbar. The vacuum conditions in the TVC will be monitored with an RGA (Residual Gas Analyser) and a QCM (Quarts Cristal Microbalance).

During the calibration of a Space instrument, its position relative to the calibration light sources (Optical Ground Support Equipment or OGSE) has to be changed with an extremely high accuracy and reproducibility. To achieve this, TNO has selected a vacuum compatible hexapod on a rotation table that meets the stringent accuracy and stability requirements. Additionally TNO has designed an active thermal system around the hexapod in order to locally create a thermal stable environment.

During this talk I will discuss the design and current manufacturing status of both the thermal vacuum chamber, including the vacuum lay-out and thermal lay-out, and the design of the hexapod on rotation table including the protective measures we have taken to keep the hexapod at stable temperature.

5:00pm **VT-MoA11 Advancements in Monitoring and Operating Thermal Vacuum Environmental Test Chambers for Next-Generation Space Exploration Hardware***, **Maxwell Martin**, A.T. Wong, W.A. Hoey, J.M. Alred, P.A. Boeder, C.E. Soares,* Jet Propulsion Laboratory, California Institute of Technology

As space exploration missions continue to develop and implement increasingly sensitive instruments and incorporate advanced detection capabilities for organics, contamination control protocols have necessarily evolved in their sophistication and stringency. Monitoring spacecraft hardware as it undergoes environmental testing requires high-precision measurements in thermal vacuum chambers. With increased sensitivity of instruments and missions, the traditional use of witness plates and solvent swabs is insufficient to characterize both chamber background, and the induced environment of the system being tested and the associated ground-support equipment. Quartz crystal microbalances (QCMs) are required to conduct *in situ* monitoring of hardware outgassing rates. QCMs are sensitive to thermal and mechanical perturbations; therefore, within an environmental testing facility, as-collected QCM data requires post-processing for signal noise due to instrumentation sensitivity, and uncertainties in data analysis. Insertion and removal of hardware into chambers introduces ambient atmosphere to the vacuum systems, providing additional sources of measurement uncertainty, particularly as relates to the collection and interpretation of pre-test chamber backgrounds. In an effort to support the next generation of space exploration, the Contamination Control team at JPL is implementing upgrades in systematic data analysis, thermal vacuum chamber operations, and instrumentation selection for use in spacecraft hardware environmental testing. These advancements in environmental test chamber monitoring support JPL’s current portfolio of space exploration missions, and challenging mission science objectives.

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