Vacuum Technology Division
Room 301 - Session VT-MoA

Vacuum Technology for Accelerators

Moderators: Giulia Lanza, SLAC National Accelerator Laboratory, **Yevgeniy Lushtak**, SAES Getters USA

1:40pm **VT-MoA-1 Developments of the Vacuum Systems Required for the Electron Ion Collider***, **Charles Hetzel**,* Brookhaven National Laboratory **INVITED**

The Electron-Ion Collider (EIC) is a new particle accelerator which collides electrons (10 GeV, 2.5A) with protons (275 GeV, 1.0A) and nuclei that will be constructed at Brookhaven National Laboratory in the coming decade. This new machine will utilize the most of the existing infrastructure and accelerator complex of the currently operating Relativistic Heavy Ion Collider (RHIC). The hadron storage ring (HSR) will reuse some of the two superconducting RHIC storage rings. An electron storage ring (ESR) will be installed in the existing RHIC tunnel to provide electrons for beam collisions with the HSR hadron beam in up to two interaction regions. Fully polarized electron bunches will be injected to the ESR at fully energy (up to 18GeV) by a rapid-cycling synchrotron (RCS) which will also be constructed in the same accelerator tunnel. In order for this complex to reach its fully envisioned potential (luminosity of 10^{34} $cm^{-2}s^{-1}$), many new and challenging vacuum systems, including more than 8km of new UHV beam pipes as well as many upgrades to the existing storage rings will be required. During this presentation, I will be providing a brief overview of the various vacuum systems as well as some of the many challenges which need to be overcome.

2:20pm **VT-MoA-3 Vacuum System of the MAX IV 3 GeV Storage Ring: Design and Performance***, **Marek Grabski**, M. Grabski,* Max IV Laboratory, Sweden **INVITED**

MAX IV 3 GeV storage ring is the first synchrotron light source implementing compact multi-bend achromat (MBA) magnet lattice and vacuum system fully coated with non-evaporable getter (NEG). The storage ring is in operation for over 6 years, providing ultra-low electron beam emittance and delivering photon beams to beamlines from insertion devices.

The storage ring vacuum system, based on the NEG coating, proved to be reliable and has very good performance. The total average pressure is below 1e-9 mbar and is reducing with the accumulated beam dose since the start of the operation. The total electron beam lifetime of approximately 5 Ah is not limited by the vacuum related beam lifetime which is greater than 39 Ah.

Several successful installations were accomplished on the storage ring during shutdowns. Some interventions were performed utilizing purified Neon venting to avoid re-activating of the NEG film, thus saving installation time without compromising the accelerator performance.

Design principles, performance and operational status of the 3 GeV storage ring vacuum system will be presented.

3:00pm **VT-MoA-5 Fabrication and Assembly Status of the APS-Upgrade Storage Ring Vacuum System***, **Jason Carter**, O. Mulvany, G. Wiemerslage,* Argonne National Laboratory

The Advanced Photon Source Upgrade (APS-U) project is progressing towards the coming dark time for APS and installation and commissioning of the new storage ring including a new vacuum system. Vacuum system design is complete and procurements and vacuum chamber production is underway for over 2400 vacuum chambers, absorbers, and beam position monitors as well as supplemental hardware. A pre-assembly phase of vacuum system and magnet modules has begun in the summer of 2022. A total of 200 modules, 5 each per 40 sectors, will be installed in the APS-U storage ring. This presentation will fabrication status of the various vacuum components, the status of vacuum system assembly, and the challenges ahead. Challenges include installation within restricted space access, preventing UHV contamination, achieving precision alignment goals, and protecting sensitive components such as thin-walled vacuum chambers, bellows, and delicate RF liners while maintaining progress in a heavy-duty assembly area.

4:00pm **VT-MoA-8 CW Superconducting Linac for the LCLS-II HE Free Electron Laser at SLAC***, **Marc Ross**,* SLAC National Accelerator Laboratory **INVITED**

This year the X-ray Free Electron Laser 'LCLSII', will start commissioning activities. LCLS-II (Linac Coherent Light Source - II) is a photon science user facility that produces ultra-short very high peak-power narrow-band X-ray pulses, up to a million pulses per second and up to 5 keV photon energy. The facility is used primarily for applied science, including for example molecular biology, matter in extreme conditions, and engineered materials. The high repetition rate and ultra-short pulses will allow scientists to make stop-action movies at atomic scales.

The heart of the facility is a new CW 4 GeV superconducting electron linac based on the well-developed 1.3 GHz TESLA technology. The linac consists of 37 Cryomodule units that house 296 nine-cell niobium cavities operating submerged in superfluid liquid helium at 2 Kelvin. A major advancement is the monolithic nature of the linac with the cryomodules directly connected to each other to make a ~ 100 meters long cryogenic volume. It is believed this advancement helps keep contaminants such as particulates and organic chemicals away from the RF cavity vacuum volume, and it is acknowledged Cryomodule exchange is more difficult. No getters or ion pumps are used in the long cryomodule string.

This is the first superconducting linac to be constructed using niobium cavities that have their surface doped with nitrogen. This recent innovation makes the superconductor 3 to 4 times less resistive and allows the entire facility to fit within the capacity of a single liquid helium cryoplant. The doping is carried out by the cavity vendors at the end of the high temperature degas vacuum bake. The doped cavity production run ended in 2019 with excellent performance results.

Assembling the cryomodules and integrating them in the accelerator enclosure tunnel requires the best available particulate and contamination control. It is believed that a single ~micron sized particle or contamination-spot near the high voltage iris of the accelerator cavity will substantially degrade its voltage performance. Following pioneering work at the Oak Ridge Spallation Neutron Source, we plan to deploy a chemically-active plasma processing technique.

In 2020 SLAC and its partners, Fermilab and Jefferson Lab, embarked on an upgrade project called LCLS-II-HE to extend the capability of the linac from 4 to 8 GeV. The upgraded linac will be 1 km long and will be complete in 2027. In this presentation we will show the application of accelerator technology to the ultra-high performance LCLS-II-HE CW superconducting linac.

4:40pm **VT-MoA-10 Upgrades for the Jefferson Lab Injector and Linac Accelerator Vacuum Systems***, **Marcy Stutzman**,* Thomas Jefferson National Accelerator Facility

The accelerator vacuum systems at Thomas Jefferson National Accelerator Facility (Jefferson Lab) were initially designed in the 1980s. Over the past several years, the injector beamline vacuum has been upgraded during the first phase of the injector upgrade, and more improvements are planned for the upcoming phase 2 work. Enhanced pumping has also been implemented in the warm girders between the accelerator cryomodules as they are refurbished and replaced in the linacs. I will describe the competing factors for the accelerator vacuum, including the implementation of improved pumping and materials processing for the injector upgrade and quantify the operational results of the enhanced vacuum system. Additionally, I'll describe the goals of the upgrades to the warm girders in the linacs, and compare performance between the zones with added NEG pumping compared to the legacy zones.

5:00pm **VT-MoA-11 Vacuum Leak Detection with Variational Smoothing for Vacuum Process Chamber***, **Taekyung Ha**,* PSK, Republic of Korea

Fault detection is an important method in semiconductor manufacturing for monitoring equipment condition and examine the potential causes of the fault. The vacuum leakage is considered one of major fault in semiconductor processing. Unnecessary O_2, N_2 mixture, major components of atmosphere, creates unexpected process results hence drops yield. Currently available vacuum leak detection systems in vacuum industry are based on helium-mass spectrometers. It is used for detecting the vacuum leakage at sole isolation condition where chamber is fully pumped, but unable to use at in-situ detection condition that while process is on-going in the chamber. In this study, a chamber vacuum leak detection method named variational smoothing autoencoder has been presented, utilizing common data which gathered during normal chamber operation. This method was developed by analyzing a simple list of data, such as temperature of the chamber body and the position of auto pressure control (APC) to detect any change of leakages in the vacuum chamber.

The weakest point of data smoothing is the loss of information. To improve this problem, a variational smoothing method was developed. The length of the process log data is slightly different for each process due to the limit of command processing according to the sequence of the computer. To improve this problem, we partition the time series data and extract the segment information. The extracted segment information is strongly related. So, the autoencoder model was applied to train well on highly relevant data. The proposed method, variational smoothing autoencoder model, showed the best performance, area under the ROC curve (AUC) by 0.84 and accuracy by 0.76. Variational smoothing autoencoder were effective in classifying abnormalities by predicting time series data of semiconductor facility sensors.

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