Vacuum Technology Division
Room A213 - Session VT-TuM

Accelerators and Large Vacuum Systems

Moderators: Yulin Li, Cornell University, Marcy Stutzman, Jefferson Lab

8:00am **VT-TuM-1 Vacuum Operation and Future Upgrade of the LHC Accelerator Complex**, ***Giuseppe Bregliozzi,*** CERN, Switzerland **INVITED**

The LHC accelerator complex returned in operation in April 2015, after almost 2 years of long shutdown (LS1) for various upgrades and consolidation programs. During Run2 of operation (2015-2018), the entire accelerator complex has shown remarkable reliability and in particular, the LHC operated for more than 3600 fills reaching a total integrated luminosity of more than 150 fb−1.

In 2019, the entire LHC accelerator complex will stop again for 2 years (Long Shutdown 2 - LS2). This period will be dedicated to the LHC Injector Upgrade (LIU) and will prepare the CERN injector complex for the final upgrade of the LHC to High-Luminosity (HL-LHC) foresee during the LS3 (2024-2025).

This paper summarizes the vacuum related major issues happened during last 3 years of operation in the entire LHC accelerator complex and a summary of the most important vacuum observations along the LHC during the physics runs are presented. In addition, an overview of the planned activities during the LS2 will be presented and an outlook on the technical challenges for the HL-LHC upgrade is given.

8:40am **VT-TuM-3 Final Design into Production for the APS-Upgrade Storage Ring Vacuum System**, ***Jason Carter,*** Argonne National Laboratory

The Advanced Photon Source Upgrade (APS-U) project is progressing from its final design phase into production for the future 6 GeV, 200 mA, multi-bend achromat upgrade of the existing APS and so too is the storage ring vacuum system design. The vacuum system will include over 2500 custom vacuum chambers ranging from 50 mm up to 2.5 meters in length and typically featuring APS-U's standard narrow 22 mm inner diameter aperture. The vacuum system must maintain UHV for the circulating electron beam while the water-cooled vacuum components intercept significant synchrotron radiation loads. The scope of NEG coatings was increased to 50% of the length of the vacuum system to ensure the vacuum system conditions quickly and pressure requirements can be met.

Vacuum chamber locations, lengths, and materials were settled in the preliminary design phase but significant effort was required to work through local and system level design challenges. Local challenges include detailing robust welds and brazes on the thin-walled vacuum chambers and performing detailed FEA thermal/stress analysis for vacuum components which intercept large synchrotron radiation heat loads. System level challenges include using CAD to design within the complex machine assembly, networking components to utilities, and planning for installation and alignment. This presentation will highlight the major design challenges and solutions for the storage ring vacuum system and also plans for production and installation.

9:00am **VT-TuM-4 The Design of the Advanced Photon Source Upgrade (APSU) Insertion Device (ID) Straight Section Vacuum Systems**, ***Jason Lerch****, M Szubert, E Anliker, T Bender,* Argonne National Laboratory

There are 35 straight sections in the APS-U, requiring 30 planar vacuum chambers (IDVC) and 5 superconducting vacuum systems (SCU VC). These vacuum systems provide Ultra-High Vacuum (UHV) continuity between storage ring (SR) sectors. The IDVC, nominally 5.363 meters long, requires bake-out before operation and expands 10mm on both ends. The SCU vacuum chambers, nominally 5.383 meters long, are cooled cryogenically and contract 14 mm on both ends. The APS-U straight sections are identical around the SR but require bellows on both ends to accommodate the change in length of both systems. The aluminum planar vacuum chamber operates in UHV with a 600 thick wall over a length of 5050 mm and requires the use of 1 ion pump and 7 NEG cartridges for pumping down the system. The SCU is comprised of two copper "warm" vacuum systems, operating at room temperature outside the cryostat, and one aluminum "cold" vacuum system (4.8m long), operating at 20K inside the cryostat. The "warm" chambers have a minimum wall thickness of 1 mm and operate as photon absorbers at either end of the system, one protecting the cryogenically pumped chamber and one protecting downstream equipment. The "cold" chamber has a minimum wall thickness of 400 and operates at UHV at 20 Kelvin. The internal geometries of these various systems are optimized to reduce dissipated heat on the chamber walls where possible and allow for seamless transitions for various apertures. Both vacuum systems require the ability to align the apertures ±50 microns along their lengths.

9:20am **VT-TuM-5 The Vacuum Commissioning and Simulation of Non-Evaporable Getter Dominated Cornell High Energy Synchrotron Source Upgrade.**, ***Yevgeniy Lushtak****, Y Li, X Liu,* Cornell University

The Cornell High Energy Synchrotron Source Upgrade (CHESS-U) converts the Cornell Electron Storage Ring (CESR) from dual-beam to single-beam operation while significantly reducing the beam emittance, increasing the beam energy to 6 GeV, and improving the facility's X-Ray beamline brightness.

The CHESS-U vacuum system was completed in the fall of 2018 and the initial beam current and energy targets were met in the spring of 2019. The majority of the CHESS-U vacuum system consists of narrow gap aluminum chambers. With pre-installation 150 C bake followed by in situ 95 C hot-water bake and relying on the high pumping speed of distributed and lumped Non-Evaporable Getters (NEGs), a low 10^{-9} Torr base pressure was quickly achieved.

Since the CHESS-U vacuum pumping system is NEG-dominated and NEGs are prone to surface saturation at high synchrotron radiation (SR) induced gas loads, the vacuum conditions during the CHESS-U accelerator commissioning were carefully monitored and periodical vacuum simulations using MolFlow were performed to ascertain the status of the NEGs. The SR-induced vacuum conditioning has proceeded very well, with the dynamic pressure holding in the low 10^{-9} range with 100 mA stored positron beam current, after an accumulated beam dose of 20 A-hr. With the moderate initial beam conditioning, a beam lifetime allowing X-ray beam operation to commence has already been achieved. Further gradual improvements in the dynamic pressure and beam lifetime are expected during the course of X-ray user operations.

In this paper, we describe the CHESS-U vacuum system, report on the SR-induced vacuum conditioning status, and detail the computational model developed to accurately simulate the vacuum conditions while taking into account the NEG saturation and the radiation-induced cleaning of the chambers.

9:40am **VT-TuM-6 Advanced Light Source Upgrade Vacuum Controls and Instrumentation Design**, ***Sol Omolayo,*** Lawrence Berkeley Lab, University of California, Berkeley

A project is underway to upgrade the existing Advanced Light Source (ALS) synchrotron. The goal of the project is to lower the horizontal emmitance to <75pm resulting in a 2 orders of magnitude increase in soft x-ray brightness. The design features two new accelerators: the accumulator ring and the storage ring. Both rings are also connected by transfer lines. The preliminary design for the vacuum systems for these rings and transfer lines in underway. With over 400m long electron beam vacuum pipe, the control and instrumentation required for the vacuum system is complex. We present the design specification and solution the project has adopted.

11:00am **VT-TuM-10 Vacuum Electronics Community Pioneers Additive Manufacturing of Copper**, ***Diana Gamzina,*** SLAC National Accelerator Laboratory*; T Horn, C Ledford,* North Carolina State University*; C Nantista,* SLAC National Accelerator Laboratory*; P Frigola,* Radiabeam **INVITED**

Even though there are many players in the world of additive manufacturing (AM), vacuum electronic devices (VED) community made a significant impact on AM of copper specifically, with recognition by industrial partners and government agencies. Copper is a challenging material to print because of its high reflectivity and high thermal conductivity; material purity is also hard to achieve due to the lack of high quality precursors. VED community has the most stringent requirements for copper. The successful implementation of copper AM for VEDs will support a wide range of applications, including thermal management, power electronics, and nuclear. Many critical to VED manufacture properties have been achieved (density, ultra-high vacuum compatibility, electrical and thermal properties), but few still remain to be challenging (reduction of oxygen content and surface roughness). A variety of components relevant to VED community have been manufactured; more interesting examples include: high efficiency klystron output cavity with micro cooling channels and weight reducing web support structure; one inch long sections of WR-10 waveguide demonstrating post-polishing techniques to reduce surface roughness to 2 microns in enclosed envelopes, coupled cavity travelling wave tube amplifier circuit structures demonstrating over 50% cost reduction capability. Most of the benefits that AM can offer still lie ahead to be explored: predesigning material properties local to specific design features while varying physical, electronic, or chemical properties locally.

11:40am **VT-TuM-12 Particle-Free Manufacturing and Installation for LCLS-II Vacuum Systems*, Arnela Gamzina,*** SLAC National Accelerator Laboratory

SLAC National Accelerator Laboratory, a multipurpose laboratory for astrophysics, photon science, accelerator and particle physics, is currently building an upgrade to the World's First X-ray Free-Electron Laser (LCLS-II). In the past years, SLAC Vacuum Laboratory has prepared, tested, and assembled many of the beamline components and the activity is still in progress.

This presentation will go through the manufacturing and quality check processes, documentation and installation check lists that were developed to meet the LCLS-II UHV and Particle Free requirements. Especially, in order to meet Particle Free requirements new equipment and facilities were acquired. The vacuum group worked to establish new procedures and made sure that selected personnel developed the requested skills, best practices, and gained the experience necessary to complete a successful installation.

12:00pm **VT-TuM-13 Development of Remote Handleable Axially Decoupled Radiation Resistant Vacuum Seal*, Geoff Hodgson,*** TRIUMF, Canada

Advanced Rare IsotopE Laboratory (ARIEL) facility is a major expansion of TRIUMF's rare isotope research program.

Aiming to triple the production of rare isotopes, ARIEL facility includes the new electron linac driver and

two target stations for electron and proton beams [1]. Particularities of ARIEL target stations design define the requirements for vacuum interfaces with both primary electron and proton beamlines and rare-isotope beamlines. None of the existing products fully met the requirements, driving the development of custom vacuum interfaces. The design of new vacuum seals is driven both by unique design specifications (limited amount of allowed axial forces, extreme radiation

resistance, remote handleability and high repeatability) as well as limitations of the proposed design of beamline nfrastructure in the target hall (limited available space and the choice of materials for certain components). This paper discusses preliminary results of the vacuum seal development and presents first results of prototype testing.

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