Vacuum Technology Division
Room: 111 - Session VT-TuM

Accelerator and Large Vacuum System Design, Outgassing and Pumping
Moderator: Y. Li, Cornell University

8:00am **VT-TuM1 Continued Work toward XHV for the Jefferson Lab Polarized Electron Source**, ***M.L. Stutzman***, *P.A. Adderley*, Thomas Jefferson National Accelerator Facility

The Jefferson Lab DC, high voltage polarized electron source utilizes deep-UHV pressures to limit photocathode damage due to ionization and acceleration of residual gasses into the photocathode, as well as preserve the surface chemistry necessary for electron emission. Continued efforts toward improving and quantifying pressures below $5x10^{-12}$ Torr for electron source vacuum chambers will be presented, including operational experience with the newly available Watanabe Bent-Belt Beam (BBB) gauge, and the incorporation of a bakable cryopump into the pumping configuration.

8:20am **VT-TuM2 Status of National Synchrotron Light Source II Vacuum Systems**, ***H.C. Hseuh***, *A. Blednykh, L. Doom, M.J. Ferreira, C. Hetzel, J.P. Hu, S. Leng, C. Longo, V. Radindranathh, K. Roy, S. Sharma, F. Willeke, K. Wilson, D. Zigrosser*, Brookhaven National Laboratory **INVITED**

National Synchrotron Light Source II is a new medium energy, ultra low emittance, high flux and high brightness synchrotron radiation facility. NSLS-II consists of a 200-MeV linac, a 3-GeV booster synchrotron, and a 3-GeV 500-mA storage ring with a circumference of 792 meter and over 60 beam lines. The construction of NSLS-II started in 2009 and will be ready for users in 2014. The storage ring vacuum chambers are made of extruded aluminium, with ante-chamber for photon extraction and for distributed NEG pumping. The precision machined extrusions are welded to aluminium-to-stainless bi-metallic flanges using robotic welding machines. Due to the high heat loads, all the photon absorbers are made of GlidCop. The details of the storage ring vacuum system will be presented and compared with those of similar facilities. The challenges encountered in the fabrication of vacuum chambers, photon absorbers and RF shielded bellows will be described. The status of the project will also be summarized.

9:00am **VT-TuM4 The Large Cryopump System for the Heating Neutral Beam Injection of ITER**, ***S. Hanke***, *M. Scannapiego, X. Luo, C. Day*, Karlsruhe Institute of Technology (KIT), Germany, *F. Fellin, P. Zaccaria*, Consorzio RFX, Italy

The ITER Neutral Beam Injection system (NBI) is one of the heating systems to achieve the required plasma temperatures to start the fusion process. Thereby, the NBI system is basing on the principle of provision and acceleration of deuterium and protium ions and the re-neutralization of the high energy ions to be injected into the plasma through the confining magnetic fields. Each heating NBI is designed to insert 16 MW of heating power to the plasma and presents major technical and physical challenges.

In order to solve these and to demonstrate the achievement of the required parameters, a robust R&D program is under way. A central milestone for this development is the establishment of a full scale test facility, which will be built on site of Consorzio RFX, Padova. Part of this test facility is MITICA (Megavolt ITER Injector and Concept Advancement), the test bed for the entire neutral beam injection system. Karlsruhe Institute of Technology (KIT), which is the lead party in design and R&D of the ITER cryopumps since more than a decade, is supporting this project with the development of a customized cryopump design which ensures that the requested density profiles for optimum beam performance can be produced.

The main operational task which has to be provided by the cryogenic pump at a speed of ~5000 m^3/s is to handle very high gas loads of protium and deuterium. As basic pumping concept, cryosorption was chosen and the cryopump is operated with supercritical helium at 4.5 K for the adsorbing and gaseous helium at 80 K for the shielding circuit. As demonstrated in other NBI applications, cryosorption provides a wide and robust operational window at acceptable cryogenic loads to the cryoplant. The design was driven by two competing requirements: The high thermal heat loads ask for a closed pump, whereas the need for a high pumping speed asks for an open structure. To reconcile both objectives in an optimized geometry, modeling simulations were performed using the Test Particle Monte Carlo code MOVAK3D. To properly describe the density distribution in the NBI vessel with large thermal and pressure gradients, the time-of-flight cell code ProVac3D was developed.

Additional to the design activities for an optimized cryopump, a considerable effort has been spent to investigate the thermal hydraulic properties of the cryopump during the different operational and failure modes.

9:20am **VT-TuM5 Design and Construction of the Vacuum System for SuperKEKB**, ***Y. Suetsugu***, *K. Shibata, H. Hisamatsu, M. Shirai, T. Ishibashi, K. Kanazawa*, KEK, Japan

The upgrade project of KEKB B-factory, that is SuperKEKB, has started last year. The SuperKEKB is a two-ring electron-positron collider with 7.0 GeV electrons and 4 GeV positrons aiming a goal luminosity of $8.0x10^{35}$ $cm^{-2}s^{-1}$, which is approximately 80 times higher than that of KEKB. In order to realize the unprecedented luminosity, the stored beam currents are increased to 2.4 A and 3.6 A for electrons and positrons, respectively. The vertical beam sizes at the collision point are also squeezed to approximately 60 and 50 nm with the beam emittances of 5/13 and 3/9 nm/pm (horizontal/vertical) for electrons and positrons, respectively. The vacuum system is accordingly improved to achieve the challenging goal. Beam pipes with antechambers are adopted for the reduction in the beam impedance of beam channel and also in the irradiation power density of synchrotron radiation from intense stored beams. Various vacuum components adaptable to the antechamber scheme with low beam impedance and high thermal strength had been developed. The bellows chambers, for example, have a comb-type RF-shield, and the main vacuum pump is NEG strips inserted into one of antechambers. Special attention is paid for the mitigation of the electron cloud issues in the positron ring to avoid unwanted increase in the beam emittance. In order to reduce secondary electron emission, the inner surface of beam pipes is coated with TiN, the grooved surface is prepared in dipole magnets, and the newly developed clearing electrodes are introduced in wiggler magnets. The antechamber scheme is also effective to suppress the photoelectron effect. The beam pipes in drift spaces, furthermore, are winded by solenoid coils. The design of vacuum system has been mostly completed, and the mass production of beam pipes has started. Copper beam pipes with clearing electrodes for wiggler magnets had been already delivered. Aluminum beam pipes for arc section of positron ring are under manufacturing, together with bellows chambers, gate valves, NEG pumps, and so on. The installation to the ring will start next year after TiN coating, expecting the start of commissioning from 2014. The overall vacuum system design and some key issues for SuperKEKB together with the present status will be reported here.

9:40am **VT-TuM6 New Perspectives in UHV-XHV via a Novel Combination of NEG and Sputter Ion Pump Technologies**, ***F. Siviero***, *A. Conte, L. Viale, A. Bonucci, P. Manini, L. Caruso,* SAES Getters, Italy, *L. Di Giacomo, G. Santella*, SAES Advanced Technologies, Italy

Current vacuum trends driven by end users requirements are demanding vacuum pumps with better performance in smaller packages. This is driving pump manufacturers to redesign their pumps and/or to consider new ways to combine pumping technologies more efficiently. In response to this trend it has been found it may be advantageous in UHV-XHV systems to use Non Evaporable Getter (NEG) pump as the main pumping element and complement it with a small ion pump to remove inert gases and methane. A novel design of such a combination, called NEXTorr®[1], was first introduced in 2010 at this conference.

Since the introduction, extensive studies have been carried out indicating the success of this configuration. Also, a broader range of pump models has been introduced, featuring pumping speed from 100 to 500 l/s (H2).

The result of the vacuum characterization carried out on the pumping performances for a variety of gases of interest for UHV-XHV applications is discussed in this paper. Pumping speed measurements, pump down, rate of rise and out-gassing tests have been conducted and in some cases compared with traditional pumping approaches based on large sputter ion pumps. The advantages coming from the synergic integration of the NEG and the ion pump elements are highlighted and discussed. Examples of applications showing how this novel family of pumps can simplify the design and operation of vacuum systems are also presented and critically reviewed.

[1] NEXTorr is an International Trademark registered by the “Madrid System” property of SAES Getters S.p.A.

10:40am **VT-TuM9 Modeling Hydrogen Outgassing in a Small Vacuum Chamber**, ***R.F. Berg***, National Institute of Standards and Technology

Reports of hydrogen outgassing usually involve large vacuum chambers made of stainless steel. Typically, the chambers were baked at temperatures up to 400 °C, but the outgassing was measured only at room temperature. In contrast, the chamber used for the present measurements had a volume of only 29 cm^3, with a correspondingly large surface-to-volume ratio, and the outgassing rate was measured at temperatures as high as 250 ° C.

The present outgassing measurements were compared with a numerical model that included (1) diffusion of hydrogen atoms in the steel, (2) recombination at the surface into hydrogen molecules (plus the reverse process), and (3) release of hydrogen from traps. A trap is a site, such as a dislocation or a grain boundary, where the hydrogen is bound more strongly than in the surrounding metal. Traps allow stainless steel to hold much more hydrogen than implied by the small solubility of hydrogen in pure iron. The larger binding energy means that increasing the temperature does more than speed up diffusion; it also increases the amount of mobile hydrogen in the steel.

The model used the values obtained by Grant, Cummings, and Blackburn for the diffusivity, recombination, and permeation of hydrogen in stainless steel. If one assumes a plausible value for the initial hydrogen concentration, it gives outgassing rates in rough agreement with the measurements.

11:00am **VT-TuM10 Modelling and Simulation of the ITER Cryopumping Systems**, ***C. Day***, Karlsruhe Institute of Technology, Germany **INVITED**

A cryopump is probably the most versatile and flexible vacuum pump. In large R&D applications where cryoplants are anyway available and high pumping speeds at high throughputs are requested, it is often advantageous to exploit a directly cryogen-supplied cryopump. The nuclear fusion project ITER is a perfect example for such a project, which triggered the development of customized cryopumps. To name just two advantages of this approach, a cryopump can be designed to perfectly fit the available space, and can be installed in-situ without any conductance losses, if regeneration frequency allows for that.

Karlsruhe Institute for Technology (KIT) is developing tailor-made cryosorption pumps for fusion applications over the last 20 years. This has been associated with an extensive design supporting R&D programme which has provided a broad parametric database and stimulated the development of modeling and design tools.

This paper will delineate the essential steps one has to consider when designing a cryosorption pump. The design process of a customized cryopump starts with the proper identification of the set of requirements, which defines the requested integral pumping speed at the given pump location and space. The tools needed for individual cryopump design are described and typical examples are given. This includes the calculation of capture coefficients and distributed pumping on the cold surfaces by means of Test Particle Monte Carlo methods.

Cryopump examples are taken from the area of large cryopumps for ITER, such as the torus cryopumps (~ 80 m^3/s) and the cryopumps for high energy neutral beam injection development (~ 5000 m^3/s). Although being cryogenic pumps, these applications are characterised by relatively moderate vacua due to the high gas throughputs during pumping. This also leads to the fact that transitional flow conditions prevail inside the pump, which results in additional challenges with regard to modelling and operation. Both pump types are currently in the stage of build-to-print design finalization and prototypes will be manufactured to validate this design in dedicated testbeds at KIT and Padova, Italy.

11:40am **VT-TuM12 Design and Construction of the Ultrahigh Vacuum System for the 3 GeV TPS Accelerator**, *G.Y. Hsiung*, ***H.P. Hsueh***, *C.L. Chen*, *J.R. Chen*, National Synchrotron Radiation Research Center, Taiwan, Republic of China

The ultrahigh vacuum system for the electron storage ring of the 3 GeV Taiwan Photon Source (TPS) accelerator has been started the construction since 2010. The critical vacuum components with lower impedance design including the bellows with spring-finger rf-contact, the metal gate valves with comb-finger rf-contact, pulsed magnet kicker ceramic chambers, beam position monitors, crotch absorbers, and the precise machined sector bending chambers and BPM chambers, have been manufactured. The large aluminum alloy (Al-) bending chambers for the arc-cells have been precisely machined with oil-free machine tools in the clean room, and undergoing the ozonate water cleaning after with the precisely in-house welding. Mass production of the vacuum equipments including the ion gauges, ion pumps, NEG pumps, and gate valves, has been contracted out and partially delivering following the schedule of the cell assembling. Each cell, contains two short Al-straight chambers and two Al-bending chambers, has been started the assembling and on-site welding on the pre-aligned girders in clean room forming an one-piece vacuum vessel about 14 m in length following by the vacuum baking to the ultra-high vacuum. The progress of prototyping development and the status of construction for the TPS ultrahigh vacuum system will be described in this paper.

Authors Index

Bold page numbers indicate the presenter