Vacuum Technology
Room: 14 - Session VT-TuA

Accelerator and Ultra-Clean Vacuum Systems
Moderator: L. Smart, Brookhaven National Laboratory

2:00pm **VT-TuA1 Design of the Vacuum System for the SuperKEKB Positron Ring**, ***Y. Suetsugu***, *K. Kanazawa, K. Shibata, T. Ishibashi, H. Hisamatsu, M. Shirai, S. Terui*, High Energy Accelerator Research Organization, Japan **INVITED**

A two-ring electron-positron collider with asymmetric energies, the SuperKEKB, has been designed as an upgrade of the KEKB B-factory (KEKB). The SuperKEKB aims for a maximum luminosity of 8×10^{35} $cm^{-2}s^{-1}$, which is approximately 40 times larger than that of the KEKB. The upgrade of the vacuum system is a key factor that will allow the SuperKEKB to achieve unprecedented high performance. As for the positron ring, most of the beam pipes are newly designed to reduce beam impedance and, especially, to manage the electron cloud effect (ECE), which is essential to keep the low-emittance beam stable. The beam pipes basically have antechambers at the both sides of a beam channel. 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 with the same cross section to the beam pipe, and the main vacuum pump consisting of NEG strips is inserted into one of the antechambers. The antechamber scheme is also effective to mitigate the ECE, that is, it structurally suppresses the photoelectron effect. A side wall of the antechamber, where the synchrotron radiation hit directly, is roughened so as to reduce photon reflections. In order to reduce secondary electron effect, on the other hand, the inner surface of beam channel is coated with titanium nitride (TiN). Furthermore, the longitudinal grooved surface and the clearing electrode are prepared for the beam pipes in dipole magnets and the wiggler magnets in the ring, respectively. In addition, the beam pipes in drift spaces are winded by solenoid coils. These mitigation techniques are the fruits of various theoretical and experimental studies so far. The SuperkKEB positron ring is the first one that will adopt these techniques in a large scale. The design of vacuum system has been mostly completed, and the mass production of beam pipes has started. The vacuum system design and some key issues for SuperKEKB positron ring will be reported here together with the present status.

2:40pm **VT-TuA3 Status of the FRIB Driver Linac Vacuum Calculations**, ***B. Durickovic***, *P. Gibson, P. Guetschow*, Michigan State University, *R. Kersevan*, CERN, Switzerland, *D. Leitner, M. Leitner, L. Lingy, F. Marti, G. Morgan, M. Schein, M. Shuptar*, Michigan State University

The Facility for Rare Isotope Beams (FRIB) is a heavy ion fragmentation facility to produce rare isotopes far from stability for low energy nuclear science. The facility will utilize a high-intensity, superconducting heavy-ion driver linac to provide stable ion beams from protons to uranium at energies greater than 200 MeV/u and at a beam power of up to 400 kW. The beam will be fragmented on a multilayer high power fragmentation target and separated in a high resolution fragment separator.

Two ECR ion source injectors will provide highly charged ions for the superconducting linac for efficient acceleration. In order to transport the heavy ions at the low velocities of the injection beam the vacuum systems need to be carefully designed to avoid beam losses due to charge exchange. For uranium 33+, for example (one of the commissioning beams), the cross-section for electron capture from the residual gas is so large at low energies (~12 keV/u in LEBT) that a residual gas pressure of 10^-6 Torr would lead to unacceptable beam losses in the analyzing magnet.

Similarly, in the warm section of the superconducting linac, beam losses due to interaction of the beam with residual gas need to be minimized in order to keep the average uncontrolled beam loss well below 1 W/m as required for maintainability of the accelerator and safety considerations.

These beam loss requirements, as well as the need for managing vacuum levels in high loss regions such as beam stripping and collimation areas, led to the establishment of minimum baseline vacuum requirements for all areas of the accelerator system. In addition, the SRF cavities must be protected from contamination that could possibly migrate from the stripper region, collimator systems, or target systems.

CAD vacuum models of each area are made based upon the accelerator lattice file, and Monte Carlo simulations of vacuum levels are performed using MolFlow+ to help determine or validate the vacuum hardware configuration needed to meet the baseline requirements. This talk will describe the FRIB facility vacuum requirements, and report on the methods and status of the FRIB vacuum calculations.

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4:00pm **VT-TuA7 Contamination Control and Cleaning Techniques for Ultra Clean Vacuum Systems**, ***H.G.C. Werij***, *N.B. Koster, J.C.J. van der Donck, A.J. Storm, R. Verberk, R. Versluis*, TNO Technical Sciences, The Netherlands **INVITED**

Cleanliness requirements in high-tech science and industry are getting more and more challenging. At the same time, the consequence of not properly adhering to these requirements could be devastating. Whereas the general way of working involves prevention, inspection/monitoring and cleaning, each particular application requires its own dedicated systems approach. For instance, is it particulate or molecular contamination we have to deal with? Do we really need an ultrahigh vacuum or should it be ultraclean with respect to certain contaminants? And what is the trade-off between ultraclean production and in-situ cleaning? Such questions have to be answered in order to find the solutions that are both adequate and cost-effective at the same time.

In the presentation several examples will be addressed, including delicate space instrumentation, (extreme ultraviolet) lithography tools and equipment for fusion energy (ITER). We will present how contamination should be dealt with in the design phase, which not only involves choice of materials, but also geometrical layout and handling. We will show that for certain applications the traditional approach of using ultra-high vacuum might not yield the optimum result. By introducing low-pressure ultraclean gases combined with differential pumping both molecular and particulate contaminants can be mitigated very efficiently, as is demonstrated in numerous experiments.

As far as inspection and monitoring is concerned, we will give a brief overview of several sensing technologies, currently being developed at TNO. These consist of ionization sensors and optical sensors, the latter being integrated nanophotonics sensors, which may be used to detect molecular contaminants. For particle detection down to 50 nm diameter an automated particle scanner has been developed, which will be touched upon as well.

In the field of cleaning, apart from more traditional methods like wet, CO_2, and ultrasonic cleaning, we will address plasma cleaning technology developed in-house. We will show experimental results obtained using our shielded microwave induced remote plasma setup and hydrogen radicals.

4:40pm **VT-TuA9 Large Thermal Vacuum Chamber for TB/TV Tests and Optical Calibration of Space Instrumentation**, ***R. Versluis***, *R. Verberk, E.C. Fritz, W.L.M. Gielesen*, TNO Science and Industry, The Netherlands

Part of the TNO Space activities is the development and qualification of Optical Instruments for Space Applications. Especially the Earth Viewing Spectrographs constitute a significant part of the calibrations. Before these instruments will be launched into orbit they undergo a series of qualification tests, which typically consist of:

Performance test (PF)

Vibration test (VB)

Thermal balance/thermal vacuum test (TB/TV)

Performance test (PF)

Optical Calibration (OC)

TNO is building a Thermal Vacuum Chamber (TVC) in one of the TNO cleanrooms that can perform all of these tests (except the vibration tests) on these instruments. In this talk we will present an overview of the design, engineering, manufacturing and qualification activities that are related to this thermal vacuum chamber. The TVC will have an internal free volume of about 72 m^3. The complete internal surface area of 100 m^2 will be entirely covered with a cooling shroud with temperature control between 95 K and 373 K. The required shroud temperature stability is less than 1 K_{pp}, the required steady state spatial homogeneity better than 5 K_{pp}. In order to reach low pump down times and allow testing of space instruments with relatively high outgassing rates, the required pumping capacity is between 5000 and 10000 L/s. Furthermore, a very high level of cleanliness is required to protect the space instrument optical system and TVC viewports from contamination, which could decrease the optical transmission, especially in the UV wavelength range. Contamination prevention is especially important because the complete calibration test can last as long as a few months, during which the system will be at vacuum and deposition of contamination can affect the optical throughput. The TVC will be equipped with a residual gas analyzer, cold finger and thermal quartz crystal microbalance to perform online and offline contamination monitoring and analysis.

For the Optical Calibration the Space instrument will be integrated in a cradle with two rotational degrees of freedom. With this the complete Field Of View of all optical ports of the instrument can be illuminated by optical stimuli placed outside the vacuum vessel.

The presentation will highlight specific issues related with this type of test facility, such as standard and emergency procedures for evacuating and venting the chamber during cryogenic operation. Product assurance issues such as contamination prevention of the test object and test object integrity. Minimising leak rates and outgassing of feedthroughs and stages, particle contamination prevention and other issues of the tests performed at high vacuum and low or high temperatures.

5:00pm **VT-TuA10 A Large Seismic Attenuation System in UHV**, ***R. Takahashi***, National Astronomical Observatory of Japan, *Y. Saito*, High Energy Accelerator Research Organization, Japan

Interferometer gravitational wave detectors require an ultra-high vacuum chambers which the laser beams pass through. KAGRA, the large-scale cryogenic gravitational wave telescope in Kamioka, has two 3-km vacuum tubes kept in ~10-7Pa of vacuum pressure so as to reduce scattering-effects due to residual gas molecules.

The interferometers consist of high quality mirrors, which should be isolated from ground vibration strongly. The vibration isolation system needs not only attenuation more than 109 at 100Hz but also reduction of root mean square motion of the mirrors. Many kinds of mechanisms for isolation at low frequencies have been suggested for gravitational wave detectors. We employed an inverted pendulum and geometric anti-spring filters as the isolator in KAGRA. We found diamond-like carbon (DLC) coatings are suitable for reduction of scattered light around the mirrors. The coatings have low outgassing, low reflectivity, and low scattering loss.

5:20pm **VT-TuA11 Vacuum System of Cornell Energy-Recovery LINAC Prototype Injector**, ***Y. Li***, *X. Liu, K.W. Smolenski, I. Bazarov, B.M. Dunham*, Cornell University

A prototype electron injector was designed, constructed and operated at CLASSE, as an important first step toward the Cornell ERL (Energy-Recovery LINAC) based synchrotron radiation facility. The injector is designed to generate average beam current up to 100-mA, and electron beam energy ranging 5-MeV to 15 MeV. Main features of the injector include a laser-driven photo-emission electron source, a cryo-module containing superconducting RF cavities, electron beam transport beamlines equipped with a suite of beam diagnostic instrument, and a 600-kW electron beam stop. Recently, significant milestones were reached for the prototype injector. Most noticeably, we have achieved an average beam current of 52-mA at a beam energy of 5-MeV from activated GaAs photo-cathodes, breaking a long-standing world record of 32-mA from a laser-driven photo-emission electron source. There are many challenges in vacuum system design for the prototype injector. It needs to provide an extremely-high vacuum (XHV) environment for the photo-cathodes, flexibilities in beam transport beamlines for development of beam instrumentation, as well as sufficient vacuum pumping capacity to handle very large dynamic gas-load at the beam stop. In the past 3+ years of operations, the injector vacuum system has performed satisfactorily. To confirm the pumping performance, we calculated pressure profile along the main transport beamlines during the high beam current runs, and calculated pressure profile agreed well with the measured pressure profile. In this paper, we describe the design and the operational experiences of the prototype injector vacuum system, and address remaining operational issues arising from high beam current operations.

5:40pm **VT-TuA12 Injection Vacuum System at the TPS**, ***C.K. Chan***, *C.C. Chang, C.L. Chen, C.S. Yang, C. Chen, Y.H. Liu, K.H. Hsu, Y.T. Huang, H.P. Hsueh, S.N. Hsu, G.Y. Hsiung, J.R. Chen*, NSRRC, Taiwan, Republic of China

The Taiwan Photon Source (TPS) is a 3 GeV synchrotron facility and aimed to have a low emittance electron beam maintaining the top-up operation. A 12-m long TPS injection section contains four kicker ceramic chambers (K1~K4) and one out-of-vacuum injection septum to provide the stored beam a horizontal bump for beam injection off axis. The kickers (K2, K3) and injection septum are placed in an adjustable plate, which can provide a 5 mm displacement for the injected beam close to the stored beam so as to decrease the kicker strength. The construction of the injection section is completed and we will describe the design, manufacturing process and some test results for the injection section.

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