Vacuum Science and Technology Division
Fachverband Vakuumphysik und Vakuumtechnik (VA)

Thomas Giegerich
Karlsruhe Institute of Technology
Institute for Technical Physics (ITEP)
Hermann-von-Helmhotz-Platz 1
76344 Eggenstein-Leopoldshafen
thomas.giegerich@kit.edu

Overview of Invited Talks and Sessions

(Lecture room HSZ 301; Poster P2-OG3)

Invited Talks

VA 1.1	Mon	9:00– 9:45	HSZ 301	**Assessment of a Pressure Gauge Filament for Neutral Gas Density Measurement using Alternating Current as Source Power** — •Nikola Jaksic, Hans Meister, Andrea Scarabosio
VA 2.1	Mon	11:00–11:45	HSZ 301	**Commissioning of the complete KATRIN Vacuum System** — •Joachim Wolf, KATRIN Collaboration
VA 3.1	Mon	13:30–14:15	HSZ 301	**High speed massive matter injection in ultrahigh vacuum environment for magnetic fusion devices** — •Mathias Dibon, Peter Lang, Gabriella Pautasso, Albrecht Herrmann, Vitus Mertens, Rudolf Neu, Bernhard Ploeckl, Volker Rohde

Invited talks of the joint symposium SYNS

See SYNS for the full program of the symposium.

SYNS 1.1	Wed	15:00–15:30	HSZ 02	**The Limits to Lithography: How Electron-Beams Interact with Materials at the Smallest Length Scales** — •Karl K. Berggren
SYNS 1.2	Wed	15:30–16:00	HSZ 02	**High precision fabrication for light management at nanoscale** — •Saulius Juodkazis, Armandas Balcytis
SYNS 1.3	Wed	16:00–16:30	HSZ 02	**Directed self-assembly of performance materials** — •Paul Nealey
SYNS 1.4	Wed	16:45–17:15	HSZ 02	**Nanometer accurate topography patterning using thermal Scanning Probe Lithography** — •Armin W. Knoll
SYNS 1.5	Wed	17:15–17:45	HSZ 02	**High resolution 3D nanoimprint lithography** — •Hartmut Hillmer

Sessions

VA 1.1–1.3	Mon	9:00–10:45	HSZ 301	**Vacuum Generation and Measurement**
VA 2.1–2.2	Mon	11:00–12:15	HSZ 301	**Large Vacuum Systems**
VA 3.1–3.2	Mon	13:30–14:45	HSZ 301	**Vacuum Physics**
VA 4.1–4.6	Mon	14:45–16:00	P2-OG3	**Poster Session**

Annual General Meeting of the Vacuum Science and Technology Division

Monday 16:00–16:30 HSZ 301

VA 1: Vacuum Generation and Measurement

Time: Monday 9:00–10:45 Location: HSZ 301

Invited Talk VA 1.1 Mon 9:00 HSZ 301

Assessment of a Pressure Gauge Filament for Neutral Gas Density Measurement using Alternating Current as Source Power — •Nikola Jaksic, Hans Meister, and Andrea Scarabosio — Max Planck Institute for Plasma Physics, EURATOM Association, Boltzmannstr. 2, 85748 Garching, Germany

Vacuum in plasma fusion research is primarily required to guarantee interference-free fusion processes of the hydrogen isotopes deuterium and tritium and additionally as an insulator between very hot particles and solid objects. Moreover, vacuum is required in cryogenic areas of the fusion device e.g. for insulation of super conducting coils which operate at 4 K. An overview of the existing vacuum measurement systems and the measurement system which fulfill the essential demands for the ITER experiment, currently under construction is presented. In plasma fusion research the neutral gas density is usually measured using hot cathode ionization gauges which are modified for the application in high magnetic fields and for a measurement range between 10^-4 Pa and 20 Pa. For obtaining sufficient electron emission, high filament temperatures in the order of 1800 K are required and thus high usually direct heating currents. The heating current to achieve the right operational temperature could be reduced by using a thinner filament in combination with alternating current with suitably chosen frequency. To estimate the suitability of such a solution a feasibility study by means of numerical methods has been carried out. The results of the filament preliminary numerical analyses are presented.

VA 1.2 Mon 9:45 HSZ 301

Measurement of the Rotor Temperature of shielded TMPs in Magnetic Fields for the KATRIN Experiment — •Fabio Bertucco and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), IEKP, Postfach 3640, 76021 Karlsruhe

When turbo-molecular pumps (TMP) are operated in an external magnetic field, one needs to know the influence of eddy currents on the rotor temperature to ensure safe operating conditions. For long-term operation a rotor temperature below 90 °C is recommended. At temperatures above 120 °C the thermal expansion of the rotor can exceed the gap between stator and rotor, causing a collision. The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment operates more than 20 magnetically levitated TMPs close to superconducting solenoids in magnetic fields up to 18 mT. Since the temperature of the fast moving rotor can not be measured directly, a test setup with Helmholtz coils and an infrared pyrometer for the temperature measurement was used at KIT to investigate the rotor temperature for different magnetic field. In order to operate the TMPs as close to the KATRIN components as possible they have been encased in a magnetic shielding. This talk will present measurements with different TMPs in magnetic fields up to 20 mT with and without shielding. We acknowledge the support by KSETA, BMBF (05A14VK2), HAP and the Helmholtz association.

VA 1.3 Mon 10:15 HSZ 301

New technologies for dry and clean vacuum — •Alexander Kaiser — Leybold GmbH, Bonner Str. 498, 50968 Köln

The history of vacuum goes back several centuries and is characterized by large and noisy machines that have the potential to pollute the environment and the vacuum chamber with oil and particles. While several high and ultra-high vacuum pumping principles offer suitable hydrocarbon-free clean pumping, there are still compromises with today's fore-vacuum pumps, which are becoming increasingly unacceptable in many research applications.

The ideal vacuum pump is a reliable tool providing clean vacuum with low operational noise, low power consumption and runs maintenance-free. Today, this can be achieved by pumps based on screw or multi-stage roots technology where optimized rotors rotate in an oil-free compression suction chamber without generating friction. Because of the non-contacting oil-free operation, no wear is produced and neither oil nor particles can contaminate the vacuum chamber and the environment. By optimizing the rotor design and vacuum channels, the pumps can be designed to run almost noise free with no disturbance for the user and with highest energy-efficiency.

This talk gives an overview of dry and clean vacuum pump technologies and the current challenges and solutions in developing a pump almost not audible for the operator.

VA 2: Large Vacuum Systems

Time: Monday 11:00–12:15 Location: HSZ 301

Invited Talk VA 2.1 Mon 11:00 HSZ 301

Commissioning of the complete KATRIN Vacuum System — •Joachim Wolf and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), IEKP, Postfach 3640, 76021 Karlsruhe

The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment uses the kinematics of electrons from the tritium β-decay to determine the effective neutrino mass with a sensitivity of $m_\nu = 200\,\mathrm{meV/c^2}$ (90% C.L.). The β-electrons are produced in the windowless gaseous tritium source (WGTS) at a pressure of 10^{-3} mbar. Superconducting magnets around the beam lines guide them through the transport and pumping section to the spectrometer, where their energy is analysed. Tritium decaying inside the spectrometer would increase the background rate. Therefore the pumping sections have to reduce the tritium flow from the WGTS by at least 14 orders of magnitude. Two techniques are employed for the tritium retention. The differential pumping section (DPS) uses cascaded turbo-molecular pumps and in the cryogenic pumping section (CPS) the tritium gas is cryosorbed on a 3-K-cold layer of argon frost that covers the beam tubes. The spectrometer section consists of the Pre-Spectrometer ($8.5\,\mathrm{m^3}$, 10^{-11} mbar), the huge Main Spectrometer ($1240\,\mathrm{m^3}$, 10^{-11} mbar), and the detector section, where electrons that pass the electrostatic filter of the Main Spectrometer are counted. The setup of the KATRIN experiment has been completed at KIT in 2016. This talk introduces the various parts of the experiment and their challenging vacuum requirements. Performance data from the ongoing commissioning phase are presented. We acknowledge the support by KSETA, BMBF (05A14VK2), HAP and the Helmholtz association.

VA 2.2 Mon 11:45 HSZ 301

Performance of the KATRIN Cryogenic Pumping Section — •Carsten Röttele and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), IEKP, Postfach 3640, 76021 Karlsruhe

The **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment uses the kinematics of electrons from the tritium β-decay to determine the effective neutrino mass with a sensitivity of $m_\nu = 200\,\mathrm{meV/c^2}$ (90% C.L.). Produced in the windowless gaseous tritium source (WGTS), the β-electrons are magnetically guided through the beam lines of the transport and pumping section to the spectrometer, where their energy is analysed. The transport and pumping section comprises two parts, the differential pumping section (DPS) and the cryogenic pumping section (CPS). Tritium decaying inside the spectrometer would increase the background rate. Therefore the pumping sections have to reduce the tritium flow from the WGTS by at least 14 orders of magnitude. This talk introduces the CPS, which has been designed to reduce the tritium flow by more than seven orders of magnitude. The tritium is cryosorbed on a 3-K-cold layer of argon frost that covers the gold-coated stainless steel surface of the beam tubes with an area of about $2.5\,\mathrm{m^2}$. The temperature distribution along the cold trap, which is important for the effective reduction factor, has been simulated with COMSOL multiphysics. Results of the simulation will be presented and compared with first experimental data. This work was supported by GRK1694, BMBF (05A14VK2), KSETA and the Helmholtz Association.

VA 3: Vacuum Physics

Time: Monday 13:30–14:45 Location: HSZ 301

Invited Talk VA 3.1 Mon 13:30 HSZ 301

High speed massive matter injection in ultrahigh vacuum environment for magnetic fusion devices — •Mathias Dibon[1,2], Peter Lang[1], Gabriella Pautasso[1], Albrecht Herrmann[1], Vitus Mertens[1], Rudolf Neu[1,2], Bernhard Ploeckl[1], and Volker Rohde[1] — [1]Max-Planck-Institute for Plasmaphysics, Boltzmannstr. 2, 85748 Garching, Germany — [2]Technical University Munich, Boltzmannstr. 15, 85748 Garching, Germany

Thermonuclear fusion devices operate with hydrogen plasma at temperatures in the range of 100 - 200 million K. Conversely, the plasma density is very low (10^{20} particles/m^3). In order to achieve this low density and a high purity of the plasma, the pressure in the plasma vessel must be below 10^{-4} Pa. Efficient plasma fuelling without impairing the quality of the vacuum is therefore often done by injecting pellets composed of cryogenic hydrogen. These pellets are injected into the plasma at speeds of about 1000 m/s, allowing particle deposition in the plasma core without degrading the surrounding vacuum. Furthermore, fusion devices of the Tokamak type rely on a very high electrical current (several MA) within the plasma. This bares the risk that the plasma disrupts within milliseconds which can cause severe damage to the fusion device. Hence, these disruptions have to be mitigated which is done by injecting massive amounts of noble gas. High speed gas valves, that operate inside or outside of the vacuum vessel, hold large amounts of noble gas which is released completely into the vacuum vessel within milliseconds (typical flow rate 10^5 Pam^3/s), putting a serious load on the vacuum system.

VA 3.2 Mon 14:15 HSZ 301

A Novel Ion Source: Theory, Experiments and Applications — •Mihail Granovskij, Sergej Uchatsch, Anton Zimare, Christian Reinhardt, Jaroslaw Iwicki, Michael Flämmich, and Ute Bergner — VACOM Vakuum Komponenten & Messtechnik GmbH, Gabelsbergerstraße 9, 07749 Jena

Pressure determination in HV/UHV-processes is generally carried out with well-known hot or cold cathode gauges. While these gauges are reliable in practice, users often face problems achieving the desired operating pressure. Most likely this is caused by leaks which can be identified with a separate leak detector or mass spectrometer. While leak detectors are highly cost-intensive, the application of mass spectrometers seems to be oversized since only the Helium signal is relevant.

Merging the capabilities of total pressure gauges with the basic performance of a mass spectrometer is an approach we present in the present talk. Our novel, simple and compact ion source is simultaneously capable of both: a precise total pressure measurement over a wide range and the determination of Helium partial pressure with a high dynamic range in the UHV without the usage of a cost-intensive electron multiplier.

In the talk we explain the physical principles of the novel ion source. We show experimental results, and provide insights into the overall performance of the gauge. Moreover, we evaluate the capability of detecting the gas composition in the range of 1-50 m/z.

VA 4: Poster Session

Time: Monday 14:45–16:00 Location: P2-OG3

VA 4.1 Mon 14:45 P2-OG3

Laser enhanced field emission — •Simon Däster — ETH Zürich

We report a setup to create femtosecond long electron pulses in an electron microscope. A commercial scanning microscope has been adapted in order to amplify a static electric field with a concentrated femtosecond laser pulse. It is shown how to measure this small electron beams. Furthermore, new research fields are indicated where to use this technique for an enhanced observation of electron dynamics.

VA 4.2 Mon 14:45 P2-OG3

Simulation of thermal and radioactive impacts on the CPS performance — •Lutz Schimpf and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), IEKP, Postfach 3640, 76021 Karlsruhe

The transport section of the **Ka**rlsruhe **Tri**tium **N**eutrino experiment (KATRIN) has two main tasks, which are the adiabatic guidance of the β-electrons from the Windowless Gaseous Tritium Source to the spectrometer section and to lower the tritium flow into the spectrometer section by at least 14 orders of magnitude. This huge reduction of the tritium flow is achieved by a reduction of seven orders of magnitude in the Differential Pumping Section and another seven orders in the Cryogenic Pumping Section (CPS). Two thirds of the beam tube inside the CPS is being operated at a temperature of 3K to adsorb the tritium molecules on a argon frost layer. The pumping performance during an operation interval of 60 days does strongly dependent on the homogeneity and the temporal stability of the beam tube temperature, as well as on the radioactive impact of tritium β decays inside the argon frost. To investigate these time and geometry dependent problems a custom-made simulation program has been developed. This program, based on time dependent desorption probabilities, is used to simulate the time distribution of the gas migration along the beam tubes, and to calculate its suppression factor. Simulation results will be presented both for deuterium used during commissioning and for tritium used in standard operation. This work has been supported by BMBF (05A14VK2), KSETA and the Helmholtz Association.

VA 4.3 Mon 14:45 P2-OG3

Gas dynamics simulations of the tritium source for the KATRIN experiment — •Florian Heizmann[1], Laura Kuckert[2], and KATRIN Collaboration[1,2] — [1]KIT, Institute of Experimental Nuclear Physics (IEKP), P.O. box 3640, D-76021 Karlsruhe — [2]KIT, Institute for Nuclear Physics (IKP), P.O. box 3640, D-76021 Karlsruhe

The Karlsruhe Tritium Neutrino Experiment (KATRIN) aims to measure the neutrino mass with a sensitivity of 200 meV/c^2 (90% C.L.) in a direct approach using the beta decay of molecular tritium. The neutrino mass is extracted by fitting model-based beta decay spectra to the measured electron spectrum. Thereby it is important to include modifications from systematic effects to the spectrum model. Especially the gas dynamics in the windowless gaseous tritium source (WGTS) play a key role for accurate modelling. Since in most cases this can not be measured directly, the modelled beta spectrum relies on gas dynamics calculations as well as on monitoring of operation parameter changes. A comprehensive pseudo-3D model has been developed. The accuracy of the gas dynamics model in the spectrum simulation including the monitoring of operation parameters is reviewed and implications on the systematics budget for the neutrino mass measurement are described. Supported by KSETA, BMBF (05A14VK2), HAP and the Helmholtz Association.

VA 4.4 Mon 14:45 P2-OG3

Time dependent TPMC simulation of the KATRIN cryogenic pumping section — •Fabian Friedel and KATRIN Collaboration — Karlsruhe Institute of Technology (KIT), IEKP, Postfach 3640, 76021 Karlsruhe

The aim of the **Ka**rlsruhe **Tri**tium **N**eutrino (KATRIN) experiment is to determine the effective mass of the electron antineutrino with a sensitivity of 200 meV/c^2 (90% C.L.). This will be achieved by measuring the β-spectrum of tritium close to the kinematic endpoint at 18.6 keV. One main component of the experiment is the transport section which magnetically guides the beta electrons from the windowless gaseous tritium source to the spectrometer for energy measurement. An important part of the transport section is the Cryogenic Pumping Section (CPS) which has been designed to reduce the tritium flow by at least 7 orders of magnitude. The inner surface of the beam tubes is covered by a layer of 3-K-cold argon frost, cryosorbing the tritium. In order to confirm that this stringent requirement, the pumping performance of the CPS is currently tested with deuterium. In addition many TPMC simulations with MolFlow+ have been performed and an algorithm was developed to describe the time dependent evolution of the tritium reduction factor. This work has been supported by BMBF (05A14VK2), KSETA and the Helmholtz Association.

VA 4.5 Mon 14:45 P2-OG3

A Passive Wide Range Gauge — •Jaroslaw Iwicki, Detlev Tietjen, Ruben Gerhardt, Michael Flaemmich, and Ute Bergner — VACOM Vakuum Komponenten & Messtechnik GmbH, Jena, Deutschland

The Pirani gauge, named after its inventor Marcello Stefano Pirani, has become one of the workhorses in vacuum technology and corresponding industries. As a stand-alone gauge, this thermal conductance based principle is widely used in industrial environments for moderate pressure determination. Despite existing needs for such a measuring tool equipped with versatility, accuracy, robustness and low cost, however, in UHV applications the Pirani gauge is rarely used. Primarily this is due to its bake-out restrictions attributed to the location of the signal processing electronics. Latter is to be installed directly onto the gauge, so that bakeable Pirani gauges are hardly or not available. Moreover, bakeable wide range gauges - consisting of a Pirani and a hot or cold cathode - do not exist. In this talk we introduce a novel Pirani gauge setup in which the gauge signal processing is realized by a microcontroller driven digital processing unit. In contrast to the conventional analogue based setup of signal processing (Wheatstone Bridge), the electronics can be spacially separated from the vacuum gauge. Decent theoretical data and experimental results will be presented to explore and support the features of the novel Pirani gauge concept. Finally, the digital setup allows integrating the Pirani sensor in a wide range gauge in a way that boundaries between transducers and passive gauges may disappear in the future.

VA 4.6 Mon 14:45 P2-OG3

Testing all-aluminum CF chambers for UHV applications — •Maximilian Biethahn, Sophie Gottschall, René Bauer, Michael Flämmich, and Ute Bergner — VACOM Vakuum Komponenten & Messtechnik GmbH, Gabelsbergerstraße 9, 07749 Jena

Stainless steel and aluminum are the most widely used materials in vacuum technology - still with the balance more on the stainless steel side. However, aluminum has some strong advantages over stainless steel, e.g.: it is lightweight, it has a very low relative magnetic permeability (approx. 1) and it shows very low outgassing in unbaked and in-situ baked condition.

In this talk, metal-sealed CF vacuum components and chambers made from aluminum are discussed. In this context, adequate knife edge stability, temperature stability and reliable outgassing properties have always been debated as major challenges. Based on detailed experimental studies it will be shown that these challenges have been solved lately. It will be shown that the knife edges are stable for hundreds of closures and outgassing rates below 2E-14 mbar*l/s/cm2 are achieved after very moderate bake-out conditions (24 h at 120 °C). Because the flange connection system is designed according ISO/TS 3669-2 (Bakeable flanges: Dimensions of knife-edge flanges), it can be easily used with conventional stainless steel flanges and chambers. By this means, Aluminum-CF components and chambers based on the AluVaC(R) technology are today a serious alternative to the established components made from stainless steel.