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

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## Overview of Invited Talks and Sessions

(lecture room HFT-FT 131)

### Invited Talks

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| VA 1.1 | Mon | 10:00–10:40 | HFT-FT 131 | **Current Techniques and Challenges in the Design of Vacuum Pumps** — •Magnus Janicki |

### Sessions

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| VA 1.1–1.3 | Mon | 10:00–11:20 | HFT-FT 131 | **Future Requirements on Vacuum Pumps and Vacuum Gauges** |
| VA 2.1–2.2 | Mon | 14:00–14:40 | HFT-FT 131 | **Desorption** |
| VA 3.1–3.2 | Mon | 14:40–15:20 | HFT-FT 131 | **Vacuum Systems and Tools** |
| VA 4.1–4.3 | Mon | 15:20–16:20 | HFT-FT 131 | **KATRIN Vacuum Systems** |

### Treffen des Fachverbands Vakuumphysik und Vakuumtechnik

Montag 16:30 HFT-FT 131

# VA 1: Future Requirements on Vacuum Pumps and Vacuum Gauges

Time: Monday 10:00–11:20 Location: HFT-FT 131

**Invited Talk** VA 1.1 Mon 10:00 HFT-FT 131

**Current Techniques and Challenges in the Design of Vacuum Pumps** — •Magnus Janicki — Oerlikon Leybold Vacuum, Bonner Str. 498, 50968 Köln

The industrial design of vacuum pumps in general tries to optimize the vacuum performance and the energy efficiency of newly developed pumps in the limits of mechanical, thermal and financial possibilities. Different simulation techniques are used to find the optimum design parameters prior to the prototype testing.

In most vacuum pumps all three flow regimes, the viscous, the Knudsen and the molecular flow are to be found simultaneously at different locations. As most flow models show good accuracy only in a specific flow regime, the calculation of the vacuum performance of the integral pump is often not covered by a single simulation model. While CFD methods are very useful in the viscous flow regime, their accuracy decreases when the flow enters the Knudsen flow regime. Monte Carlo methods on the other side are very helpful in calculating molecular flow but become computationally intensive with higher gas pressures due to the necessity of high particle numbers and the inclusion of collisions between the particles. Additionally there are nearly no commercial tools to calculate the flow of rarefied gases in three dimensional geometries.

This talk gives an overview of simulation models that are used in the industrial design of vacuum pumps, especially with screw vacuum pumps, roots blowers and turbo molecular pumps. It is shown, how far these techniques help during the development process of new pumps and where their simulation capabilities are limited.

VA 1.2 Mon 10:40 HFT-FT 131

**Fusionskraftwerke - Anforderungen und gegenwärtige technische Entwicklungen der Vakuumpumpsysteme** — •Thomas Giegerich und Christian Day — Institut für Technische Physik (ITEP), Karlsruher Institut für Technologie (KIT), Campus Nord, Eggenstein-Leopoldshafen, D-76344, GERMANY

Die Entwicklung zukünftiger Fusionskraftwerke stellt besondere Herausforderungen an deren Vakuumsysteme einschließlich der Vakuumpumpen und der Abgasaufbereitung.

Hochverfügbare, zuverlässige und ökonomische Pumpen werden benötigt, um einen Druckbereich von <10-7 bis 1000 mbar abzudecken. Dabei müssen unter rauen Einsatzbedingungen (hohe Temperaturen und Magnetfelder, Mikrowellenstrahlung, Staub) hohe Gasströme gefördert werden. Die gepumpten Gase bestehen überwiegend aus Deuterium, Helium und Tritium sowie Verunreinigungen.

Das Vorhandensein von Tritium - ein radioaktives Gas, das mit dem Luftsauerstoff zündfähige Mischungen bildet - stellt besondere Anforderungen an die Sicherheit und die Materialverträglichkeit der verwendeten Komponenten. Fette und Öle als Schmier- und Dichtstoffe sind in den Vakuumpumpen ebenso verboten wie das Verwenden von Spül- und Sperrgas oder Gleitringdichtungen.

In diesem Vortrag wird das Vakuumsystem eines Fusionsreaktors vorgestellt und auf die veränderten Anforderungen bei dem Sprung von einem experimentellen Reaktor auf einen kommerziellen Fusionsreaktor eingegangen. Technische Lösungsansätze sowie deren Entwicklungsstatus werden aufgezeigt und diskutiert.

VA 1.3 Mon 11:00 HFT-FT 131

**New Bayard-Alpert Gauge for UHV and XHV Measurement down to 5E-12 mbar** — •Nikolas von Freyhold, Ivan Pongrac, Jaroslaw Iwicki, Heiko Wunderlich, and Ute Bergner — VACOM Vakuum Komponenten & Messtechnik GmbH, Jena, Germany

An increasing number of UHV applications require vacuum gauges for measuring total pressures in the range of 1E-10 mbar to 1E-11 mbar (abs.) with a certain accuracy and reproducibility. For this purpose, ionization vacuum gauges of different types are the preferred sensors. They measure ion or discharge currents that are proportional to the pressure, however nonlinearities must be taken into account towards their lower measurement limits. Bayard-Alpert hot cathode ionization gauges as well as the different cold cathode gauge types are quite dissatisfactory regarding the pressure range mentioned above, since their measurement range is limited to some E-11 mbar. Besides, the calibration of frequently used "nude" Bayard-Alpert gauges is depending strongly on the distance between sensor electrodes and the surrounding wall of the vacuum chamber.

We will present a new Bayard-Alpert hot cathode gauge optimized for UHV measurements. This gauge combines a stable calibration with successfully demonstrated improvements in terms of lower pressure limit, featuring pressure readings from 1E-2 to 5E-12 mbar. Experimental results in comparison to other Bayard-Alpert gauges and an Extractor gauge will be presented and discussed.

# VA 2: Desorption

Time: Monday 14:00–14:40 Location: HFT-FT 131

VA 2.1 Mon 14:00 HFT-FT 131

**Outgassing rate measurement by using the difference method** — •Katharina Battes and Volker Hauer — Karlsruhe Institute of Technology (KIT), D-76344 Eggenstein-Leopoldshafen, Germany

Outgassing plays an important role in the field of vacuum technology, especially if ultrahigh vacuum conditions shall be reached. For example hydrogen desorption from stainless steel is a common problem. For building new vacuum systems the outgassing rates of the materials should be strongly considered.

Often, outgassing rates of different materials are reduced by a pretreatment like electro-polishing, baking or vacuum-firing.

However, the theory of outgassing is quite complicated and not yet fully understood. Also, experimental results reported in the literature are often not consistent. This is why new experimental efforts are under way at KIT to provide a better understanding.

The two main methods to measure outgassing rates are the pressure-rise method and the throughput method.

The new outgassing measurement apparatus currently being built at KIT uses the difference method (a modified throughput method). With this method the pressure difference between two identical vacuum chambers, with one containing the sample and the other acting as a reference, is measured to achieve the outgassing rate of the sample. Like this, the outgassing of the vacuum chamber can be subtracted and also very low sample outgassing rates can be measured.

This paper introduces in the various outgassing measurement concepts and describes the current status of the new facility.

VA 2.2 Mon 14:20 HFT-FT 131

**AP-TDS characterization of $CO_2$ methanation catalysts** — •Matthias Städter and Dieter Schmeisser — Brandenburg University of Technology, Cottbus, Germany

Development of new catalysts and their characterization by TDS (thermal desorption spectroscopy) is used in a wide field of applications. In our group we focus on catalysts usable to convert $CO_2$ towards methane by the Sabatier reaction ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$ at 375°C). For measuring large numbers of samples we designed an AP-TDS (ambient pressure TDS) chamber where various desorption experiments can be performed without bringing the catalyst into vacuum. The well-defined reaction chamber, in terms of temperature, pressure and gas composition (Ar atmosphere), is separated by a pin hole ($\emptyset = 6\ \mu m$) from an external UHV chamber. Evolving species and their composition are monitored by a mass spectrometer attached to the UHV chamber. Our first measurement results on commercially available $NiO/SiO_2$ and $Ru/Al_2O_3$ based catalysts, with focus on the identification and enumeration of different adsorption sites for $CO_2$, will be presented. $CO_2$ saturated samples were heated from RT to 1100°C (heating rate $\beta = 0.3$ K/s) while measuring the evolution of the $CO_2$ content. Our measurements show large numbers of different adsorption sites for NiO (200-750°C) whereas Ru shows only few different sites around 440°C. For both catalysts, most of the formerly adsorbed $CO_2$ remains at the surface (at 375°C) available for methanation.

# VA 3: Vacuum Systems and Tools

Time: Monday 14:40–15:20 Location: HFT-FT 131

VA 3.1 Mon 14:40 HFT-FT 131

**Fast Ionization Chambers for Time Resolved XAFS Measurements** — •Oliver Müller, Dirk Lützenkirchen-Hecht, and Ronald Frahm — Bergische Universität Wuppertal

Time resolved XAFS (X-ray Absorption Fine Structure) methods, e.g. QEXAFS (Quick Extended X-ray Absorption Fine Structure) is a valuable tool for in situ investigations of materials of any kind. The increase in intensity at modern 3rd generation synchrotron radiation sources allow the acquisition of complete EXAFS spectra within a few milliseconds. To meet the increasing demand in time resolution and data quality specialized high speed ionization chambers have been build. By introducing a Frisch grid, the bandwidth of the ionization chambers could significantly be extended. It was shown that the improved step response of the new ionization chamber yield higher energy resolution of EXAFS spectra at very high acquisition frequencies.

VA 3.2 Mon 15:00 HFT-FT 131

**Vacuum system design of the MITICA Test Facility - Challenges for the cryopump** — •Santiago Ochoa, Stefan Hanke, and Christian Day — Karlsruhe Institut of Technology KIT, Institute for Technical Physics ITEP, D-76344 Eggenstein-Leopoldshafen, Germany

MITICA (Megavolt ITER Injector and Concept Advancement) is a testbed for the full-sized heating neutral beam injector currently being built in Europe and will start operation more than five years before the heating beam system will be used on the nuclear fusion device ITER.

In order for this neutral beam injector to heat the plasma properly a high ion fraction with small divergence has to be delivered and the demanding pressure profile along the beam line has to be achieved.

The vacuum system should overcome several challenges as the space available is limited, the pumping speeds needed are extraordinarily high, and strong temperature differences have to be considered in the design. A wrong design would lead to an insufficient pump performance, therefore to a higher pressure and consequently to problems as charge exchanges, voltage breakdowns or even back scattering of the beam.

In this work, it will be presented an overview of the requirements for the correct operation of the MITICA testbed, their classification in two groups: vacuum requirements and additional requirements for the specific case MITICA. Finally, it is shown how the vacuum system, designed by the Vacuum Group of the ITEP (KIT), accomplished them.

# VA 4: KATRIN Vacuum Systems

Time: Monday 15:20–16:20 Location: HFT-FT 131

VA 4.1 Mon 15:20 HFT-FT 131

**Tritiumnachweis per $\beta$-induzierter Röntgenspektroskopie** — •Marco Röllig — für die KATRIN Kollaboration, Karlsruher Institut für Technologie, Institut für Experimentelle Kernphysik

Das **KA**rlsruher **TRI**tium **N**eutrino-Experiment KATRIN untersucht spektroskopisch das Elektronenspektrum des Tritium $\beta$-Zerfalls $^3\mathrm{H} \rightarrow {}^3\mathrm{He} + \mathrm{e}^- + \bar{\nu}_\mathrm{e}$ nahe dem kinematischen Endpunkt von $18,6\,\mathrm{keV}$. Mit einer fensterlosen, molekularen, gasförmigen Tritiumquelle hoher Luminosität und einem hochauflösenden elektrostatischen Filter mit bisher unerreichter Energieauflösung $\Delta E = 1\,\mathrm{eV}$, wird KATRIN eine modellunabhängige Bestimmung der Neutrinomasse mit einer erwarteten Sensitivität von $0,2\,\mathrm{eV}$ (90% CL) ermöglichen. Für eine derart präzise Massenbestimmung ist insbesondere die Stabilität der Quelle bezüglich ihrer $\beta$-Aktivität ein Schlüsselparameter. Ein präzises Monitoring ist für die erforderliche Stabilität der Quelle von $0,1\%$ notwendig.

Die Nachweisgenauigkeit eines Tritium-Bremsstrahlungsmonitors wird unter anderem durch das zu erwartende Untergrundsignal limitiert. Untergrund entsteht durch Permeation von Tritium durch das Bremsstrahlung erzeugende Element (Be-Fenster mit Au) sowie durch Adsorption von Tritium auf Gold- und Edelstahloberflächen. Die Machbarkeit eines Bremsstrahlungsmonitors für Tritium wurde mithilfe eines Testaufbaus am Tritiumlabor Karlsruhe (TLK) gezeigt. Gleichzeitig wurde die Sensitivität auf adsorbiertes Tritium von wenigen Monolagen auf Edelstahloberflächen demonstriert. Dieser Vortrag stellt den Aufbau und die Resultate vor.

VA 4.2 Mon 15:40 HFT-FT 131

**The Tritium gas-flow reduction factor of the Differential Pumping Section (DPS2-F) in the vacuum system of KATRIN** — •Andreas Kosmider[1] and Strahinja Lukic[2] — [1]KIT - Karlsruher Institut für Technologie, Institut für Kernphysik, Postfach 3640, 76021 Karlsruhe, Germany — [2]Laboratory for Physics - 010, Vinca Institute of Nuclear Sciences, M. Petrovica Alasa 12-14, 11001 Belgrade, Serbia

KATRIN, the world's largest experiment for the direct measurement of the mass of the electron-neutrino, is currently being setup at KIT. Our goal is the determination of the neutrino-mass with a sensitivity of 0.2 eV. KATRIN will deploy a seminal vacuum system that will allow a reduction of the Tritium source gas-flow by a factor of $10^{22}$ over a path length of $\approx 70$ m. The DPS2-F is a crucial module in this vacuum system featuring a 6 m long fourfold buckled beamline at liquid Nitrogen temperature and four Leybold MAG W 2800 TMP.

Design-values for the DPS2-F called for an reduction factor for Tritium in the order of $10^5$. Simulations using the Molflow+ code delivered an expected value of the actually build system of $1.6 \cdot 10^4$ for Deuterium. The experiments carried out to verify these numbers are the main subject of this talk. They were carried out using the non-radioactive gases D, He, Ne, Ar & Kr injected at flow-rates between $1.8 \cdot 10^{-3}$ and $2.8 \cdot 10^{-2}$ mbar l/s. The output was measured using a finely calibrated residual gas analyzer. The simulations were confirmed and the gas-flow reduction factor for Tritium was estimated to be $2.5 \cdot 10^4$.

VA 4.3 Mon 16:00 HFT-FT 131

**Kompatibilitätsexperiment von Turbomolekularpumpen mit Tritiumgas** — •Florian Priester — für die KATRIN-Kollaboration, Karlsruher Institut für Technologie

Das KArlsruher TRItium Neutrino-Experiment KATRIN untersucht spektroskopisch das Elektronenspektrum des Tritium $\beta$-Zerfalls $^3\mathrm{H} \rightarrow {}^3\mathrm{He} + \mathrm{e}^- + \bar{\nu}_e$ nahe dem kinematischen Endpunkt von 18.6 keV. Mit einer fensterlosen, molekularen, gasförmigen Tritiumquelle hoher Luminosität und einem hochauflösenden elektrostatischen Filter mit bisher unerreichter Energieauflösung $\Delta\mathrm{E} = 1$ eV, wird KATRIN eine modellunabhängige Bestimmung der Neutrinomasse mit einer erwarteten Sensitivität von 0.2 eV (90 % CL) ermöglichen. Für eine derart präzise Massenbestimmung ist insbesondere die Stabilität der Quelle bezüglich ihrer $\beta$-Aktivität ein Schlüsselparameter, um die geplante Nachweisgrenze für den Wert der Neutrinomasse zu erreichen. Um die erforderliche Stabilität der Quelle auf 0,1 % zu gewährleisten ist eine stabile Tritiumeinspeisung in die Quelle sowie ein aktives Pumpen erforderlich. Dieses erfolgt mit leistungsstarken Turbomolekularpumpen. Um die Tritiumverträglichkeit dieser zu überprüfen wurde am Tritiumlabor Karlsruhe das Testexperiment TriTOP (Tritium Test Of Pumps) aufgebaut und wird derzeit betrieben. Dieser Vortrag präsentiert das Experiment sowie die nach ca. neun Monaten Dauerbetrieb gewonnen Resultate. Gefördert vom BMBF unter Förderkennzeichen 05A08VK2 und dem Sonderforschungsbereich Transregio 27 "Neutrinos and Beyond".