TUT 1: Next generation of SI-Units (joint session VA/TT/TUT)

Time: Sunday 16:00–18:20 Location: H2

Tutorial TUT 1.1 Sun 16:00 H2

A Quantum-Based Pressure Standard for a New SI Realization of the Pascal — •Jay Hendricks — NIST Thermodynamic Metrology Group, Gaithersburg, MD, US

Moving forward, the next generation of pressure standards will provide a new route of SI traceability for the pascal. By taking advantage of both the properties of light interacting with a gas and that the pressure dependent refractive index of helium can be precisely predicted from fundamental, first-principles quantum-chemistry calculations, a new route of realizing the pascal has been demonstrated. This lecture will briefly cover the classical methods of realizing pressure that have served the metrology community well for the past 375 years. And then will take a deeper dive into the next generation of light-based pressure standards that will enable the elimination of mercury manometers, replacing them with a smaller, lighter, faster, and higher precision standards. From a metrology stand point, the new quantum-based SI pascal will move us from the classical force/area definition, to an energy density (joules per unit volume) definition. Should the technique be further miniaturized, it will lead to a revolution in pressure metrology, enabling a photonics based device that serves both a gas pressure sensor and a portable gas pressure standard all in one.

Tutorial TUT 1.2 Sun 16:35 H2

Redefinition of the Kelvin - With what accuracy can temperatures be measured? — •Steffen Rudtsch — Physikalisch-Technische Bundesanstalt (PTB), Abbstraße 2-12, 10587 Berlin

On 20 May 2019, World Metrology Day, the revised International System of Units (SI) will enter into force. From this day on, all units will be traced back to natural constants. The redefinition of the Kelvin via the Boltzmann constant opens up new possibilities in the field of high-precision temperature measurements and metrological traceability. The lecture gives an overview of the currently used precision measurement methods in contact thermometry, in the range from 1 mK to 2000 °C, and shows which changes result from the new definitions.

Tutorial TUT 1.3 Sun 17:10 H2

The new kilogram - Now approachable for extraterrestrials and nonhumans — •Frank Härting — Physikalisch-Technische Bundesanstalt (PTB), Abbstraße 2-12, 10587 Berlin

The presentation gives an overview of the work that have been done and which is still in progress in order to realize the new kilogram after the redefinition of the SI on Mach 20, 2019. Beside some historical information, the presentations will focus on the actual and future scientific challenges that have to be solved in mass metrology.

Tutorial TUT 1.4 Sun 17:45 H2

Counting electrons for the new ampere — •Frank Hohls — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

On November 16th 2018 the General Conference for Weights and Measures, CGPM, adopted the resolution on the biggest revision of the International System of Units (SI) in its history: From May 20th on the SI system is completely determined by fixing the values of 7 constants of nature. One of these constants is the elementary charge which will have the exact value e = 1.602 176 634 * 10-19 As. For the unit of electrical current, the Ampere, this has the nice consequence, that the physics of electrical current and the definition of the ampere are rejoined: Counting or controlling the number of electrons passing a conductor in each second will be the natural realization of the ampere. This could be achieved by a single-electron transport (SET) pump that transfers exactly n electrons in each of its operation cycles, generating a quantized current I = nef when operated at a frequency f. The present state of the art of the SET based current standard with emphasis on the most advanced candidate will be reviewed, a SET pump based on dynamic semiconductor quantum dots with electrically tunable energy barriers.

TUT 2: Statistical Physics Methods for Data Science in Physics (joint session SOE/DY/TUT)

Big Data is an ubiquitious buzzword, but beyond storing and processing large datasets, challenges in applications often lie in high-dimensional and nontrivial structures (= the content!) within the datasets. Artificial intelligence approaches, paired with statistical physics methods, can provide powerful tools which can go far beyond standard statistical methods. The tutorial gives an overview both on methods from stochastic blockmodeling, network analysis, inference and machine learning and on applications ranging from socioeconomic networks to biomolecular simulations. (Session organized by Jens Christian Claussen and Andreas Fery with the divisions of SOE, DY, BP and CPP.)

Time: Sunday 16:00–18:30 Location: H3

Tutorial TUT 2.1 Sun 16:00 H3

Statistical network inference and community detection — •Tiago Peixoto — University of Bath, UK

Network structures are shaped by evolutionary mechanisms and determine the central aspects of how a system functions. However, differently from systems that are naturally embedded in space, we cannot simply "look" at network in order to extract its most important structural patterns. Instead, we must rely on well-founded algorithmic methods to extract this information from data in an interpretable way. In this tutorial, we review a principled approach to this problem based on the elaboration of probabilistic models of network structure, and their statistical inference from empirical data. We focus in particular on the detection of modules (or "communities") in networks.

We aim to cover the following topics: 1. The stochastic block model (SBM) and its variants (degree correction, overlapping groups, etc.); 2. Bayesian inference and model selection: Distinguishing structure from noise; 3. Generalizing from data: Prediction of missing and spurious links; 4. Model extensions: Layered, dynamic SBMs, and generalized models on continuous latent spaces; 5 Fundamental limits of inference, and the undetectability phase transition; 6. Efficient inference algorithms; 7. Network reconstruction from noisy or indirect data.

Tutorial TUT 2.2 Sun 16:50 H3

Network filtering for big data — •Tiziana Di Matteo — Department of Mathematics - King's College London

In this lecture I will present network-theoretic tools to filter information in large-scale datasets and I will show that these are powerful tools to study complex datasets. In particular I will introduce correlation-based information filtering networks and the planar filtered graphs (PMFG) and I will show that applications to financial data-sets can meaningfully identify industrial activities and structural market changes. It has been shown that by making use of the 3-clique structure of the PMFG a clustering can be extracted allowing dimensionality reduction that keeps both local information and global hierarchy in a deterministic manner without the use of any prior information. To advance the PMFG (currently O(N3)), I will introduce a new algorithm, the TMFG (Triangulated Maximally Filtered Graph), that efficiently extracts a planar subgraph which optimizes an objective function. The method is scalable to very large datasets and it can take advantage of parallel and GPUs computing. The method is adaptable allowing online updating and learning with continuous insertion and deletion of new data as well changes in the strength of the similarity measure. Finally I will also show that filtered graphs are valuable tools for risk management and portfolio optimization too and they allow to construct probabilistic sparse modeling for financial systems that can be used for forecasting, stress testing and risk allocation.

Tutorial TUT 2.3 Sun 17:40 H3

Multiscale simulations of soft matter augmented by data-driven methods — •Tristan Bereau — Max Planck Institute for Polymer Research

Multiscale simulations, all the way from quantum chemistry to continuum mechanics, probe a variety of length and time scales relevant to soft-matter systems. In this tutorial, I will describe different strategies to help improve physics-based simulations with recently-developed data-driven methods and concepts. Applications discussed will include Bayesian inference for molecular kinetics, machine learning to vastly improve force-field transferability, and high-throughput screening to explore chemical compound space.

TUT 3: Resistive Switching: From basic physics of memristive devices to neuromorphic systems (joint session HL/TUT)

The miniaturization of electronic devices combined with the ongoing digitalization of our live calls for a change in the paradigms of information processing. This goes hand in hand with the discovery of new physical effects that can be harnessed for electronic systems. A most promising candidate for this are resistive switching materials, in which atoms are used instead of electrons for information storage. In the last years, significant progress has been made in understanding the underlying physics and with its transfer into novel electronic devices, often called memristors or memristive devices. This Tutorial starts with an introduction to the physics of resistive switching and aims to explain how to use memristive effects to create new devices and architectures for tomorrows electronics. Furthermore, some concepts for bio-inspired, neuromorphic electronics based on resistive switching are presented.

Organizers: Martin Ziegler and Erich Runge (TU Ilmenau)

Time: Sunday 16:00–18:15 Location: H4

Tutorial TUT 3.1 Sun 16:00 H4

Oxide based memristive devices: Current status of understanding and future prospects — •Regina Dittmann — PGI-7, Forschungszentrum Jülich GmbH

Transition metal oxides exhibit a reversible, non-volatile change in electrical resistance upon electrical stimulus, a phenomenon known as resistive switching. In the simplest case resistive switching memory cells, or so called memristive devices, can be switched between a low resistance state (LRS) and a high resistance states (HRS) which can be interpreted as the logical "1" and "0", respectively. Moreover, resistive switching cells often exhibit multiple resistive states rather than only two logical states, which can be highly interesting for neuromorphic applications. Based on the current knowledge, resistive switching in memristive elements based on transition metal oxides can be ascribed to electrically induced redox-processes at the oxide/electrode interface, which occur either in a spatially confined switching filament, multiple filaments or in a spatially homogeneous, area-dependent manner. In most cases, the redox-process in the metal-oxide goes along with a change in the valence state of the metal ion modifying the Schottky barrier at the oxide/electrode interface. Therefore, this type of switching mechanism is also called valence change mechanism (VCM). In this tutorial, we will present the current knowledge about microscopic mechanisms which drive electroforming and resistive switching in different variants of VCM-type memristive elements. Afterwards, a brief overview about the current and future fields of application will be presented.

Tutorial TUT 3.2 Sun 16:45 H4

Memristors and memristive devices: theory, physics, criticisms — •Thomas Mussenbrock — Brandenburg University of Technology, Chair of Electrodynamics and Physical Electronics, 03046 Cottbus, Germany

The research in the field of memristive devices dates back to the 1970s when Chua introduced his idea of a missing lumped circuit element, which he named *memristor*. The idea has emerged a considerable interest only after 2008 when researchers at HP Labs linked their resistive switching device to Chuas's theory. Today, memristive (or synonymously resistive switching) devices have been identified as promising candidates for future non-volatile memory applications due to their distinct key features, the most important of which are i) low power consumption, ii) passivity, and iii) scalability into the nanometer scale. Beyond their potential applications as non-volatile memories, memristive devices turned out to be applicable as artificial synapses in neuromorphic circuits. It is interesting to notice that a large number of different devices and concepts turn out to show memristive behavior, while the underlying physics is not completely understood in most of the cases. Furthermore, the scientific dispute is still ongoing, whether the devices which show memristive behavior are in fact memristors in terms of Chua's theory. This contribution is intended to provide an introduction to memristors and memristive devices. Theoretical aspects as well as fundamental physical phenomena are discussed, while the criticism regarding the memristor concept is not concealed.

Tutorial TUT 3.3 Sun 17:30 H4

Memristive devices for bio-inspired electronics — •Hermann Kohlstedt — Chair of Nanoelectronics, Faculty for Electrical Engineering and Information Technology, Kiel University, Germany

Information processing in biological nerve system is characterized by highly parallel, energy efficient and adaptive architectures in contrast to clock driven digital Turing machines. Even simple creatures outperform supercomputers when it comes to pattern recognition, failure tolerant systems and cognitive tasks. Fundamental building blocks leading to such remarkable properties are neurons as central processing units, which are (with variable strengths) interconnected by synapses to from a complex dynamical three dimensional network. The field of neuromorphic engineering aims to mimic such biological inspired information pathways by electronic circuitries. The advent of memristive devices opened novel pathways to mimic basal synaptic functionalities as e.g., spike-time-depended plasticity (STDP). In the tutorial I will explain how such local learning mechanisms are mimicked by memristive. In addition I will address the opportunities and challenges to integrate memristive devices as a part of cognitive electronic circuits, in particular for the interesting field of non-linear dynamics in the context with correlation and synchronization phenomena in nerve systems. Acknowledgement: This work is support by the DFG Research Unit 2093 "Memristive devices for neuronal systems.

TUT 4: Diamond-Growth, characterization, electronics and applications (joint session KFM/TUT)

This tutorial is dedicated to growth mechanisms of diamond (single and polycrystalline) and corresponding physical properties, used for electronic applications. Process technologies and production of diamond devices tailored for special technical applications will be discussed. Applications for diamond in high power and high frequency components will be presented.

Organized by Theo Scherer (KIT)

Time: Sunday 16:00–18:15 Location: H10

Tutorial TUT 4.1 Sun 16:00 H10

Diamond′s bright future in electronics and quantum technology — •Matthias Schreck — Institut für Physik, Universität Augsburg

The present talk gives first a general introduction into diamond growth by chemical vapor deposition (CVD). Then, it describes the different approaches and the crucial steps for the realization of single crystal diamond on wafer scale. The focus will be on the heteroepitaxial multilayer system Dia/Ir/YSZ/Si which is currently the most advanced as demonstrated by the successful synthesis of a monocrystalline disc with a diameter of 92 mm and a mass of 155 ct.
The second part addresses current and potential future applications. Cutting tools for high precision machining, scalpels for eye surgery as well as visible/infrared optical elements based on CVD grown single crystals are already available on the market. Detectors for high energy ionizing radiation required at large particle physics research facilities like GSI or CERN are under development. In the field of high power electronics, diamond should outperform all other wide bandgap materials according to its intrinsic material parameters, but highly competitive devices that may be grown on the new wafers are still to be demonstrated. Finally, emerging quantum technologies based on color centers hosted in the diamond crystal lattice open a fascinating new field.

Tutorial TUT 4.2 Sun 16:45 H10

Microwave CVD of Diamond — •Volker Buck — Uni. Duisburg-Essen

The contribution starts with historic remarcs concerning microwave CVD of Diamond. Then basic physics of microwave plasmas are presented to explain the concepts of usual microwave reactors. After this, standard process parameters for deposition of microcrystalline diamond films are given. An overview of problems related with epitaxy leads to actual research and within this context also the state of the art of doping is discussed. Some general aspects of nanotechnology then leads to ultrananocrystalline diamond films (UNCD) and color centers. An outlook concludes the contribution.

Tutorial TUT 4.3 Sun 17:30 H10

High power and high frequency applications of diamond — •Dirk Strauss — KIT Karlsruhe, Deutschland

Content of this tutorial is the presentation of basic properties of polycrystalline as well as single crystalline CVD diamond in high frequency (GHz-THz) and high power (MW) applications with extreme low microwave losses. Starting with growth conditions of diamond, optimization of dielectric and thermal properties up to implementation in diamond window assembly structures for multi-frequency applications (step tunable and Brewster windows) the complete development process and the state of the art today will be presented. Main applications of this field are heating and diagnostic systems in nuclear fusion reactors, accelerator and laser devices, where such windows can be implemented with outstanding physical properties.