TUT 2: Quantum Technologies (joint session HL/TT/TUT)

This tutorial features both the high hopes in Europe regarding quantum technologies and the underlying physics of several promising routes towards economically relevant quantum information science as well as the physics of a whole range of novel quantum devices.

Organized by Christian Enss (Heidelberg) and Erich Runge (Ilmenau) on behalf of the divisions TT and HL.

Time: Sunday 16:00–18:25 Location: H 0105

Tutorial TUT 2.1 Sun 16:00 H 0105

Quantum Technology - how is research funded? — •Gerd Leuchs — Max Planck Institute for the Science of Light, Erlangen, Germany

Quantum technology is a field in physics which experienced considerable growth recently and is about to generate real world applications with significant economic potential. Scientists and research oriented companies succeeded raising the awareness of politicians in Germany and Europe.
As a consequence, the European Quantum Flagship, which will be supported by national initiatives (in Germany, QUTEGA, a BMBF funded project), is currently in the process of being established. The goal is to provide infrastructural and financial support to projects associated to Quantum Technologies. The major focus is on connecting scientific groups with players from industry who are interested in investing into emerging quantum technologies such as quantum communication, quantum metrology, quantum simulation and quantum computing.
For younger scientists, the structure and the political initiation process of such funding initiatives is often lacking transparency. As the national coordinator of the quantum initiative in Germany, I will try to shed some light on this topic by reporting about the currently ongoing foundation of the Quantum Flagship and the associated national initiatives. Since the final structure of the Flagship is not yet fully established, I will also share my experience with similar projects from the past.

5 min. break

Tutorial TUT 2.2 Sun 16:40 H 0105

Superconducting Quantum Circuits — •Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — Physik-Department, TU-München, Garching, Germany — Nanosystems Initiative Munich, München, Germany

Superconducting quantum circuits, consisting of inductors, capacitors and Josephson junctions, can be flexibly engineered using modern thin film and micro/nano-fabrication techniques. These quantum electronic circuits behave quantum coherently with coherence times approaching the millisecond regime. They are successfully used to study fundamental quantum effects and develop components for applications in quantum technology. Examples are the tailoring of light-matter interaction, the development of sources and detectors for quantum light, or the implementation of quantum information processing, quantum metrology and quantum simulation systems. Meanwhile, several companies such as Google, IBM or Intel have started the race towards a universal quantum computer based on a superconducting hardware platform.

Superconducting quantum circuits can also be successfully coupled to nano-mechanical and magnetic systems. In the resulting hybrid quantum systems different quantum degrees of freedom can be strongly coupled, allowing for the coherent exchange of elementary excitations such as pho-tons, phonons and magnons on a single quantum level.

I will give an introduction into the field of superconducting quantum circuits and address recent advancements in the rapidly growing field of superconducting quantum technology.

Tutorial TUT 2.3 Sun 17:15 H 0105

Josephson junction based interferometers and amplifiers — •Sebastian Kempf — Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany.

Advances in science, health care or other areas of everyday life are often accompanied by progress in physical instrumentation. The development of ultra-sensitive detectors and sensors is therefore of great importance and will not only influence our understanding of nature but also future examination methods in medical care or search strategies for natural resources. Quantum technology plays an important role in these developments as superconducting quantum devices (SQDs) are among the most sensitive measurement instruments presently existing and enabling fascinating investigations of tiniest signals.

Josephson junction based interferometers and amplifiers are a special class of SQDs which are very well suited for measuring variations of tiny magnetic fields or any other physical quantity that can be naturally converted into magnetic flux. They are based on the Josephson effects as well as magnetic flux conservation and are used not only for measuring biogmagnetic signals as induced for instance by the electrical currents within the human brain but also to read out cryogenic particle detectors, to explore mineral deposits within geoscience or for magnetic sensing at nanoscale level.

I will give an introduction into this fascinating field, discuss different kinds of devices such as the well-known superconducting quantum interference device and highlight several applications for which Josephson junction based interferometers and amplifiers are a key technology.

Tutorial TUT 2.4 Sun 17:50 H 0105

Manipulation of quantum bits based on defect centres in diamond — •Oliver Benson — Institut für Physik der Humboldt-Universität zu Berlin, Newtonstrasse 15, 12489 Berlin

Quantum information processing relies on initialisation, manipulation, read-out and transmission of individual quantum bits. Defect centres in diamond are an example of stable, optically addressable single quantum systems in a solid-state matrix [1-4]. Their electronic states couple efficiently to light, and their energy level structure allows for long spin coherence time in the ground state. Moreover, coupling to nuclear spins in the diamond host provides storage of quantum bits for seconds. With this all ingredients for a full quantum information processing (QIP) architecture are present in one material platform. In this presentation, we introduce the fundamental concepts of QIP in diamond. We then describe recent breakthroughs, such as stationary to flying quantum bit conversion and entanglement of distant quantum bits [5]. Other applications of defect centres in diamond for quantum sensing [6] will be discussed as well.

[1] F. Jelezko and J. Wrachtrup, Phys. Status Solidi A, 203, 3207 (2006). [2] V. Acosta, P. Hemmer, MRS Bull. 38, 127 (2013). [3] J. R. Weber, et al., PNAS 107, 8513 (2010). [4] I. Aharonovich, et al., Rep. Prog. Phys. 74, 076501 (2011). [5] H. Bernien, et al., Nature 497, 86 (2013) [6] S. Hong, et al., MRS Bull. 38, 155 (2013).