Understanding our world

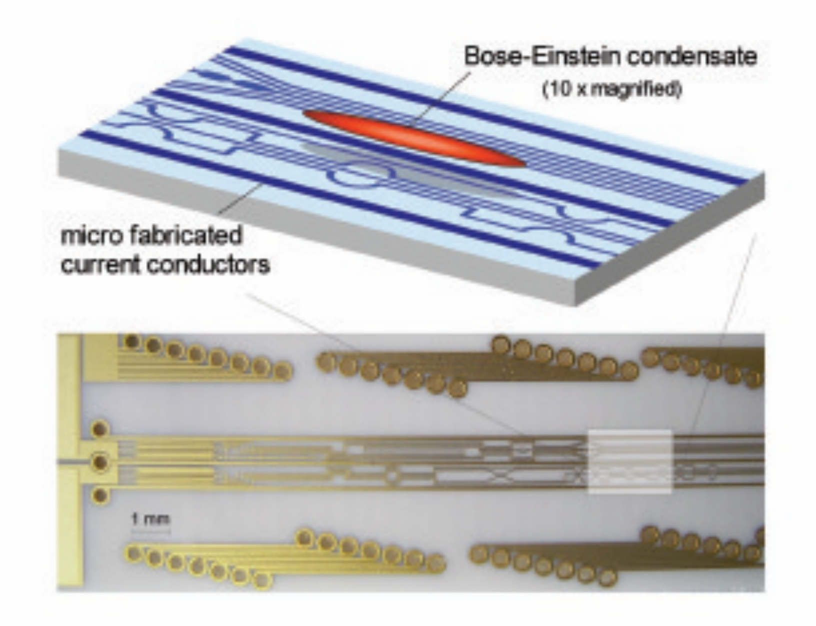
From the building blocks of matter to the structure of the Universe…

Exploring the foundations of physics and evaluating their impact on technological applications has been the concept of the 'Physikalisches Institut' at the University of Tübingen since its foundation in 1887 by Nobel Laureate Ferdinand Braun. He combined both goals by transferring the newly discovered cathode rays to the invention of the cathode-ray tube, the so-called 'Braun tube'. Since then many famous scholars have worked at the institute, such as Friedrich Paschen, Ernst Back, Hans Geiger and Walther Kossel.

Today, the institute houses three major disciplines:

- Solid state physics, focusing on superconductivity, magnetism and hybrid quantum systems down to the nanometre scale;
- The laser-driven quantum optics of ultra-cold atoms and Bose-Einstein condensates;
- Particle and nuclear physics with the main emphasis on astroparticle physics issues.

The latter activities are embedded in the 'Kepler Center for Astro and Particle Physics', which combines the university's research activities in astronomy and astrophysics with nuclear and particle physics. The first two subjects form the core of the 'Center for Collective Quantum Phenomena', which includes participation from the Institute of Applied Physics and the Institute of Theoretical Physics.



Mission and research profiles

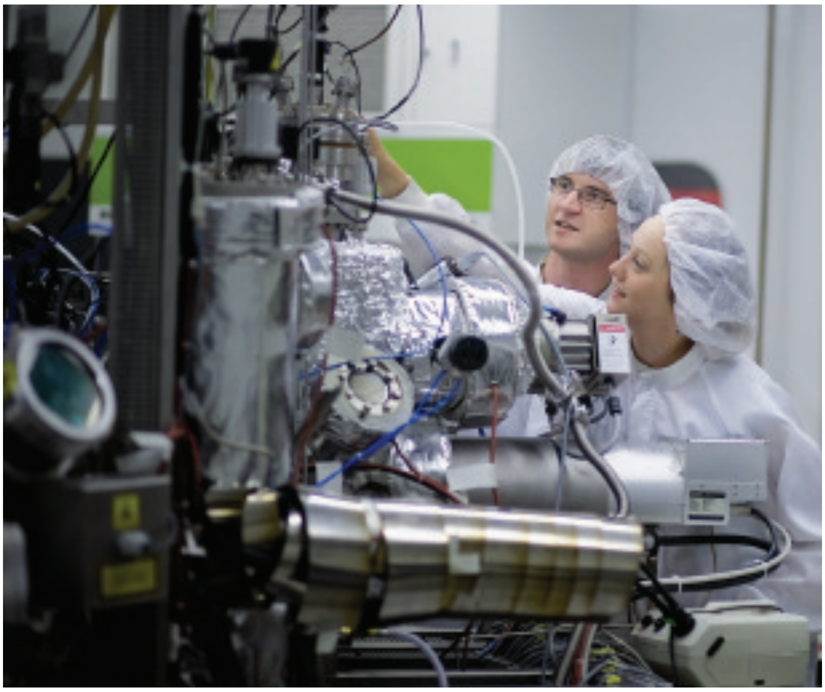
Within the Center of Collective Quantum Phenomena (CQ)

Modern physics and nanotechnology has learnt how to control matter down to the level of individual atoms, where quantum phenomena leads to a plethora of new effects. Building up new states of matter from such quantum states and realising novel computing elements or sensors is a dominating target for both atom and solid state physics. The research of several groups in the Physics Institute is devoted to this subject.

The groups of Reinhold Kleiner and Dieter Kölle (solid state physics) focus on superconductive and magnetic materials and devices, which are typically investigated at low temperature – down to a few millikelvin. The main targets are the Josephson effects, quantum interferometry, the manipulation of magnetic flux quanta and magnetic tunnel structures. A large research effort is the development of hybrid quantum systems that, within solid state physics, combine superconductors and ferromagnets. In collaboration with the quantum optics group of Jozsef Fortagh, they run experiments aimed at hybrids consisting of superconducting structures and cold atoms. This activity forms the basis of an advanced grant from the European Research Council and is also anchored within the trans-regional Research Center 21 of the Deutsche Forschungsgemeinschaft.

Experimental techniques of the solid state physics group include low temperature electric transport and noise measurements, deposition, characterisation and nanopatterning of thin films; and direct imaging of (super) current flow or electric field distribution using a low temperature scanning laser or electron beam microscopy. The latter technique is unique worldwide.

The cold atom part of the CQ is represented by three research groups. The experimental group of Claus Zimmermann concentrates on quantum optics, laser physics and ultra-cold quantum gases. The group's key areas of expertise are degenerate Bose and Fermi gases,



ultra-cold molecules, atoms in cavities, atom interferometry and the quantum optics of surfaces.

The experimental group of József Fortágh studies the interactions between atoms and nanoscale objects. Cold atoms at the surface of superconductors and carbon nanotubes form novel hybrid quantum systems and establish an interface between solid state and cold atom physics.

The theory group of Thomas Judd simulates hybrid quantum systems and nanotechnology with high performance computers. The group specialises in the interactions of ultra-cold atoms with solid state structures and the description of quantum nanosystems under realistic, finite-temperature conditions. The work is tailored to support the experimental groups.

Within the Kepler Center for Astro and Particle Physics

The building blocks of matter and their fundamental interactions are the basic ingredients for understanding the world at its smallest scales – on femto- and attometre – and at its largest – the Universe. The research activities are embedded in the European and German funding for basic research (EU, DFG, BMBF).

The experimental group of Heinz Clement concentrates on the properties of strong interaction, ie. the force that holds atomic nuclei together. The studies on the femtometre scale are carried out with international collaborations on dedicated microscopes in the form of particle accelerators, like COSY at the Research Center Jülich.

The experimental group of Josef Jochum, Peter Grabmayr and Tobias Lachenmaier is studying rare processes to look for physics beyond the present standard model of particle physics. Together with other groups worldwide, large detector systems are set up in the Gran Sasso National Laboratory in Italy to study the so far unknown nature of dark matter in the Universe and the mass scale of neutrinos. Neutrino properties are investigated in detail close to a nuclear power plant in France, which is a strong neutrino source. Control on background signals from radioactivity is required at the very highest level in these experiments, which try to answer key questions in our understanding of the elementary structure of matter and of the structure of the Universe.

The GERDA team inside the completed water tank for the muon veto at the underground lab Gran Sasso (with a light detector in front)

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