Goal: developing the best atomic clock in the world

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They are masters at working with light: the scientists at the newly founded QUEST Institute at the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig. And they want to work on some of the most exciting questions relating to physics today: on unimaginably precise methods of measurement for observing the Earth, on the pressing question of the fundamentals of physics, of whether the fundamental constants are really constant, and on the development of the best atomic clock in the world made of a single aluminium atom.

These are just some examples from the catalogue of tasks which the scientists have drawn up for themselves. This gives us an idea of why optics is often described as "the" key technology of the 21st century.

QUEST stands for "Quantum Engineering and Space-Time Research" and it is the name of a whole Excellence Cluster to which the new institute belongs. It is already a prime example of good cooperation between completely different but perfectly complementary partners: Next to PTB as the state research institute of the Federal Ministry of Economics (BMWi) with its special knowledge in the field of metrology, i.e. precise measurement technologies, there are six institutes from the Leibniz University of Hannover, the Laser Zentrum Hannover, the German-British Gravitational Wave Detector GEO600 in Ruthe, the Center of Applied Space Technology and Microgravity (ZARM) in Bremen and the Albert Einstein Institute (Max Planck Institute for Gravitational Physics). Now strengthened once more by the new QUEST Institute at PTB, the joint research is not only to answer the deep fundamental issues of physics, but also to lead to new high tech products with industry. In its start-up phase the institute is being financed by the German Research Foundation (DFG). After this period of funding, the professorship will be permanently continued by PTB and German Federal Ministry of Economics and Technology (BMWI).

A long, intensive search - this is the meaning of the word "quest". A good secondary meaning for the acronym, which primarily came about as the abbreviation of fields of research which previously existed more in parallel. "Quantum Engineering", the first part of the name stands for a relatively new branch of research, which deals with the control of quantum physics at the engineering level. "Space-Time Research", the second part, is research dealing with all aspects of space and time, for example the development of ever more exact atomic clocks or new processes to explore space, for instance precise measurement procedures in geodesy. Because in atomic clocks as well as in novel quantum sensors the main focus is on nothing more than using quantum phenomena with the aid of state-of-the-art technologies, founding the Excellence Cluster QUEST in November 2007 was a success right from the start. For this made it possible to gather the competence of the specialised scientists and institutions in a completely new way and much more intensively.

This success story is now opening another chapter: at PTB, in the immediate vicinity of the unique measuring equipment and some of the best atomic clocks in the world, a new research group has started working: the QUEST Institute at PTB consists of a Professorship ("Experimental Quantum Metrology"), a Junior Research Group ("Cold Ion Quantum Sensors"), a Research Project ("Sub-hertz Lasers and novel optic resonators") as well as several so-called "Task Groups".

Prof. Dr. Piet O. Schmidt, Head of the Institute, specialises in new methods of spectroscopy. "We use, for example, the exactly identical frequency distances of the spectral lines in an optical frequency comb in order to investigate atomic or molecular systems", explains Schmidt. "What is also very interesting are the methods of quantum logic originally developed for future quantum computers with stored ions, but which can also be used for investigating special classes of atoms or molecules which were not spectroscopically accessible or could only be accessed with difficulty previously." He also wants to use the quantum logic spectroscopy to develop an optical atomic clock on the basis of an extremely narrow transition in a single aluminium ion. "There is a chance that it might become the best atomic clock in the world", says Schmidt.

The clock that Schmidt has in mind is to attain a relative uncertainly of 10-18 (to date the limit at PTB lies at 10-15, held by the so-called caesium fountain clocks). The researchers will, thus, be able to pursue more intensively the question of whether the fine-structure constant, the gravitational constant or the mass ratio between the electron and the proton, change in space or time, as predicted by some modern theories in physics such as the String Theory. But concrete measurement capabilities will also be connected to this. "The availability of such sensitive clocks will lead to other highly sensitive measuring instruments, which will be able to determine, for example, a change in the gravitational potential of the Earth with an accuracy corresponding to a height difference of one centimetre", explains Schmidt. "Currently the geoid of the Earth is known with an uncertainty of 30 cm to 50 cm." With QUEST, interdisciplinary cooperations between engineers who deal with the development of navigation systems, geodesists as well as researchers in the field of laser cooled atoms, are to be stimulated. This is to lead to the development of novel sensors for geoscience and navigation.

And probably the most important characteristic of QUEST lies right here: the intensive cooperation of thematically related but to date organisationally separate research groups: that is between university research, several federal research institutions and an international project on basic research. Not least, the novel quantum engineering technologies will probably also lead to forward-looking cooperations with industrial partners and, thus, to new commercial applications.

Source: Physikalisch-Technische Bundesanstalt