# Press release

## Examining Einstein – precise experiments using lasers in space

**Tests carried out in zero-gravity on board the FOKUS research rocket. Successful demonstration of technology for the QUANTUS mission.**

Berlin, April 23, 2015

Albert Einstein tells us that clocks run slower the deeper they are in the gravitational potential well of a mass – the closer they are to a heavenly body, for example. This effect is described by General Relativity Theory as the gravitational red shift – it is detectable in spectral lines that shift toward the red end of the spectrum. General Relativity Theory also predicts that the rates of all clocks are equally influenced by gravitation independent of how these clocks are physically or technically constructed. However, more recent theories of gravitation allow for the possibility that the type of clock indeed influences the degree of gravitational red shift.

To test this theory-about-a-theory, project FOKUS funded by the German Aerospace Centre (DLR) today launched a high-altitude research rocket to send various types of clocks into space and back again. This is where the most suitable experimental conditions are found because of the large gradient in the gravitational potential (gravity varies there a lot). This permits testing whether there really are differences in how clocks run – and in the end, also whether one of the newer theories of gravity provides a more exact description than Einstein did. The first experiments in space have now been successfully carried out. A team of scientists launched an extremely stable quartz oscillator into space that ticks like a modern wristwatch – but at a very high frequency – together with a complete laser system for purposes of comparison. The centerpiece of the laser system is a micro-integrated semiconductor module that was developed and tested by the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin. The integration of entire laser system took place at Humboldt-Universität zu Berlin (HU Berlin). The frequency of the semiconductor laser was stabilized by locking it to a specific electron transition of a rubidium atom in an advanced module developed by Universität Hamburg. These rubidium atoms in conjunction with the lasers provide an “optical atomic clock” that works according to a different physical principle that the quartz clock and "ticks" about ten million times faster than the quartz unit. To compare how the two clocks run, the company leading the project, Menlo Systems, is employing an optical frequency comb they developed.

The scientists demonstrated with the tests for the first time that these types of “optical atomic clocks” and the laser systems required for them can be employed in space for testing gravitational red shift and other precision measurements. The demanding demonstration of the technology also allowed them to lay the technical foundations for examining Einstein’s equivalence principle using potassium and rubidium atomic interferometers under the MAIUS project. MAIUS is part of the QUANTUS mission funded by DLR in which new technologies involving quantum physics will be developed for cooling, entangling, and manipulating atoms. It should also advance miniaturizing the laser modules and testing a fully automated quantum sensor in space. The long-term objective in this case is to examine Einstein’s equivalence principle by which the acceleration of a body by a gravitational field is independent of the nature of the body – i. e. all objects subjected to the same gravity “fall at the same speed”.

### Compact and extremely robust diode laser modules for space from FBH

Countless drop-tower experiments at the Center of Applied Space Technology and Microgravity (ZARM), University of Bremen were used to prepare for the sophistiacted experiment in space. The laser module was built at the Ferdinand-Braun-Institut through the Joint Lab Laser Metrology together with the Optical Metrology research group at HU Berlin. The Joint Lab has been investigating and developing ultra-precise and extremely compact semiconductor laser modules for use in space for some time. Their centerpiece is a DFB (distributed feedback) laser that emits light in an extremely narrow wavelength or frequency region. This narrow spectral band characteristic is one of the main requirements for the laser module needed for spectroscopy of the rubidium atoms and the associated precision measurements. With the help of a unique hybrid micro-integration technique, the diode laser chip is assembled together with electronic and optical components into an exceedingly compact, space-certified package. The palm-sized modules absolutely have to operate flawlessly under the extremely harsh conditions of space. They are subjected to heavy mechanical loading during liftoff when the acceleration rises to eight times' that of Earth's gravity. "Our integration techniques can even withstand up to 30-times' Earth's gravity," says Dr. Andreas Wicht, head of the Laser Metrology Group at FBH, who views his group as well-prepared for future challenges. "In addition, we are working on even narrower bandwidth lasers with a hybrid integrated optical amplifier that is highly suited to even more complex experiments." FBH is expanding its know-how in both the area of precision optical and spectroscopic measurements. These represent some of the most precise and exact measurement techniques of our time and will open up further applications.

The related press picture and further images are provided on our website: http://www.fbh-berlin.com/press/download-center. 

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**Background information – the FBH**

The Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH) researches electronic and optical components, modules and systems based on compound semiconductors. These devices are key enablers that address the needs of today's society in fields like communications, energy, health, and mobility. Specifically, FBH develops light sources from the visible to the ultra-violet spectral range: high-power diode lasers with excellent beam quality, UV light sources and hybrid laser systems. Applications range from medical technology, high-precision metrology, and sensors to optical communications in space. In the field of microwaves, FBH develops high-efficiency multi-functional power amplifiers, and millimeter wave frontends targeting energy-efficient mobile communications as well as car safety systems. In addition, compact atmospheric microwave plasma sources that operate with economic low-voltage drivers are fabricated for use in a variety of applications, such as the treatment of skin diseases.

The FBH has a strong international reputation and ensures rapid transfer of technology by working closely with partners in industry and research. The institute has a staff of 290 employees and a budget of 23 million Euros. It is part of the Forschungsverbund Berlin e.V., a member of the Leibniz Association and plays an active role in various networks.

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