Leibniz Ferdinand Braun Institut

Press Release

Einstein put to the test – two precision experiments in space with lasers from Berlin

Projects KALEXUS and FOKUS successfully carried out on board the sounding rocket TEXUS-53 in microgravity

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According to Albert Einstein's theory of relativity, all bodies in a vacuum regardless of their properties are accelerated by the Earth's gravity at the same rate. This principle of equivalence applies to stones, feathers and atoms alike. Under the conditions of microgravity very long and precise measurements can be carried out to determine whether different atoms of different mass actually "fall equally fast".

For the first precision measurements in space with cold atoms, potassium and rubidium are suitable candidates. In preparation for the measurements two experiments were conducted at the same time onboard a sounding rocket launched from Kiruna, Sweden, on January 23. Preliminary analysis of the data shows that the campaign was successful. The Humboldt Universität zu Berlin (HU) and the Ferdinand-Braun-Institut, Leibniz-Institut fuer Hoechstfrequenztechnik (FBH) test modern laser technologies within the framework of the projects KALEXUS and FOKUS. The demanding technology demonstrators lay the foundations for the precision tests of the equivalence principle with so-called potassium and rubidium atom interferometers as well as for further experiments aiming at tests of Einstein's theory of relativity. Researchers are hoping that eventually these experiments will provide the information needed to address one of the greatest challenges of modern physics: The unification of gravity with three other fundamental interactions into one comprehensive theory.

Laser experiments with potassium and rubidium atoms: KALEXUS and FOKUS

A stable laser system for the manipulation of potassium atoms was set up in the project KALEXUS under the guidance of the Optical Metrology group at HU. The centerpiece consists of two micro integrated semiconductor laser modules developed by FBH. In KALEXUS the wavelength of these laser modules is matched to an atomic transition of potassium. During the six-minute period of microgravity the experiment automatically stabilizes the wavelength of both lasers. In addition, the laser system can autonomously switch back and forth between the laser sources during flight. After all, such experiments are not easy to repeat, and scientists cannot take corrective action during the flight. Moreover, the measurements may not be compromised if one of the lasers should fail.

Another laser module designed by FBH and assembled by HU took part in the FOKUS campaign, which is managed by Menlo Systems. A laser was stabilized to an atomic transition of rubidium in order to demonstrate the technological maturity of corresponding technology for subsequent drop tests of atoms under microgravity conditions. The laser system also allows for clock comparisons. Here, the frequency of an "optical oscillator", the laser, is compared to the frequency of a quartz oscillator that "ticks" in the radio frequency range, like a modern wristwatch. The general theory of relativity presumes that the "ticking" of all clocks is affected by gravity in the same way, regardless of how these clocks are implemented physically and technically. An initial test in April 2015 confirmed the suitability of such "atomic clocks" and of the laser systems required to test the general theory of relativity in space. The goal is now to confirm the initial results after some technical improvements have been applied to the system.

Two applications of technology in direct comparison

The two experiments use different types of lasers from the FBH. This allows a comparison of the different laser technologies for the application scenario. The centerpiece of the FOKUS module is a DFB (Distributed Feedback) laser, which emits light in a narrow frequency or wavelength range at 780 nm. This spectrally narrow bandwidth is one of the key requirements for the laser module, which is used for the spectroscopy of rubidium atoms and thus for precision measurements.

KALEXUS uses an ECDL concept (Extended Cavity Diode Laser), which thanks to an external grating, provides an even narrower linewidth. The laser is optimized for spectroscopic measurements with potassium atoms and emits at a wavelength of 767 nm. However, the external grating makes it potentially more prone to malfunction - as opposed to the monolithic structure of the FOKUS laser. Ultimately, the palm-sized modules have to withstand the mechanical loads during rocket launch with accelerations of up to 15 times the acceleration of gravity and have to function trouble-free in space.

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About the Joint Lab Laser Metrology

Narrow-linewidth diode lasers, i.a., for precision optical spectroscopy in space, are developed by the joint lab. The Ferdinand-Braun-Institut and the Research Group on Optical Metrology of the Mathematics and Natural Sciences Faculty of the Humboldt-Universität zu Berlin work closely together here. This allows the common interests and complementary expertise of HU and FBH to be bundled optimally.