Zawartość zarchiwizowana w dniu 2024-06-18

High-Performance Mass Spectrometry Using a Quantum Sensor

Sprawozdania

Informacje na temat projektu

TRAPSENSOR

Identyfikator umowy o grant: 278648

Projekt został zamknięty

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Spain

Final Report Summary - TRAPSENSOR (High-Performance Mass Spectrometry Using a Quantum Sensor)

The project aimed at connecting two ions stored in different traps through the current they induce in a common electrode to improve sensitivity and accuracy in the field of precision Penning-trap mass spectrometry for applications to superheavy elements produced in fusion-evaporation reactions in minute yields, and/or to contribute in the determination of a new upper limit for the mass of the electron

(anti)neutrino. The project is attractive as it is based on an idea published in the nineties and not accomplished yet in any laboratory, i.e. nobody has demonstrated that an ion stored in one trap, which is cooled to temperatures in the order of miliKelvin allows monitoring the energy transferred by another ion stored in a different trap separated by a common electrode. The second ion is unknown and one has to probe its motional frequency by applying an external field in resonance with the ion`s motion, i.e. like a forced harmonic oscillator. When this is done in a Penning trap, one can obtain the mass very precisely from the sum of the squares of the ion’s eigenfrequencies. Energy transfer is done through the current induced in a common electrode which is modulated with the motional frequency of the ion but must be equal to a level below 1 ppm. The energy transferred is quantified by observing the fluorescence-photon distribution of the laser-cooled 40Ca+ ion, as we have observed recently in a Paul trap, when the ion gains energy from an external field. See “A Single-Ion Reservoir as High-Sensitive Sensor of Electric Signals” Scientific Reports 7, 8336 (2017)
https://www.nature.com/articles/s41598-017-08782-5.
The advantage of using the single laser-cooled ion as Quantum Sensor, is that one is sensitive to very small oscillation amplitudes and the system opposite to the other non-destructive method can be applied to any ion or charged particle, regardless of its mass, charge and polarity.

Within the project we have built the double micro-trap system, so that one of the traps will allow storing the Quantum Sensor (laser-cooled 40Ca+ ion). The construction is described in the paper “An optimized geometry for a micro Penning-trap mass spectrometer based on interconnected ions” in International Journal of Mass Spectrometry 420, 22-30 (2016)] (http://dx.doi.org/10.1016/j.ijms.2016.10.010). In order to put this system into operation we had to build the only Ion Traps laboratory in Spain, which has been nominated as “Singular Laboratory in Advanced Technologies” of the University of Granada (see http://trapsensor.ugr.es and the promotional video in Spanish
https://www.youtube.com/watch?v=fHXUR9yTvTs
that will be posted at http://livemetrics.ugr.es. We have proceeded gradually towards the final aim building up three experiments. The most remarkable setup is the Penning-traps beamline with a similar structure of those existing in accelerators, which allows producing any ion of interest but having as a measurement trap an open-ring Penning trap, to perform laser-cooling on a single 40Ca+ ion in 7 Tesla. This is to our knowledge the only open-ring Penning trap in the world. Our workhorse is to reach the Doppler limit in this field, which is the strongest magnetic field used in Penning-trap experiments devoted to Quantum Optics, and in parallel, investigate the ion-ion coupling in the double micro-trap system installed in a separate vacuum chamber. In all these developments, besides 9 publications (most of them technical), 2 of them in special volumes, and invited and contributed talks in conferences, workshops and seminars, there were four Bachelor these, six Master these and one PhD thesis, which I hope will be the seed, together with the singularity of the laboratory in Spain, to create a Spanish school of ion trappers, not only for nuclear physics experiments, but also towards applications in quantum technologies.

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