Symposium Tests of Fundamental Physics with AMO Systems (SYFP)

jointly organised by
the Quantum Optics and Photonics Division (Q),
the Atomic Physics Division (A),
the Molecular Physics Division (MO), and
the Mass Spectrometry Division (MS)

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The continued advance in control over atomic, molecular and optical systems has led to impressive progress in measurement precision. New techniques have been developed to master novel systems, such as highly charged ions, muonic atomic systems, and antimatter. Their investigation provides insights into our understanding of nature, such as dark matter candidates as well as symmetry violation mechanisms beyond the standard model.

Overview of Invited Talks and Sessions

(Lecture hall RW 1)

Invited Talks

SYFP 1.1	Fri	11:00–11:30	RW 1	**Searches for new bosons with isotope shift spectroscopy and the thorium nuclear transition** — •Elina Fuchs
SYFP 1.2	Fri	11:30–12:00	RW 1	**Precision spectroscopy of muonic atoms** — •Randolf Pohl
SYFP 1.3	Fri	12:00–12:30	RW 1	**Quantum-Controlled Molecules for Fundamental Physics and Quantum Science** — •Nicholas Hutzler
SYFP 1.4	Fri	12:30–13:00	RW 1	**Testing Baryon Asymmetry with Antiprotons** — •Stefan Ulmer

Sessions

SYFP 1.1–1.4	Fri	11:00–13:00	RW 1	**Tests of fundamental physics with AMO systems**

Related session in the Quantum Optics and Photonics Division

Q 82.1–82.8	Fri	14:30–16:30	P 11	**Matter Wave Interferometry, Metrology, and Fundamental Physics IV**

SYFP 1: Tests of fundamental physics with AMO systems

Time: Friday 11:00–13:00 Location: RW 1

Invited Talk SYFP 1.1 Fri 11:00 RW 1
Searches for new bosons with isotope shift spectroscopy and the thorium nuclear transition — •Elina Fuchs — Leibniz Universität Hannover, Institut für Theoretische Physik

The long-standing open questions about the non-gravitational interactions of dark matter and the origin of the observed matter-antimatter asymmetry require tests of the Standard Model and searches for new physics across different energy scales. High-precision frequency measurements in atoms, ions and the thorium nucleus have opened up a novel window to search for feebly interacting effects beyond the Standard Model, such as ultralight dark matter and mediators to a dark sector. I will present the implications of very precise isotope shift measurements in ytterbium and calcium on new, light dark bosons as well as on the nuclear structure. Furthermore, I will discuss the strongly enhanced sensitivity of the nuclear transition in thorium in particular to dark matter that couples to gluons, resulting in competitive constraints already with the present resolution of the nuclear transition.

Invited Talk SYFP 1.2 Fri 11:30 RW 1
Precision spectroscopy of muonic atoms — •Randolf Pohl for the QUARTET-Collaboration — JGU Mainz

In muonic atoms, a single muon replaces all of the atomic electrons, resulting in a 2-body system whose hydrogen-like theory is very well understood. The large muon mass of 200 times the electron mass results in a 200^3 = 10 million fold improved sensitivity of muonic-atom energy levels to nuclear structure.

Using laser spectroscopy, we have investigated the charge radii of Z=1 and 2 (H to 4He). Next we will determine the magnetic "Zemach" radius of the proton. Currently we're measuring muonic Li to Ne by means of X-ray spectroscopy with metallic magnetic calorimeters (MMCs), a novel x-ray detector technology with vastly improved energy resolution.

A novel target concept allows x-ray spectroscopy of radioactive atoms. I will report on some recent measurements with a Ge detector array.

Invited Talk SYFP 1.3 Fri 12:00 RW 1
Quantum-Controlled Molecules for Fundamental Physics and Quantum Science — •Nicholas Hutzler — California Institute of Technology, Pasadena CA USA

Quantum-controlled molecules have emerged as a promising platform for studies of fundamental physics, chemistry, and quantum science. The rich internal structure of molecules offers many opportunities compared to atoms, but navigating their complex structures remains a challenge; for this reason, most studies have so far used diatomic molecules. Our group uses polyatomic molecules, whose additional degrees of freedom can be engineered to simultaneously realize combinations of features not available in simpler species. In this talk I will discuss three relevant advances in this area. First, we have engineered transitions in polyatomic YbOH to search for fundamental symmetry violations with robustness against noise and errors. Second, we have synthesized, cooled, and performed high resolution spectroscopy on several radium-containing molecules which offer large enhancements of fundamental nuclear physics effects. Finally, we discuss a new approach to rapid, broadband, high resolution optical spectroscopy with radicals, which can be used to map out dozens of molecular bands in a few hours.

Invited Talk SYFP 1.4 Fri 12:30 RW 1
Testing Baryon Asymmetry with Antiprotons — •Stefan Ulmer — Heinrich-Heine-Universität Düsseldorf, Germany — RIKEN, Japan

The BASE collaboration at CERN operates ultra sensitive multi-Penning-trap systems to compare the fundamental properties of protons and antiprotons with highest possible precision. We have compared the proton-to-antiproton charge-to-mass ratio with a fractional resolution of 16 parts in a trillion, which is the current most precise test of matter antimatter symmetry with baryons. In addition, our proton/antiproton magnetic moment comparisons reached a fractional accuracy of 1.5 parts in a trillion, measurements that improved the previous results in that sector by more than a factor of 3000. We have recently demonstrated the first coherent spectroscopy with a single antiproton spin, which heralds up to 100-fold improved magnetic moment measurements. Our experiments are currently limited by noise induced by CERN's accelerators. Thus, we are currently developing the transportable antiproton trap BASE-STEP, as well as state of the art offline laboratories at Heinrich-Heine-University Düsseldorf. Our ultimate goal is to transport antiprotons to this new facility to further improve resolution in high precision antiproton studies.