A 17: Precision spectroscopy of atoms and ions I

Time: Tuesday 14:00–16:00 Location: V55.01

Invited Talk A 17.1 Tue 14:00 V55.01

Single-photon interference experiments with single ions — •Gabriel Hétet[1], Lukas Slodicka[1], Nadia Rock[1], Markus Hennrich[1], and Rainer Blatt[1,2] — [1]Institute for Experimental Physics, University of Innsbruck, A-6020 Innsbruck, Austria — [2]Institute for Quantum Optics and Quantum Information of the Austrian Academy of Sciences, A-6020 Innsbruck, Austria

We present experiments that study the interaction of single Barium ions with single photons and weak coherent fields in front of high-numerical aperture optical elements.

First, we show the experimental observation of the ion as the optical mirror of a Fabry-Perot cavity. This was achieved by tightly focussing a laser field onto the ion trapped in front of a far-distant dielectric mirror. We then demonstrate the very first steps towards entanglement of two far-distant ions using only single-photon detection events. Last, we will present our current efforts in the design of ion traps with even higher numerical aperture objectives and mirrors for efficient single photon collection and high entanglement rates.

A 17.2 Tue 14:30 V55.01

A Novel, Robust Quantum Detection Scheme for Ions — •Florian Gebert[1], Boerge Hemmerling[2], Yong Wan[1], and Piet O. Schmidt[1] — [1]QUEST Inst. for Exp. Quantum Metrology, PTB Braunschweig and Leibniz Univ. of Hannover — [2]Department of Physics, Harvard University, Cambridge, MA02138, USA

Protocols used in quantum information and precision spectroscopy rely on efficient detection of the internal quantum state of the system under investigation. The basic principle of state discrimination in ions relies on electron-shelving, where two different energy states (qubit) are distinguished by their state-dependent fluorescence via coupling to a third level. In its simplest form, the number of collected photons during a single detection cycle determines whether the ion is assigned to a so called bright (dark) state depending on this number being higher (lower) than a chosen threshold. Detection fidelities can be further improved if photon arrival times are taken into account. Despite their high fidelities this Bayesian inference or maximum likelihood detection methods are affected by fluctuations of the power of the detection laser. We demonstrate a novel detection technique which combines two detection outcome with an intermediate well-controlled state inversion [1]. Observation of anti-correlated detection events acts as a post-selective statistical filter, which effectively improves the detection fidelity. It is therefore extremely robust against fluctuations of detection parameters and particularly well-suited for systems in which only very few photons are detected and a method for efficient state inversion exists. [1] B. Hemmerling et al., arXiv:1109.4981v2

A 17.3 Tue 14:45 V55.01

Experimentelle Bestimmung des ersten Ionisationspotentials von Actinium — •Johannes Rossnagel[1], Sebastian Raeder[1,2], Amin Hakimi[1], Rafael Ferrer[3], Norbert Trautmann[4] und Klaus Wendt[1] — [1]Institut für Physik, Universität Mainz — [2]TRIUMF, Vancouver, Kanada — [3]Instituut voor Kern- en Stralingsfysica, K.U. Leuven, Belgien — [4]Institut für Kernchemie, Universität Mainz

Das erste Ionisationspotential (IP) von Actinium (^{227}Ac) konnte durch resonante Laserionisationsspektroskopie präzise bestimmt werden. Hierfür wurden in zweistufigen Anregungsschemata Rydbergzustände gerader Parität bevölkert und die Konvergenzen dreier unabhängiger Rydbergserien bestimmt, die gegen den Grundzustand sowie gegen den ersten und zweiten angeregten Zustand des einfach positiv geladenen Actinium-Ions konvergieren. Eine kombinierte Analyse dieser Serien mit zusätzlichen Korrekturen aufgrund interferierender Ionisationskanäle liefert einen Wert von V_{IP}(Ac) = 43394,45(20) cm^{-1} für das erste Ionisationspotential von Ac, entsprechend 5,380226(24) eV, in Übereinstimmung mit einer früheren, nicht reproduzierten Messung, wobei die Genauigkeit stark erhöht werden konnte.

A 17.4 Tue 15:00 V55.01

Resonanz-Ionisations-Spektroskopie an neutralem Aktinium — •Sebastian Raeder[1], Amin Hakimi[2], Thomas Fischbach[2], Jens Lassen[1], Johannes Rossnagel[2], Volker Sonnenschein[3], Andrea Teigelhöfer[1], Hideki Tomita[4], Norbert Trautmann[5] und Klaus Wendt[2] — [1]Trilis, Triumf, Vancouver, Canada — [2]Institut für Physik, Universität Mainz — [3]University of Jyväskylä — [4]University of Nagoya — [5]Institut für Kernchemie, Universität Mainz

Geplante laserspektroskopische Untersuchungen zur Isotopieverschiebung und Hyperfeinstrukturaufspaltung an der Isotopenkette des Aktiniums benötigen spektroskopische Informationen bzgl. einer effizienten resonanten Anregung und Ionisation von atomarem Aktinium. Als Vorbereitung wurde hierzu mittels Resonanzionisations-Spektroskopie das atomare Spektrum von Aktinium mit einem weit abstimmbaren gepulsten Ti:Saphir Lasersystem detailliert untersucht. Hierbei konnten zudem die verfügbaren Literaturangaben zu den atomaren Anregungslinien, die bisher auf einer einzigen Referenz beruhten, weitgehend bestätigt und vervollständigt werden. Die Identifikation bisher unbekannter hochliegender gebundener Zustände und autoionisierender Resonanzen ermöglichte die Etablierung eines effizienten resonanten Ionisationsschemas. Unter Verwendung eines über injection-locking schmalbandigen gepulsten Ti:Saphir Lasers wurden zudem erste spektroskopische Messungen zur Hyperfeinstruktur am neutralen Aktinium unternommen, wobei geeignete Übergänge für die vorgesehenen Untersuchungen an kurzlebigen Aktiniumisotopen identifiziert werden konnten.

A 17.5 Tue 15:15 V55.01

Multipass laser cavity for efficient transverse illumination of an elongated volume — •Jan Vogelsang and the CREMA collaboration — Max-Planck-Institute for Quantum Optics, Garching

The recent measurement of the Lamb shift (2S-2P energy difference) in muonic hydrogen has attracted a lot of interest. The laser spectroscopy measurement has utilized a novel multipass cavity design which we will present.

The muon beam is stopped in a 200mm long and 5mm high stop volume inside hydrogen gas. Since the muon beam can not pass any mirrors we had to illuminate the long stop volume from the transverse direction. The cavity is very robust against mechanical misalignment, so no active mirror stabilization is required. A similar cavity will be used in the upcoming laser spectroscopy experiment in muonic helium ions.

A 17.6 Tue 15:30 V55.01

Towards laser spectroscopy of trans-fermium elements — •Mustapha Laatiaoui[1,2], Hartmut Backe[3], Michael Block[2], Fritz-Peter Hessberger[2], Peter Kunz[4], Felix Lautenschläger[1], Werner Lauth[3], and Thomas Walther[1] — [1]Institut für Angewandte Physik, TU-Darmstadt, 64289 Darmstadt — [2]Helmholtzzentrum für Schwerionenforschung, 64291 Darmstadt — [3]Institut für Kernphysik, Universität Mainz, 55099 Mainz — [4]TRIUMF, Vancouver, Canada

The atomic structure of the heaviest elements allows to investigate relativistic effects and their description in modern theories. However, beyond the element fermium with a charge number Z=100, detailed atomic spectroscopy, even with the most sensitive laser methods, is hampered by their low production rates in nuclear fusion reactions. At present no experimental information on atomic levels is available for these elements. In our experiments [H. Backe et al., Eur. Phys. J. D **45** (2007) 99] behind the velocity filter SHIP at the GSI, we employ the radiation detected laser resonance ionization technique to search for the predicted $5f^{14}7s7p$ ^{1}P$_1$ level in ^{254}No (Z=102). In a first 54 h experiment, the evaporation temperature of nobelium was determined and the atomic level search was started. In this talk, a brief status report on these activities will be given.

A 17.7 Tue 15:45 V55.01

Minimizing Time Dilation in Ion Traps for an Optical Clock — •Karsten Pyka[1], Norbert Herschbach[1], Kristijan Kuhlmann[1], Jonas Keller[1], David-Marcel Meyer[1], and Tanja E. Mehlstäubler[1,2] — [1]Quest-Institute, Physikalisch-Technische Bundesanstalt, Braunschweig — [2]Department of Time & Frequency, Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

We present a new experimental setup to test scalable chip-based ion traps for the development of trap structures with reduced excess micromotion that allow precision spectroscopy on a large ensemble of ions.

Based on our finite-element calculations [1] a novel trap is built employing high-precision laser machining and surface coating processes at PTB.

In a prototype made of Rogers4350B^{TM} we have succesfully trapped linear chains and 3D-Coulomb crystals of $^{172}Yb^+$ ions. We emphasize on the precision measurement of excess micromotion of a single $^{172}Yb^+$ ion using photon-correlation spectroscopy. We are able to resolve a micromotion amplitude of ≈ 1.1 nm corresponding to a fractional frequency shift of the atomic transition of less than 10^{-19}.

With this resolution we were able to characterize our prototype trap to have an axial rf electric field gradient that allows the trapping of linear Coulomb crystals of twelve ions, that experience a fractional frequency shift due to time-dilation of less than 10^{-18}.

[1] Herschbach et al., Appl. Phys. B, (2011), DOI: 10.1007/s00340-011-4790-y