Q 67: Precision Spectrosocopy VII (nuclear systems) (joint session A/Q)

Time: Friday 10:30–12:30 Location: K 1.016

Q 67.1 Fri 10:30 K 1.016

A direct nuclear laser excitation scheme for ^{229m}Th — •Lars von der Wense[1], Benedict Seiferle[1], Simon Stellmer[2], Johannes Weitenberg[3], Georgy Kazakov[2], Adriana Pálffy[4], and Peter G. Thirolf[1] — [1]Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [2]Technische Universität Wien, 1040 Vienna, Austria — [3]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [4]Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany

Direct nuclear laser excitation has been a long-standing goal. By today there is only one nuclear excitation known which would allow for direct laser excitation due to its exceptionally low energy of only a few eV above the ground state. This is the metastable first excited state in ^{229}Th. While direct nuclear laser excitation of ^{229}Th ions in a Paul trap is still hindered by insufficient knowledge of the exact isomeric energy value, here a new laser excitation scheme for neutral ^{229}Th atoms on a surface will be presented [1]. This excitation scheme circumvents the requirement of an improved knowlede of the isomeric energy, thereby paving the way for nuclear laser spectroscopy of ^{229m}Th. It is making use of the recently detected internal conversion decay channel of the isomeric state [2] in combination with a short isomeric lifetime [3].

[1] L. v.d.Wense et al., PRL 119, 132503 (2017).
[2] L. v.d.Wense et al., Nature 533, 47-51 (2016).
[3] B. Seiferle et al., PRL 118, 042501 (2017).

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Q 67.2 Fri 10:45 K 1.016

Towards a precise energy determination of the ^{229}Th nuclear clock transition — •Benedict Seiferle, Lars v.d. Wense, and Peter G. Thirolf — LMU München, Am Coulombwall 1, 85748 Garching

The first isomeric excited nuclear state of ^{229}Th (denoted with ^{229m}Th) exhibits the lowest transition energy in nuclear physics which has been measured indirectly to be 7.8(5) eV. The uniquely low transition energy which corresponds to a wavelength of approximately 160 nm makes it possible to drive the transition with lasers. This in turn may pave the way for a long list of interesting applications (such as a nuclear optical clock) which has so far been hindered by the rather large uncertainty in the reported energy value. In this talk an experimental scheme is presented that uses internal conversion electrons which are emitted in the ground-state decay of ^{229m}Th [1,2] and first results are shown. With these measurements a precise and direct determination of the excitation energy is in reach.

[1] L. v.d. Wense et al., Nature 533, 47-51 (2016).
[2] B. Seiferle et al., PRL 118, 042501 (2017).

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Q 67.3 Fri 11:00 K 1.016

Laser spectroscopic characterization of the nuclear clock isomer ^{229m}Th — •Johannes Thielking[1], Maksim V. Okhapkin[1], Przemysław Głowacki[1], David-Marcel Meier[1], Lars von der Wense[2], Benedict Seiferle[2], Christoph E. Düllmann[3,4,5], Peter G. Thirolf[2], and Ekkehard Peik[1] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig, Germany — [2]Ludwig-Maximilians-Universität München, 85748 Garching, Germany — [3]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany — [4]Helmholtz-Institut Mainz, 55099 Mainz, Germany — [5]Johannes Gutenberg-Universität, 55099 Mainz, Germany

The thorium-229 nucleus possesses a unique first excited state at an energy of only about 7.8 eV, coupled to the ground state by a transition with a natural linewidth in the mHz range. This transition can be used as a reference for an optical clock that is highly immune to field-induced frequency shifts and as a sensitive probe of temporal variations of fundamental constants. Despite many experimental efforts, fundamental properties of the isomer were still unknown. In this presentation we report on the first measurement of the nuclear moments and the mean square charge radius of the isomer [1]. This was achieved via high-resolution spectroscopy of the hyperfine structure of trapped ^{229}Th^{2+} ions using two-step laser excitation. Our results yield a key feature in the ongoing experimental search for the direct optical excitation of the nuclear transition, as well as the future nuclear clock operation.

[1] J. Thielking et al., arXiv preprint arXiv:1709.05325 (2017).

Q 67.4 Fri 11:15 K 1.016

Hyperfine structure and isomeric shifts in ^{229}Th^{2+} — •Robert A. Müller[1,2], Andrey V. Volotka[3], Stephan Fritzsche[2,4], and Andrey Surzhykov[1,2] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Technische Universität Braunschweig, Germany — [3]Helmholtz-Institute Jena, Germany — [4]Friedrich-Schiller-Universität Jena, Germany

In the past decade systems that are sensitive to possible time variations of α attracted much interest [1]. Besides the comparison of two atomic clocks, nuclear transitions could be used for the search of such variations. The isotope ^{229}Th is a particularly suitable candidate, because of its low lying isomeric state ^{229m}Th which is accessible to optical lasers. The sensitivity of the ^{229}Th$\rightarrow^{229m}$Th transition to variations of α has been only estimated so far [2]. For a more accurate determination of this sensitivity and for the analysis of related experiments precise knowledge about the nuclear moments, as well as the isomeric shift of electronic levels is needed. In this contribution we will, therefore, discuss highly accurate calculations for the hyperfine structure of the ^{229}Th^{2+} ion. We used these results to precisely determine the nuclear moments of the nuclear isomer ^{229m}Th. Moreover we calculated the isomeric shift of electronic levels in Th^{2+}. All calculations have been performed using the multi-configurational Dirac-Fock method as well as a combination of configuration interaction and many-body perturbation theory.

[1] J. K. Webb *et al.*, Phys. Rev. Lett. **87**, 091301 (2001)
[2] V. V. Flambaum, Phys. Rev. Lett. **97**, 092502 (2006)

Q 67.5 Fri 11:30 K 1.016

Towards coherent control of the ^{229}Th isomeric transition in VUV-transparent crystals — •Brenden Nickerson and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Current efforts in the development of a nuclear frequency standard based on the isomeric state of ^{229m}Th at approx. 7.8 eV have been centered around precisely determining its energy. The unique lowest transition in the ^{229}Th nucleus with frequency in the vacuum ultraviolet (VUV) range and very narrow linewidth promises enhanced precision and amazing stability [1]. A very exact measurement of the isomeric transition energy has been elusive, with the first confirmation of the level decay coming only recently [2].

Here, we investigate collective effects that may allow for coherent control of the isomeric transition in ^{229}Th:CaF_2 VUV-transparent crystals. The collectively enhancement scattering in forward direction is considered [3]. Starting from this setup, we investigate the effect of pulsed lasers, coincident pulses, different pulse phases and of magnetic fields for the intensity spectrum. By taking advantage of such effects we aim to design a more sensitive nuclear excitation scheme to resolve not only the transition energy but provide a clear signature of the excitation.

[1] W. G. Rellergert *et al.*, Phys. Rev. Lett. 104, 200802 (2010).
[2] L. von der Wense *et al.*, Nature 533, 47-51 (2016).
[3] W.-T. Liao *et al.*, Phys. Rev. Lett. 109, 262502 (2012).

Q 67.6 Fri 11:45 K 1.016

Laser spectroscopy of the heaviest actinides — •S. Raeder[1,2], D. Ackermann[2,3], H. Backe[4], M. Block[1,2,4], B. Cheal[6], P. Chhetri[2,5], C. E. Düllmann[1,2,4], M. Eibach[2,7], J. Even[8], R. Ferrer[9], F. Giacoppo[1,2], S. Götz[1,2,4], F.P. Hessberger[2,5], O. Kaleja[2,4,10], J. Khuyagbaatar[1,2], P. Kunz[11], M. Laatiaoui[9], F. Lautenschläger[2,5], W. Lauth[4], L. Lens[2,4], N. Lecesne[3], A. K. Mistry[1,2], E. Minaya Ramirez[12], Th. Walther[5], A. Yakushev[1,2], and Z. Zhang[13] — [1]Helmholtz-Institut Mainz — [2]GSI — [3]GANIL — [4]JGU Mainz — [5]TU Darmstadt — [6]Uni of Liverpool — [7]Universität Greifswald — [8]KVI-CART, Uni of Groningen — [9]KU-Leuven — [10]MPIK — [11]TRIUMF — [12]IPNO — [13]IMP Lanzhou

Laser spectroscopy of transfermium elements with $Z>100$ probes the influence of electron correlation, relativistic and QED effects on the atomic shell structure. These studies are hampered by low production rates and the fact that atomic information is initially available only from theoretical predictions. Applying the sensitive Radiation Detected Resonance Ionization Spectroscopy technique at the SHIP velocity filter in GSI, optical transitions in the element nobelium (Z=102) were detected for the first time. Besides the characterization of a strong optical ground-state transition in the isotopes ^{252,253,254}No, Rydberg states were measured enabling the extraction of the first ionization potential of nobelium with a high precision. These results will be discussed as well as the prospects for future investigations involving the study of additional nobelium isotopes and the exploration of the atomic structure of the next heavier element, lawrencium (Z=103).

Q 67.7 Fri 12:00 K 1.016

Development of an Ion Mobility Spectrometer for Mobility Measurement of Actinides — •E. Rickert[1,3], H. Backe[3], M. Block[1,2,3], Ch. E. Düllmann[1,2,3], T. Kron[1,2], M. Laatiaoui[1,2,4], W. Lauth[3], S. Lohse[1], F. Schneider[1,3], and S. Raeder[1,2] — [1]Helmholtz-Institut Mainz — [2]GSI — [3]JGU Mainz — [4]KU Leuven

Ion mobility measurements are a powerful tool to investigate ion-atom interaction potentials. Their sensitivity to the electronic configuration has been demonstrated for many elements across the periodic table. Especially for heavy elements, the impact of relativistic effects on the electron configuration may lead to deviations in the periodicity, hence to distinct ion mobilities [Laatiaoui2012] as recently proven in the lanthanide region. A conceptual design for an ion mobility spectrometer is being developed to enable systematic ion mobility spectrometry also across the actinide series. Actinide ions will be created via a two-step photoionization in argon gas. This will allow an element-selective detection. In the talk, the current status and future plans are presented.

[Laatiaoui2012]:Laatiaoui, M. et al., EPJD (2012) 66:232

Q 67.8 Fri 12:15 K 1.016

Desorption enthalpy studies of the heaviest actinides for laser spectroscopic investigations — •T. Murböck[1], D. Ackermann[1,2], H. Backe[3], M. Block[1,3,4], B. Cheal[5], P. Chhetri[1,6], Ch. E. Düllmann[1,3,4], M. Eibach[1,7], J. Even[8], R. Ferrer[9], F. Giacoppo[1,4], S. Götz[1,3,4], F.P. Hessberger[1,4], O. Kaleja[1,3,10], J. Khuyagbaatar[1,4], P. Kunz[11], M. Laatiaoui[1,4], F. Lautenschläger[1,6], W. Lauth[3], L. Lens[1,3], N. Lecesne[2], A. K. Mistry[1,4], E. Minaya Ramirez[12], S. Raeder[4], P. Van Duppen[9], Th. Walther[6], A. Yakushev[1,4], and Z. Zhang[13] — [1]GSI — [2]GANIL — [3]Universität Mainz — [4]HI Mainz — [5]University of Liverpool — [6]TU Darmstadt — [7]Universität Greifswald — [8]KVI-CART, University of Groningen — [9]KU-Leuven — [10]MPIK — [11]TRIUMF — [12]IPN Orsay — [13]IMP Lanzhou

To probe the atomic shell structure of the heaviest actinides with Z>100, the Radiation Detected Resonance Ionization Spectroscopy (RADRIS) technique is applied at SHIP at GSI. After production in high-energy fusion-evaporation reactions the recoil ions are stopped in a buffer-gas cell and collected onto a filament. Subsequent thermal evaporation as neutral atoms allows to probe the atomic structure using laser spectroscopy. The desorption enthalphy of these elements crucially determines the efficiency of the evaporation and the RADRIS method. In this talk, evaporation of nobelium (Z=102) and lawrencium (Z=103) from tantalum is revisited. Prospects for desorption studies from a larger variety of surfaces to extend laser-spectroscopic investigations to heavier elements will be discussed.