Resonance ionization spectroscopy of thorium isotopes—towards a laser spectroscopic identification of the low-lying 7.6 eV isomer of $^{229}$Th

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Abstract

In-source resonance ionization spectroscopy was used to identify an efficient and selective three-step excitation/ionization scheme of thorium, suitable for titanium:sapphire (Ti:sa) lasers. The measurements were carried out in the preparation of laser spectroscopic investigations for an identification of the low-lying $^{229}$m$^{+}$Th isomer predicted at 7.6 ± 0.5 eV above the nuclear ground state. Using a sample of $^{232}$Th, a multitude of optical transitions leading to over 20 previously unknown intermediate states of even parity as well as numerous high-lying odd parity auto-ionizing (AI) states were identified. Level energies were determined with an accuracy of 0.06 cm$^{-1}$ for intermediate and 0.15 cm$^{-1}$ for AI states. Using different excitation pathways, an assignment of total angular momenta for several energy levels was possible. One particularly efficient ionization scheme of thorium, exhibiting saturation in all three optical transitions, was studied in detail. For all three levels in this scheme, the isotope shifts of the isotopes $^{228}$Th, $^{229}$Th and $^{230}$Th relative to $^{232}$Th were measured. An overall efficiency including ionization, transport and detection of 0.6% was determined, which was predominantly limited by the transmission of the mass spectrometer ion optics.

(Some figures in this article are in colour only in the electronic version)

1. Introduction

High-resolution $\gamma$-spectroscopic experiments predict the existence of an isomeric state of $^{229}$Th, $^{229\text{m}}$Th, $I = \frac{7}{2}^+$, with an excitation energy of only 7.6 ± 0.5 eV [1] above the ground state $^{229}$Th, $I = \frac{5}{2}^+$. This is the lowest excitation energy of an excited state in any nucleus known so far, lying in the range of typical atomic excitation and ionization energies. The $\gamma$-spectroscopic measurements used a differencing technique of $\gamma$-ray decay paths to infer the excitation energy from the observed spectra. Direct observation of the decay of the isomer via an M1 transition to the nuclear ground state was not successful. The reason for this was in part attributed to earlier expectations, which pointed towards a lower excitation energy of about 3.5 eV [2]. This resulted in several searches for UV emission from $^{229\text{m}}$Th in an incorrect wavelength regime [3–5]. In addition, non-radiative decay paths, such as internal conversion and electron scattering [6, 7], as well as absorption of the 160 nm VUV decay photons in most media might obscure the results and would require a dedicated experimental setup. The half-life of $^{229\text{m}}$Th is theoretically estimated to be about 1–5 h by extrapolation from a comparable transition of the $^{233}$U isomer [1] connecting the same Nilsson states but with an energy difference of 312 keV,
as well as from calculations based on another M1 transition in the $^{229}$Th nucleus [8]. Nevertheless, large deviations from this estimate could be possible depending on the exact electronic configuration [6]. Earlier calculations, based on the lower excitation energy of 3.5 eV, neglected the possibility of internal conversion that becomes possible when accepting the energy of 7.6 eV, which is higher than the ionization potential of 6.32 eV for thorium. A recent experiment [9] hints at a half-life of less than 2 h, probably affected by the chemical conditions of the sample.

Aside from the basic nuclear physics interest, the low-lying isomer would provide a unique opportunity for fundamental research on laser-optical atom-to-nucleus coupling. For example, its use as a nuclear time standard of ultimate precision was proposed [10]. With respect to state-of-the-art atomic clocks, a nuclear clock could exhibit significant advantages, e.g., the nucleus is shielded from its environment by the surrounding electron shell, preventing or at least tremendously reducing line-shifts induced by external fields. The currently estimated half-life of the isomeric state would result in a linewidth of less than 1 mHz, leading to a theoretical precision of $\Delta \lambda/\lambda \approx 10^{-19}$, outbalancing current high-precision clocks by about two orders of magnitude. In addition, the strong dependence of the transition on the balance of individual fundamental forces within the nucleus could yield an amplification of several orders of magnitude of any frequency shift effect, e.g., induced by a potential variation of the electromagnetic coupling constant with time [11], or of the constituent quark masses [12]. In this manner, long-term comparisons of a hypothetical $^{229}$Th clock to a conventional atomic clock could stimulate the ongoing research on the cosmological evolution of the fundamental force coupling constants. Regarding the field of quantum optics and quantum computing, a nuclear isomeric state that could be directly interrogated by laser light could also serve as a dedicated qubit with extraordinary features. Finally, the isotope $^{229}$Th is most likely a suitable candidate for NEET (nuclear excitation by electron transition), a process which could help in pumping the isomeric state from the ground state [13].

In order to ascertain the existence of the predicted low-lying isomeric state of the nucleus $^{229}$Th, an alternative approach to gamma spectroscopy or other means of direct observation of the decay is needed. This could involve the identification of the isomer through a measurement of its specific hyperfine structure within a selected optical resonance in the atomic spectrum in comparison with the well-known structure related to the influence of the nuclear ground state coupling to the electron shell. In this work, we describe laser spectroscopic experiments which serve as important preparation of such experimental activities.

One method to produce the radioisotope $^{229}$Th is via the alpha decay of the parent nucleus $^{233}$U, whereby a small branching ratio of about 2% of the decay populates the low-lying isomeric level [9]. In the last few years, effort at the Jyväskylä IGISOL isotope separator facility, Finland, has been concentrated on the development of a novel ion guide system optimized for the extraction of daughter recoil nuclei originating from the $\alpha$-decay of, e.g., a $^{233}$U source [14]. The source, electroplated onto stainless steel strips, is mounted on the inside surface of a helium-filled gas cell. Gas flow and an electrical guiding field efficiently extract the decay recoils as positively charged ions, primarily in a singly or doubly charged state. After a number of gas cell improvements, the extraction efficiency for decay products of $^{233}$U, namely $^{221}$Fr ($T_{1/2} = 4.9$ min) and $^{217}$At ($T_{1/2} = 32$ ms), has been increased to about 16%. On the other hand, the extraction efficiency for $^{229}$Th does not exceed 1.6% [15], a factor of 10 lower. This difference is ascribed to a considerable fraction of thorium persisting in or converting into the neutral state. With a generation rate of $\approx 10^5$ recoils of $^{229}$Th per second in the present setup, a $^{229}$Th beam production with an intensity of approximately 30 ions s$^{-1}$ is expected. For both the nuclear ground state and the isomeric atoms, the optical excitation probability of each atomic transition is distributed over several hyperfine components differing in their total angular momentum. This fact significantly reduces optical line strength on a given wavelength of resonance. Combined with a limited fluorescence detection efficiency of typically only about 0.02% and considerable background in a laser spectroscopy arrangement providing high resolution such as, e.g., collinear fast beam laser spectroscopy [16], successful unfolding of the isomeric hyperfine structure from that of the ground state is highly unlikely. However, considering a reasonably large fraction of neutral thorium recoils, the opportunity for increasing the extraction efficiency through the use of laser ionization via in-source resonance ionization on the neutral species, becomes highly favourable.

Laser ion sources give access to efficient and selective ionization [17] at on-line facilities such as ISOLDE at CERN, Geneva, Switzerland; ISAC at TRIUMF, Vancouver, Canada or others [18]. Today, state-of-the-art solid state laser systems are increasingly used for efficient multi-step resonant excitation and ionization of the atoms of a specific element. This technique of resonance ionization spectroscopy (RIS) is also under development for application at the IGISOL system in Jyväskylä using Titanium-sapphire (Ti:s) lasers. There it will be adapted for use in combination with the aforementioned gas cell and an ion guide technique with a special focus on the production of $^{229}$Th ions. As a first step for the preparation of a highly sensitive laser-based detection technique of the isomer $^{228m}$Th, Ti:s laser RIS on thorium has been carried out in the LARISSA laboratory at Mainz University, Germany, in order to identify suitable resonant laser excitation and ionization schemes.

A number of laser spectroscopic investigations on thorium have been performed earlier, e.g., for analytics or for addressing the study of isotope shifts and the hyperfine structure of $^{229}$Th in order to determine nuclear charge radii and nuclear moments [19]. Previous RIS investigations on thorium applied pulsed as well as continuous-wave dye lasers within a simple two-step excitation/ionization scheme. The pulsed laser RIS localized low-lying excited levels of odd parity around 26 000 cm$^{-1}$ as well as numerous even parity auto-ionizing (AI) levels just above the ionization potential at 50 867 cm$^{-1}$ [20]. Due to the use of high laser power considerable background was generated, which
Figure 1. Schematic experimental setup: laser system consisting of three Ti:sapphire lasers and a Nd:YAG pump laser, mass spectrometer with graphite oven, quadrupole mass filter and ion detector. The components are controlled by the data acquisition system.

hampered the foreseen development of a high-precision, high-accuracy determination technique for thorium isotope ratios in geological samples [21]. Correspondingly, the technique of continuous-wave laser RIS was also established by one of the groups using non-resonant ionization by a high-power argon ion laser. An impressive overall efficiency of this technique of up to 0.4% has been demonstrated [20]. In this work, an excitation/ionization scheme involving three resonant steps is favoured, which promises comparable or even higher efficiency in combination with high suppression of background from uranium, which could be generated either by non-resonant ionization or by fragmentation of uranium oxide induced by any blue to UV laser radiation.

2. Experimental setup

The laser system used for the measurements presented in this work is composed of a set of three tunable nanosecond Ti:sapphire lasers jointly pumped by a commercial frequency doubled Nd:YAG laser (Photonics Industries DM 532-80) with a repetition rate of typically 10 kHz. Output power reaching up to 3 W is obtained with a pump laser power of about 16 W per Ti:sapphire laser. Frequency selection is achieved by a combination of birefringent filter and etalon within the laser resonator [22], which results in a spectral bandwidth of 5 GHz. However, such a laser construction provides only limited wavelength tunability. Therefore, one of the lasers is equipped with a grating mounted on Littrow configuration for frequency selection [23]. This laser exhibits a continuous frequency tuning range from 710 nm up to 950 nm, which is ideally suited for the long-range search of unknown atomic transitions. Single-pass second harmonic generation of the fundamental Ti:sapphire laser radiation in an optical nonlinear crystal ($\beta$-BaB$_2$O$_4$) is employed to obtain up to 500 mW output power in the blue to UV spectral range. The typical pulse length is approximately 40 ns. Pulses of individual lasers are temporally synchronized within 5 ns using fast Pockels cell switching. The time structure and the wavelength of each laser are monitored by fast photodiodes and commercial wavemeters (High Finesse WS6, ATOS LM007), respectively. The laser beams are finally overlapped and focussed, resulting in a beam waist radius of about 0.1 mm within the centre of the graphite oven (inner diameter of 2.2 mm and length of 50 mm) of the MABU (Mainz Atomic Beam Unit) spectroscopic setup. A schematic sketch of the latter is given in figure 1.

Samples for spectroscopic investigations contained about $10^{15}$ atoms of $^{232}$Th in nitric acid solution. Each solution was dried on a small piece of zirconium foil, which was folded for improved reduction of thorium oxides into neutral thorium, and inserted into a graphite oven. A long-term stable atom source was achieved by carefully heating the oven resistively up to 1600 K. The evaporated thorium atoms were then resonantly excited and subsequently ionized by laser radiation inside the oven. The resulting photo-ions, as well as thermally produced interfering surface ions, were extracted and guided by ion optics to a static quadrupole deflector. Reflecting the ion beam by 90° separated the ions from the neutral particles and allowed for a convenient injection of the laser radiation into the interaction region inside the oven. A subsequent quadrupole mass filter was used to suppress surface ions of different masses produced in the hot cavity. To ensure reasonable transmission of the order of 10%, the mass filter was tuned to a somewhat reduced mass resolution of $m/\Delta m \approx 200$ during the spectroscopic experiments. Ions of interest were finally detected quantitatively by an off-axis channeltron detector operated in single-ion counting mode. Data acquisition was performed with a LabView program and included reading of the ion count rate, monitoring of the wavelengths of the lasers run with fixed frequencies as well as the control of the grating laser tuning and the quadrupole mass filter settings.

3. Measurements and results

An efficient excitation and ionization scheme for atomic thorium requires knowledge of suitable high-lying energy levels as well as Al states above the ionization potential (IP). Existing information on the spectrum of thorium is
Figure 2. Selected strong transitions for the first excitation step of suitable ionization schemes for thorium. $J$-values, $A$-factors and configurations are taken from [25, 26].

Figure 3. Three scans for high-lying levels of even parity starting from different FES of odd parity, denoted as A, B and C according to figure 2. For clarity, the individual scans are separated by an artificial offset. Resonances addressed in further studies are indicated by A1, A2, A3 and C1. The inset shows a detailed scan of one of the intermediate states used for the precise evaluation of level energies. Along the horizontal axis, earlier known and newly determined resonances are marked by short and slightly larger dashes, respectively.

quite limited, with transitions and configurations known only for energy levels up to 38 000 cm$^{-1}$ and the ionization potential of thorium is reported to be 50 867(2) cm$^{-1}$ [24]. Correspondingly, for all investigations reported in this study, three-step ionization schemes with the first excitation step in the blue to UV wavelength region followed by two excitation steps in the infrared were selected.

3.1. Intermediate states

Three well-known energy levels [25, 26] accessible by frequency doubled Ti:sapphire laser radiation and exhibiting high transition strengths from the atomic ground state (GS) were chosen as first excited states (FES) as shown in figure 2. For further excitation into unknown high-lying excited states from one of these FESs, the grating-assisted Ti:sapphire laser was scanned over an extended wavelength range from 715 to 880 nm with a spectral step width of about 0.01 cm$^{-1}$ (0.3 GHz). A third laser operating at a wavelength around 730 nm ensured non-resonant photo-ionization from levels populated by the scanning laser. Numerous even parity levels in an energy region from 37 500 cm$^{-1}$ to 40 500 cm$^{-1}$ with a total angular momentum $J_2 = J_1 - 1$, $J_1$, $J_1 + 1$, where $J_1$ indicates the angular momentum of the FES, were identified. Information on the angular momentum of each energy level was obtained by exciting the same energy level from different FES with different $J$-values. Figure 3 shows the combined laser scans from all three FESs with an artificial individual offset introduced for visual clarity. In these spectra, 24 transitions to previously unknown levels were identified in addition to the confirmation of 43 levels already mentioned in the literature [26]. Finally, detailed laser scans with high spectral resolution were performed for all newly observed
levels as well as for a few of the earlier known levels for reference. The experimental data of each individual resonance were found to be well described by a saturated Gaussian function given by

$$y = y_0 + A_0 \cdot \frac{S_0 \cdot G(E_0, w_G)}{S_0 \cdot G(E_0, w_G) + 1}$$

(1)

with

$$G(E_0, w_G) = \frac{1}{\sqrt{2\pi \cdot w_G^2}} \cdot e^{-\frac{(E-E_0)^2}{2w_G^2}}$$

(2)

and the centroid energy $E_0$, the Gaussian linewidth $w_G$, the saturation parameter $S_0$, the amplitude of the peak $A_0$ and an offset $y_0$. This confirms the assumption that the spectroscopic signal is dominated by the Gaussian spectral distribution of the laser convoluted with a similarly shaped Doppler profile of the atom ensemble inside the source, while a contribution from the natural linewidth is not visible. An example for such a fit is shown in the inset of figure 3, exhibiting an FWHM of about 0.2 cm$^{-1}$. All newly observed levels of even parity as discovered in this work are tabulated in table 1 with their centroid energy, relative signal strength and possible $J$-values. The latter are restricted by the excitation of the individual levels from different FESs, with the most probable $J$-value printed in bold in case of ambiguity. The statistical error for the centroid energy, relative signal strength and possible 0 offset $y_0$ is specific for the experimental arrangement and the conditions used in this work. However, this rough classification is sufficient for the identification of an efficient excitation scheme, while absolute transition strengths could not be determined with the present setup.

3.2. Auto-ionizing and Rydberg states

Suitable final excitation steps towards ionization were determined in a similar manner as the second excited states (SES). While the first two excitation steps were kept fixed on selected resonances, the grating-tuned Ti:sapphire laser was scanned to cover the region ranging from 50 700 to 53 000 cm$^{-1}$ of total excitation energy. The four intermediate excitation steps with strong ion signal, which were chosen for these further investigations, are shown in figure 4. As visualized in figure 5, the level density observed in the energy region covered is much higher than the one in the region of the SESs around 38 000 cm$^{-1}$, which is shown in figure 3. All spectra recorded are highly complex, containing numerous peaks with different linewidths. In addition, overlapping of different structures and the occurrence of significant interference effects are observed. Correspondingly, no Rydberg series could be identified unambiguously in any of the spectra.

The inset in figure 5 shows a detailed view of the most interesting region for the determination of a suitable, highly efficient ionization scheme. It enlarges the region of strongest transition strengths but also of highest level density. A number of narrow transitions with resonance widths comparable to the laser linewidth of 5 GHz is observed here. These AI levels provide very high ionization rates, a factor of ~100 above the background of non-resonant ionization. Table 2 indicates the ten strongest AI resonances determined in these scans, all starting from the same SES (A3) located at 38 700.25 cm$^{-1}$ and exhibiting rather similar ionization probability.

3.3. Characterization of the ionization scheme

3.3.1. Saturation. The excitation scheme finally chosen involves a strong, yet narrow AI level at 51 762.84 cm$^{-1}$. The scheme is depicted in figure 6 in combination with the saturation behaviour as well as detailed spectral scans of each step. The latter were performed using significantly higher laser power for better statistics and correspondingly a slight Lorentzian contribution in the line shape appeared due to saturation effects. Peaks were thus fitted with a saturated Voigt profile, in which the Voigt convolution was used in (1) instead of the simple Gaussian distribution. The third excitation step towards ionization shows an interference structure together with a weak overlapping peak. Both effects are clearly visible in the logarithmic scaling chosen but cannot be assigned unambiguously to any known configuration.

For saturation measurements the ion signals were recorded as a function of the laser power of each of the excitation steps, while the power in the remaining two
Table 2. Summary of the energetic positions of resonances used for further investigation.

| J1   | 26,113.26 cm⁻¹ | 38,219.03 cm⁻¹ | 39,321.81 cm⁻¹ | 39,997.59 cm⁻¹ |
|------|----------------|----------------|----------------|----------------|
| J2   | 26,878.16 cm⁻¹ | 38,700.25 cm⁻¹ | 39,867 cm⁻¹    | 50,867 cm⁻¹    |
| A1   | 26,878.16 cm⁻¹ | 38,700.25 cm⁻¹ | 39,867 cm⁻¹    | 50,867 cm⁻¹    |
| A2   | 26,878.16 cm⁻¹ | 38,700.25 cm⁻¹ | 39,867 cm⁻¹    | 50,867 cm⁻¹    |
| A3   | 26,878.16 cm⁻¹ | 38,700.25 cm⁻¹ | 39,867 cm⁻¹    | 50,867 cm⁻¹    |

Figure 4. Schemes for the search for AI resonances of odd parity. From four SESs of even parity and different J-values, laser scans for excitation just above the ionization potential were performed.

Figure 5. Spectra of AI resonances just above the IP, which is indicated on the left-hand side. A very high-level density is observed. Excitation started from one of four different high-lying SESs as given. The inset shows the region of 51,700 – 52,100 cm⁻¹ with the strongest AI resonances in more detail. The energetic position of resonances used for further investigation as summarized in table 2 are indicated by dashes. The strongest AI resonance indicated by the arrow is selected for the final ionization scheme.

3.3.2. Isotope shifts and hyperfine structure. The determination of the isotope shifts as well as the prediction of a potential isomer shift for the individual energy levels of the excitation scheme of interest can be fully saturated with the available laser powers. Corresponding saturation power values measured in this setup are 2.2 mW for the first transition, 68 mW for the second and 125 mW for the third transition. Utilizing the totally available laser power for each excitation step, it can be estimated that saturation could be obtained on an atom–laser interaction area about ten times larger than the 0.03 mm² used here. This fact could prove useful in future experiments, for example, regarding the rather large gas cell volume of the 229Th recoil ion guide mentioned previously.
may be deduced by subtraction. Isotope shifts of 230Th for the
229Th versus 232Th in the first two levels is given in
to the changes in mean-square nuclear charge radii of thorium
isotopes as given by [19]. This behaviour is expected in this
high-Z region where the volume effect dominates the isotope
shift and a possible mass effect can be neglected.

A two-dimensional spectrum of the isotope shifts of
229Th versus 232Th in the first two levels is given in
figure 7(B), depicting a limited optical isotope selectivity
with slight overlap of the two peaks. The two-dimensional
resonance peak shapes and widths are dominated by the
laser linewidth and the scanning step size. The pronounced
diagonal peak enhancement predominantly visible for the
near-resonant and the sum energy exactly matching the level
energy of the SES. As briefly mentioned above, no indication
of the 229Th hyperfine structure has been observed in either of
the two transitions, indicating that its overall spread is always
well below the experimental linewidth of 0.3 cm⁻¹.

3.3.3. Ionization efficiency. The overall ionization efficiency
was determined by evaporating a precisely known number of
atoms of 229Th until complete exhaustion and accumulation of
the corresponding resonance ion counts in the detector,
as shown in figure 8. The signal showed highest release of
thorium at about 1900 K oven temperature, while maximum
heating reached up to 2300 K. From the behaviour of the count
rate as a function of the steadily increased oven temperature,
Table 3. Energy level positions of the ionization scheme for the isotopes $^{228}\text{Th}$, $^{229}\text{Th}$, $^{230}\text{Th}$, and $^{232}\text{Th}$ and level isotope shifts; the literature values as indicated.

|                | $^{228}\text{Th}$ | $^{229}\text{Th}$ | $^{230}\text{Th}$ | $^{232}\text{Th}$ |
|----------------|--------------------|--------------------|--------------------|--------------------|
| **First excited state (FES)** |                    |                    |                    |                    |
| Measured (cm$^{-1}$) | 26 878.81(4)       | 26 878.70(6)       | 26 878.48(4)       | 26 878.18(4)       |
| Literature (cm$^{-1}$) | 26 878.76$^c$      | 26 878.49$^b$      | 26 878.16$^b$      | 26 878.16$^b$      |
| Level IS$^a$ (cm$^{-1}$) | 0.63(4)            | 0.52(6)            | 0.30(4)            | 0                  |
| **Second excited state (SES)** |                    |                    |                    |                    |
| Measured (cm$^{-1}$) | 38 701.25(4)       | 38 701.07(8)       | 38 700.76(4)       | 38 700.28(4)       |
| Literature (cm$^{-1}$) | 38 700.75$^b$      | 38 700.75$^b$      | 38 700.25$^b$      | 38 700.25$^b$      |
| Level IS$^a$ (cm$^{-1}$) | 0.97(4)            | 0.79(6)            | 0.47(4)            | 0                  |
| **AI state** |                    |                    |                    |                    |
| Measured (cm$^{-1}$) | 51 763.77(7)       | 51 763.63(9)       | 51 763.34(5)       | 51 762.92(5)       |
| Level IS$^a$ (cm$^{-1}$) | 0.85(4)            | 0.71(6)            | 0.42(4)            | 0                  |

$^a$ Isotope shift ($^{232}\text{Th}$–$^{232}\text{Th}$), $^b$ taken from [26], $^c$ taken from [27].

we conclude that at this maximum value the sample is almost totally evaporated. An efficiency value of 0.6% was obtained by subtracting the background from the integrated signal. The value was reproduced with only marginal variations in three individual measurements. It includes all possible losses within the individual processes of evaporation, chemical reduction of the oxide, atomization, resonance excitation and ionization and ion beam transmission through the apparatus. In the present setup, which was optimized for spectroscopic application instead of analytics, the latter is expected to cause the dominant limitation. From ion optical simulations the transmission is estimated to be of the order of only about 10%. Thus a further significant enhancement of the overall efficiency for in-source resonance ionization of thorium is expected by correspondingly optimizing the transmission with the trade-off of a reduced mass resolution or by alternatively choosing a high-transmission magnetic sector field mass separator for these experiments.

4. Conclusion and outlook

For the identification of a suitable efficient three-step resonance ionization scheme for thorium, in-source resonance ionization spectroscopy was carried out. From hundreds of observed resonances, the level energies and restrictions on the angular momenta for 24 previously unknown intermediate atomic energy levels and ten strong AI states were extracted. A dedicated resonance ionization scheme was selected and characterized by measurements on saturation power and isotope shifts, while the hyperfine structure of the odd-A isotope $^{229}\text{Th}$ could not be resolved. An overall ionization...
efficiency of 0.6% was determined for our experimental arrangement, which agrees well with the expectations. This excitation scheme will be used in the near future at the $^{229}\text{Th}$ source for experiments at the Jyväskylä IGISOL facility. By accessing the large neutral fraction of the recoil nuclei, a significantly efficiency increase in the low-energy radioactive ion beam production is envisaged. In this manner, the required beam intensity for high-resolution collinear fast beam laser fluorescence spectroscopy on the hyperfine structure of the nuclear ground and isomeric state of $^{229}\text{Th}$ may hopefully become possible.

A high-resolution measurement of the hyperfine structure of the ground state of $^{229}\text{Th}$ has recently been realized, utilizing an injection-locked narrow bandwidth Ti:sa laser. These data are presently under evaluation and the results will be published soon. In order to finally fully establish the existence of the still mysterious $^{229}\text{mTh}$ isomer via its atomic hyperfine structure, these kinds of measurements serve as an important prerequisite by delivering a precise template of the nuclear ground state and the corresponding hyperfine pattern beforehand.

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