A high resolution measurement of the $1s^22s_{1/2} \rightarrow 1s^22p_{3/2}$ transition using the coherent resonant excitation of Li-like Uranium ions

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Introduction

Relativistic projectile ions passing a thin crystal-target experience a coherent periodic perturbation of the frequencies:

$$\nu_{field} = \gamma\, \mathbf{g} \cdot \mathbf{v}_{ion} \tag{1}$$

where γ is the Lorentz factor, **g** is the reciprocal lattice vector of the crystal target and $\mathbf{v}_{ion}$ is the projectile velocity.

If the frequency of the crystal field, being seen by the projectiles, is equal to the frequency ν_{ij} of the transition, from the i into j state in the ions, Resonant Coherent Excitation (RCE) may occur. In the case of planar channeling conditions the transition energy E_{ij} is given as:

$$E_{ij} = \hbar\gamma\nu_{ion}\left(\frac{\mathrm{k}\cos\theta}{\mathrm{A}} + \frac{\mathrm{l}\sin\theta}{\mathrm{B}}\right), \tag{2}$$

where k and l are the crystal Miller indices, θ is the angle between the ions velocity vector v_{ion} and one of the crystal axes, A and B are constants determined by the crystal structure. This relation shows that the excitation energy can be controlled by energy of the projectile and the crystal orientation.

RCE can serve as an efficient tool for the population control of the excited states of the ions in a wide energy range. In earlier studies RCE was demonstrated in middle-heavy highly-charged ion, such as Ar^{17+} or Fe^{25+} [1,2]. Later on, the RCE has been applied for the heaviest stable element, uranium. The $1s^22s_{1/2} \rightarrow 1s^22p_{3/2}$ transition in U^{89+} was observed by RCE in the field of 10 μm Si crystal, in planar channeling conditions in an earlier experiment [3]. In the present work the experimental conditions were improved in order to measure the transition energy with higher precision [4, 5].

Experiment

A cooled beam of Li-like U ions at 192 MeV/u was supplied by the GSI-ESR facility. The momentum spread of the ion beam $\Delta p/p$ was reduced to 10^{-4} using the electron cooler of the Heavy Ion Storage Ring (ESR). The beam line optics was upgraded to minimize angular divergence. A cooled well-collimated beam of relativistic ions was passing a Si-crystal target placed at (220) planar orientation in the high-precision goniometer.

The RCE was identified from the x-ray emission from the decay of the excited sates of the projectile ions measured as a function of the crystal orientation by rotating the target with a small step using the goniometer. Measurement of the X-ray emission was performed for the same number of the projectiles controlled by the position sensitive particle detector installed behind a charge-state analyser, in the end of the beam line. Four X-ray detectors were mounted around the target under different observation angle, inside the goniometer vacuum chamber. Sum of the four measured X-ray yields as a function of θ angle is presented in figure 1. Number of the detected photons has been normalised to the number of projectile ions.

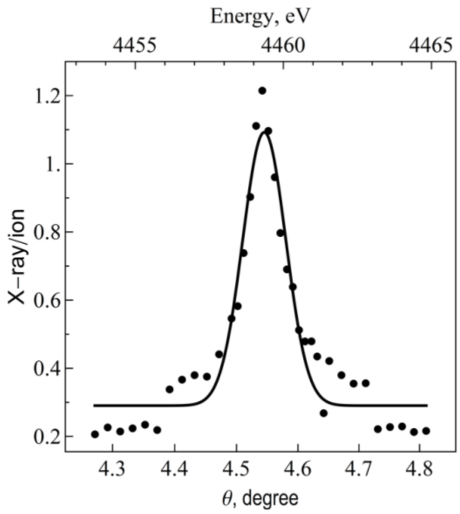

Figure 1: X-ray emission from the decay of the $2p_{3/2}$ excited state of U^{89+} ions passing in 2.5 μm Si crystal at (220) planar channeling conditions.

Maximum of X-ray emission is observed at θ rotation angle around 4.55 degrees. The angular scale has been transformed to electron volts using equation (2). A value of 4459.35±0.72 eV was found for the $1s_{1/2} \rightarrow 2p_{3/2}$ transition. The precision of the method has been improved by order of magnitude, from 10^{-3} to10^{-4}, by reducing momentum spread and angular divergence of the ion beam.

References

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