Laser spectroscopy for the charge radius determination of ^{7,9,10,11}Be

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In 1985 Tanihata and coworkers performed scattering experiments with light elements like helium, lithium and beryllium [1,2] and found, completely unexpected, a huge matter radius for some of the isotopes close to the neutron drip line. These so-called halo-nuclei consist of a compact core nucleus and one or more neutrons which are only very weakly bound (<1 MeV separation energy) and have wave functions that extend extremely far away from the core. For the investigation of the interaction of these weakly bound neutrons on the compact core, precision laser spectroscopy is applied. The nuclear charge radius is extracted from the measurements of the isotope shift, which is the sum of the mass and the field shift. For a determination of the charge radius, an accuracy in the order of a few 100 kHz is necessary. This accuracy must be reached in the experimental measurement of the isotopic shift and in the theoretical calculation of the mass shift contribution. The feasibility of this approach has recently been demonstrated for light halo-nuclei ^{6}He [3], ^{8}He [4] and ^{11}Li [5]. While these have two or even four weakly bound halo neutrons, the next heavier halo nucleus ^{11}Be is the archetype of a single-neutron halo nucleus. Since the crucial theoretical prediction of the mass-dependant isotopic shift contribution can only be calculated for atomic systems with up to three electrons, the isotope shift for beryllium has to be measured on Be^{+} ions.

We want to use radioactive beryllium ions that are produced at ISOLDE, CERN, precooled and accumulated in the gas filled RFQ structure at the ISOLTRAP setup. The ions will be transferred into a linear segmented Paul trap, where they will be laser-cooled to less than 7mK to perform precision laser spectroscopy to reach the required accuracy on single ions.

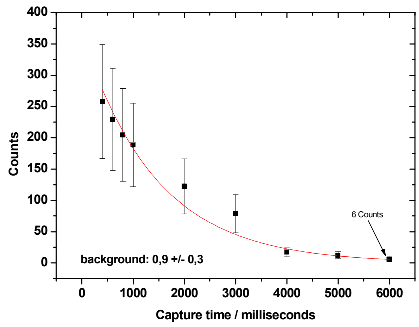

Figure 1: Storage time versus number of extracted ions.

Two main aspects of the experimental apparatus have been developed during 2007. Two designs of RFQ traps have been realized and tested: a circuit board design and a conventional setup with massive rods. The traps were loaded by non-resonant ionization of atoms along the trap axis with a frequency tripled Nd:YAG laser. Due to the lack of an optical detection system, which has been finished just recently, trapping has been verified by extraction from the trap and detection with a channeltron after varying trapping time. No significant ion signal above detector background has been observed with a circuit board design yet, while in the classical Paul trap design storage of several hundred ions could be demonstrated. Figure 1 shows the number of ion counts as a function of the trapping time before the ions were released. A storage time of about 1.5 s can be extracted which is ascribed to collisions of the trapped ions with residual gas (10^{-6} mbar) and the constant flux of neutral atoms from the atom source through the trap axis in this test setup.

For laser cooling and spectroscopy two tuneable dye lasers have been set-up and a frequency-lock on a fiber based frequency comb was established (Figure 2). The observed linewidth of 900 kHz is sufficient for the requirements of the beryllium spectroscopy with a natural linewidth of 20 MHz in the 2s-2p transition. Moreover this locking scheme allows for precision tuning of the locked laser, by controlled scanning of the repetition rate of the mode-locked frequency comb.

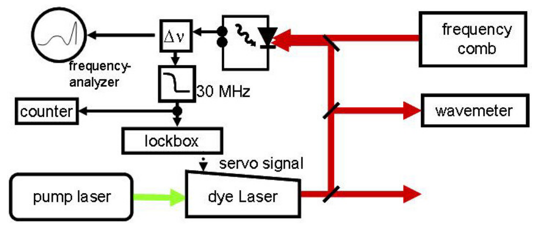

Figure 2: Locking and scanning scheme of the tuneable dye laser.

Further tests of the trap system with optical detection and of the laser system are planned for the first half of 2008. A test of both components at the ISOLDE on-line facility is foreseen later that year.

References

[1] I. Tanihata *et. al.,* PRL **55**, 2676 (1985)
[2] I. Tanihata *et. al,*. Phys. Lett. B **206**, 592 (1988)
[3] L.-B. Wang *et. al.,* PRL **93**, 142501 (2004)
[4] P. Müller *et. al*, PRL **99**, 252501 (2007)
[5] R. Sanchez *et. al.,* PRL **96**, 033002 (2006)

* this work is supported by BMBF Contract Nos. 06MZ215TP6, 06TU263I, 06UL264I and by the Helmholtz Association under Contract VH-NG-148