Setup for a Charge Radius Measurement of the Beryllium Halo Nuclei *

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Although light nuclei with extraordinary large nuclear matter radius are known since the eighties of the last century [1,2], charge radii of such halo isotopes have been determined in a series of laser based high precision measurements just during the last three years. The charge radii of the neutron-rich helium isotopes ^{6}He and ^{8}He are studied in a magneto-optical trap at the Argonne National Laboratory [3], while the charge radius of ^{11}Li has been successfully determined with two- photon spectroscopy by the ToPLiS group from GSI [4 and Sanchez *et al.* in this annual report].

A new experiment aims to measure the charge radius of the Beryllium halo nuclei. ^{11}Be with a lifetime of 13.6 s is the prototype of a one-neutron halo, while ^{14}Be ($t_{1/2}$ = 4.8 ms) is assumed to be a four-neutron halo. Some properties of the beryllium isotopes are listed in Table 1. The charge radius of the halo nuclei is determined by high-resolution measurements of the isotope shift. For these light nuclei a theoretical prediction of the mass shift contribution with adequate precision is required as input parameter. Up to now this can only be provided for two- or three-electron systems [5] and thus the study of the beryllium charge radius has to be carried out on the singly charged positive beryllium ion. Calculations of the mass shift contributions for all beryllium isotopes in the $2s_{1/2} - 2p_{1/2}$ transition are currently performed [6].

The proposed setup for the new experiment consists of a rather compact vacuum chamber system and a dedicated laser system, which has to be transferred to an on-line facility with sufficient beryllium yields. At the current stage it is planed to adapt this setup at the trap experiments at ISOLDE, CERN. A beryllium ion beam from the on-line laser ion source will be accumulated and cooled at the ISOLTRAP buncher [7], extracted and focused by adapted ion optics into a linear Paul trap. Inside the trap the velocity of the low-energy ions will be further reduced by laser cooling with the second harmonic of a continuous wave dye laser at 626 nm. A second dye laser will be used for the spectroscopic study on the $2s_{1/2} - 2p_{1/2}$ transition. For precision laser wavelength control a frequency comb will be used. Detection of the fluorescence in the trap will be provided by a photomultiplier system. At present an off-line setup of the suggested experiment is assembled at GSI and the institute for nuclear chemistry at the University of Mainz. There, stable beryllium ions will be provided by non-resonant laser desorption from a beryllium foil with a low-repetition rate nitrogen laser. This has been successfully tested recently. Off-line tests shall provide the ideal ion trap parameters, increase the trapping and single ion detection efficiency as well as help to eliminate systematic effects and uncertainties on the isotope shift measurement.

Table 1: Spins, half-lifes, matter- [2] and charge radii [8] of known beryllium isotopes.

Isotope	I	$T_{1/2}$	$R^{\text{matter}}_{\text{rms}}$ [fm]	$R^{\text{charge}}_{\text{rms}}$ [fm]
^{7}Be	$3/2^-$	53d	2.33 (2)	?
^{9}Be	$3/2^-$		2,38(1)	2,52(1)
^{10}Be	0^+	1,6 My	2.28(2)	?
^{11}Be	$1/2^+$	13,8 s	2,71(5)	?
^{12}Be	0^+	21,3 ms	2,57(5)	?
^{14}Be	0^+	4,4 ms	3,11(38)	?

This trap and laser cooling development is also performed with respect to other applications. Once cold beryllium ions are stored in the trap, other ion species can be injected and sympathetically cooled, removing the necessity to develop laser systems for direct laser cooling of such systems. This will provide efficient laser spectroscopy of rarely produced radioactive ions and might be applied at SHIPTRAP for the spectroscopy of heavy and super-heavy elements or at the LaSpec setup at FAIR's low-energy beamline. Moreover, the laser system will also be used for cooling of beryllium ions in the RETRAP Penning trap setup to sympathetically cool highly charged ions, which are delivered from the HITRAP facility. At RETRAP, cold highly-charged ions will allow precision tests of QED in strong electric and magnetic fields as well as studies of the nuclear magnetization distribution (Bohr-Weisskopf effect).

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