THE ION SOURCES AT THE KARLSRUHE CYCLOTRON

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ABSTRACT:

At the Karlsruhe fixed-frequency cyclotron two external ion sources are used for nuclear physics experiments. LISKA (Lithium Ion Source Karlsruhe), a two stage ECR source specially designed for Li^{3+} ions, delivers a current of 60 µA Li^{3+} after 90° deflection. PASKA (Polarised Atomic Beam Source Karlsruhe) delivers 30 µA of polarized d^+ ions after 90° deflection. Accelarated to maximum energy (26 MeV/amu) up to 5 µA of Li^{3+} and 2 µA of polarized d^+ can be obtained.

INTRODUCTION:

The Karlsruhe cyclotron is a fixed-frequency (33 MHz) cyclotron for accelerating particles with e/m = 1/2 to an energy of 26 MeV/amu. Due to this charge to mass ratio only completely stripped light particles are appropriate for acceleration. An internal Penning source is used for unpolarized d^+ and He^{2+} ions. An ECR source for Li^{3+} ions and an atomic beam source for polarized d^+ ions are installed in a separate building and connected to the cyclotron by a 16 m long beamline and the axial injection system. The arrangement of the external ion sources is shown schematically in Fig. 1.

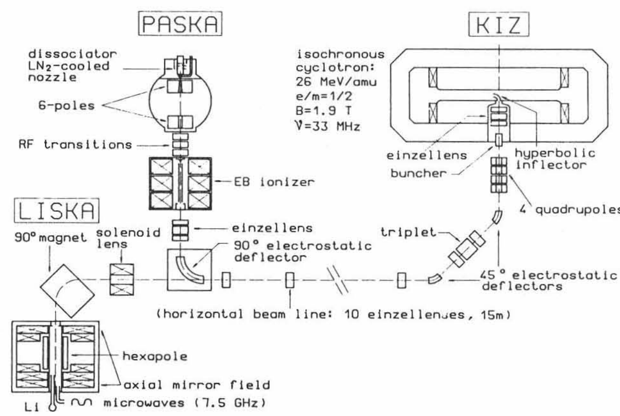

Fig.1: The external iom sources of the Karlsruhe cyclotron

THE LITHIUM ION SOURCE LISKA

The ion source LISKA is a two stage ECR source specially designed for Li^{3+} ions. At 350° C a suitable vapour pressure to operate an ECR discharge is obtained. Otherwise at room temperature the lithium condenses immediately at the surface of the vacuum system. Thus, as a construction principle the Li plasma must not be allowed to see any cold surface. Fig.2 shows the essential characteristics of the Li source. Lithium vapour from an oven is guided into a small cylindrical tube (diameter 28 mm, length 80 mm) where it is ionized by 7.5 GHz microwaves in the 2 ω_{CE} mode [1].

Lithium ions and vapour then diffuse into the main plasma chamber (diameter 68 mm, length 300 mm), where further ionization takes place in the ω_{CE} mode. This plasma chamber is a double-wall construction with vacuum insulation. The inner wall is completely

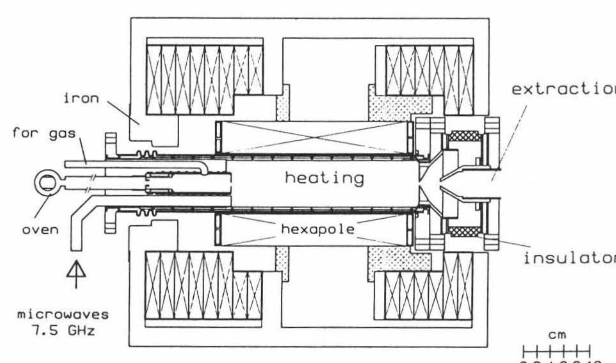

Fig.2: Schematic view of the Lithium ion source

heated including the plasma electrode. In order to achieve the optimum Li vapour pressure five heating systems (Li oven, transfer pipe, first stage plasma chamber, second stage plasma chamber and plasma electrode) have to be adjusted.

The microwave power is fed into the second stage off-axis. There is no additional microwave line for the first stage, instead the 3 mm exit hole of the first stage is extended to a slit of approximately λ/2 (length 24 mm, width 0.2mm). Thus only one microwave power has to be adjusted to about 100 W.

The extraction system consists of two electrodes. The plasma electrode has a diameter of 6 mm and the gap between the electrodes is 30 mm. Without any focusing elements the Li source is connected directly to a 90° double focusing analyzing magnet. Fig.3 shows the charge state distribution of lithium. The small admixture of ^7Li enables the calculation of the $^6Li^{3+}$ ion current if one assumes the relative charge state distribution of both Li isotopes to be equal. So one can conclude that 60 µA of Li^{3+} are delivered by the source.

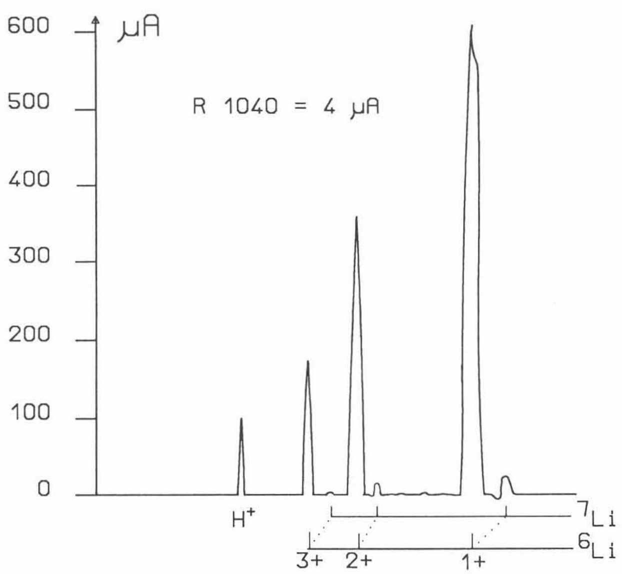

Fig. 3: Charge state distribution of the Li source

THE POLARIZED D$^+$ SOURCE PASKA

The polarized atomic beam source PASKA was built by SENTEC (ANAC) Genf. At the KfK the source output was increased considerably and its reliability improved. 30 µA of polarized d$^+$ are obtained routinely after 90° deflection.

Fig. 4 gives a schematic view of this source . In an RF discharge (100 W, 12.57 MHz) hydrogen atoms are produced from molecules. The gas input is of the order of 25 nccm/min and the dissociation degree is 50 %. The atoms pass through a 20 mm long LN_2 cooled saphire nozzle where they are cooled down. They then expand into the vacuum of the dissociator chamber (2 10^{-5} mbr). The suitable part of this diverging beam is peeled out by a skimmer.

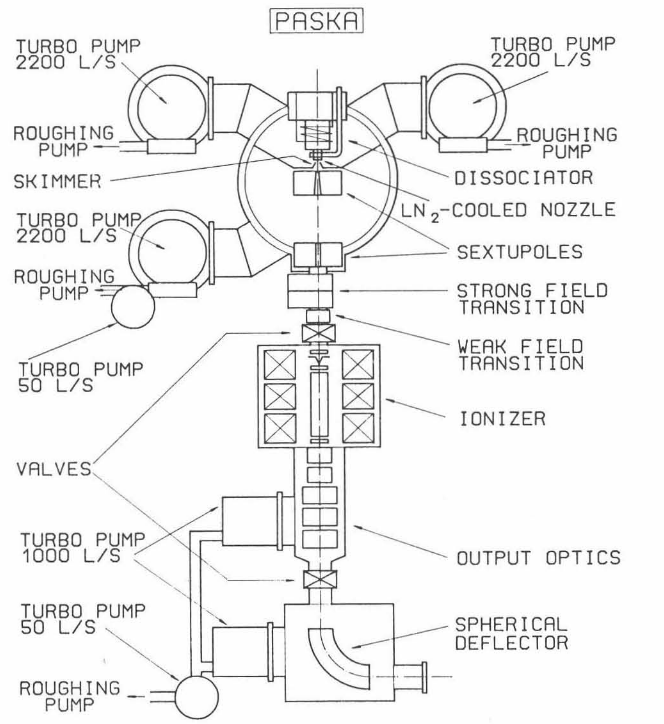

Fig.4: Schematic view of the polarized ion source

These atoms enter the inhomogenous part of two sextupoles by which the atoms with electron spin anti-parallel to B are defocused, while those with spin parallel are focused and thus selected. Both sextupoles have a length of 100mm and are separated by 200 mm The aperture of the first one is tapered from 8 to 16 mm, while the second has a constant aperture of 16 mm.

After the sextupoles the atoms pass through two strong field RF transitions (330 and 450 MHz) and one weak field transition (10 MHz) by which the electron polarization is transferred to the nucleus in the up or down direction by interchanging of hyperfine structure states.

The atoms then enter an Electron Bombardment ionizer. A solenoid field of 120 to 150 mT confines an oscillating electron current drawn from a heated filament. Fig 5 shows the distribution of the magnetic and electric fields. The efficiency of this ionizer is of the order of 5 %. But due to the high electron current (about 1 A/cm^2) the space-charge-related energy spread is considerably high: +/- 250 eV and also the emmitance of the extracted beam after 90° deflection: 100 mm mrad $\sqrt{}$MeV. The polarized d^+ current is 80 µA behind the ionizer and 30 µA after deflection.

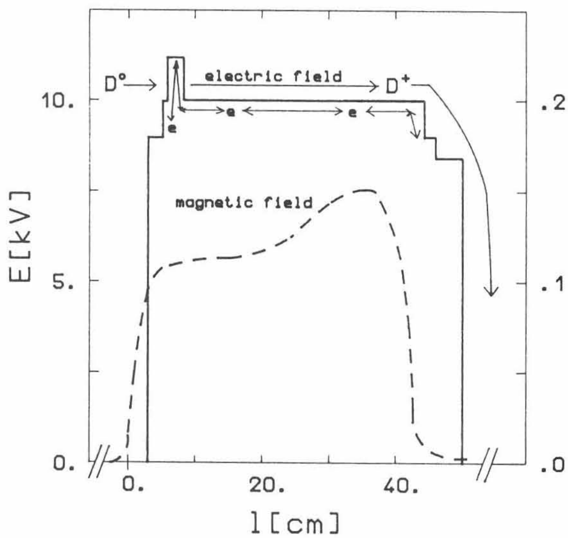

Fig.5: Magnetic and electric field distribution of the EB ionizer

ECR IONIZER FOR ATOMIC BEAM SOURCES?

For further improvement of efficiency, brightness and energy spread of an atomic beam source the replacement of the EB ionizer by an ECR ionizer was proposed[2]. Within a cooperation between the KfK and the PSI an ECR ionizer was built at the KfK and installed in a test stand equipped with a 25 K cold atomic beam at the PSI. After some modifications a polarized beam of 150 µA within an emmittance of 60 mm mrad $\sqrt{}$MeV was obtained[3].

Fig.6 presents a schematic view of this ionizer. The plasma is confined axially by the field of two iron-shielded solenoids and radially by the field of a permanent sextupole. The plasma chamber (length 300 mm, diameter 80 mm) is made of pyrex in order to prevent recombination of atoms by wall collisions. Microwaves (2.45 GHz, 30 W) are transmitted through the pyrex tube. The atomic beam enters the ionizer through a 20 mm pyrex tube. A three-electrode system with 40 mm apertures and 20 mm electrode separation is used as extraction system.

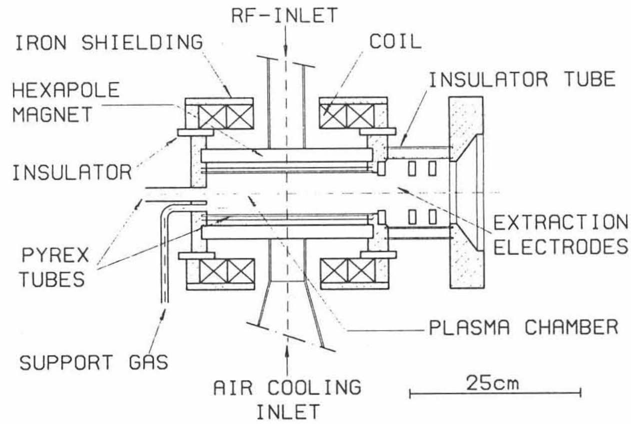

Fig.6 Schematic view of the ECR ionizer

A slightly modified version of this ionizer has been used to replace the EB ionizer of the PASKA. After 90° deflection 60 µA of polarized d^+ were measured and 3 µA accelerated to full energy. This is about twice the value which was obtained by the EB ionizer. Using hydrogen as support gas led to a further increase of the intensity. But the polarization measured by elastic d-C scattering at 52 MeV was only 2/3 of that obtained by the EB ionizer.

EMITTANCE MEASUREMENTS

The emittance of the ion sources was measured with the apparatus shown in Fig. 7. A part of the beam is cut out by a movable slit. The position and the width of the partial beam was measured with a beam scanner positioned 333 mm beyond the slit. A value of 90 mm mrad$\sqrt{}$MeV was found for the lithium ion source and 100 mm mrad$\sqrt{}$MeV for the polarized ion source.

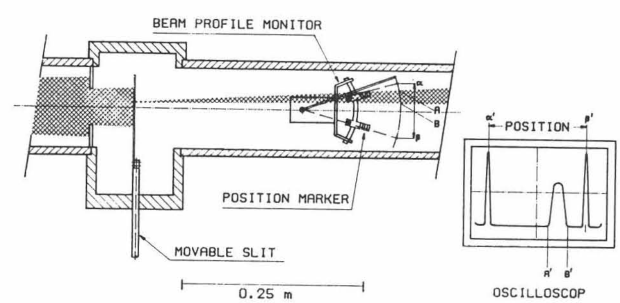

Fig.7: Emittance measurement device

References:

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