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Abstract

The investigation of different charge exchange reactions shows that positively charged polarized hydrogen ion beams can be produced with a Lambshift type ion source. The special features of the Karlsruhe polarized Lambshift type ion source C-LASKA which is designed for operation at the Karlsruhe isochronous cyclotron are discussed. Beams of negatively charged polarized deuterium ions have been obtained with high beam qualities and the source C-LASKA will deliver polarized deuteron beams for injection into the cyclotron with an intensity of the order of 1μA at an emittance of 1 cm rad $\sqrt{eV}$.

Untersuchungen von verschiedenen Ladungsaustauschreaktionen haben ergeben, daß sich Lambshift-Typ Ionenquellen auch für die Erzeugung von positiv geladenen polarisierten Wasserstoffionenstrahlen eignen. Die speziellen Eigenschaften der Karlsruher Lambshift-Typ Quelle für polarisierte Ionen C-LASKA werden diskutiert. Diese Quelle wurde für den Betrieb am Karlsruher Isochron-Zyklotron entwickelt. Negativ geladene polarisierte Deuterium-Ionenstrahlen wurden mit sehr guten Strahlqualitäten erzeugt, und die Quelle C-LASKA wird polarisierte Deuteronen-Strahlen mit einer Intensität von etwa 1 μA bei einer Emittanz von 1 cm rad $\sqrt{eV}$ für die Injektion in das Zyklotron liefern.

Lambshift type sources for polarized ions exhibit some special characteristics which make them advantageously suitable for applications at different types of accelerators. The most evident of these features are: a high phase space density of negatively charged polarized ions [1]); a very small emittance leads to an ion beam with excellent properties which can be accepted almost completely by any type of accellerator. Furthermore the source provides a rather inexpensive experimental set up which can easily be operated.

We have extended our investigations to problems dealing with the production of positively charged polarized hydrogen beams. Such a Lambshift type ion source C-LASKA was designed and constructed for operation at the Karlsruhe isochronous cyclotron. Designing the source it was taken into account that this type of source might also be operated in producing negatively charged ions for tandem accellerators. The charge of the polarized ion beam can easily be altered by only changing the gas or vapour used for the selective ionisation process.

The set up of C-LASKA is schematically shown in fig. 1. In comparison to the sources described elsewhere in the literature [2]) the Karlsruhe Lambshift source is characterized by the following special features.

a) As usually the metastable atomic beam is produced by charge exchange in cesium. But the design of our cesium cell was modified with regard to several aspects. These aspects were to achieve firstly a very low cesium consumption. Secondly we aimed at a very stable long period operation. Thirdly a very small contamination by diffusing cesium is desirable and fourthly the cesium should be steadily repurified. These requirements are fulfilled by a cell operating in a closed loop cesium distillation circuit. The volume used for the charge exchange reaction is defined by the spatial overlap of the directed cesium vapour beam with the primary ion beam.

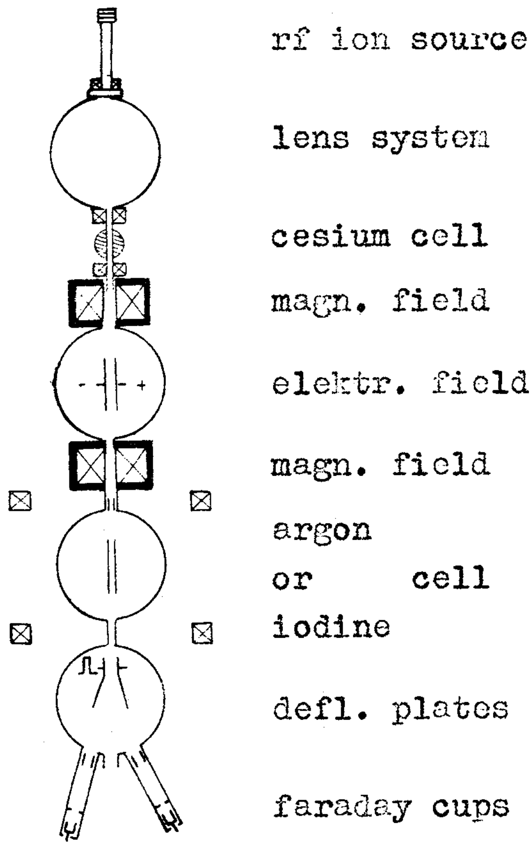

fig. 1 A-LASKA schematic

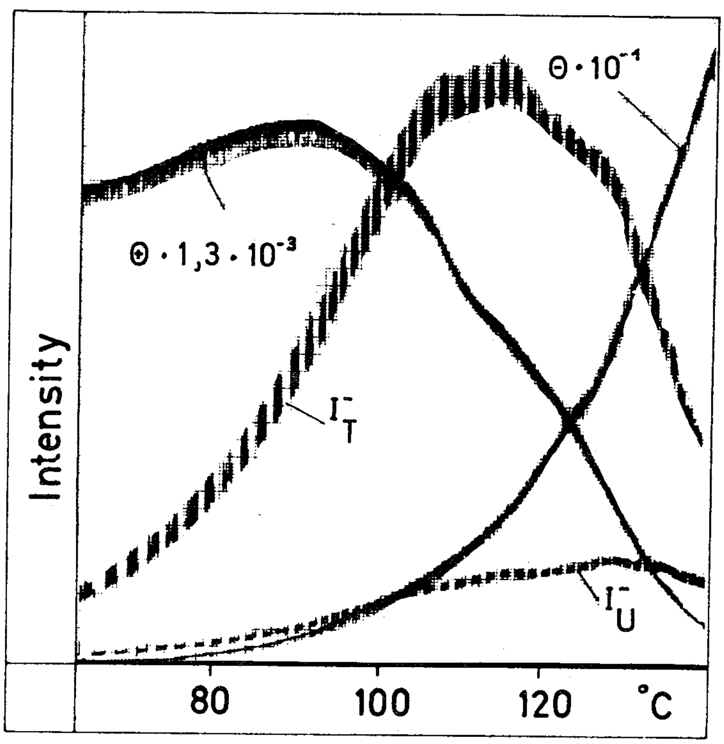

fig. 2 The absorption and different yields of cesium measured at 1 keV beam energy

To prevent the cesium from diffusing into the surrounding parts of the apparatus baffles were installed additionally.

b) Applying a zero crossing magnetic field the degree of polarization is increased by a nonadiabatic process [3,4]) which changes the occupation numbers of the hyperfine structure levels. One aspect of the magnetic field design was to keep the length of the source at a minimum. The distance between the two solenoid magnets is 23 cm only. The shape of the magnetic field is determined by the shape of the iron shielding. The dimensions of the two magnets are: 7 cm in length, 4.5 cm i.d. and 18 cm o.d. The process is easily controlled by the magnet current only and no additional correcting coils are needed.

c) A rotating homogeneous electrical field is provided inside the two magnets mentioned in b). The electric field is needed for two purposes. Firstly it removes all the charged components from the neutral beam and secondly it is necessary for the coupling of the 2S to the 2P1/2 states. The rotational character of the electrical field assures a rotational symmetric disposal of the charged beam components and simplifies the adjustment of the beam.

d) The source contains a monitor device. Periodically the polarized ion beam is electrically deflected into two Faraday cups. This is accomplished by a rectangular electrical pulse of 2×10^{-4} sec in width with a repetition rate of 50 cycles. This device allows to monitor the beam intensity as well as the beam polarization (by quenching) with only negligible loss in beam intensity.

A prototype of this Lambshift source (A-LASKA) is in operation since 1968 to investigate the physical problems involved with the development of Lambshift sources [1,4,5,6,7,8]). A very similar source (B-LASKA) is operated at a small Cockkroft-Walton accellerator. This source produces negatively charged polarized ions and the accelerator is designed for tandem

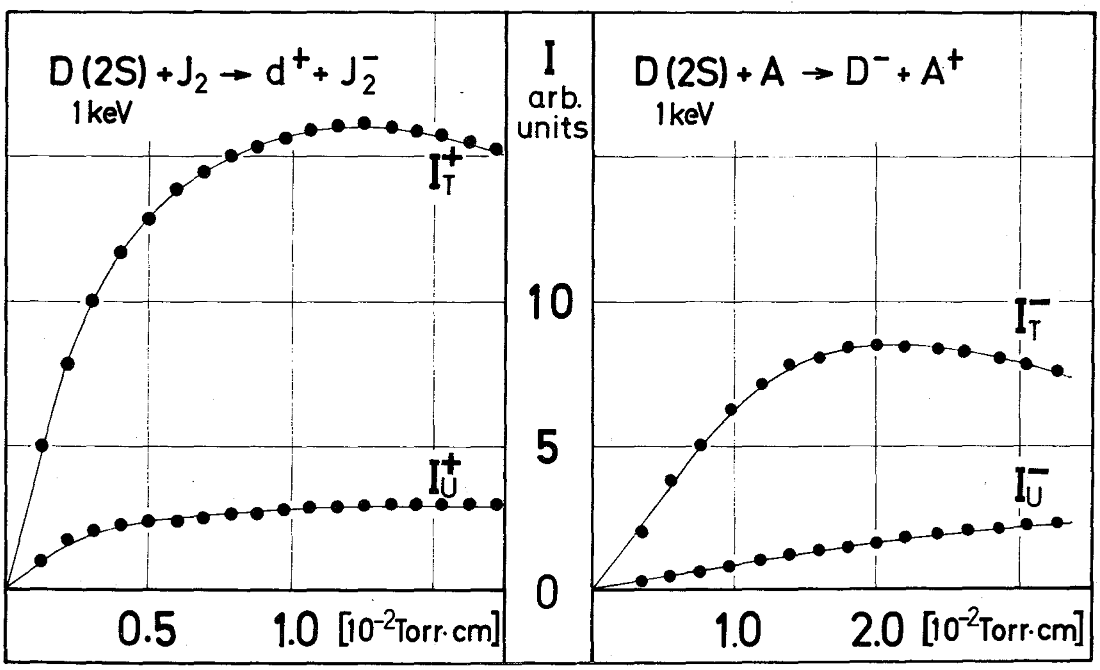

fig. 3 Yield of the selective ionisation by iodine and argon respectively

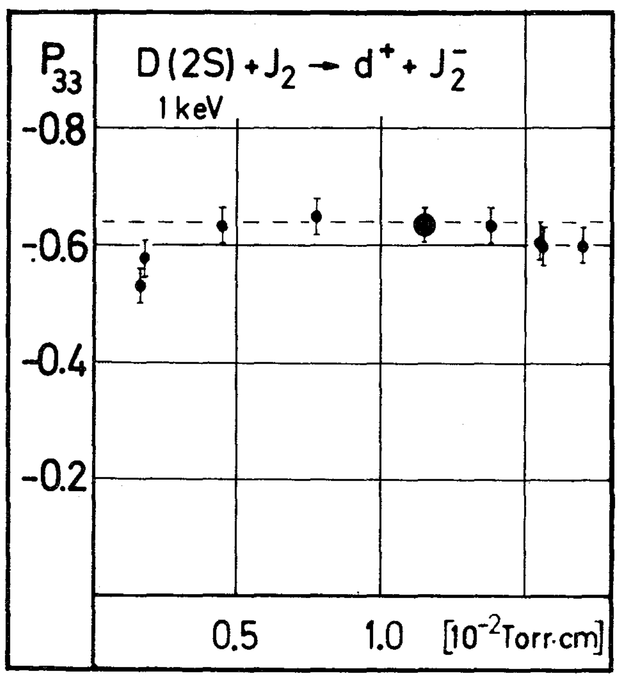

fig. 4 The experimentally measured tensor polarization P_{33} versus the iodine density of mass

operation. Many different charge exchange reactions were studied systematically. Our main interest was to reveal the properties connected with the production of an intense metastable atomic beam and to ionise the metastables selectively to positive or negative ions.

Fig. 2 shows the characteristic of the cesium charge exchange reaction. The diagram shown was registered with an X-Y recorder. The temperature of the cesium reservoir is taken to be the abscissa and intensities are plotted on the ordinate. The curve denoted by ⊕ shows the absorption of the primary positive beam. The curve denoted by ⊖ demonstrates the yield of negative ions which are produced in the cesium cell. The neutral beam components (metastables and ground state atoms) were registered by using the charge exchange reaction in argon. I_T^- denotes the total negative beam intensity produced by the neutral beam. I_U^- was measured by quenching all the metastables in the neutral beam. At optimum conditions this cell is to be operated at 150° C. Up to now cesium turned out to be the best candidate for production of intense metastable beams [5]).

The selective ionisation was studied in a very similar way. Fig. 3 shows as an example the yields I_T and I_U in iodine (positive ions) and in argon (negative ions) at an energy of 1 keV. The intensities were measured as a function of the gas density in the charge exchange cell. The arbitrary scale of the intensity I is identical for all four measurements. The polarization to be expected can be calculated from these intensity measurements [8]).

The comparison of the argon and iodine reaction shows that iodine yields an IP^2 which is almost two times greater than the corresponding value for the argon charge exchange collision [7]). L.D. Knutson has independently investigated the iodine charge exchange reaction and communicated very similar results for particularly chosen iodine vapour densities [9]).

The nuclear tensor polarization P_{33} of the beam was studied by measuring the neutron asymmetry of the $T(d,n)^4He$ reaction. Fig. 4 shows as an example the results obtained for the iodine charge exchange reaction. P_{33} is almost completely independent of the iodine vapour pressure and at 1 keV a value of P_{33} = -0.64 is obtained which is comparable with the polarizations achieved either for negative ions from Lambshift sources or for positive beams from atomic beam sources.

In summarizing it can be concluded that the Lambshift type ion source is very suitable to produce either positively charged or negatively charged polarized beams. Negative beams were reliable obtained with an emittance of less than 0.7 $[\text{cm rad} \sqrt{\text{eV}}]$ and at intensities above 0.1 μA. The source C-LASKA which will produce positive ions for the Karlsruhe isochronous cyclotron will be able to deliver a polarized beam of the order of 1 μA at an emittance of 1 $[\text{cm rad} \sqrt{\text{eV}}]$.

References:

1) H. Brückmann, D. Finken, L. Friedrich
Z.f.Physik 224 (1969), 486

2) e.g. W. Haeberli
An.Rev.Nuclear Sci. 17 (1967) 406;
T.B. Clegg, G. Plattner, L. Keller, W. Haeberli,
Nucl.Instr.Meth. 57 (1967), 167

3) P.G. Sona
Energia Nucl. 14 (1967), 295

4) V. Bechtold, H. Brückmann, D. Finken, L. Friedrich
Z.f.Physik 231 (1970), 98

5) V. Bechtold, H. Brückmann, D. Finken, L. Friedrich,
K. Hamdi, E. Seitz
KFK-Report Nr. 1256

6) Contributed paper for the conference: "Third International Symposium on Polarization Phenomena in Nuclear Reactions, Madison, Wisconsin 1970
V. Bechtold, H. Brückmann, D. Finken, L. Friedrich,
K. Hamdi, E. Seitz: The energy dependence of charge exchange reactions favourably used in Lambshift type ion sources.

7) H. Brückmann, D. Finken, L. Friedrich
Nucl. Instr. Meth. (in press)

8) H. Brückmann, D. Finken, L. Friedrich
Phys. Lett. 29B (1969), 223

9) L.D. Knutson, to be published in Physical Review A2