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Abstract

A special arrangement consisting of two iron shielded solenoids was minimized in order to achieve intense metastable hydrogen atom beams with longitudinal polarization. A transverse polarization of the metastables is obtained by superposing the longitudinal magnetic field with a properly designed field in transverse direction. This whole set-up makes it feasible to ionize the metastables in the transverse magnetic field. The loss of the metastables by quenching in the transverse magnetic field can be almost avoided by electrical compensation. The measured transverse tensorpolarization was $P_{33}=-0.73$.

Zusammenfassung

Um einen intensiven Strahl metastabiler Wasserstoffatome mit longitudinaler Polarisation zu erzeugen, wurde eine Anordnung minimaler Länge von zwei Solenoiden mit Eisenabschirmung entwickelt. Wird dem longitudinalen Magnetfeld des zweiten Quenchingmagnets ein geeignetes Transversalfeld überlagert, so erhält man einen Strahl polarisierter metastabiler Atome mit transversaler Polarisation und kann diesen ohne Polarisationsverminderung in einem homogenen transversalen Magnetfeld ionisieren. Durch elektrische Kompensation kann eine Intensitätsabnahme der metastabilen Atome durch Quenchen im transversalen Magnetfeld nahezu vermieden werden. Die gemessene transversale Tensorpolarisation betrug $P_{33}= - 0{,}73$.

For injection in the Karlsruhe Isochronous Cyclotron a transverse polarized ion beam is necessary. This transverse polarization can be achieved in a Lambshift source without the additional spin rotating devices usually following the source.

The Lambshift source takes advantage of the different lifetimes of the metastable α- and β-$2S\frac{1}{2}$ states of hydrogen in a combined magnetic and electrical field |1|. A beam of metastable atoms is polarized by quenching the different Hfs-states selectively while the beam is running through two special longitudinal magnetic fields with opposite directions |2|.

In figure 1 the two quenching magnets and the shape of the

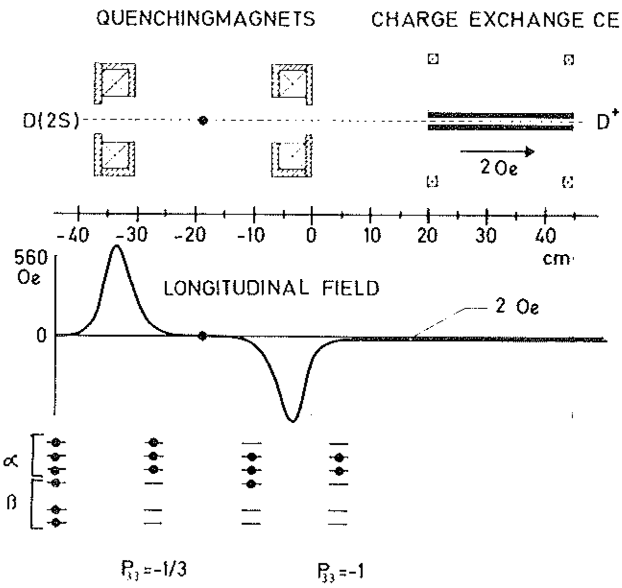

fig. 1

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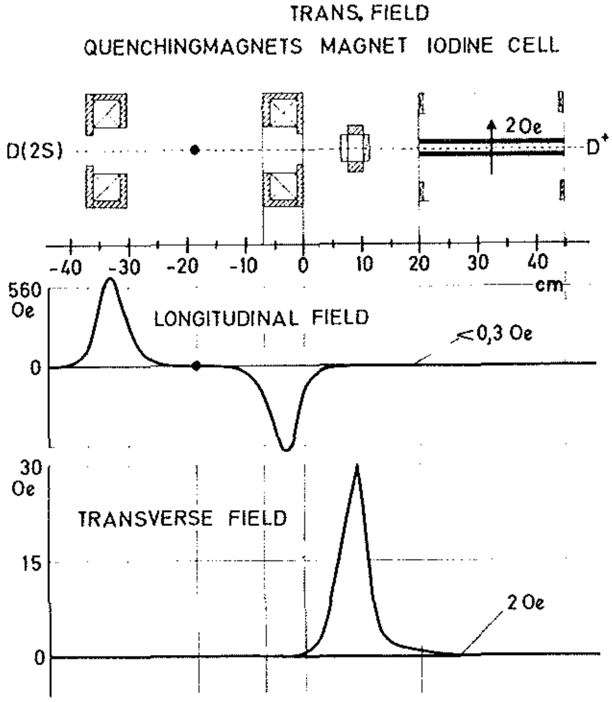
longitudinal magnetic field are shown. In addition the change of occupation numbers is given while the beam is passing the longitudinal field.

The polarized metastable atoms are ionized by charge exchange with iodine in a homogeneous longitudinal magnetic field of 2 Oe |3, 4|, giving a positively charged ion beam with longitudinal polarization. For getting transverse polarized ions the metastable atoms have to be ionized in a transverse magnetic field.

The charge exchange process can also take place in a transverse magnetic field. But in this case a beam broadening results from the transverse magnetic field because the charged particles originate from different parts of the cell. Therefore the magnetic field has to be compensated by an electrical field to avoid loss of intensity and deformation of beam emittance. Before entering the charge exchange cell it is necessary to rotate the polarization of the metastable atoms from the longitudinal to transverse direction. This is feasible by using a specially-formed magnetic field turning from longitudinal to transverse direction along the beam. The experimental arrangement and the field shape are shown in figure 2.

In between the second quenching magnet and the charge exchange cell is placed the transverse field magnet. The magnet produces a narrow field with a maximum of 30 Oe shown in the lower curve. The position of the transverse field magnet is in the region where the longitudinal field of the second quenching magnet has nearly the same value as the transverse field. The resulting field changes its direction along the beam in such a way that the Larmor precession frequency of the atoms in this field is always higher than the rotation frequency of the magnetic field seen by the metastable atoms |2,5|. This adiabatic condition allows the beam energy to vary over a wide range and requires therefore no special care in designing the magnet.

fig. 2



A difficulty however arises if metastable atoms run through a transverse magnetic field. For a moving atom in a transverse field there are opposite Lorentz forces effecting the electron shell and the nucleus. This causes a Stark-effect, reducing the metastable intensity by quenching. This difficulty can be overcome by electrical compensation of the transverse magnetic field. The electrical field is produced by properly designed electrodes inside the transverse field magnet. The total arrangement is shown schematically in figure 3.

At left is sketched the second quenching magnet. Between the pole shoes of the transverse field magnet are inserted the two electrodes of the electrical compensation field. They must be curved to get optimum compensation.

The charge exchange cell is sliced into 12 segments held at different potentials. The sliced cell produces inside a nearly homogeneous electrical field. This is necessary to compensate the transverse magnetic field H_f. The dimensions of the cell are 1,8 cm inner diameter and 25 cm length.

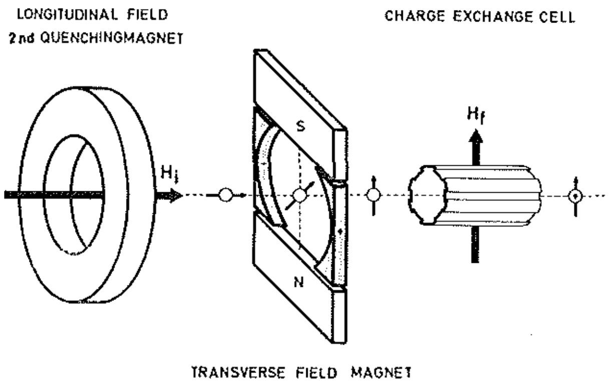


fig. 3

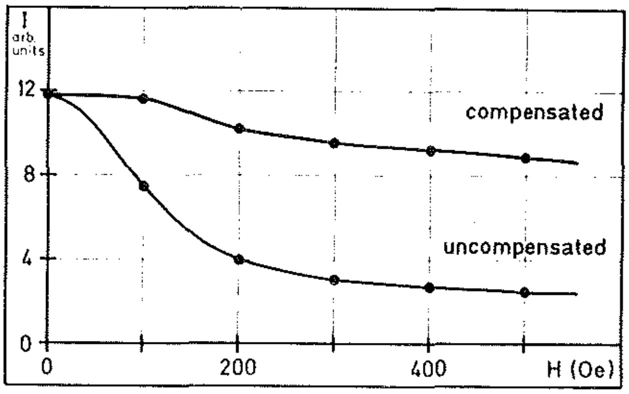
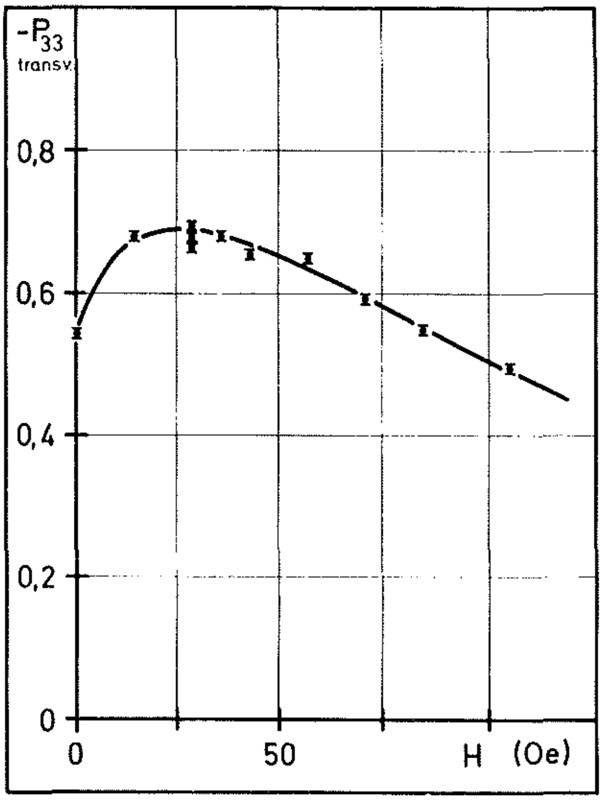


fig. 4

The transparency of the compensated transverse magnetic field for metastable atoms has been investigated as a function of magnetic field strength. For this purpose the ion intensity produced by charge exchange of the α-metastables was measured. In figure 4 the experimental results of this arrangement are plotted.

In both cases the intensity decreases with rising magnetic field. However by electrical compensation of the transverse magnetic field, loss of intensity is reduced. This loss may be explained by the difficulty to compensate completely the magnetic field at any point of the beam region. Remaining field components (magnetic and electrical) quench the metastable atoms. The quenching effect by these remaining field components becomes higher with increasing transverse magnetic field. In lower fields the loss of metastable intensity is negligible.

fig. 5



In figure 5 the transverse polarization P_{33} measured by the $T(d,n)^4He$ reaction is given as a function of the transverse field. This transverse field is always optimally compensated. For getting maximum polarization a field strength of 30 Oe has to be applied. Lower fields are not able to rotate the polarization completely. With increasing fields there is a loss of metastables by quenching. Because of an unpolarized background the loss of metastables reduces the polarization of the ion beam delivered by the source. Another effect which also may cause the loss of polarization, is connected with the special arrangement of the source used for these investigations. The beam of the polarized metastable atoms is admixed with charged particles. This particles are deflected and separated in this arrangement by rotating electrical fields. If the transverse magnetic field is not completely compensated some of these charged particles are reflected again into the beam of the metastable atoms. This causes a higher unpolarized background. In present state the reported set-up of the Karlsruhe Lambshift source delivers a positively charged deuteron beam with tensor polarization of $P_{33} = -0.73$ in the transverse direction. The polarization was measured by the neutron asymmetry of the $T(d,n)^4He$ reaction at 140 keV.

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