THE POLARIZED GAS TARGET FOR ANKE AT COSY-JÜLICH

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Abstract

The polarized atomic beam source (ABS) will be utilized in future experiments at the magnetic spectrometer ANKE to feed a storage cell gas target. A state-of-the-art system of sextupole magnets has been developed for the source. A maximum intensity of $(6.9 \pm 0.3) \cdot 10^{16}$ atoms/s at a nozzle temperature of 72 K is achieved for two hyperfine states of hydrogen. The medium field rf-transition unit (MFT) is currently being tested and an efficiency of 0.90 ± 0.05 has been measured for the 2-3 transition. For future experiments at COSY with polarized internal targets a Lamb-shift polarimeter, built at the University of Cologne, has been installed at the ABS. First measurements of the nuclear polarization of the atomic hydrogen beam, produced by the MFT unit, yield a preliminary value of $|P| = 0.89 \pm 0.01$. First studies of the properties of the COSY beam have been carried out with an aperture at the ANKE target position.

A polarized atomic beam source (ABS) will be utilized to feed a gas-storage cell with polarized hydrogen or deuterium atoms. By the use of a storage cell the luminosity will be increased by about two orders of magnitude compared to an atomic gas jet crossing the stored, circulating COSY beam [1]. The ABS has been assembled and tested, more details of the components are found in ref. [2]. Due to the limited space in the ANKE target region [3] between the magnets D1 and D2 it will be mounted vertically (see Fig.1). The layout of the ABS is shown in figure 2.

A powerful pumping system yields pressures of about $10^{-4}, 10^{-6}, 10^{-7}$, and 5×10^{-8} mbar in chamber I, II, III, and IV, respectively, at a primary H_2 inlet flux of 1.5 mbar·l/s. In the dissociator (labeled 1 in the figure) a plasma discharge is maintained by inductive coupling of 13.56 MHz. The inner Duran-glass discharge tube (11 mm inner diamter) is cooled by a coaxial water flow. The nozzle at the lower end can be cooled down to about 65 K by a cryocooler via a flexible Cu connection and a Cu bridge (label 2). The upper

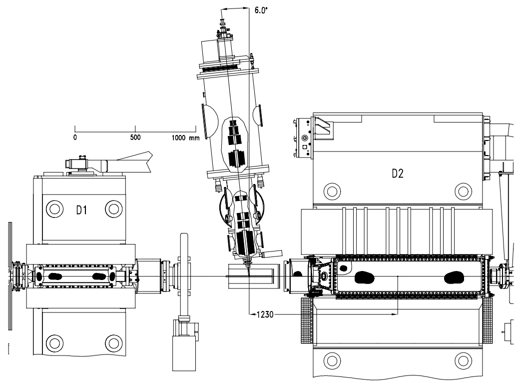

Figure 1. Sideview of the ABS position.

baffle, separating the chambers I and II, carries the beam skimmer. The nozzle-to-skimmer distance can be optimized from outside without breaking the vacuum.

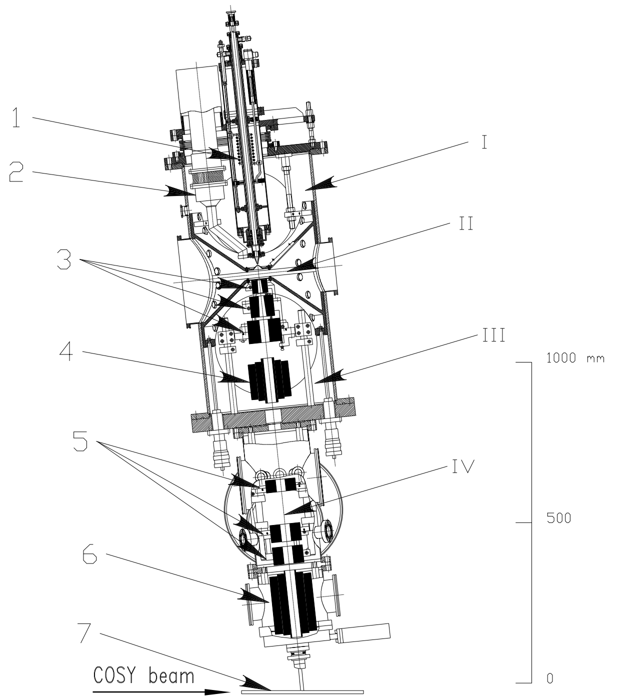

Figure 2. The general layout of the ANKE polarized atomic beam source. Explanations are given in the text.

Two groups of permanent sextupole magnets, delivered by Vacuumschmelze [4], have been installed. The excellent properties of the magnets are described in ref. [5]. Numerical calculations, performed with the computer code MAFIA, are in perfect agreement with the results of the measurements (see Table 1). The upper group (label 3), containing three magnets, separates the neutral atoms according to their electron-spin orientation. Only the atoms in the hyperfine states 1 and 2 for H and 1, 2, and 3 for D (labeling as in ref. [6]) are focused into the "medium-field" rf transition unit (label 5), described, e.g., in ref. [7]. There the transition from state 2 to 3 in H or from state 3 to 4 in D can be induced. The H atoms in state 3 or the D atoms in state 4 are then defocused by the lower group of magnets (label 6), whereas H atoms in state 1 or D atoms in states 1 and 2 are focused into the feeding tube of the cell. The lower weak- and strong-field rf transition unit (label 7) allows additional hyperfine transitions to inject atoms with the wanted nuclear polarization into the storage cell (label 8). The obtained absolute beam intensity as a function of the nozzle temperature is shown in Fig.3. The maximum of about $(6.9 \pm 0.3) \cdot 10^{16}$ H atoms per second is achieved at nozzle temperature around 72 K, primary H_2 flow of 1 mbar·l/s, O_2 admixture of 0.1% and dissociator power of 300 W. The measured slope above the measured maximum is reproduced well by the results of trajectory calculations [8]. The discrepancy at lower temperatures may be explained by increasing intra-beam and rest-gas scattering, which is not taken into account by the simulations. The present results are compared with the maximum intensities given for the

Table 1. Length (ℓ), inner and outer radii (r_1 and r_2) and pole-tip fields of the six sextupole magnets.

	Dimensions			Pole-tip fields	
Magnet	ℓ [mm]	r_1 [mm]	r_2 [mm]	B_{MAFIA} [T]	$B_{measured}$ [T]
1	40	5/7[a]	20	1.633	1.630
2	65	8/11[a]	32.5	1.641	1.689
3	70	14	47	1.642	1.628
4	38	15	47	1.564	1.583
5	55	15	47	1.605	1.607
6	55	15	47	1.605	1.611

[a] - Conical opening, the first value denotes the radius at the entrance, the second gives the radius of the exit aperture.

sources operated at HERMES (DESY) [9], PINTEX (IUCF) [10], and the polarized ion source of the tandem accelerator in Munich, Germany [11].

At present only the medium-field rf transition unit has been installed. Its efficiency has been measured with the compression-tube set-up. With the H beam states 1 and 2 are equally populated behind the upper group of magnets. If an intensity I_0 is measured with the high frequency switched off, $I_0/2$ would be observed with the high frequency switched on for 100% efficient transition from state 2 to state 3, since the atoms in state 3 are defocused by the lower group of magnets and do not enter the compression tube. Preliminary results show that the efficiency of the medium-field rf transition unit is 0.90±0.05, which corresponds to a polarization larger than 85%.

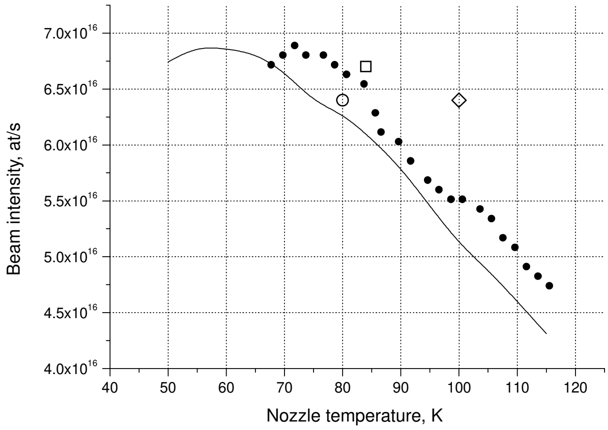

Figure 3. Absolute beam intensity as a function of the nozzle temperature. or the comparison, data from HERMES (◇), PINTEX (□) and Munich ion source (○), and are shown. Solid line gives the results of simulations [8].

This result is confirmed by measurements with the recently installed Lamb-shift polarimeter (LSP), which yields the polarization of the H beam behind the second group of magnets to be $|P| = 0.89 \pm 0.01$. The polarimeter has been designed, built, and tested at the Institute for Nuclear Physics of the University of Cologne [12]. At present its commissioning is completed and it is used for the studies of the ABS beam and for fine-tuning of the transition units. Later it will serve for investigations of the nuclear polarization of the gas in the storage cell. Figure 4. shows a photo of the ABS and the LSP in the laboratory test position. The construction of the LSP necessitates a horizontal position. Thus a 90° electrostatic spherical deflector was installed between the vertical ionizer and the subsequent components of the LSP (Wien filter, Cs cell for charge exchange and creation of excited atoms in the metastable 2s state, spin filter as the heart of the set-up to select the atoms in the different nuclear spin states +1/2 and -1/2 for H, +1, 0, and -1 for D), and finally at the lower left end the quenching chamber with the photomultiplier to measure the light from the Lyman-α transitions).

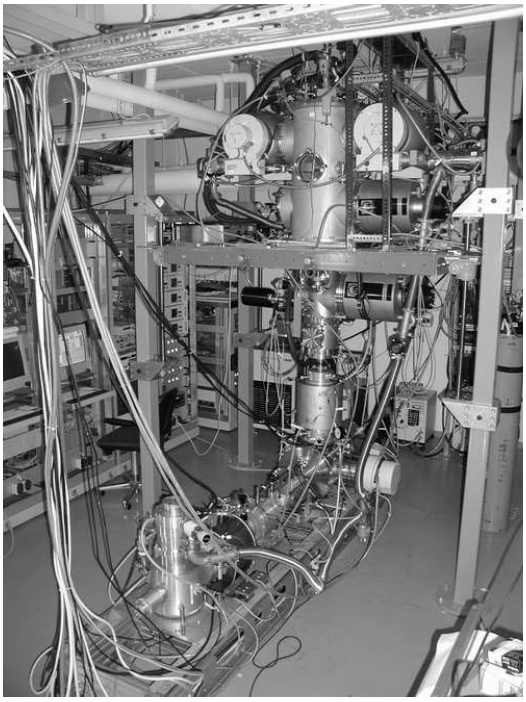

Figure 4. Atomic beam source (top) and Lamb-shift polarimeter (bottom).

Since the future experiments (e.g. p-d breakup [13]) with ANKE require the use of the storage cell, it is important to study the properties of COSY beam in order to define the dimensions of the storage cell. Such studies have been started with use of rectangular and elliptical diaphragms of 10 mm $\times$ 30 mm (vertical and horizontal size, respectively) placed at the ANKE-target position. The first results demonstrate that $9.6 \cdot 10^9$ protons could be stored in COSY with the diaphragm installed compared to a slightly higher number of $1.2 \cdot 10^{10}$ without it. However, in order to reduce the appreciable beam losses in the bent section due to vertical steering with the present installations, additional vertical beam steerers and beam-position monitors and near the ANKE target position are needed.

A new large target chamber (length 800 mm, width 600 mm and height 400 mm) is under construction. It will allow to extend the beam studies with storage cell prototypes. It also will house new beam-position monitors, a set of silicon vertex detectors and other necessary equipment.

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