THE PFEIFFER SOURCE FOR POLARIZED PROTONS AND DEUTERONS
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Polarized protons and deuterons are produced using the atomic beam method with an ECR-ionizer in a vertically mounted source. It will be used at the Svedberg Laboratory in Uppsala together with the \( k = 200 \)–cyclotron and the Celsius storage ring; an injection energy up to 20 keV is provided.

The atomic beam emerges from a 27 MHz driven rf-dissociator (following the design of Jaccard\(^1\)), cooled in a sapphire nozzle to 20 – 100 K. The cryogenic temperature is produced by a regulated two-stage helium compressor. Nitrogen is fed-in near the nozzle as advocated by Schmelzbach\(^2\).

Two short multipole magnets are mounted in an optimized distance to give a maximum concentration of the focused components. Two rf-transition units are mounted between the multipole magnets (position A and B), one behind the second one (position C). The second magnet acts as a spin separator, deflecting out the spin-flipped component. Thus it produces one (pure) hyperfine component in the ionizer region with the disadvantage of a smaller intensity. However, the shorter distance between second magnet and ionizer compensates this; the intensity should be — according to computer simulations — similar as for the common geometry.

The used RF–transitions are shown in the following table:

<table>
<thead>
<tr>
<th>Position</th>
<th>Transition</th>
<th>Frequency (MHz)</th>
<th>B-field (Gauss)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2 → 3</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>C</td>
<td>1 → 3</td>
<td>30</td>
<td>22</td>
</tr>
<tr>
<td>A</td>
<td>3 → 5</td>
<td>330</td>
<td>85</td>
</tr>
<tr>
<td>B</td>
<td>2 → 6</td>
<td>460</td>
<td>85</td>
</tr>
<tr>
<td>C</td>
<td>1 → 4</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>A</td>
<td>1 → 4</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
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<td>85</td>
</tr>
</tbody>
</table>

The hydrogen (2 → 3)–transition is the socalled intermediate field transition used successfully for sodium\(^3\). In the above arrangement, different transitions are required in positions A and C. A sliding mechanism allows to interchange the rf–coils, using the same B–field magnet.

The design of the atomic beam system has been optimized by computer simulation using the velocity distribution measured by Grüebler\(^4\) and Kubischta\(^5\), i.e. with 1000 m/s as the most probable velocity (for a throughput of 0.5 mbar·l/s) and a width of 400 m/s (FWHM). The transmission was calculated for 5000 to 10000 individual trajectories and weighted with the velocity to estimate the density distribution in the ionizer region. Also a ring-shaped cross section for the accommodator was simulated; it gives a larger number of acceptable trajectories compared with the normally used conical nozzle with 3 mm exit diameter. All calculations were made without assumptions on gas scattering; a final decision will be made after tests.

A special turbo molecular pump has been designed, manufactured and tested, well suited especially for atomic beam applications by superior pumping speed and conductance in the beam region. Four rotors of the Pfeiffer TPH 2200 are integrated in one housing located around a 25 cm bore between the
rotor/stator packs of each pump. The pump is running very smoothly, and a pressure of $2 \cdot 10^{-4}$ mbar can be maintained in the first stage under a 1 mbar-l/s hydrogen gas load. The inner walls are forming a differentially pumped system, stepping down to the expected $10^{-7}$ mbar at the ionizer entrance.

Multipole magnets, vacuum separations and rf-transitions can be assembled and tested before installation in the integrated pump. The multipole magnets are constructed in a conventional way with high-$\mu$-iron pole pieces. Parallel pole shoes have been used, because calculations gave only little (few percent) advantage over conical shapes.

The ECR ionizer uses $2.5 \text{GHz}$ microwaves to initiate a plasma discharge in a minimum B-field configuration; the longitudinal field is produced by pancake coils, the radial field by CoSm-magnets in sixpole configuration. Microwave power is fed in through a standard $2.5 \text{GHz}$ wave guide into a copper cavity located outside the vacuum system and isolated from the ground part of the wave guide. Also both flux return steel plates are isolated to provide the necessary plasma potential. The discharge chamber is a 6 cm diameter quartz tube, the metal parts facing the discharge are covered by quartz. The extraction opening is kept large in order to obtain sufficient pumping in the discharge region. The necessary buffer gas is fed in through the supporting structure of the extraction system, containing a three element lens system. The positive beam is focussed and magnetically deflected $90^\circ$.

In conclusion the essentials of the Pfeiffer source are summarized:

a. Specially designed integrated turbo molecular pump, highest pumping speed and conductance, atomic beam system mounted inside pump.

b. Atomic beam from a $30 \text{K}$ accommodator fabricated from sapphire, two short multipole magnets with optimum matching.

c. Separation of one (pure) hyperfine component by using the $(2 \rightarrow 3)$-transition, the second multipole magnet acts as a spin-separator.

d. Ionization in a $2.5 \text{GHz}$ ECR plasma.

The expected yields (guaranteed values) are:

- Ion current $(p^+,d^+): 100 \mu\text{A} (90\% \text{ within } 600 \text{mm} \cdot \text{mrad} \text{ at } 10 \text{keV})$
- Polarization: $75\%(p^+), 85\%(d^+)$ of the theoretical maximum.

References:

5. J. C. Berney et al., ref.2 (1986) p.578