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POLARIZED H^- SOURCES FOR THE AGS -- PRESENT AND FUTURE*

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ABSTRACT

The AGS polarized H^- source presently produces 30-40 μA of $\vec{H}^-$ in 500 μs pulses, with a polarization of 70-75%. The source operates reliably and has been used for polarized physics runs the past two years. There is now a development program in progress which has as its goal an operational $\vec{H}^-$ source producing milliamperes of current for the AGS.

1. Introduction

In the AGS polarized H^- source, hydrogen atoms are polarized in a ground-state atomic beam source and then ionized via the reaction [1]:

$$Cs^\circ + \vec{H}^\circ \rightarrow Cs^+ + \vec{H}^-.$$

Both the $\vec{H}^\circ$ beam and the Cs° beam are pulsed. The source has operated with repetition rates from 0.3 to 1.7 Hz and a pulse width of approximately 500 μs. Since the previous workshop, where currents of 7.5 μA were reported [2], extensive modifications have been made to improve the intensity and reliability of the source. Presently, the source output, measured approximately 250 cm from the exit of the source, is in the 30-40 μA range.

The atomic beam stage, $\vec{H}^\circ/Cs^\circ$ interaction region, and extraction stage were built by ANAC, Inc., with dissociator nozzle cooling added at Argonne National Laboratory. Subsequent modifications to improve the intensity were performed at BNL. The neutral cesium source was built at BNL, as well as the power supply and computer control systems. A description of the source, as well as some details of our operating experience, will be given. In addition, our program to develop a source delivering mA's of $\vec{H}^-$ will be briefly mentioned.

2. Features of the Polarized Source

Figure 1 shows schematically the present source. High purity hydrogen is dissociated in a 20 MHz rf discharge. The gas and rf power are pulsed [3]. The dissociator nozzle (3 mm I.D.) is cooled by a closed cycle helium refrigerator to lower the velocity of the emerging H° beam. Although nozzle temperatures as low as 30 K can be attained, the optimum $\vec{H}^-$ output is at a temperature of 90 K, which is close to the temperature for minimum recombination of H° on Pyrex [4]. The

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atomic beam then passes through a 6.6 mm diameter skimmer and four 10 cm long sextupoles. The distance from the nozzle to the skimmer can be optimized while running via a motor drive on the dissociator assembly housing (the optimum spacing is typically 4 cm). In addition, the alignment of the dissociator can be optimized while running via transverse motion of this housing. The atomic beam then passes through two rf transition units, pulsed on alternate beam pulses to reverse the nuclear polarization direction on a pulse-to-pulse basis. The beam finally enters the strong field ionization region.

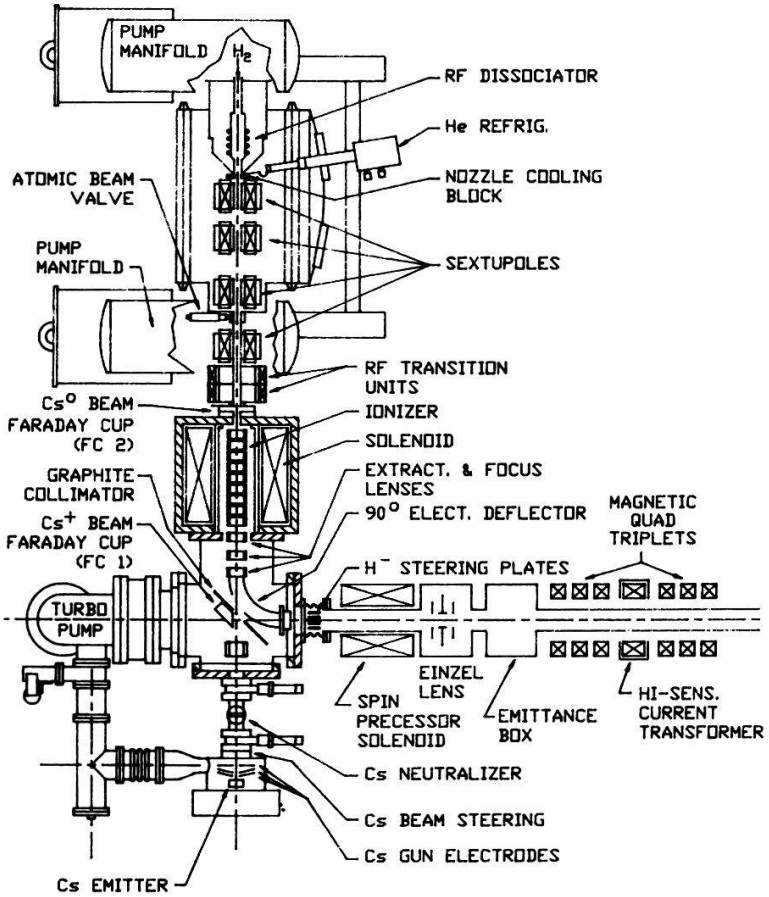

Figure 1 - Layout of the AGS polarized H^- source.

At the opposite end, a 40-50 keV Cs° beam is produced as shown in Figure 2. A Cs^+ beam is produced by surface ionization of Cs vapor on hot (approximately 1000°C) porous tungsten. Between pulses, this ionizer is held more negative in voltage than the intermediate electrode, preventing ion emission and causing an accumulation of Cs on the surface. When the ionizer voltage is then pulsed positive, one gets a Cs^+ beam, which falls off in intensity as the surface coverage is depleted. Although operating in this manner limits the pulse width,

it is usually reasonably flat over the 500 μs required by the AGS. What one gains by pulsing are improved reliability of the rest of the system, and extremely low Cs consumption compared to d.c. operation. The intermediate electrode is biased negative to prevent backstreaming of electrons, which would erode the ionizer and which would also prevent the space charge neutralization of the Cs^+ beam required for good beam optics. The extraction gap can be changed while the source is operating to optimize the Cs optics. In addition, the entire Cs source is easily steered mechanically to optimize the Cs° beam reaching the interaction region.

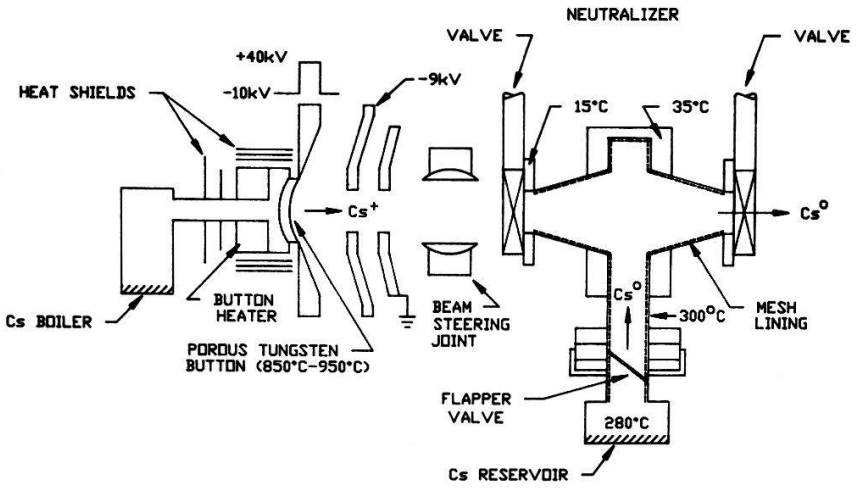

Figure 2 - Detail of the cesium source and Cs vapor neutralizer.

The cesium ion beam is neutralized by charge exchange in Cs vapor. The Cs vapor neutralizer is made from a laminate of stainless steel mesh, diffusion bonded onto stainless steel plate. This provides a wicking action to improve the recirculation of Cs. Loss of Cs out the ends of the neutralizer is kept small by cooling the end flanges. In addition, the Cs vapor is pulsed by a magnetically driven flapper valve between the Cs reservoir and the main neutralizer channel. The neutralization efficiency is greater than 80%.

The interaction region, where the Cs° and the H^+° beams overlap producing H^-, is 35 cm long. The axial magnetic field in this region is typically 500 G, this being a compromise since one gets both higher polarization and larger beam emittance as this field is increased. The voltage of the electrodes in the interaction region is -20 keV, with an additional 70 V bias over the 35 cm length to accelerate H^- ions produced at any point toward the extraction end. The H^- ions are then focused as they are accelerated to ground potential and deflected 90° into the transport line by spherical electrostatic plates.

The 20 keV $\vec{H}^-$ beam is transported 400 cm to an RFQ, which accelerates the beam to 760 keV. Following this, the beam goes through two 60° bending magnets and into the 200 MeV Linac, and is finally injected into the AGS.

3. Performance

The source output is now 30-40 μA, with an average polarization of 70-75%. The normalized emittance is 0.02 π cm-mrad. Approximately 75% of the beam is transported through the RFQ, and the intensity at 200 MeV is typically 50% of the source current. The reliability of the source has been very good. All power supplies are computer interfaced, giving reproducible operation without having to retune each time the source is turned on.

The source normally operates unattended during AGS physics runs, with someone on call should a problem arise. The atomic beam stage operates for months between maintenance periods (cleaning of the dissociator bottle). The Cs neutralizer operated for over a year (not continuous) without having to be cleaned or reloaded with Cs. The only routine maintenance when operating continuously for the AGS has been the changing of the porous tungsten Cs ionizer at about two-week intervals. The Cs intensity drops over this time to about 2/3 of its original value, caused, we believe, by a slow contamination of the ionizer which changes the work function of the surface, as well as a reduction in the porosity of the ionizer. One is much more sensitive to surface conditions in pulsed operation than when operating the Cs beam steady state. It takes six to eight hours to cool down, change, and reheat an ionizer and be operational again, although the actual replacement of the ionizer assembly (time during which the system is not under vacuum) takes only a few minutes.

Within the past year, several modifications provided significant gains in intensity. A gain of approximately 50% was realized by replacing the first sextupole magnet, having a 10 mm diameter aperture, with one having an aperture tapered from 8 mm at the entrance to 12 mm at the exit (10 cm long). In addition, the skimmer aperture had to be increased from 4 mm to 6.6 mm to realize the full gain from the taper. In a second area, previously the rf transitions and the final (compressor) sextupole were outside the vacuum, with the atomic beam traveling through a 15 mm diameter, 25 cm long tube. We suspected that atomic beam intensity was being lost due to gas scattering in this tube. In order to improve the pressure in this region, both transition cavities and accompanying magnets, as well as the compressor sextupole, were redesigned and placed in a vacuum box, pumped by a small turbomolecular pump. This resulted again in an approximately 50% gain in intensity. We now estimate that when we measure 40 μA of $\vec{H}^-$, the Cs° current through the interaction region is 5 particle-mA, and the $\vec{H}^\circ$ density in the interaction region is 3×10^{11} cm^{-3}.

4. High Current $\vec{H}^-$ Source Development

If one could produce tens of milliamperes of polarized H^-, one would open new possibilities for polarized physics experiments, as well as allowing the AGS to run a normal physics program in parallel with polarized experiments. A program to develop a higher current polarized source is presently in progress at BNL. This source will incorporate three separate improvements. The H° density in the ionization region will be increased by cooling the atomic beam to 6 K [5]. The spin selection will be done using a superconducting solenoid rather than a sextupole. This should improve the focusing of the atomic beam into the ionizer [6]. Finally, the ionization efficiency will be improved through the use of D^- charge exchange with $\vec{H}^\circ$ in a ring magnetron [7]. In addition, the short length of this ionizer will allow one to focus more of the $\vec{H}^\circ$ beam into the ionizer (larger acceptance). Experiments on the cooling of the atomic beam and ionization in a ring magnetron have given very encouraging results. The solenoid should be tested this summer.

5. References

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Secretary's report, Session (C), T.B. Clegg:

T. Clegg : What is the source pulse rate?
Answer PONY 1 pulses are ∿500 μs at ∿2 sec intervals.

J. Arvieux : Why do you not pulse your source for a broader time interval?
Answer We would not gain. We are already limited by the cesium coverage of the porous plug cesium ionizer.

W. Haeberli : In your source you use 2 sextupoles. Is this really optimum? Is your result a confirmation of calculations?
Answer (Schmelzbach): The cooled beam calculations always show a need for 2 sextupoles with a large drift space in between. The fast atoms are roughly parallel to axis between sextupoles. The slow atoms cross over axis between sextupoles.

R. Viennet : Do you pulse the gas?
Answer Yes; the gas flow is on and stable when the rf turns on. When the gas is off, there is a much slower time recovery to the base vacuum.