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THE AGS POLARIZED H^- SOURCE*

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Introduction

The AGS polarized H^- source is now operational. During a month-long experimental physics run in July 1984, pulses equivalent to 15 μA x 300 μs (~3 x 10^{10} protons) were injected into the RFQ preaccelerator. Beam polarization, measured at 200 MeV, was ~75%. After the run, a program to increase the H^- yield of the source was begun and significant progress has been made. The H^- current is now frequently 20-30 μA.

A description of the source and some details of our operating experience are given in the following sections. We also briefly describe the improvement program.

Description

A layout of the source is shown in Fig. 1. Its design is based on W. Haeberli's prototype at the University of Wisconsin.[1] Oppositely directed beams of thermal proton-polarized H° and 40-50 keV Cs° collide and H^- is produced in the charge exchange reaction:

$$Cs^\circ + H^\circ \rightarrow Cs^+ + H^-$$

Both beams are pulsed at repetition rates of from ~ 0.3-1.4 Hz.

The hydrogen source, ionizer, and 90° deflector were built by ANAC, Inc. Some modifications were made to increase the H^- output and improve the operational reliability.

Hydrogen Source

Hydrogen with a purity of 99.9995% is dissociated in an rf discharge (~20 MHz and 100 W) (Fig. 2). Both the gas and rf power are pulsed.[2] The nozzle of the dissociator bottle is cooled by a closed-cycle He refrigerator, providing cooling of the emerging H° beam.[3]

Four 10 cm long sextupole magnets focus the m_J = 1/2 component (Fig. 3) of the ground state atoms into the ionizer while defocussing the m_J= -1/2 component. The electron polarization of the beam emerging from the last sextupole magnet is converted to nuclear polarization by the "adiabatic passage" method,[4] involving rf induced transitions between states 1 and 3 or 2 and 4. Alternately driving these transitions modulates the beam polarization on a pulse-to-pulse basis.

Cesium Gun and Neutralizer

A cesium gun, Fig. 4, and pulsed power supply were designed and built at BNL. Cesium from the boiler flows through the hot porous tungsten button and is ionized at the surface. Between pulses, the button is held at -10 kV to suppress Cs^+ emission. Cesium builds up on the surface and is extracted during the next pulse. A constant surface coverage of the button is never realized in pulsed operation and the characteristics of the extracted pulse are not totally predictable. However, the pulse is reproducible over long periods of time once an equilibrium set of parameters has been reached. A detailed treatment of the gun has been given elsewhere.[5]

During the AGS polarized physics run, the tungsten button was replaced approximately every two weeks. After about a week of running, the intermediate electrode had to be wiped clean of a fine layer of cesium. The "down time" for either procedure is about six hours.

The cesium ion beam is neutralized by resonant charge exchange with a cesium vapor target (Fig. 3). The walls of the neutralizer were fabricated from a laminate of stainless steel mesh, diffusion bonded on stainless steel plating.[6] Its wicking action improved cesium recirculation. Cesium loss from the neutralizer was minimized by pulsing the vapor (using a magnetically driven flapper valve), keeping the Cs° beam entrance and exit apertures as small as possible, and cooling the end flanges.

The efficiency of the neutralizer is about 80%.

Ionizer and 90° Electrostatic Deflector

Ionization takes place in a region about 35 cm long and 1.5 cm diameter. An axial magnetic field of $\gtrsim$ 500 G preserves the polarization during ionization. The maximum polarization at this field is 85%.

The electrodes are at -20 kV with an additional voltage to produce a weak field of ~1.5 V/cm, which guides the H^- ions to one end of the ionizer. The ions are accelerated to 20 keV and focused into the spherical deflector by the cylindrical lenses shown.

At the exit of the deflector, the ions have transverse horizontal polarization (left-right modulation). A solenoid spin precessor rotates the spins into the vertical (up-down modulation).

Diagnostics

Faraday cups FC1 and FC2 monitor the Cs^+ and Cs° beams. FC1 measures Cs^+ after it is deflected off axis by deflecting plates, and FC2 monitors Cs° or Cs^+ by their secondary emission electron currents.

The H° beam intensity is monitored by measuring the ratio of the extracted H^- current to the Cs° current through the ionizer (FC2). The H^- current is measured by a very sensitive current transformer in the 20 keV beam line. A typical H^- pulse is shown in Fig. 5. The duration of the Linac rf pulse is 500 μs.

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Instrumentation

The use of computer controlled equipment has played a major role in the reliable operation of the source. Almost all power supplies and all pulsed equipment are under comptuer control. Therefore, once the source is tuned, the operating parameters are easily reproduced.

The Improvement Program

An improvement program was begun after the first physics run, to increase the H^- current from the source.

A gain of ~ 60% was realized by replacing the first sextupole magnet, which had a 10 mm diameter aperture, with a magnet whose aperture tapered uniformly from 8 mm diameter to 12 mm at the entrance and exist respectively, and by replacing the 4 mm diameter skimmer with one 6.6 mm in diameter, positioned so that it coincided with the geometrical acceptance solid angle of the magnet.

The fourth sextupole magnet and the rf transition units (cavities and magnets) are now housed in a vacuum box in order to eliminate a 25 cm long by 15 mm diameter tube. Gas scattering in this tube was believed to be reducing the H° beam flux. An additional gain of ~ 60% was obtained by this modification.

Pulses equivalent to ~ 5×10^{10} protons--28 μA peak and 500 μs (FWHM)--are now obtained from the source. We are expecting even higher intensities, because the present intensity of the neutral cesium beam is lower by ~ 40% from its value during the physics run, due to low emission from the tungsten button.

We have discovered that by grinding the outer surface of the Pyrex dissociator nozzle so that it fit better in the cooling block, leaving the surface matt after grinding, has resulted in more efficient cooling of the beam. Using the conventional nozzle, we observed that the H° beam intensity increased down to the minimum cooling block temperature of ~ 30 K. With a similar setup, Schultz[3] found that the velocity of the cooled beam was equivalent to only ~ 110 K.[7] With the ground nozzle, the H° intensity peaks at ~ 90 K, in agreement with the known temperature dependence of the recombination coefficient of H° on pyrex.[8]

Work is continuing on the improvement of the cesium beam pulse width and intensity of the cesium beam pulse. We are studying the performance of alternative tungsten surface ionizer designs, as well as alumino-silicate Cs ion emitters.[9]

Acknowledgments

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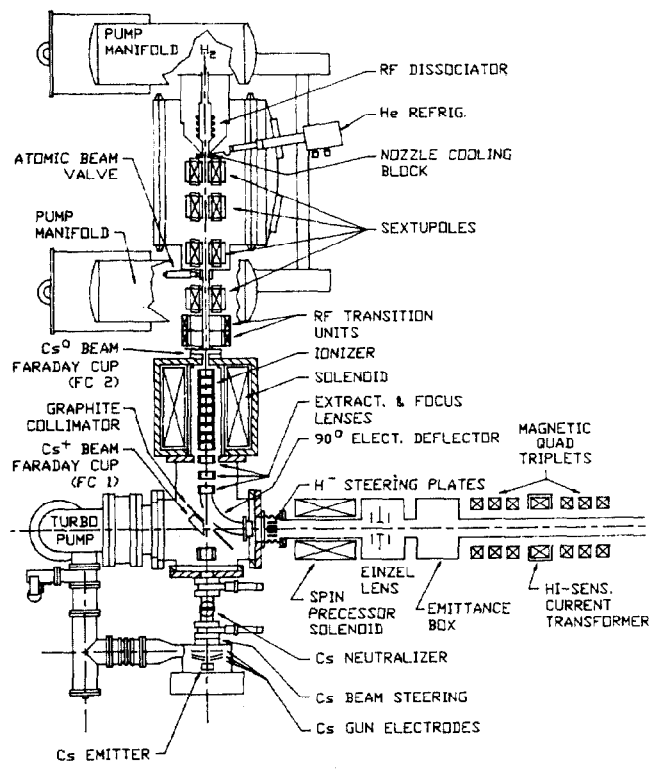

Fig. 1 - Layout of the AGS polarized H^- source.

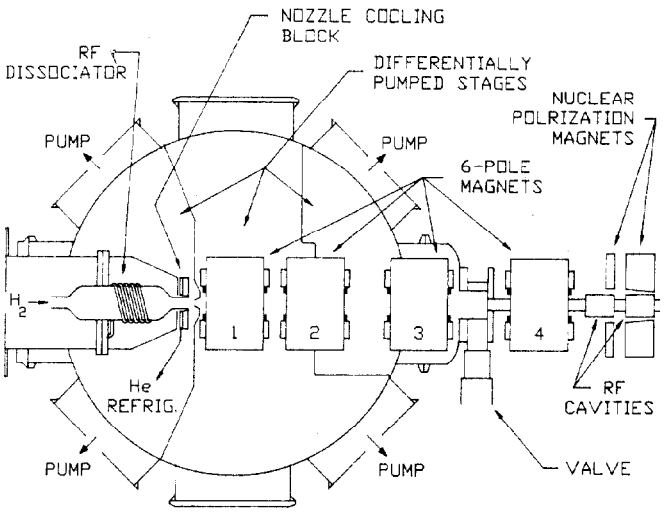

Fig. 2 - Detail of the hydrogen source.

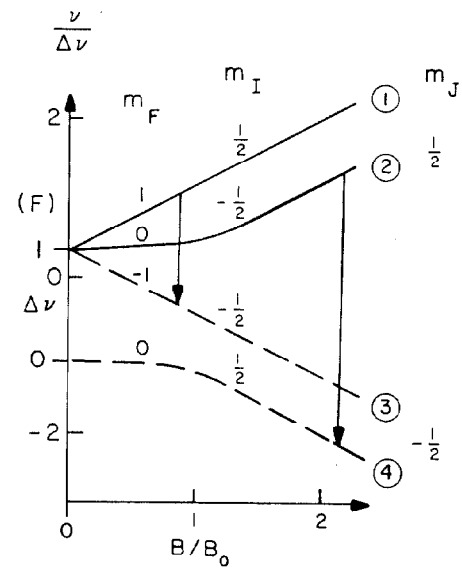

Fig. 3 - Breit-Rabi diagram for the ground state of the hydrogen atom. $\Delta\nu$ = 1.42 GHz and B_0 = 507 G.

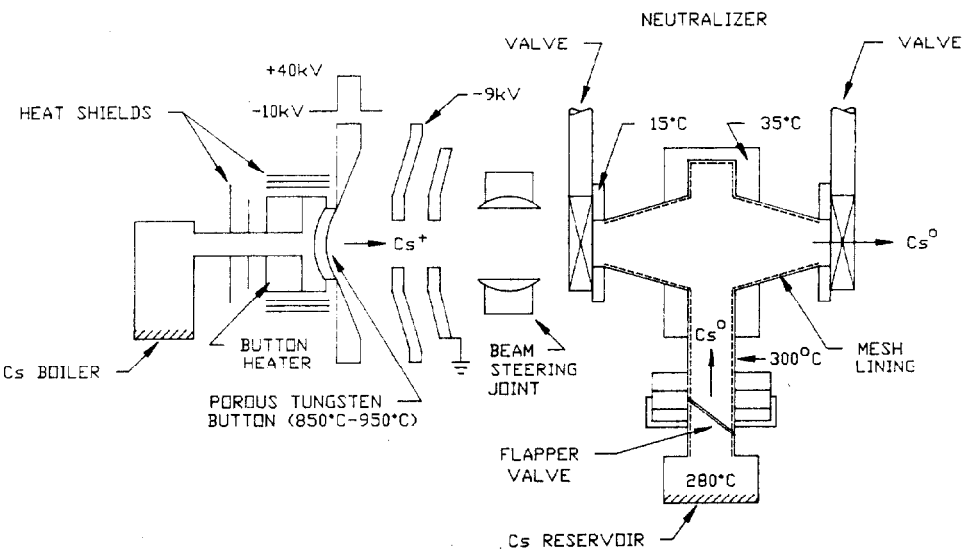

Fig. 4 - Detail of the cesium gun and neutralizer. The ball joint is for mechanically steering the beam.

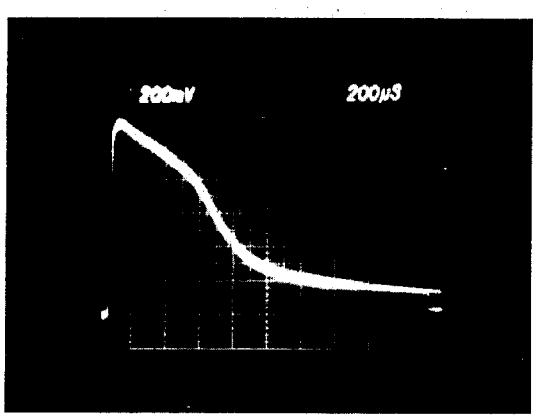

Fig. 5 - A polarized H^- pulse at 20 keV. The calibration is 20 μA/V. The duration of the 200 MeV Linac rf pulse is 500 μs.