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THE LAMPF POLARIZED ION FACILITY: STATUS REPORT*

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Abstract

The current status of the LAMPF Lamb-shift polarized ion facility will be described. The 750-kV Cockcroft-Walton injector is now installed and work is proceeding on the ion source system. Engineering details will be described along with an estimated operation date. Improvements in two polarized ion sources now operating at the Los Alamos Scientific Laboratory are being incorporated into this source and include recent modifications to the argon charge-changing region. The status of rapid spin-reversal techniques will be reviewed.

Introduction

The polarized ion facility is the third ion source to be incorporated into the injector complex on the LAMPF 800 MeV accelerator. A diagram of this area is shown in Fig. 1. The present requirements for simultaneous operation of the two existing on-line injectors and the desire for maximum flexibility in beam usage has necessitated construction of a third injector. This injector has been positioned so that it will be able to deliver beam to either the H^+ or the H^- beam lines. Initially, H^- polarized beams will be run simultaneously with the high intensity H^+ beam. Future operation will require a H^+ polarized beam if the high intensity H^- source under development is installed.

The Lamb-shift type of source was chosen for the present usage because it produces an H^- beam having both higher intensity and lower emittance than does a ground-state source which uses a charge-changing canal to transform its H^+ ions into H^- ions. The design is patterned after the two existing Lamb-shift sources[1, 2, 3] that have been in operation for some time with the 16 MV Tandem Van de Graaff in the Physics Division of LASL. One generates H^- & D^- beams while the more recent source generates T^- beams.

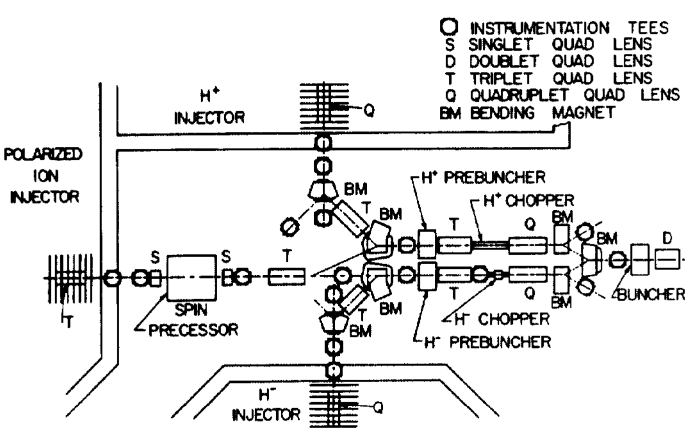

Fig. 1. Layout of the Injector Complex at LAMPF.

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The new LAMPF source was engineered in a modular arrangement so that maintenance and modifications may be easily effected. Figure 2 illustrates the source arrangement. The general design objectives for this polarized source are summarized in Table I.

TABLE I

Lamb-Shift Polarized Ion Source Design Objectives

Beams	H^+ or H^-
Beam Emittance	0.02 cm-mrad normalized
Peak Current	0.5 μA
Duty Factor	6% (12% in future)
Average Current	30 nA (60 nA at 12% duty factor)
Expected Linac Current	20 nA (40 nA at 12% duty factor)
Polarization	> 85%
Spin Selection System	Nuclear spin filter
Spin State	$m_I = +1/2$, $m_J = +1/2$
Spin Reversal Systems	1) B field reversal in spin filter and argon cell for slow spin reversal. 2) Resonant passage system for fast spin reversal.
Spin Precessor System	Crossed B and E field Wien filter on 750 kV beam transport line.

Initial operation of this polarized ion facility is expected in April of this year.

Design Considerations

Installations

The Lamb-shift source is housed in a large equipment dome, 3.2 m x 3.6 m x 3.0 m high, and is powered by a 750-kV Cockcroft-Walton generator of 2 mA capacity made by Haefely. Electrical power in the dome is supplied by a 25-kVA generator driven by a motor at ground potential. The ion source components are mounted on ball bushings operating on a pair of rods 3.81 cm in diameter. The 246-cm-long track is long enough to permit the individual modules of the source to be separated at any joint and rolled apart for access. The five electronics racks in the dome are mounted on casters so they may be rolled out of the way. Cables to each rack extend from overhead trays through service loops long enough for free rack movement.

As in the other injectors, information for control and data readout is passed across the 750-keV gap by infrared LED light links. The LED-optics system has been redesigned and the bandwidth extended to 1 MHz so closed-loop control using voltage-to-frequency conversion may

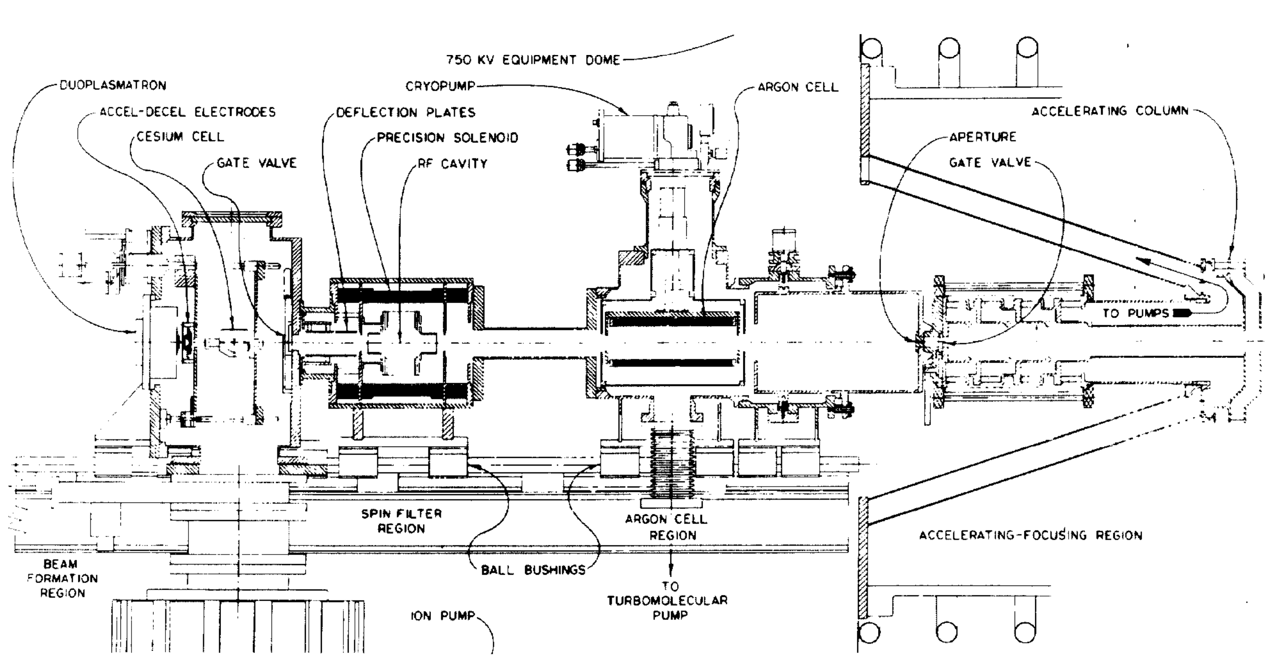

Fig. 2. Lamb-Shift Polarized Ion Source for LAMPF.

be used in the fast spin reversal experiments.

A 1200-ℓ/s ion pump is located below the duoplasmatron on the vacuum tank for pumping hydrogen. Argon is pumped with a cryogenic system. A 200-ℓ/s turbopump is used for scavenging and for pumping of the hydrogen that escaped into the cryopumped region.

Ion Source Design

As already indicated, the LAMPF Lamb-shift source has incorporated many features of the other two sources at LASL. The H^- & D^- source now reliably delivers 400-nA of 100 keV ions at 85% polarization into a beam cup located in the middle of the precession magnet. The same type of duoplasmatron and accel-decel extraction system as was developed on the H^- & D^- source is being used at LAMPF since it is known that it is capable of forming a well directed 500 eV beam necessary for successful operation. Provision has also been made for future use of the same duoplasmatron used on the other LAMPF injectors as they were designed specifically for pulsed operation and may provide a more intense beam.

The 500 eV H^+ beam is converted into a H(2S) metastable beam by passing it through a cell 1.0 cm in diameter by 15 cm long containing cesium vapor at about 100°C. This cell is a variation on the design of the one used on the polarized-triton source. The ends of the cell are cooled to condense the cesium vapor and the cesium loss out the ends is extremely low. The cell has a stainless-steel gauze swaged onto the interior of a stainless-steel tube and the wicking action of the gauze recirculates the liquid cesium condensed at the ends back to the center where it is revaporized. The cesium cell in the polarized-triton source has operated for more than six months without requiring recharge.

A duplicate of the spin filter in use on the triton source has been installed. This is a much shorter version of the original unit still in use on the H^- & D^- source. At the exit of the spin filter, which has a precision axial magnetic field, the beam is longitudinally polarized. If slow reversal of the spin is adequate, (5s), then the magnetic fields of the spin filter and argon cell can be reversed. An automatic sequencing circuit to perform this reversal has been installed as this is the preferred method of spin reversal. Space for fast reversal between the spin filter and argon cell has been provided, however. This will be discussed shortly.

The polarized-metastable beam, along with an intense unpolarized beam in the ground state, next passes into the second charge-changing cell. We will be using argon for the production of H^- ions as it has high selectivity against making H^- ions out of the ground-state atoms. For H^+ polarized ions, iodine vapor[4] has been shown to give about the same intensity beam in the H^- & D^- source on the tandem. At about one half at this intensity, a beam of greater than 98% polarization was produced with iodine. In either case cryogenic pumping will be used. For argon, 20-K-pumping surfaces at the entrance and exit of the argon cell have been provided. The argon cell, along with the field windings and magnetic shield, will be maintained at 100 K and will provide radiation shielding for the 20-K surfaces. Cryogenic cooling is provided at both 20 K and 80 K by a 10-watt two-stage helium-cycle refrigerator. The refrigerator will operate from a helium compressor installed at ground potential and the helium will be circulated to the equipment dome through insulating lines located within its legs.

The polarized H^- beam from the argon cell is accelerated and focused by lenses and passed into the 750 kV accelerating tube. At ground potential the spin orientation can be precessed to any required angle by a Wien filter or crossed-field analyzer. The unit being constructed is quite similar to the one used with the H^- & D^- source. At 750 keV, a 1.5-kG dipole magnet, 0.97 m long, accompanied by a 21-kV/cm-electric field to keep the trajectory straight, will precess the spin of the H^- ions by 180°. This precessor, together with the magnetic-quadrupole-singlet lens at each end, can be rotated about the beam axis. The quadrupole triplet in the column-exit cone causes the beam to cross over in the middle of the precessor to minimize its cylindrical-lens properties.

Fast Spin Reversal System

Several experiments at LAMPF will require rapid reversal of spin to minimize background problems. The reversal will occur during the 8-ms period between beam pulses and can be programed into a pseudo-random or periodic sequence. The period of reversal will be chosen so as to not match the period of any existing cyclic fluctuations in the 800 MeV accelerated beam. Tests are presently being made to determine the frequency spectrum of the beam.

Several fast reversal techniques have been considered. One such spin-reversal technique[2] is now being employed in the H^- & D^- source. With the spin-filter axial-magnetic field opposite to that in the argon cell, a zero in the axial field is generated. A weak transverse-magnetic field is rapidly turned on and off about this zero, often at 1000 Hz. When the transverse field is off the metastable atoms pass by the zero without change of spin orientation; however, when the transverse field is on their spins adiabatically follow the field around.

An associated effort is in progress that is using the above reversal system on the H^- & D^- source in attempting to observe parity violation in the scattering of longitudinally-polarized 15-MeV protons in H_2, D_2, and ^4He. This effort has pointed out certain problems and suggests four criteria to use in the design of new fast spin reversal systems. We have found recently that the source can distort the polarization direction across the profile of the beam so that a false forward-to-backward asymmetry is observed; i.e., there is an apparent tensor polarization with protons when none is believed to be present. We have seen that a 1 μA beam of electrons that is gated on and off into the argon cell causes a large false forward-to-backward asymmetry in this experiment. It is believed that the associated magnetic field from the electron beam, when added to the 6-gauss-axial field in the argon cell, causes enough distortion of the polarization profile to cause the effect. A similar distortion of the polarization profile is produced in the neutral beam when it passes through a zero in the longitudinal field. This experience suggests that a successful scheme for rapidly reversing the spin needs to meet the following criteria:

1. Intensity modulation must be kept to a minimum. Metastable atoms are quenched by small fields--0.1 V/cm gives an observable effect when turned on and off. Transverse-magnetic fields also quench the H(2S) beam through the Lorentz force and must have compensating electric fields.

2. The beam should be quite neutral when it comes through the reversal region. This means that the argon pressure must be very low in the reversal region to prevent H^- formation there.

3. The flow of electrons to and from the argon cell must not be gated on and off by the rapid reversal cycle.

4. A large diameter H(2S) neutral beam has its polarization distorted as it passes by a zero in the longitudinal field with the distortion being proportional to the radial distance from the zero. Therefore, a rapid reversal scheme should not have such a zero in either of its phases.

Two promising new methods are under development. In the first, the neutral beam passes out of the longitudinal field of the spin filter into a weak transverse field. The transverse field is reduced to zero somewhat ahead of the argon cell which is run at zero field. We have found that this arrangement will produce a transversely polarized beam with high polarization. Now a weak solenodial field of only 5.4 gauss-cm located between the transverse field and the argon cell can be used to reverse the polarization direction. Such a field should cause no difficulty with the first three criteria and only a small problem with the fourth.

The second technique utilizes the fact that the metastable beam is nonoenergetic[5] within ± 1%. The apparatus consists of a uniform transverse field H_o, as in the previous method, together with an axial rf field of strength H_1 and frequency ω_1. If $\omega_1 = \gamma H_o$ and the length of the field H_1 is chosen such that $\gamma H_1 T = \pi$, then spin reversal is accomplished. T is the time that the metastable beam spends within H_1. The strength of H_o must not be more than a few gauss in order to minimize H(2S) quenching. To meet the above criteria, the following parameters will be tried:

a) DC field (H_o): 5.0 gauss--25 cm long.
b) RF field (H_1): 0.5 gauss @ 14 MHz--12 cm long.

The spin filter and argon-cell-axial-magnetic fields are both operated at normal levels and are oriented with the same polarity when using this method.

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