DEVELOPMENT OF A 0.025-A, 12% DF H^- SOURCE FOR LANSCE

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Abstract

Present operations at the Los Alamos Neutron Science Center (LANSCE) accelerator use a surface conversion source to provide 80-keV, 16 to 18-mA H^- beams with typical lab emittance of 7(πcm-mrad). Operational flexibility of the 800-MeV linac, proton storage ring, and other experimental facilities will be increased by a higher current H^- source. The present goal is to achieve a 25 mA H^- surface converter source with modest (20%) emittance increase without sacrificing the present LANSCE production source 12% duty factor (df) and 28-day lifetime. The LANSCE 80-kV ion source test stand (ISTS) has been brought into reliable 24-hour per day operation with computer control and modern electronics. A fourth production source has been fabricated, and is now operating on the ISTS. H^- currents up to 25 mA have been observed with 8-9 (πcm-mrad) lab emittances. An experimental study of surface converter geometries and electron filters at the emitter electrode are planned to optimize source current and emittance.

INTRODUCTION

The development of a new LANSCE H^- injector is being pursued for two principal reasons. First, the 16-18mA H^- production source presents limits to 800 MeV linac and experimental facilities operations[1]. Forty mA H^- sources previously developed for LANSCE were accompanied by an undesired emittance growth[2,3]. Sources with these larger emittances were studied in the LANSCE 750-keV H^- injector (injector B) with the conclusion that significant changes in the beam line would have to be made to accommodate the larger emittance beams[4]. An intermediate goal of 25 mA H^- source with smaller emittance growth compatible with linac operations has been established. Second, electronics in the present injector B dome are not compatible with planned control system upgrades at LANSCE.

0.025-A H^- SURFACE CONVERTER SOURCE DEVELOPMENT

A fourth version of the LANSCE production source has been fabricated for development purposes on the ISTS. Table 1 contains a summary comparison of the LANSCE production sources, and the best performance configuration to date of the development source. A design criterion is to increase the H^- current without significant increase in discharge power. This accomplishes two objectives: first, the 28-day lifetime should be maintained; and, second, the beam emittance growth with discharge power increase[3] may be minimized. The initial production source modification increased the emission (Pierce) aperture radius, r_P, from 0.5 to 0.6cm, and the repeller radius r_{rep} was increased from 0.64 to 0.86 cm to eliminate aperturing of the 260eV H^- beam. See Fig. 1 for source component description. Assuming a uniform H^- beam illumination of the repeller/Pierce assembly, these steps would give 25-mA H^- current with 20% emittance increase.

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Table 1. Comparison of the LANSCE production and development sources.

	Parameter	Production Source	Development Source
1	r_P (cm)	0.50	0.60
2	r_{rep} (cm)	0.64	0.86
3	r_{cnv} (cm)	1.9	1.9
4	ρ_{cnv} (cm)	12.5	12.5
5	Admit. (cm-mrad)	304	379
6	B_c (kG)	2.0	3.4
7	I_{H^-}, electron repeller	Line cusp	Line cusp
8	Disch. power (kW)	8	7.6
9	$(I_{H^-})_{max}$ (mA)	18	25
10	e/H^-	3.0	5.9
11	ε_l, electron repeller	Line cusp	PM solenoid
12	ε_l (πcm-mrad), meas	7	8-9*

*$(I_{H^-})_{max}$=20mA

One physics constraint on the assumption of uniform H^- current density at the emission aperture is the transverse sputter energy of the H^- ions as they leave the converter surface. This effect has been modeled in the PBGUNS code[5]. For comparison purposes, Fig. 1 shows 260eV H^- ion trajectories from the converter to the

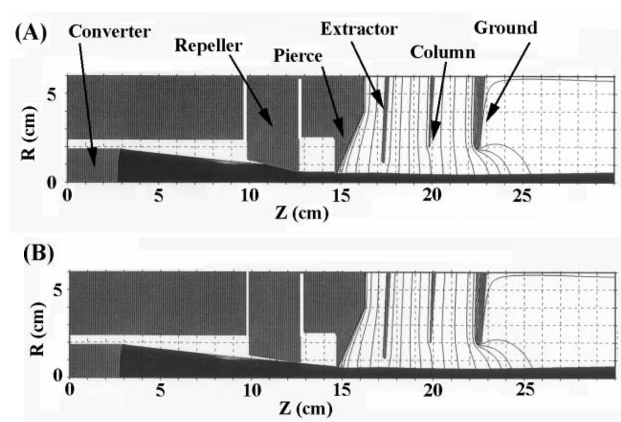

Fig. 1. PBGUNS electrode, trajectory, and equipotential plot for the production source (A) , and the development source (B).

Pierce aperture. Both calculations use a 12eV sputter energy, a converter radius r_{cnv} = 1.9cm, a converter curvature radius ρ_{cnv} =12.5cm, and a H^- converter current I_{H^-cnv} = 18mA. Figure 1(A) shows some 260eV beam interception on the unmodified source, while most of the H^- beam passes through the repeller/Pierce electrode assembly in (B). The converter surface area is calculated by $A_{cnv} = 2\pi\rho_{cnv}(\rho_{cnv}-l)$ = 11.4cm^2 where $l = (\rho_{cnv}^2 - r_{cnv}^2)^{1/2}$.

Figure 2 shows a summary of the PBGUNS simulations for r_{rep} = 0.86cm. The dependence of H^- converter current density ($j_{H^-cnv} = I_{H^-cnv}/A_{cnv}$) for a 12eV sputter energy on beam current (I_{H^-}) accelerated to 80 keV is shown. The parametric linear curves are for r_P = 0.5, 0.55, and 0.60cm. Since I_{H^-cnv} is unknown (a speculation on the true value of this current is made below), the PBGUNS calculations are normalized to the 18mA production source prediction (r_P = 0.5cm). This gives j_{H^-cnv} = 2.4mA/cm^2. This normalization is extended to r_P = 0.55 and 0.60cm by the horizontal line shown in Fig. 2. This normalization condition imposed on the simulations would ensure discharge power is maintained at the level of the LANSCE production source, while giving 25mA I_{H^-}. (see the intersection of the 2.4mA/cm^2 line with the r_P = 0.60cm prediction). Thus, this upgrade to 25mA should not be at the sacrifice of ion source lifetime. The

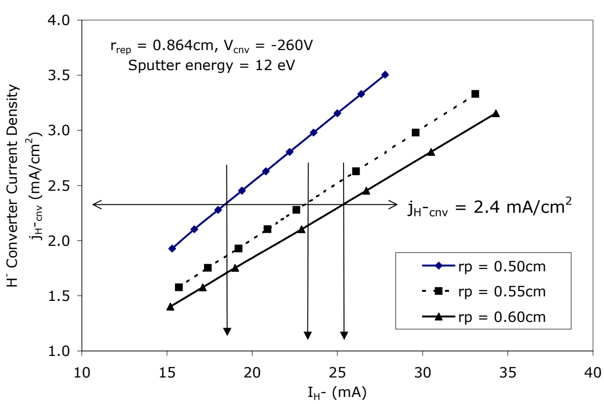

Figure 2. PBGUNS predictions for 80keV H^- current and j_{H^-cnv} at a H^- sputter energy of 12eV.

simulations predict laboratory emittance at 95% beam fraction of ε_l = 7.6 (πcm-mrad) for 18 mA (production source) to ε_l = 9.3 (πcm-mrad) for 25mA (development source), an emittance growth of 1.22. The 1rms normalized emittance (ε_{1rms}) is related to ε_l by $\varepsilon_{1rms} = \beta\varepsilon_l/7$ where β is the relativistic velocity. Emittance growth predicted by comparing the two sources admittance (cf Table 1) is 1.25. If the simulations contained in Fig. 2 are repeated for 6eV sputter energy, then the j_{H^-cnv} normalization decreases to 1.6mA/cm^2. For the 6eV H^- sputter energy, all of the converter current passes through the repeller/Pierce assembly, and the three parametric curves for r_p = 0.50, 0.55, and 0.60cm collapse to a single line in the j_{H^-cnv} vs. I_{H^-} plot.

Several different magnetic repeller fields have been tested. With a line cusp repeller magnet, up to 25 mA H^- current was obtained at the source exit beam current transformer, with 22 mA being delivered to a Faraday cup at the end of the 80 keV LEBT. The e/H^- ratio is 5.9, about double the production source. Figure 3 shows the maximum I_{H^-} with variation in the converter voltage. The discharge power, given by the product of V_d = -195 V and discharge current, was 7.6 kW.

The e/H^- = 6 is too great for 120 Hz LANSCE operations. In order to reduce the e/H^- ratio, a PM solenoid magnet with 500 G on-axis field was installed in the repeller assembly. The e/H^- was reduced to 3.2, but I_{H^-} was also reduced to a maximum 20 mA. During the

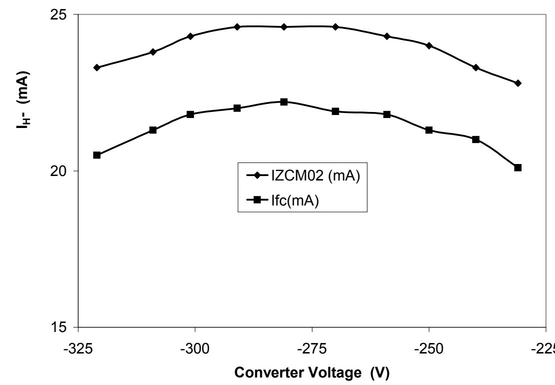

Fig. 3. Plot of the experimentally measured H^- currents from the development source.

solenoid magnet test period, an emittance survey was conducted on the development source. At the ISTS emittance station 2, ε_l = 8-9 (πcm-mrad) was measured, depending on the horizontal or vertical emittance station. The experimental emittance results as function of the extraction voltage setting are shown in Fig. 4, and summarized in lines 11 and 12 of Table 1.

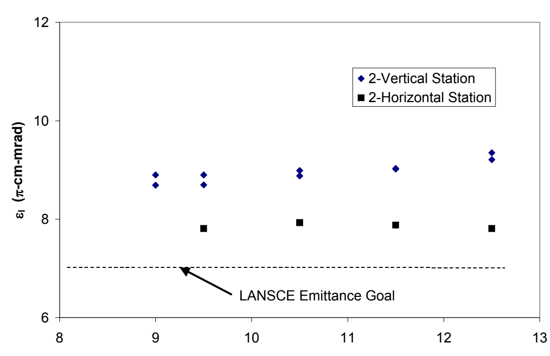

Fig. 4. Plot of 95% beam fraction laboratory emittance for 20 mA H^- beam from the development source.

DISCUSSION

An unexpected result is the development source e/H^- ratio of 6 where we expected a ratio of 4.2. This might be accounted for by the higher contact magnetic cusp field magnets used in the development source (line 6, Table 1). Plasma leakage at a multicusp source wall[6] has been established to be proportional to $(B_c)^{-1}$. It is planned to reduce the development source's B_c to 2 kG (as in the production source) with the thought that the source electron current will be rebalanced so as to improve the e/H^- ratio.

Because the H^- current from the development source scaled as the repeller-Pierce area increase, the PBGUNS model for the higher sputter energy (12eV) seems to be confirmed (cf. Fig. 2). One can speculate as to other possible mechanisms that would lead to a spreading of the converter H^- beam and a uniform illumination of the repeller-Pierce apertures. Consider that this H^- surface converter source falls into the general category of cathodic surface plasma source (SPS) H^- production (cf. Fig. 1f in ref [7]). Further, total converter currents I_{cnv} in both the production and development sources are measured to be 4A. Secondary electron production coefficient $\gamma = I_e/I^+$ may vary from 1 to 7 while the secondary H^- production coefficient $K^- = I_{H^-}/I^+$ may vary from .1 to .7 in cesiated SPS[8]. Since $I_{cnv} = I^+ + I^- = 4A$, a prediction for possible I_{H^-cnv} may be made over the limits of the γ and K^- parameters. Here, $I^- = (\gamma+K^-)I^+$. This prediction varies from $(I_{H^-cnv})_{min}$ = 40 mA at γ =7, K^- =0.1 while $(I_{H^-cnv})_{max}$ = 1000mA, found at γ=1, K^-=0.7. For a well-cesiated molybdenum surface the parameters γ and K^- may be 7 and 0.7[8] which yields I_{H^-cnv} = 300 mA. This H^- converter current is factor 17 greater than the PBGUNS sputter model currents presented in Fig. 2.

Another possible cause (in addition to sputter energy) of H^- converter beam expansion is incomplete neutralization of the converter beam space charge. An approximate plasma density of $1X10^{11}$ $(cm)^{-3}$ has been derived by using the converter as a floating probe. Using this plasma density and an electron temperature of 1eV, a converter plasma sheath thickness of 1.7 mm is derived[9]. A 2-D particle in cell (PIC) code is being developed at Los Alamos for application to ion source plasma problems[10]. A preliminary result from the PIC code simulation as applied to the LANSCE H^- surface conversion source is shown in Fig. 5. The plasma density in this simulation is $3X10^{10}$ $(cm)^{-3}$. The H^- beam is born on the plasma converter on the left of Fig. 5(A). The sheath region has formed approximately 3mm

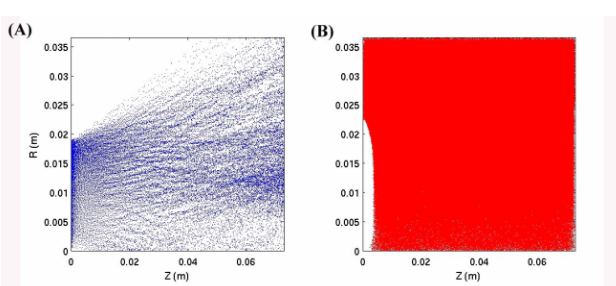

Fig. 5. Preliminary 2-D PIC code simulation for H^- beam being accelerated off the surface converter located on the left in Figs. 5(A) and (B). Fig. 5(B) shows the plasma electrons, and formation of the sheath at about 3 mm from the converter.

downstream from the converter. The modeled 300eV H^- beam is indeed predicted to have a strong divergence at the converter from residual negative space-charge, and from a defocusing electric field at the converter edge. These sheath predictions are suggestive of further experimental work, such as addition of a heavy neutral gas to the plasma discharge to alter the converter sheath formation and experimentation with shaped converters.

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