RECENT OPERATING EXPERIENCE WITH THE H^- ION INJECTOR AT LAMPF/LANSCE

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Abstract

A cusp-field, cesium conversion ion source has provided H^- beams at LAMPF/LANSCE since 1984. Three interchangeable sources are now used during beam production cycles to minimize down-time during scheduled source change-outs. Ion source change-outs are scheduled to prevent unscheduled loss of beam time due to finite filament lifetime. Ion source operating parameters and filament lifetime data are presented.

Introduction

A surface conversion H^- ion source has been in use at LAMPF (now the Los Alamos Neutron Science Center, LANSCE) since 1984. References [1] and [2] describe the development of this ion source; the recent operation of the ion source is described below. From 1984 to 1993 two sources were used during production cycles. One source was used for beam production while the other source was made ready for operation. In 1991 an off-line processing stand came into use to shorten time required to bring a fresh source into production capable condition. In 1993, a third ion source was assembled and added to the rotating inventory of sources used during LANSCE production cycles in 1994. We have found that having three ion sources available during production cycles allows not only for a smooth transition during a scheduled source maintenance period but also offers the additional advantage of having a back-up source available should something unforeseen occur, either during the recycle or at some time during production.

Ion Source Operation

During normal operation for production the H^- Ion Injector is expected to continuously deliver approximately 16 mA of quiescent (≤ 1% noise) 750 kV beam with an emittance (phase space area) of 4 πcm-mrad (for 98% beam fraction) to ground level where it is then transported to the linac for final acceleration to 800 MeV. The 750 kV beam is produced by operating the ion source on an 80 keV transport system located inside the equipment dome of a 670 kV Cockcroft-Walton. The transport system inside the dome consists of an 80 keV accelerating column mounted on a two-solenoid transport. The transport also has provision for beam steering[1]. A beam deflector between the two solenoids permits changing the length and repetition rate of the beam pulse delivered to ground while the ion source operates at a continuous duty factor of almost 10%

The ion source duty factor is determined by the rate and length of time at which the hydrogen discharge is pulsed by modulating the arc voltage with a solid-state switch. During recent years the discharge has operated at a length of 815 μsec at a repetition rate of 120 Hz. All other power supplies for source operation run continuously d.c. Recent ion source operating parameters are given in Table 1.

Table 1
Ion Source Operating Parameters

Parameter	Units	Normal Range
Arc Voltage[a]	V	190 to 200
Arc Current	A	35 to 45
Pulse Repetition Rate	Hz	120
Pulse Length	μsec	815
Filament Voltage	V	11 to 13
Filament Current	A	86 to 96
Converter Voltage	V	250
Converter Current	A	0.4 to 0.8
Hydrogen Flow	sccm	2 to 3
Cesium Temperature	°C	165 to 185
Repeller Voltage	V	0
Accelerating Voltage	kV	80
Drain Current @ 80 kV[b]	mA	5 to 7
Beam Current[c]	mA	18 to 20
Electron Component[c]	mA	2 to 3

a. Power Supply
b. Average
c. Measured at approximate mid-point of two-solenoid transport.

Refurbished ion sources are pre-conditioned and stored under vacuum on a processing stand dedicated to this purpose. The ion source processing (see below) requires running a pure hydrogen discharge, with no cesium added to the discharge. An ion source thus prepared is installed in the injector high voltage dome at scheduled intervals of four weeks. The time scheduled for removing the used source and return to production quality beam with the new one is two days. Linac development experiments are often performed at the end of the scheduled source change-out, however, so it is desirable to return to production quality beam as quickly as possible.

The determining factor for the length of time required for the change-out is most often the relative ease of what is called the cesium transfer. The transfer of cesium from the external reservoir (by ohmic heating) is started only after the discharge reaches a minimum pulsed current of 25 to 30 amps. In the first several hours of operation it is often necessary to raise the filament currents above their eventual operating points to attain this initial discharge current. In this ion source cesium is continuously deposited on the converter to enhance the H^-

ion production from plasma-generated H^+ ions striking the converter surface. The attainment of the proper rate of cesium evolution to both coat the converter for production of the H^- ions and maintain the coating as the source conditions is a somewhat unpredictable process. It is an equilibrium process that depends not only on the temperature of the cesium reservoir, but also on other parameters such as discharge and filament power, hydrogen flow rate, and converter voltage. It is possible to over-cesiate the source and thus have problems with sparking or to under-cesiate and not produce sufficient H^- beam current. When the cesium transfer has gone very smoothly, it has been possible for the linac to be delivering beam to target in as little as nine to twelve hours from the start of the change-out. A more realistic expectation for the length of time required to return to production-quality beam is twenty-four hours.

Other than unexpected difficulties, the arc down rate of the 80 kV accelerating column is usually the only factor that can cause delays in the return to quality beam production. Prior to the advent of the processing stand mentioned below, the 80 kV column arc-down rate was a problem that often took many hours to overcome by conditioning of the three column gaps.

The column conditioning procedure, when necessary, now takes approximately three hours to complete. During the most recent LANSCE extended maintenance period we disassembled and cleaned all elements of the column. We have not had to condition it since it was re-installed on the dome transport and have thus saved three hours of time during the change-over.

Processing Stand

An off-line, cryopumped processing stand is used to pre-condition and store under vacuum the two ion sources that are not in use for production. The processing stand has all the power supplies and equipment necessary to run a discharge in an ion source.

When a source is removed from production service it is refurbished before being placed on the processing stand. The cesium accumulated during the four weeks of continuous operation is removed from all surfaces, new filaments are installed, and the cesium reservoir is cleaned and refilled with fresh cesium.

The source is then mounted on the stand and tested for both vacuum leaks and water leaks. It is then operated to produce an un-cesiated discharge of 25 to 30 amps. This process removes undesirable residues that may remain from the cleaning and re-assembly procedures. It is this initial source operation that caused voltage-holding problems with the 80 kV column in the H^- injector dome prior to the use of the processing stand.

The filament side-plates are then carefully removed and cleaned of tungsten deposited during the first operation and the source body is wiped out. The ion source is then operated again. The last step of this processing procedure is to briefly open the valve on the cesium reservoir to pump out any residual argon from the filling procedure. The ion source is then left under vacuum on the processing stand until it is needed for production service in the injector dome. The approximately 16 hours of filament usage during processing is not included in the lifetime prediction calculations mentioned below.

Filament Lifetime

The ion source is scheduled to continuously deliver beam for four weeks between scheduled change-outs. The determining factor for the interval between change-outs is the finite lifetime of the 0.15 cm diameter tungsten wire filaments. Daily filament current measurements at a specified voltage provide a resistance measurement of each filament that is compared to its resistance at the beginning of the change-out. This yields an evaporation rate for each filament. The remaining filament lifetime is then estimated by comparing the least-squares fit of the last five days of data with the assumption that the filament will break open once it attains 12% evaporation. The graphical presentation of such data for a well-behaved filament pair is shown below in Figure 1.

Filaments do not always behave as well as those shown in the figure. If a hot spot develops because of a weak point somewhere along the filament length then the evaporation curve will often begin to take on a strongly quadratic, if not exponential character. Such behavior generally means that the filament will fail in only a day or two. The daily acquisition of filament evaporation data thus serves to provide an indication of impending premature failure and we can be prepared to perform an unscheduled change-out.

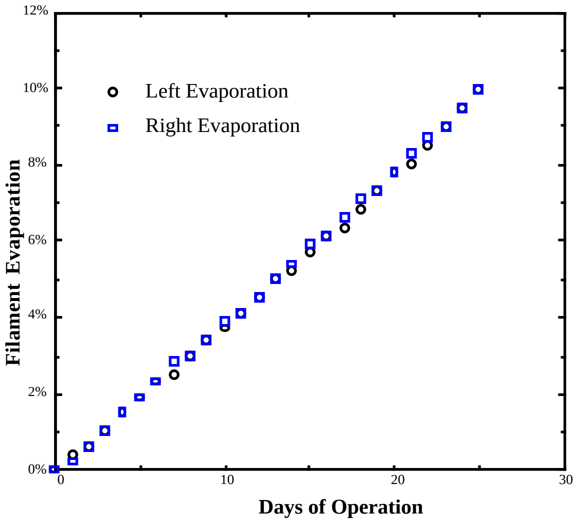

Fig. 1. Filament lifetime data. The number of days of remaining lifetime is based on the assumption of filament failure at 12% evaporation.

Filaments are formed on a mandrel designed to produce filaments of the desired shape. The mandrel consists of circular brass pegs of different diameters arrayed in an arc on an aluminum plate. The 0.15 cm diameter, 29 cm long tungsten filament wire is bent around the pegs to produce a filament. Figure 2 depicts the way in which the brass pegs are arrayed and also shows the shape of the filament that is produced. Not shown are the tag ends of the filament which are bent at 30° to attach the filament to the filament posts. The bending of the stiff tungsten welding rod used for the filaments is made somewhat easier by using a 2000 watt heatgun to locally heat the tungten rod as it is passed around the forming pegs.

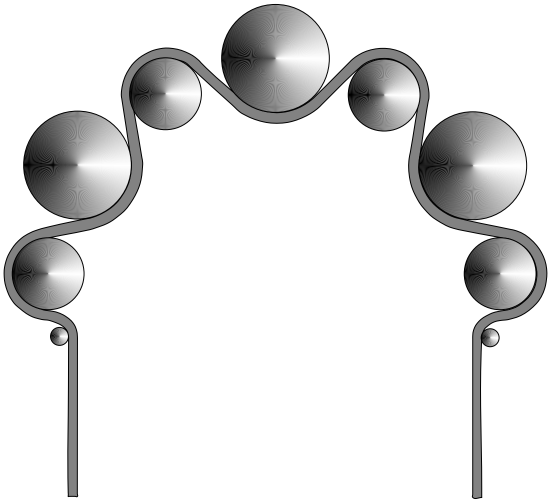

Fig. 2. Filament mandrel and filament. The figure shows how the tungsten wire is bent around the mandrel pegs to form the filament, as described in the text..

Bending of the straight tungsten wire welding rod used to form the desired filament shape can introduce stress points that are prone to forming hot spots, the suspected cause of premature filament failure. We have recently been using the forming mandrel in a different way to reduce the amount of induced stress when filaments are formed. The forming pegs are inserted into the mandrel sequentially as the filament wire is bent around them. This removes the stress induced by lifting the straight wire out of the plane of the mandrel base to pass over pegs not yet used in the bending process. Filaments formed in this manner have not failed because of hot spot formation.

Summary

Three ion sources used in rotation allow us to smoothly change out a source with limited remaining lifetime and replace it with a fresh one.

An off-line processing stand is maintained for the pre-conditioning of ion sources after they have been cleaned and supplied with new filaments. Its use diminishes voltage-holding difficulties that used to occur when ion sources were changed.

At least one potential cause of premature filament failure due to hot spot formation has been mitigated by using the filament forming mandrel in a different way.

References

[1] R. l. York, R. R. Stevens, Jr., R. A. DeHaven, J. R. McConnell, E. P. Chamberlin and R. Kandarian, Nucl. Instr. and Meth. B **10/11**, 891-895 (1985).

[2] K. W. Ehlers and K. N. Leung, Rev. Sci. Instrum. **51**(6), 721-727 (1980).