REDUCTION OF BEAM LOSSES IN LANSCE ISOTOPE PRODUCTION FACILITY*

Y.K. Batygin#, LANL, Los Alamos, NM 87545, USA

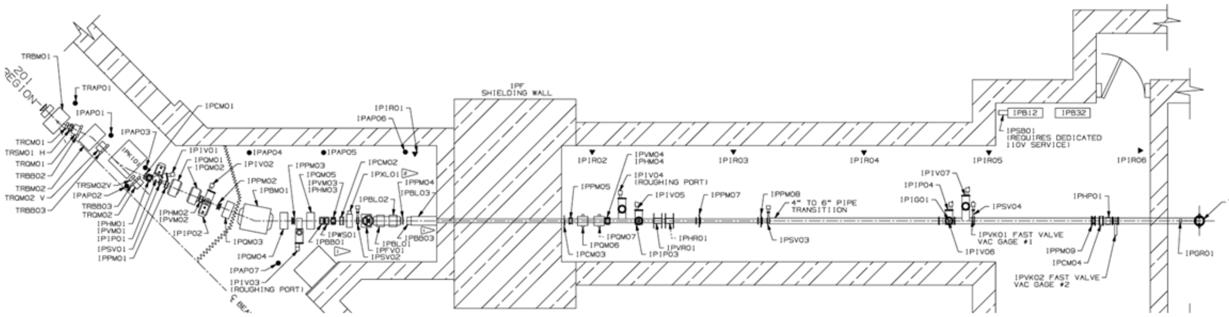

Figure 1: LANSCE Isotope Production Facility beamline.

Abstract

The LANSCE Isotope Production Facility (IPF) utilizes a 100-MeV proton beam with average power of 23 kW for isotope production in the fields of medicine, nuclear physics, national security, environmental science and industry. Typical tolerable fractional beam loss in the 100-MeV beamline is approximately 4 x10^{-3}. During 2015-2016 operation cycle, several improvements were made to minimize the beam losses. Adjustments to the ion source's extraction voltage resulted in the removal of tails in phase space. Beam based steering in low-energy and high-energy beamlines led to the reduction of beam emittance growth. Readjustment of the 100-MeV quadrupole transport resulted in the elimination of excessive beam envelope oscillations and removed significant parts of the beam halo at the target. Careful beam matching in the drift tube linac (DTL) provided high beam capture (75% - 80%) and minimized beam emittance growth in the DTL. After improvements, beam losses in the 100-MeV beamline were reduced by an order of magnitude and reached the fractional level of 5 x10^{-4}.

IPF ACCELERATOR FACILITY

The Isotope Production Facility is a part of the Los Alamos accelerator facility. It has been in operation since 2004, producing isotopes for a variety of applications [1]. Rubidium chloride and gallium metal targets are irradiated by a 100-MeV proton beam with average current of 230 μA, accelerated by the LANSCE drift tube linac. The proton beam injector contains a duoplasmatron proton ion source mounted to a 750-keV Cockroft-Walton accelerating column. The low-energy beam transport line (LEBT) consists of a quadrupole lattice, 81^{o} and 9^{o} bending magnets, RF prebuncher, main buncher, diagnostics and steering magnets [2]. After acceleration in the DTL, 100-MeV protons are transported in the Transition Region (TR) and in the IPF beamline, where it is incident to the IPF production target (see Fig. 1). TR and IPF beamlines include four bending magnets (total 45^{o} bend), nine quadrupole magnets, six steering magnets, four current monitors, eight beam position monitors (BPMs), a wire scanner and a harp for beam profile control. Horizontal and vertical raster-steering magnets perform circular sweeping of the beam on the IPF target, with the average radius of 18 mm and frequency of 5 kHz (see Fig. 2).

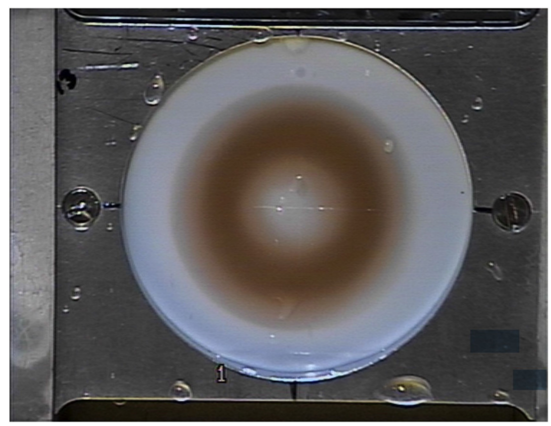

Figure 2: Rastered 100 MeV proton beam at Isotope Production Target.

BEAM CHARACTERISTICS IN LEBT AND DTL

The current proton ion source is a duoplasmatron with a Pierce extraction geometry. The source was originally developed for production of 50-mA beam. Later, the source was modified for greater brightness with lower current (20 mA) [3]. Presently the source delivers a proton beam with a current of 5 mA at 100 Hz x 625 μsec pulse length. Typical value of the normalized rms proton beam emittance is ε_{rms} = 0.003 π·cm·mrad. Reduction of beam current from 20 mA to 5 mA resulted in the appearance of tails in phase space

*Work supported by US DOE under contract DE-AC52-06NA25396
#batygin@lanl.gov

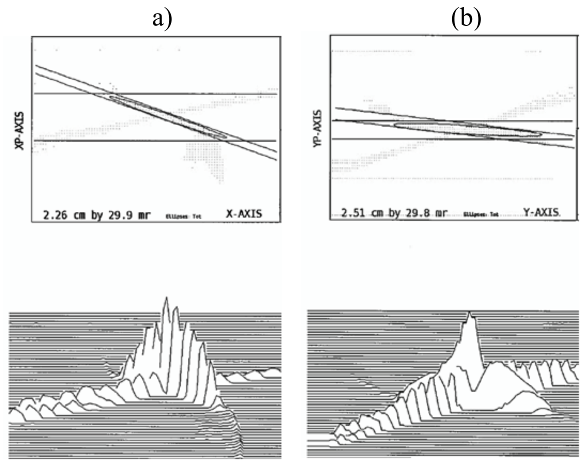

Figure 3: Emittance of the beam extracted from a proton ion source: (a) before and (b) after source adjustments. Beam distribution contains additional H_2^+/H_3^+ components.

(a)

	H+ %
IPAP01	1
IPAP02	0
IPAP03	14
IPAP04	0
IPAP05	1
IPAP06	2

(b)

	H+ %
IPAP01	0
IPAP02	0
IPAP03	2
IPAP04	0
IPAP05	0
IPAP06	0

Figure 4: Activation Protection devices reading (a) before and (b) after retuning.

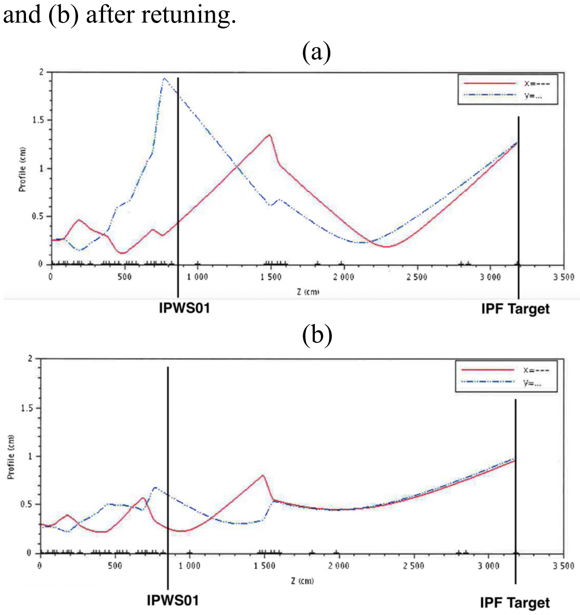

Figure 5: Beam envelopes (a) before and (b) after retuning of beamline.

distributions (see Fig. 3a). Recent study of LANSCE proton source [4] indicates that beam emittance can be controlled with appropriate selection of ion source extraction voltage. Reduction of the voltage from 27 kV to 21 kV resulted in significant suppression of beam tails (see Fig. 3b).

Proton beam is bunched in a 2-buncher system before injection into DTL. The proton beam is operated in conjunction with another injector for H^- beam. The main buncher and last four quadrupoles, before injection into DTL, are common for both beams. Setup for main buncher and last four quadrupoles is a result of compromise between H^+ and H^- beams to provide high capture in the DTL (mutually between 75%-80%).

The proton beam experiences increased emittance in the LEBT, by a factor of 2 due to RF bunching. Additional source of emittance growth is associated with beam offset in LEBT quadrupoles. The application of beam based steering procedure [5] resulted in significant suppression of emittance growth due to beam misalignment. After acceleration in DTL, the normalized rms proton beam emittance reached 0.02 π·cm·mrad, which is significantly smaller than the normalized transverse acceptance of DTL of 1 π·cm·mrad.

BEAM DYNAMICS IN IPF BEAMLINE

After the DTL, 100-MeV protons enter the transition region and continue on to the IPF beamline. Operation of TR and IPF beamlines include BPM control of the beam centroid, correction of beam position at the target and control of beam losses at the Activation Protection (AP) devices. Each AP device is a one-pint can, consisting of a photomultiplier tube immersed in scintillator fluid. The AP detectors integrate the signals and shut off the beam if the losses exceed the specified limit. They are calibrated with 6-μA point beam losses at the energy of 100 MeV. Most of beam losses are observed around IPAP03 (see Fig. 4a). Typical beam losses in IPF beamline are characterized by summed AP device readings of 15% - 20%, which is equivalent to 1-μA beam losses, or relative beam losses of 4 x10^{-3}.

During 2015-2016 accelerator run cycle, series of beam development experiments were undertaken to reduce beam losses. Analysis of beam dynamics, using 100-MeV beam emittance scan, indicated that beam envelopes had excessive variation (see Fig. 5a). New quadrupole setup provided more relaxed beam envelopes during transport (see Fig. 5b). Wire scans at IPWS01 confirmed improvements of beam dynamics (see Fig. 6).

Additional improvement of beam quality was achieved with realignment of the IPF beamline. Recent laser tracking of beam elements, performed by the LANSCE Mechanical Team, indicated noticeable displacements of the magnets (see Fig. 7). A combination of the steering and bending magnets were adjusted to center the beam through the sequence of quadrupoles (see Fig. 8). The procedure used was similar to that described in a Ref. [5]. As a result of improved beam matching, the beam losses were reduced significantly and reached 5 x10^{-4}, which corresponds to a reading at IPAP03 of 2%, or 0.12 μA (see Fig. 4b). During 2016-2017 operation cycle, beam losses were kept at a low level and IPF beam availability was 92.5%.

ISBN 978-3-95450-182-3

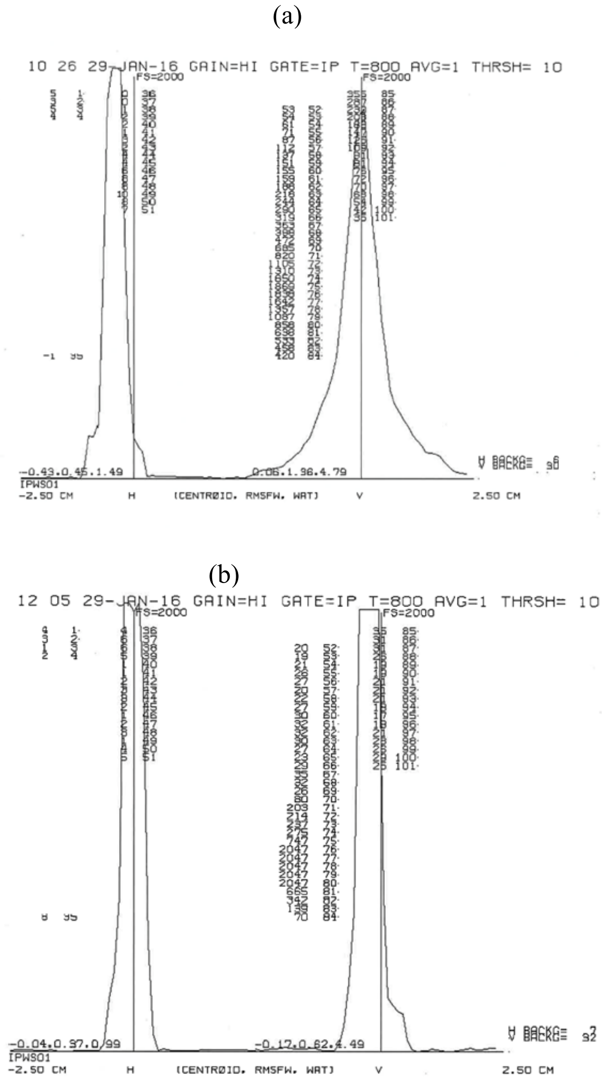

Figure 6: Beam profiles at IPWS01 wire scanner (a) before and (b) after retuning of IPF beamline.

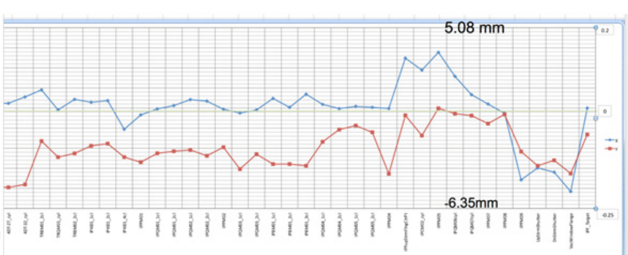

Figure 7: Misalignment of IPF beamline elements.

Further improvement of beam performance can be achieved with an upgrade to the IPF beamline, scheduled for the summer of 2017 [6]. This upgrade includes an additional beam emittance station and wire scanner. A new adjustable collimator will allow for improved beam shaping at the target. Finally, a new rastering system will allow irradiation of the target through multiple concentric rings. This will provide a more uniform exposure and increase the isotope production.

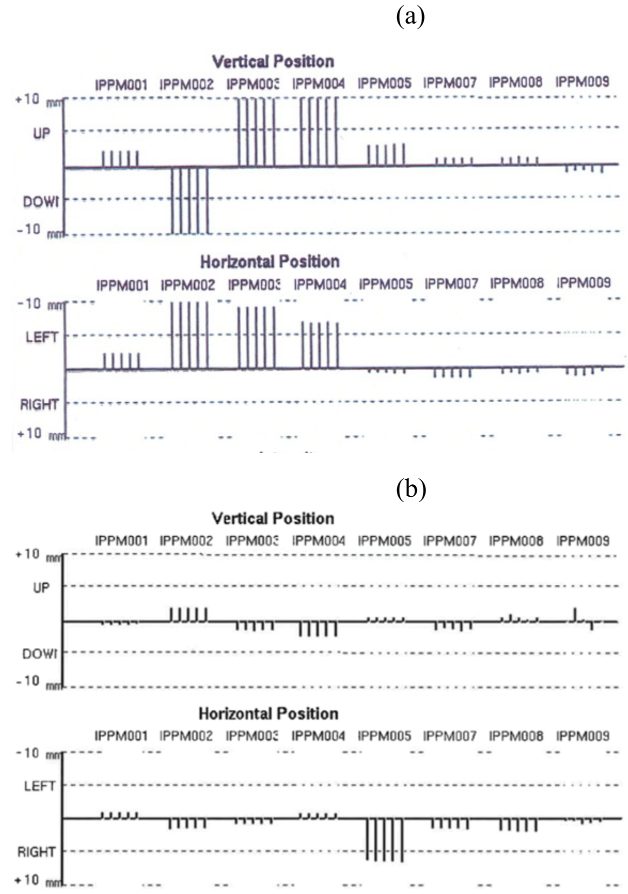

Figure 8: Beam position monitors bar graph (a) before and (b) after beam based alignment.

ACKNOWLEDGEMENTS

Author is indebted to Rodney Mccrady, LANSCE Operation Team and Radioisotope Production Team for invaluable assistance, and to Charles Taylor for careful reading of manuscript and providing multiple useful comments.

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