COMPACT ION LINACS FOR RADIONUCLIDE PRODUCTION

Robert W. Hamm

AccSys Technology, Inc.
1177 Quarry Lane, Pleasanton, CA 94566

Revolutionary new technology developed during the past few years has now made ion linear accelerators (linacs) practical as commercial accelerators for the production of medical radionuclides. Large research proton linacs at Brookhaven National Laboratory and Los Alamos National Laboratory have already been used for many years to generate a wide variety of radionuclides. The new compact linacs now being commercially developed are significantly smaller and less complex than these earlier research linacs. The radionuclide production applications of this new linac technology extend from the acceleration of 3 MeV deuterium for the continuous generation of ^{15}O in a clinical environment to the acceleration of 100 MeV protons for producing large quantities of most of the accelerator-generated radionuclides used in nuclear medicine.

In addition to their compact size and simplicity, other key features of these commercial linac systems include high efficiency, high current capability, excellent output beam quality and low beam losses. The low beam losses reduce the radiation levels, keeping the activation low compared to other accelerators operating at the same currents, and the very bright output beams allow easy transport to well shielded target areas. The pulsed operation of these linacs yields a high input power efficiency, with the average output beam current being limited by the rf power system and input power capability once a pulsed beam current has been chosen.

These compact accelerators utilize the radio frequency quadrupole (RFQ) linac, a unique rf accelerating structure capable of simultaneously accelerating, focusing and capturing a high current, low energy ion beam. This device can typically capture more than 90% of a proton beam at a current of more than 20 mA with an input energy less than 50 keV, and accelerate it to several MeV in 2-3 meters. The ions can then be injected into a conventional drift tube linac and accelerated to higher energies of up to 100 MeV or more at a rate of several MeV per meter.

Like the medical electron linacs in common use today for high energy x-ray radiation therapy, these ion linac structures are rigid devices that are rugged, reliable and lightweight. The design and operation of the resonant cavities at frequencies above 400 MHz makes possible smaller structures with increased accelerating gradients, resulting in shorter accelerator systems than "conventional ion linacs." The use of permanent magnet quadrupoles for focusing in the drift tube structure has made this reduction in size possible and has also eliminated the power required in earlier systems for electromagnetic focusing. The injectors for these new linacs are based on conventional duoplasmatron ion sources, the reliability of which has been proven over many years of use at large research laboratories. The modest injection voltages required by the RFQ result in simple injector accelerating structures, thus minimizing high voltage stand-off problems for the ion source power supplies which must be floated at the injection voltage. Recent development of an rf power source for these linacs has yielded the design of a compact modular system that uses redundant planar triode tubes, has a high efficiency and requires modest dc voltages (up to 10 kV). The use of multiple rf tubes allows tailoring the rf system output to the linac requirements and results in gentle degradation of the power with tube failure.

The modular design of both the linac and rf power system allows an existing linac to be upgraded to higher current or higher energy after installation by the addition of rf power units and/or rf structures, along with increased input power and cooling water. A linac initially built for operation at 200 µA output current can be easily upgraded for operation at 1 mA average current by increasing the pulse duration and pulse repetition rate of the linac rf system and ion injector.

The pulsed structure of the output beams requires unique handling techniques when bombarding radionuclide production targets and target windows. Since the instantaneous beam is more intense than that from a cw or dc accelerator, these beams must be defocused or expanded using magnetic lenses in front of the targets, and the targets and target materials must be mechanically and thermally stable. Recent work on pulsed beam bombardment of targets has shown that appropriate target designs can minimize the target or target window temperature oscillation about the equilibrium caused by the pulsed beam structure.

Listed below are the preliminary specifications and operating parameters for several radionuclide production linacs designed by AccSys Technology, Inc. These systems demonstrate the advantages and flexibility of this new commercial accelerator technology for radionuclide production:

Model	DL-3	PL-11	PL-66
Accelerated particle	d^+	p^+	p^+
Beam energy (nominal, MeV)	3.0	11.0	66.0
Beam current/pulse (mA)	10	25	25
Beam pulse width (µsec)	30-245	35-215	35-120
Pulse repetition rate (Hz)	1-120	1-120	1-120
Pulsed rf power (kW)	240	1250	8000
Maximum target current (µA)	300	650	350
Accelerator length (m)	2.8	5.0	22.5
Accelerator weight (kG)	700	1500	6500
Electrical requirement (kVA) at 100 µA average current	12	25	180