Examination of Medical Radionuclides Production System Using an Electron Accelerator (4) Compact X-band Electron Linac for Research and Production of Medical Radionuclides

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Abstract

Aiming at regional installation of electron linacs dedicated to production of medical radionuclides, we designed a compact electron linac with beams of 35 MeV and 11.2 kW, into which two 6 MW klystrons supply X-band microwaves. Our downsized linac will provide local hospitals with direct access to Mo-99/Tc-99m, and researchers with new routes to radionuclide-based biological experiments.

Keywords: X-band electron linac, X-band klystron, Nuclear medicine, Medical radionuclides, Mo-99/Tc-99m

1. Introduction

In a given length, electron beams are accelerated about four times more in X-band radio frequency (RF; 8–12 GHz) than the conventional S-band RF (2–4 GHz). Therefore, it is possible to downsize an electron linear accelerator (linac) with X-band RF. We are planning to use this compact X-band electron linac as a source of γ-rays for production of medical radionuclides, with emphasis on Mo-99/Tc-99m via Mo-100(γ,n)Mo-99. In addition, because there are various channels of photonuclear reactions, we expect that the linac γ-ray source can pave the way for active utilization of novel radionuclides in biological research.

2. Basic design of an X-band electron linac

Fig. 1 describes an X-band linac with electron beams of 35 MeV and 11.2 kW. Two 6 MW klystrons supply X-band RF into four acceleration tubes. Standing wave acceleration and side-coupled cavities were adopted.

Using such high frequency of X-band RF and having high beam power are mutually contradictory. To overcome this conflict, we are optimizing parameters of linac components based on computer simulations of electrodynamics.

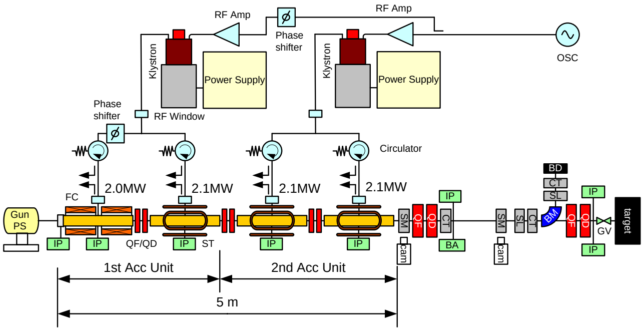

Fig. 1 An electron linac with beams of 35 MeV and 11.2 kW.

3. Numerical analysis

Fundamental parameters of the linac components were calculated with Superfish and General Particle Tracer (GPT). We figured out that electron beams of 160 mA can be loaded when the beam energy is to be 35 MeV. **Table 1** summarizes some of the calculation results.

Table 1 Simulation results of the designed X-band e$^-$ linac

Electron beam	
Peak energy	35 [MeV]
Average current	0.32 [mA]
Average power	11.2 [kW]
Klystron ※ Model: *Toshiba E37113*	
Frequency	X-band (11.424 GHz)
Peak power	6 [MW]
Pulse	5 [μs] and 400 [pps]
Duty factor	0.002
Number of klystrons	2
Acceleration tube	
Acceleration type	・Standing waves ・Side-coupled cavities
Total length	5 [m]
Number of acceleration tubes	4

4. Discussion

Enriching the proportion of Mo-100 from 9.63% to over 95% in a given sample can increase the production yield of Mo-99, but requires great expense. Therefore, use of natural Mo in place of enriched Mo-100 as a target material was investigated. It was found that byproduct nuclides such as Nb-92m are also produced, as a function of beam energy, from a target of natural Mo due to the existence of isotopes of Mo other than Mo-100.

What is hence critical to the current step of our research is to find optimum beam parameters that produce a minimum amount of impurity nuclides and can tolerate the high frequency of X-band RF.