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STATUS OF THE PNC HIGH POWER CW ELECTRON LINAC

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ABSTRACT

Design and construction of a high power CW(Continuous Wave) electron linac for studying feasibility of nuclear waste transmutation was started in 1989 at PNC. The PNC linac is the 10MeV, 20mA (average current, 20% duty) accelerator with eight normal conducting TWRR(Traveling Wave Resonant Ring) disk loaded accelerating tubes. Various methods have been proposed to transmute long-lived fission products using accelerators. The transmutation by photonuclear reaction using a electron accelerator has advantages of the small production for secondary radioactive waste and broad base of accelerator technology.

The PNC high power CW electron accelerator has been pre-commissioned with the injector and the first accelerating tube. By December 1995, the accelerator was partially built and the injector pre-commissioning began. Then 3 MeV beam had coasted though the beam dump. We have been very successful to produce 3 ms pulse width electron beam with 100 mA peak and energy about 2.9 MeV at present.

The whole facility will be completed in March 1997.

1. INTRODUCTION

Many research efforts have been spent in PNC to establish technologies for safety disposal of radioactive waste. The high level radioactive waste produced from the reprocessing of spent fuel is essential for the completion of nuclear fuel cycle. Current national policy in Japan is to solidify the high level radioactive waste into a stable form and to dispose it in a deep geological repository after 30 to 50 years of storage for decay heat reduction. However, the Japanese Atomic Energy Commission approved the long-term program for research and development on nuclide partitioning and transmutation in October 1988 beside solidification disposal mentioned above. The objective of the program (called OMEGA) is to explore a possibility to utilize the high level radioactive waste as useful resources and make the geological disposal more efficient.

The program is composed of two major area. One is the nuclear partitioning from the high level radioactive waste based on its potential value for utilization. The other is the transmutation of minor actinides and long-lived fission products into short-lived or stable nuclide. It is usually difficult to transmute long-lived fission products in reactors because of small neutron capture cross section. Various methods have been proposed to transmute long-lived fission products using accelerators. The transmutation by photonuclear reaction using a electron accelerator has advantages of the small production for secondary radioactive waste and broad base of accelerator technology. A high power electron accelerator will be required in future transmutation system.

Upon this projection, design and construction of a high power CW electron linac to study feasibility of nuclear waste transmutation was started in 1989 at PNC[1]. Until now, a high power L-band klystron and a prototype high power TWRR accelerating tube were built and successfully validated many of design concepts until end of 1992[2]. By December 1995, the accelerator was partially built and the injector pre-commissioning began. Then 3MeV beam had coasted though the beam dump. The whole facility will be completed in March 1997.

2. LINAC PARAMETERS

The parameters of the beam produced by the linac are summarized in Table 1. These are very unique specifications for among the existing electron linear accelerators. The long pulse, 4 msec, is used for the beam stability studies of CW linac. The RF source parameters are summarized in Table 2.

The injector consists of a 200kV DC gun[3], magnetic lens, a RF chopper[4], chopper slits, a prebuncher, and a buncher. Solenoid coils cover these elements from the exit of the gun to the first accelerating tube except between the RF chopper and chopper slits. Fig. 1 shows these injector components and schematic with the solenoid magnetic fields.

The accelerator property is a traveling-wave accelerator with TWRR excited with microwave power at a frequency of 1249.135 MHz. The accelerating tube has a cylindrical, disk-loaded shape made by OFHC (Oxygen

Free High-purity Copper). The structure is designed to produce a constant axial electric field over the length of each independently fed. The number of the accelerating sections is seven and one injector section. Each of the accelerating section whose length is 1.2 meters contains 13 of $2/3\pi$ mode cavities and two coupling cavities.

All accelerating sections are designed to have constant gradient structure under the condition of 100mA beam loading. The choice of short accelerating section and low attenuation constant structures made possible increase the threshold BBU current and liberate the tolerance of the TWRR resonate frequency, temperature stability, and fabrication. A detail TWRR with accelerating section is described else where [5].

Table 1 Beam parameters for the linac.

Energy	10 MeV
Max. Beam Current	100 mA
Average Beam Current	20 mA
Pulse Length	0.1 ~ 4 ms
Pulse Repetition	0.1Hz ~ 50 Hz
Duty Factor	0.001 ~ 20 %
Norm. Emittance	50 π mm mrad*
Energy spread	0.5 %*

* estimated value by simulation

Table 2 Parameters of the RF source.

Accelerating Frequency	1249.135 MHz
Accelerating Mode	$2\pi / 3$ mode
Number of Klystron	2
Klystron Power	1.2 MW

3. COMMISSIONING

Pre-Commissioning

The commissioning was carried out with partially build accelerator. The injector, the first accelerator section, the beam dump, and RF source was completed in December 1995. The RF conditioning was made in site using own RF source. Within a few days after the RF conditioning, the buncher and accelerating section was able to store about 1 MW RF peak power in the resonant ring. The unique aspect of this power RF conditioning is burst-pulse operation, which is nine short pulse(100μsec) within 4 msec period. The 4 msec pulse power and the CW klystron allow to this kind operation.

Beam-Commissioning

Beam commissioning began and 3MeV beam had coasted though the linac to the beam dump. By March 22, 50mA of 1 msec beam was achieved. The resonant ring of the buncher and first accelerating section were tuned to the maximum resonated RF power. The RF chopper and the chopper slits were adjusted by the RF power to apply the cavity with a fundamental (f_0) RF power, then DC magnetic bias, finally second harmonic ($2f_0$) RF power. Fig. 2 shows the beam current in each beam current monitor. The beam current after the chopper shows one third current from the electron gun exit. The energy spectrum measured by bending magnet are shown in Fig. 3. After using the RF chopper, the energy resolution ($\Delta E/E$) is about 1.5%. This is rough adjustment because the bunch monitors have not been prepared and all phase and bunch length have not be tuned yet. Until now ~100 mA beam with pulse width 3 msec repetition 0.1 Hz has been accelerated. Studies continued at design goal of 100 mA beam with 4 msec and repetition 50Hz, including the resonant rings control with high power operation. The temperature control of resonant rings and accelerating tubes is getting critical with high duty operations.

4. CONCLUSION

The PNC high power CW linac injector and first accelerating section was installed and pre-commissioned during the beginning of 1996. This pre-commissioning shows important results that the accelerator with the traveling wave resonant ring under 100 mA beam loading is easily handled and verified the acceleration of long pulse beam such as 3 msec. Studies continued at design goal of 100 mA beam with 4 msec repetition 50Hz. The rest of accelerating section will be installed by March 1997, then 10MeV high power CW(average 20mA 20%duty) electron linac commissioning will be ready.

REFERENCES

[1] S.Toyama et. al., "Transmutation of long-lived Fission Product (^{137}Cs, ^{90}Sr) by a Reactor-Accelerator System" , Proceeding of the 2nd International Symposium on Advanced Nuclear Energy Research (1990).

[2] S. Toyama et. al., "High Power CW Linac in PNC", Proceeding of the Particle Accelerator Conference, (1) 546 (1993).

[3] Y. Yamazaki et. al.,"The Electron Gun for the PNC High Power Linac", Proceedings of the 17th International Linac Conference 219 (1994).

[4] Y.L.Wang et.al., "A Novel Chopper System for High Power CW Linac",Proceedings of the 17th International Linac Conference 202 (1994) .

[5] Y.L.Wang et.al.,"Design of High Power Electron Linac at PNC", Journal of Nuclear Science and Technology, 30 [12] 1261 (1993).

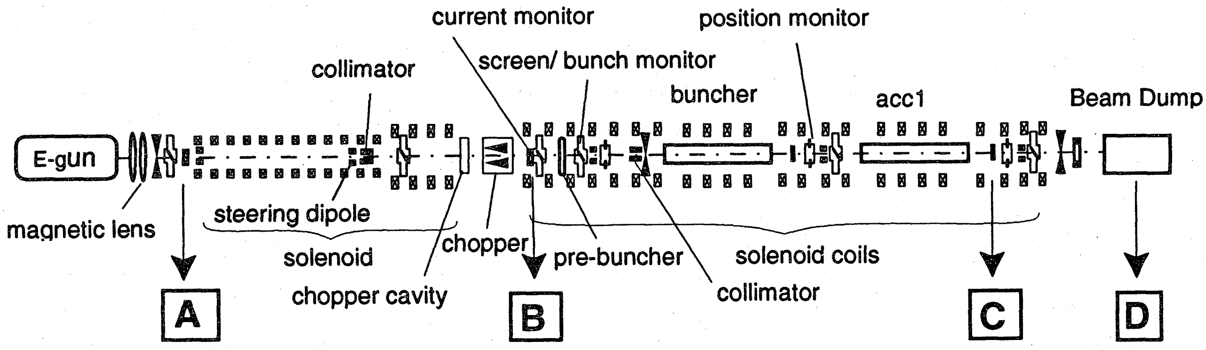

Fig. 1 Injector components and schematic.

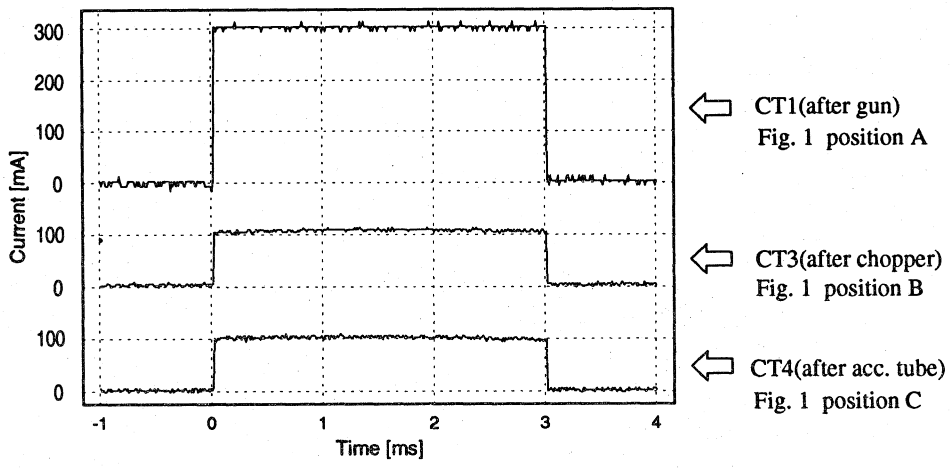

Fig. 2 The beam current in each current monitor.

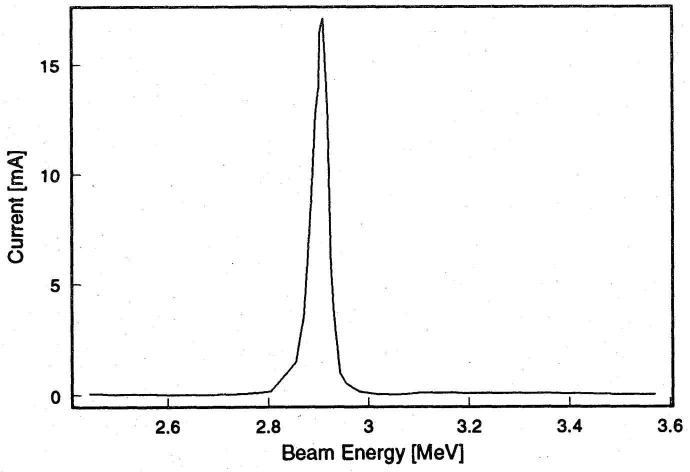

Fig. 3 Energy spectrum.