REPETITIVE PULSED-POWER GENERATOR "ETIGO-IV"

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Abstract A new repetitive pulsed-power generator "ETIGO-IV" has been developed for the applications in materials science, pulsed ion-beam acceleration, and high-power microwave generation. It is capable of delivering, to a matched load, an output pulse of 400 kV in peak voltage, 13 kA in peak current, and 120 ns in pulsed length, at the repetition rate of 1 Hz. This paper reports the design details and operation results of "ETIGO-IV", as well as the initial experimental results on electron beam production.

I. INTRODUCTION

A repetitive, high-voltage, pulsed-power generator "ETIGO-IV" has been developed. It is basically the pulsed power generator by the combination of step-up transformers and magnetic switches.[1] The main purpose of this machine is to generate pulsed light-ion beam for the experimental studies of thin film deposition, solid-surface treatment, and pulsed ion implantation.[2-6] The pulsed light ion beam has been proved to be an effective tool in generating high-density ablation plasma. Experimental results have shown that the ion-beam ablation plasma has special advantages over other plasma sources that are presently used in material development. "ETIGO-IV" is expected to demonstrate the compact, high repetition-rate ablation plasma generation.

In addition, it is expected that "ETIGO-IV" can be used for the generation of relativistic electron-beam which has potential applications in flue gas treatment and high-power microwave generation.

"ETIGO-IV" has utilized the up-to-date technologies to generate and compress the high-voltage pulse and deliver it to the load. High current thyratrons are used as the first-stage switches that unload the stored energy from the capacitors. After that, two step-up transformers, two magnetic switches, and a coaxial pulsed forming line function automatically, resulting in an output of 400 kV, 13 kA, and 120 ns at the load.

Fig. 1 Repetitive pulsed power generator "ETIGO-IV".

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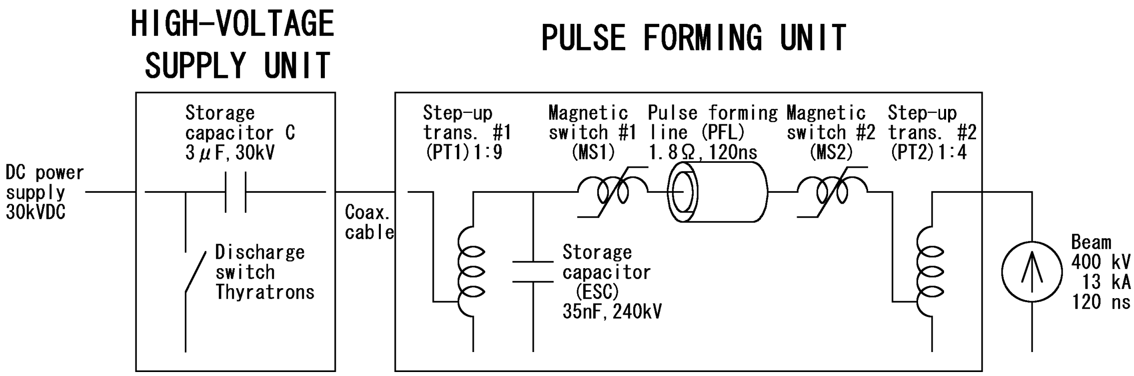

Fig. 2 Equivalent circuit of "ETIGO-IV".

II. STRUCTURE AND PRINCIPLE

Figure 1 shows the photograph of the pulsed power generator "ETOGO-IV". It basically consists of three units: the high-voltage supply, the pulse-forming line, and the central control. The equivalent circuit of "ETIGO-IV" is shown in Fig. 2. The capacitors (3μF) in the high-voltage supply unit are charged by the DC high-voltage supply to 30 kV. When the thyratron switches are closed, the output of the capacitor is applied to the first step-up transformer (PT1) in the pulse-forming unit, so that the energy storage capacitor (ESC) is charged to 240 kV. When this energy transfer is completed, the magnetic switch (MS1) saturates and allows the energy transfer from ESC to the pulse forming line (PFL). Similarly, as the PFL is fully charged, the magnetic switch (MS2) turns on to allow the pulsed power output of PFL to the load, through the second step-up transformer (PT2). If the load has a matched impedance, the output voltage, current, and pulse length are 400 kV, 13kA, and 120 ns, respectively.

So far, "ETIGO-IV" is capable of repetitive operation at 1 Hz. However, this repetitive frequency is only determined by the output power of the DC high-voltage supply. The other parts of the machine can stand up to much higher repetitive frequency. Therefore, "ETIGO-IV" can be easily upgraded to higher frequency by simply increasing the capacity of the DC high-voltage supply.

Table I Major parameters of the magnetic cores

Parameter	Unit	PT1(2nd)	MS1	MS2	PT2(2nd)
Charge voltage	V	260,000	240,000	220,000	400,000
Outer diameter of core	m	0.356	0.451	0.6	0.356
Inner diameter of core	m	0.206	0.331	0.51	0.206
Thickness of core	m	0.0508	0.0508	0.0508	0.0508
Quantity of cores		3	4	4	2
Cross section of cores	M^2	0.0114	0.0122	0.0091	0.0076
Number of winding		9	5	2	4
Core material		2605SC	2605SC	2605SC	2605SC
Magnetic flux swing	T	2.1	2.1	2.1	2.1
V x t	Vs	0.216	0.128	0.038	0.064
Saturation time	s	1.66E-06	1.07E-06	3.49E-07	1.60E-07

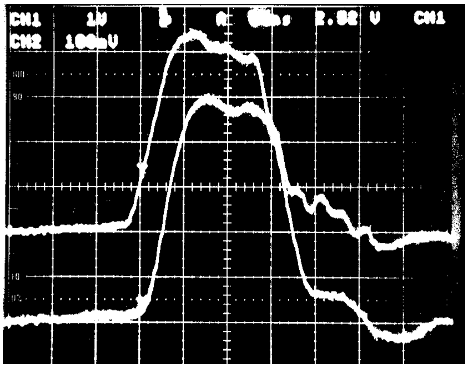

Fig. 3 Output voltage (upper, 100kV/div) and current (lower, 3kA/div) to an dummy load, where the time scale is 20ns/div.

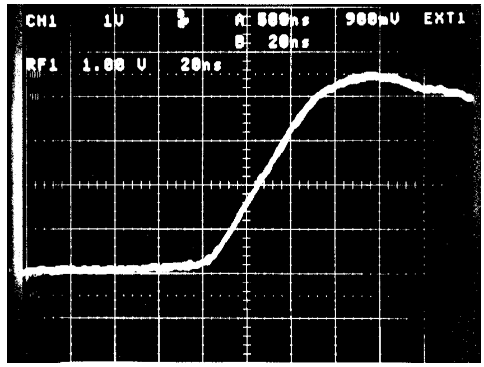

Fig. 4 Jitter of the output voltage relative to the external trigger pulse with, where the time scale is 20 ns/div.

The primary switch consists of five thyratrons in parallel, each of them is connected in series with a capacitor (0.6μF) in order to obtain current balance between the thyratrons.

Amorphous cores (Honeywelll 2605SC) are used in PT1, MS1, MS2, and PT2. The major parameters of these magnetic cores are shown in Table I. It is designed that each core allows the maximum magnetic-flux swing of 2.1 T. The total energy loss in these cores for each operation is less than 100 J.

Several efforts have been made in order to have "ETIGO-IV" as compact as possible. The pulse-forming unit is mounted on the top of the high-voltage supply unit to save the floor space. Also, PT1 and MS1 are located inside ESC and PFL respectively, as can be seen in Fig. 1. In addition, the insulation oil and pure water are used selectively, so that the transformers and magnetic switches (PT1, MS1, MS2, and PT2) are immersed in the insulation oil and the energy storage units (ESC and PFL) are in water because of higher dielectric constant.

III. OPERATION RESULTS

Figure 3 shows the typical waveforms of the output voltage and current of "ETIGO-IV", obtained with the primary charging voltage of 26.5 kV. It is seen that the peak output voltage of ~ 400 kV and the peak output current of ~ 12.5 kA have been obtained. The output voltage has a rising time (10 % to 90 %) of ~ 39 ns and a FWHM of ~ 150 ns.

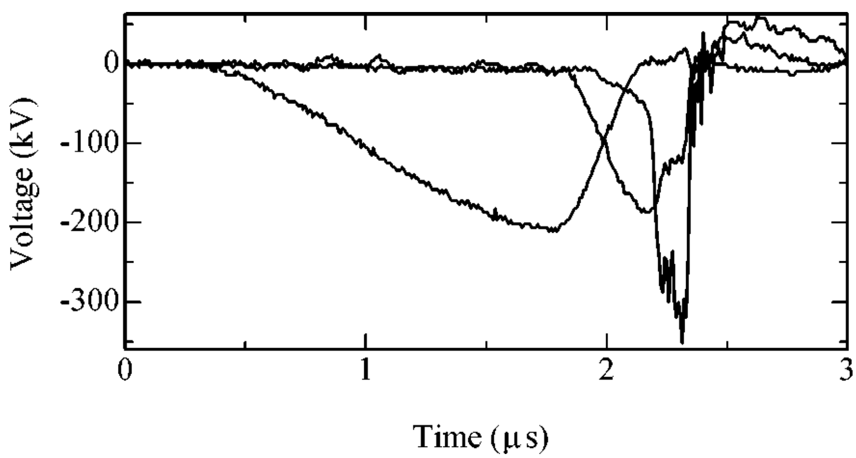

Fig. 5 Voltage waveforms of (from left-hand side) ESC, PFL output, and electron-beam diode

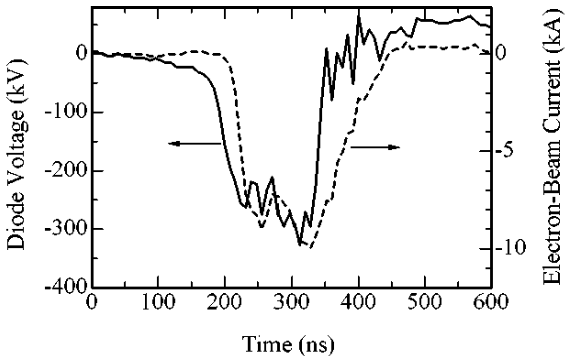

Fig. 6 Typical diode voltage and current waveforms for electron-beam operation.

Figure 4 shows the time jitter of the output voltage relative to the external trigger pulse, which is an accumulative recording of 20 shots. It is obtained from Fig. 4 that the jitter is less than 3 ns.

Figure 5 shows the waveforms of different position of "ETIGO-IV", obtained with charging voltage of 26 kV and with the electron beam diode as the load. They are (from the left-hand side) ESC voltage, PFL output voltage, and the final output voltage, respectively. The diode voltage and electron-beam current is plotted in Fig. 6. It is seen from Fig. 6 that the peak diode voltage of ~ 300 kV and the peak electron-beam current of ~ 10 kA have been obtained.

IV. CONCLUSIONS

Initial operations of "ETIGO-IV" with dummy load has shown that pulsed-power generator "ETIGO-IV" is capable of generating the output pulse of 400 kV, 12.5 kA, 150 ns at the repetitive frequency of 1 Hz. The rising time of the output voltage is 39 ns and the jitter relative to the external trigger pulse is ~ 3 ns. In addition, pulsed electron beam of 300 kV, 10 kA and 120 ns has been obtained by using "ETIGO-IV".

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