LASERTRON

Laser Switched Microwave Source for Linear Collider in the TeV Region

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ABSTRACT

R & D on a new RF-Source "LASERTRON" was started. This source is necessary for an electron-positron linear collider in the multi-TeV region. In the LASERTRON, pulsed electron beams are generated from its cathode by irradiating a photocathode with laser pulses modulated at the RF-frequency and are accelerated into an output cavity.

A prototype LASERTRON, Mark-I, was fabricated and studied. RF-power of 1.6 kW was generated successfully at the RF-frequency of 2884 MHz by applying the accelerating voltage of 30 kV.

INTRODUCTION

RF sources with a peak power output of the multi-GW and relatively short pulse length will be required for future electron-positron linear collider in the multi-TeV region[1,2].

This peak power is much beyond the level which can be achieved with conventional technologies. There are several candidates for this power source such as Klystrons, Gyrotrons, Magnetrons, Pulse Compression Technique, Photocathode Microwave Source, etc[3]. Among them, we proposed and started the studies on the new RF sources, LASERTRON[4], which produces a RF current by direct emission modulation of the photocathode. The principle of this device is as follows. The laser beam whose intensity is modulated at the RF frequency illuminates a photocathode. The photo-emitted electron beam is accelerated by a DC-voltage towards the anode, and then goes into the collector through the output cavity from which the RF-power is extracted (see Fig. 1). The merit of the LASERTRON is that high conversion efficiency of the beam power to the RF power is expected in the high power region because the electron beam is bunched from its origin.

In order to realize the high power LASERTRON, many studies were started on such items as photocathode that can emit high current, the stable and intense mode-locked laser, space charge effect[5], the high voltage power supply with a fast time response, the RF output cavity and collector.

A prototype of the LASERTRON, Mark-I, was fabricated and the measurements of the fundamental properties were carried out. The RF-power of 1.6 kW was generated successfully at the RF-frequency of 2884 MHz by applying an accelerating voltage of 30 kV. The detailed descriptions on Mark-I and its experimental results and discussions will be given in the following sections.

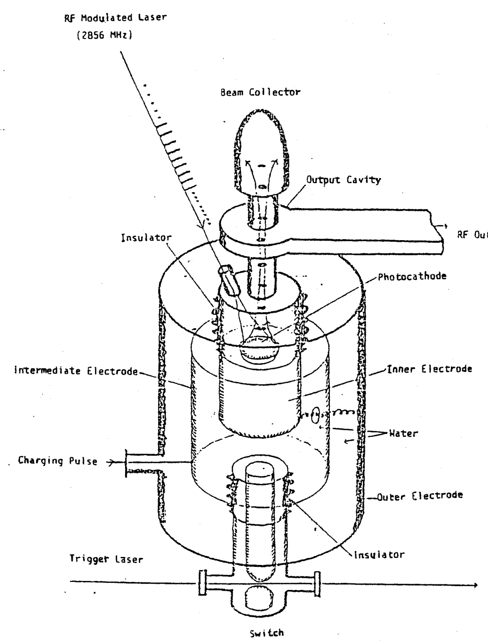

Fig. 1 A conceptual drawing of a new RF source consisting of a laser, a photocathode, a high voltage power supply and an output cavity.

PROTOTYPE LASERTRON

A cross sectional drawing of the LASERTRON Mark-I with the experimental arrangement is shown in Fig. 2. The LASERTRON consists mainly of a photocathode electron gun, which is supplied by Hamamatsu Photonics Inc.[6], a cylindrical output cavity and a mode-locked laser. The cathode is made of a bi-alkali and the effective area of the photocathode is 1.33 cm^2. The gap distance between the cathode and the mesh anode is 0.75 cm. The cavity is mounted on a drift tube. The resonant frequency of the cavity is adjusted to 2884 MHz and the measured Q-value is 75. The output coupler consists of a SMA-connector and a loop, and the experimental value of the coupling coefficient is 0.3. Two partition meshes are set at the center of the cavity in the drift tube to improve the transit angle in the case of a low accelerating voltage. The gap distance between these meshes is 0.5 cm. The photocathode is irradiated with the laser light through the glass window,

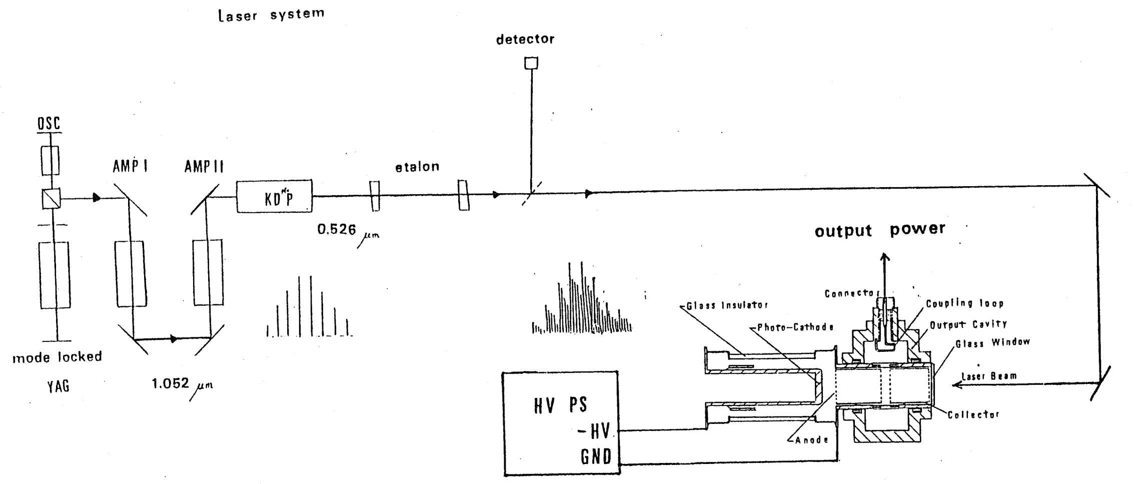

Fig. 2 A cross sectional view of the LASERTRON Mark-I and the experimental arrangement.

a collector mesh, partition meshes and the anode mesh.

The triggering laser is a passive and active mode-locked YAG laser. After the amplification, the wavelength is converted from 1.052 to 0.526 μm with a KD*P crystal in order to shift the wavelength to the sensitive region of the cathode.

The maximum output energy of the laser is 50 μ-joule per burst. In a burst, there is a pulse train with the frequency of 169.6 MHz, as shown in Fig. 3, and the frequency of the laser is converted using a etalon to 2884 MHz, which is 17 times of 169.6 MHz.

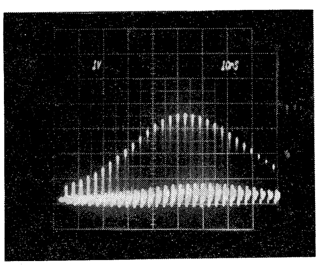

Fig. 3 The output laser from the oscillator, in which pulse train of 169.6 MHz are contained. The pulse width is 50 nsec.

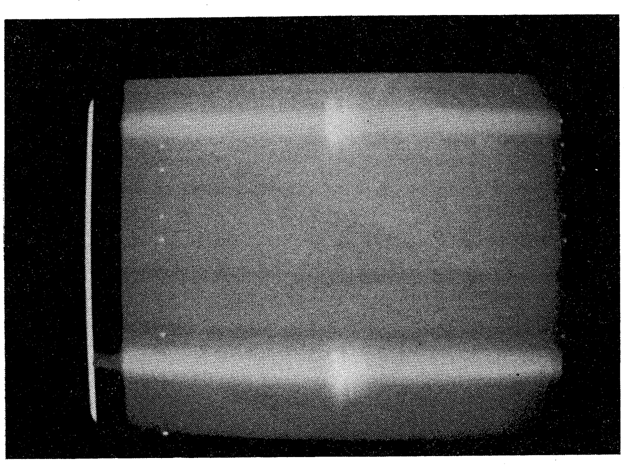

Fig. 4 The output laser from the etalon. The width of a laser pulse is 30 psec and the time interval between two pulses is 350 psec.

The picture of the output pulses taken by a streak camera is shown in Fig. 4. The width of the laser pulse is 30 psec, and the duty factor of the laser is about 10% in each burst. A high DC-voltage was applied to the cathode through a coaxial cable which form a capacitor to feed charge with a fast time response.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Measurements were made on the return current I_e of the power supply and on the RF-output power P_{out} of the LASERTRON, as a function of the applied voltage V for the fixed laser power. The return current I_e corresponds to the total emitted current from the photo-cathode. It was found that the current I_e and the power P_{out} depend on the applied voltage V differently from a conventional klystron, as shown in Figs. 5 and 6.

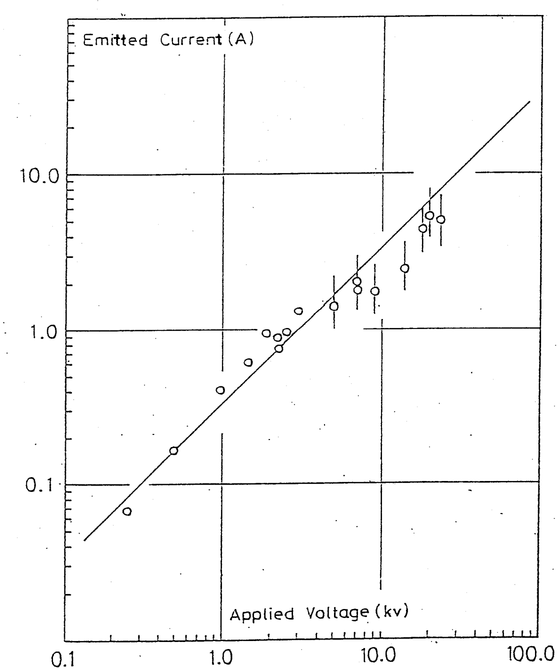

Fig. 5 The average emitted current from the cathode per burst of laser versus the applied voltage.

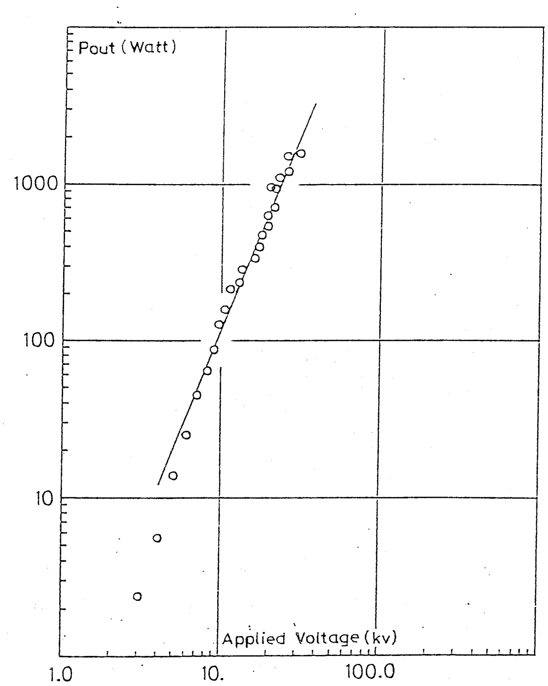

Fig. 6 The output RF-power versus the applied voltage.

For the conventional klystrons, the space charge limited current I is represented by

$$I = kV^{3/2}$$

where k is the pervience and V is the applied voltage. On the other hand, it was found that the emitted current I_e is proportional to V in the present experiment and is represented by

$$I_e = k'V$$

where k' is a constant.

The linear dependence of the limitation current is a characteristic property for the bunched beam[5]. We can only get the surface charge on cathode of the laser irradiated area. At the maximum applied voltage of 30 kV, which was limited by the breakdown, the emitted current and output power were about 10 A and 1.6 kW, respectively. Since the pulse width of the one burst at the half maximum is 50 nsec, the emitted electrons at this voltage is 500 nC and the peak current density is 75 A/cm^2.

The output power P_{out} is represented by

$$P_{out} = f(V)k'V^2$$

where f(V) is the conversion efficiency of the beam power to the RF-output, including the beam coupling with the cavity and the output coupler. The observed dependence of Pout on the applied voltage V in the present experiment is 2.8 power.

CONCLUSION

R & D on a new RF-source "LASERTRON" was started. A prototype LASERTRON, Mark-I, was fabricated and studied. RF-power of 1.6 kW was generated successfully at the RF-frequency of 2884 MHz by applying the accelerating voltage of 30 kV, which was limited by the breakdown.

Further experimental studies on a new prototype of the LASERTRON with improvements on the voltage immunity and output cavity are currently underway. Several kinds of cathode materials with negative electron affinity have been also studied to obtain high current and to develop the demountable photocathode gun.

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