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LASERTRON
Laser Triggered RF-Source for Linacs in TeV Region

M.Yoshioka, M.Mutou, Y.Fukushima[*], T.Kamei[*], H.Matsumoto[*],
H.Mizuno[*], S.Noguchi[*], I.Sato[*], T.Shidara[*], T.Shintake[*],
K.Takata[*], H.Kuroda[**], N.Nakano[**], H.Nishimura[**], K.Soda[**],
M.Miyao[+], Y.Kato[++], T.Kanabe[++] and S.Takeda[*]

The Institute for Nuclear Study, The University of Tokyo
Midori-cho, Tanashi-shi, Tokyo 188, Japan

Summary

A prototype of new RF-sources, LASERTRON, has been developed for an electron-positron linear collider in the multi-TeV region. In the LASERTRON, pulsed electron beams are generated by irradiating a photocathode with laser pulses modulated at the RF-frequency and are accelerated into a cavity. Fundamental characteristics of the prototype LASERTRON, Mark-I, was studied, and 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

An electron-positron collider in the multi-TeV energy region is the next target of high energy physicists beyond LEP[1]. But, it is generally accepted that the construction of a circular electron-positron collider in the TeV region is not practical[2]. One possibility to achieve the TeV energy is to construct a linear collider, whose accelerating gradient is about 100 MV/m. In order to realize such a high accelerating gradient, pulsed RF-sources with a peak power of the GW have to be developed. This peak power is much beyond the level which can be achieved with conventional technologies. Therefore, the studies have been started on the new RF-sources using a electron beam triggered by a laser pulse, LASERTRON[3].

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 output cavity from which the RF-power is extracted. The merit of the LASERTRON is that the high transmissivity of the emitted current from the cathode to the output cavity and high conversion efficiency of the beam power to the RF-power are 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 are necessary on such items as the photocathode that can emit high current, the stable and intense mode-locked laser, the high voltage power supply with a fast time responce and the RF-output cavity. 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 will be given in the following sections.

Prototype LASERTRON

A cross sectional drawing of the LASERTRON Mark- I with the experimental arrangement is shown in fig. 1. The LASERTRON consists mainly of a photocathode electron gun, which is supplied by Hamamatsu Photonics Inc.[+], a cylindrical output cavity and a mode-locked laser. The cathode is made of a bialkali and the effective area of the photocathode is 1.33 cm^2. The gap distance between the cathode and the anode mesh is 0.75 cm. The cavity is mounted on a drift tube after the chip off of the tube. The resonant frequency of the cavity is adjusted to 2884 MHz and the measured Q-value is 70. 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 even in the case that the accelerating voltage is low. The gap distance between these meshes is 0.5 cm. The photocathode is irradiated with the laser light through the glass window, a collector mesh, partition meshes and the anode mesh.

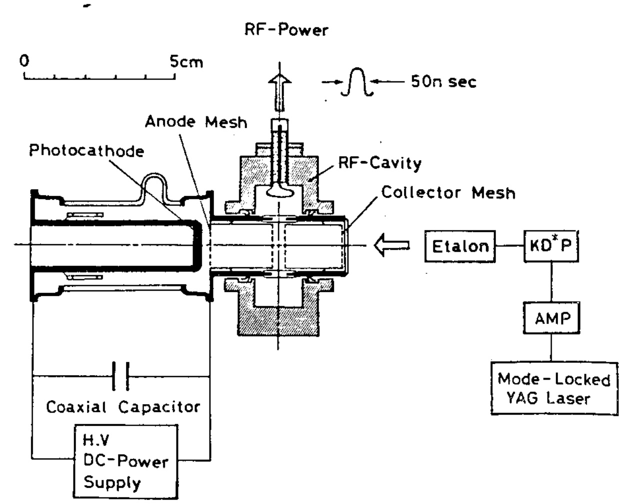

Fig. 1. A cross sectional view of the LASERTRON Mark-I and the experimental arrangement.

The triggering laser is a passive and active mode-locked YAG laser. After the amplification, the wavelength is converted from 1.06 to 0.53 micro-m 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 micro-joule per burst. In a burst, there is a pulse train with the frequency of 169.6 MHz, as shown in fig. 2, and the frequency of the laser pulses is converted with an etalon to 2884 MHz, which is 17 times of 169.6 MHz.

The picture of the output pulses taken by a streak camera is shown in fig. 3. The width of the pulse is 35 pico second, and the duty factor of the laser is about 10 % in each burst.

A high DC-voltage was supplied to the cathode through a coaxial cable which formed a capacitor to feed charge with a fast time responce.

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* National Laboratory for High Energy Physics
** The Institute for Solid State Physics, The University of Tokyo
\+ Research Institute of Electronics, Shizuoka University
\++ Institute of Laser Engineering, Osaka University
\# Institute of Scientific and Industrial Reseach, Osaka University

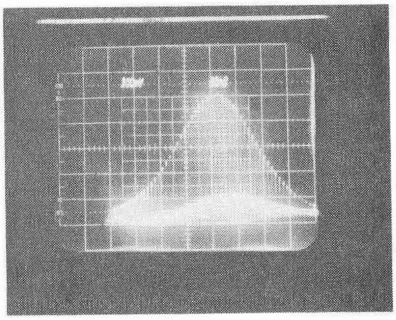

Fig. 2. The output laser from the oscillator, in which pulse train of 169.6 MHz are contained. The width of the pulse train at the half maximum of the laser power is 50 nano second.

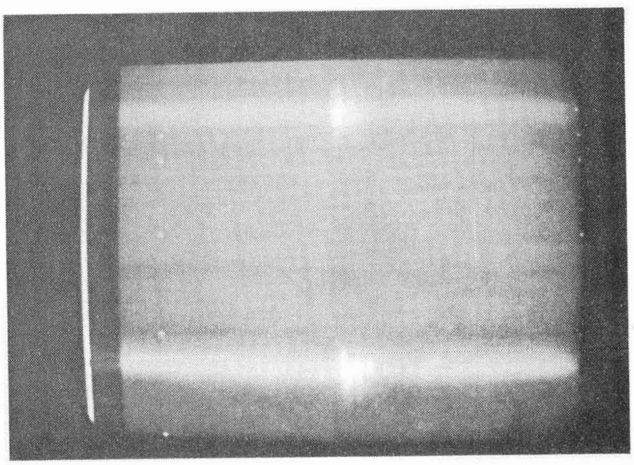

Fig. 3. The output laser from the etalon. The width of a laser pulse is 35 pico second and the time interval between two pulses is 350 pico second.

Experimental Results and Discussions

Measurements were made on the return current Ie of the power supply and on the RF-output power Pout of the LASERTRON, as a function of the applied voltage V for the fixed laser power. The return current Ie corresponds to the total emitted current from the photocathode.

It was found that the current Ie and the power Pout depend on the applied voltage V differently from a conventional klystron, as shown in figs. 4 and 5.

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

$$I = k\, V^{3/2} , \qquad (1)$$

where k is the perviance and V is the applied voltage.

On the other hand, it was found that the emitted current Ie is proportional to V in the present experiment and is represented by

$$Ie = k' V , \qquad (2)$$

where k' is a constant.

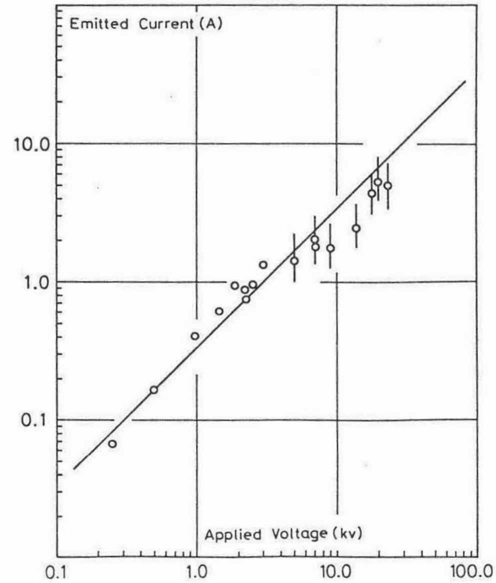

Fig. 4. The average emitted current from the cathode per burst of laser versus the applied voltage.

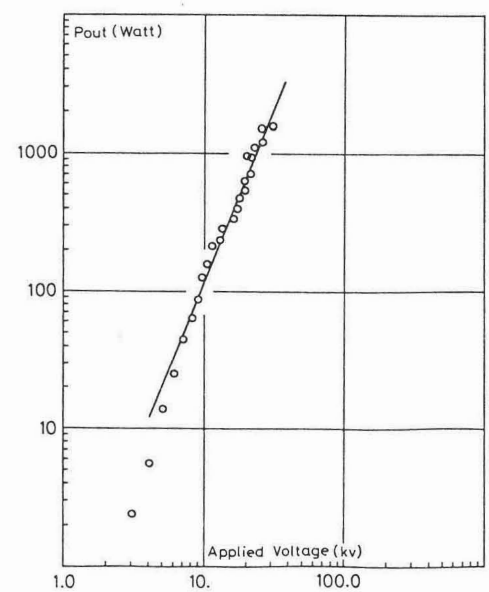

Fig. 5. The output RF-power versus the applied voltage.

The linear dependence of Ie shows that the limitation of the current for the bunched beam is different from the space charge limit for the coasting beam, which is discussed in detail by Nishimura[5] at the present conference.

At the maximum applied voltage of 30 kV, the emitted current was 10 A. Since the pulse width of the one burst at the half maximum is 50 nano second, the emitted electrons at this voltage is 500 nano coulomb and the peak current density is 75 A/cm^2.

The output power Pout is represented by

$$Pout = f(V)\ k' V^2 , \quad (3)$$

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 that the Pout increases as 2.8 power of V.

Conclusion

For the present prototype LASERTRON Mark-I, the maximum applied voltage and therefore the maximum output power were limited by the breakdown at 30 kV and 1.6 kW, respectively. In order to investigate the maximum current of the bunched beam which can be emitted from the cathode, a particle simulation code was developed[5].

A new prototype of the LASERTRON has been prepared with improvements on the DC-power supply, the output cavity and the electron gun. Also the other type of cathode material with the negative electron affinity has been studied to obtain high current and to develop the demountable photocathode gun.

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