Possible Efficiency-Enhancement of Metal Photocathode for DISKTRON Electrostatic Accelerator

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Abstract

Possibility of increasing quantum efficiency of metal photocathodes by geometric alteration is being investigated. The fourth harmonic light of Nd:YAG is used to produce photoelectrons on a metal surface. The pulse length is about 50 ps (FWHM) and the peak current is greater than 2 A at 0.7 MeV. This scheme employs grooved surface with adjusted polarization and other pertinent parameters such as extraction voltage. The measurements are done after acceleration by DISKTRON® electrostatic accelerator which, with a combination of a laser-induced photocathode, gives fairly controllable bright short-pulse-electron-beam up to the energy of over 1 MeV. This configuration permits us to find the overall improvement of e-beam characteristics for the future laser-undulator-experiment.

I. INTRODUCTION

In the last few years laser-induced photocathodes have become one of the most preferred methods to generate a bright short-pulsed electron beam. However no material that possesses both a high quantum efficiency and high ruggedness so far has been found. Therefore one could either improve the properties of the efficient but weaker materials or employ other means to enhance the efficiency of rugged ones. We have chosen to use the latter method for the improvement due to a rather moderate vacuum level in our experimental facility and our operational requirements such as high stability of operation and low maintenance.

II. PRINCIPLES

There are several ways to improve photoelectron-emission-efficiency of a metal. One is to use surface plasma waves (SPW) excitation that can also be explained by Brewster angle reflection by modulated surfaces of complex refractive index [1-3]. This method appears to be very promising as long as the wavelength, incident angle of the laser light, and the pitch of the surface modulation are properly tuned. The second one is to employ multiphoton process that requires a laser with high power and short pulse [4].

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The easiest and most general way to enhance the emission efficiency is to change the geometric shape of the target to fully utilize the surface emission, namely to choose the direction of the light polarization and the shape of the target to maximize the probability that electrons can escape the surface of the metal.

It has been known that the quantum efficiency of photoelectric effect depends on the relative relation between electric field and the plane of incidence [5]. In this experiment we have shown a simple but effective way to increase the emission efficiency of a photocathode, especially at low power level of the input laser. In order not to degrade the beam emittance, a finely grooved target is used. The dimension of the grooves is much larger than the wavelength of the input laser to avoid unexpected interference. Fig. 1 shows the microscopical picture of the edge and surface of the target. The angle of the slope with respect to horizontal direction is 55 degree and the area with grooves is 50% of the illuminated surface. This method can be used in many of existing FEL photo injector just by replacing the target and adjusting the polarization of the laser.

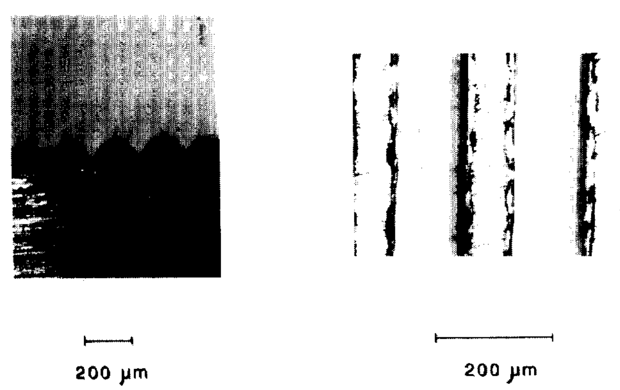

Fig. 1 Microscopical pictures of Al photocathode.

III. EXPERIMENT

A series of experiments was conducted in the configuration of relativistic electron beam source (DISKTRON® electrostatic accelerator and a laser-induced photocathode) for the future laser undulator experiment at the Institute of Physical and Chemical Research (RIKEN) [6]. Fig. 2 shows a schematic of the experimental configuration. The fourth harmonics light of a mode-locked Nd-YAG laser illuminates the target to produce an electron beam which is subsequently accelerated by static electric field to the energy of 0.7 MeV. The e-beam is wholly collected by a piece of graphite and the current is fed to 50Ω input. The laser power is initially measured by a power meter for calibration and is monitored by a PIN diode during the measurements. A half-wave plate is placed in front of the entrance-beam-port to alter the direction of the polarization of the laser light. The degree of polarization of the fourth harmonic of the Nd-YAG has been measured to be more than 90% and the use of the half-wave plate does not cause any difference in terms of transmitted laser power on the target in two cases of which the direction of the light polarization is perpendicular each other. The grooves are lined vertically to the experimental plane so that the horizontally polarized light is regarded as P-polarization.

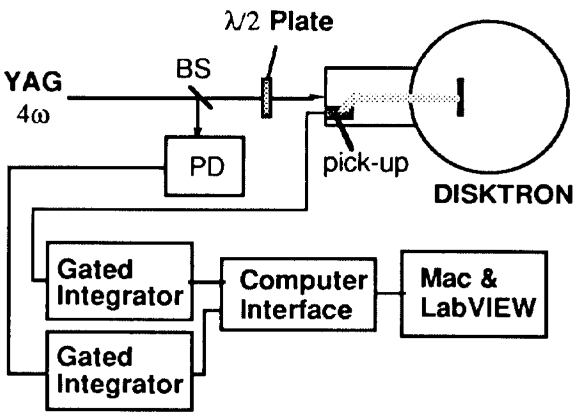

Figure 2. Schematic of the experimental configuration.

Fig. 3a and 3b show the relations between laser power density and produced e-beam current density for an aluminum target which has a flat surface. There is no clear difference between two cases with perpendicular polarization as is expected. Fig. 4a and 4b are the results of the same kind of measurement after replacing the target with the one having a grooved surface. It is distinctly shown that the case of P-polarized light yields higher than that of S-polarized light. Compared to the flat target the former case gives slightly more than three times higher quantum efficiency. Even though the available surface area is increased for the grooved target, after taking into it into the account that only 50% of the surface has slopes, the real yield increase appears to be more than three times. No noticeable degradation of emittance was observed after comparing the sizes of e-beam spots at the focus in two cases.

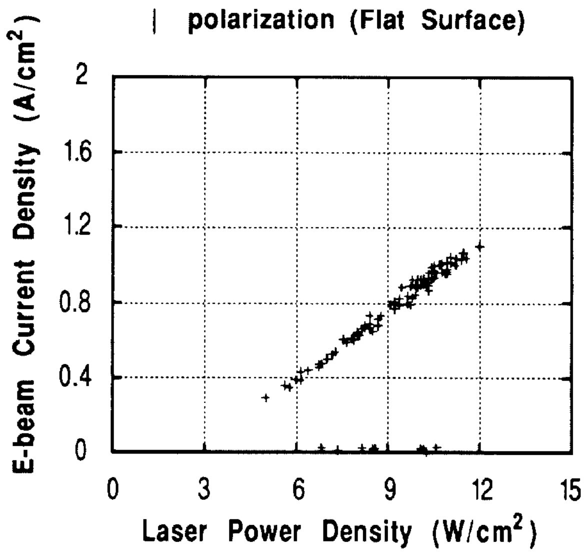

Fig. 3 (a) Laser power density v.s. e-beam current for the light of *vertical* polarization using the *flat* target.

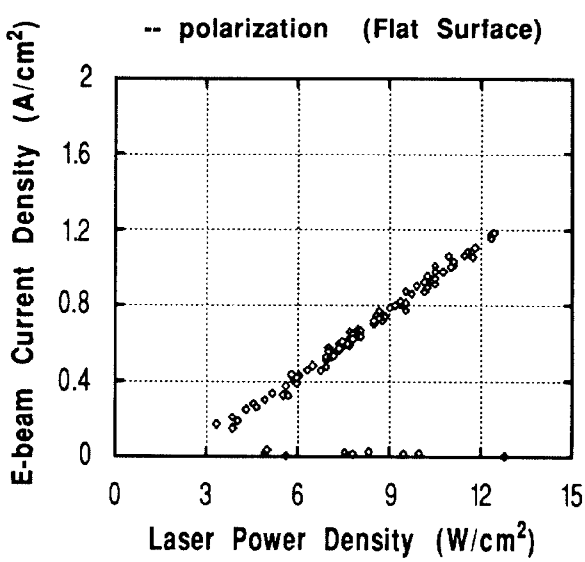

Fig. 3 (b) Laser power density v.s. e-beam current for the light of *horizontal* polarization using the *flat* target.

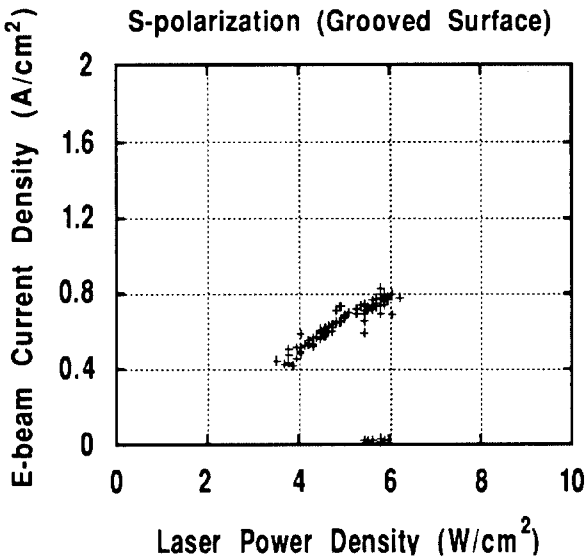

Fig. 4 (a) Laser power density v.s. e-beam current for the light of *S* -polarization using the *grooved* target.

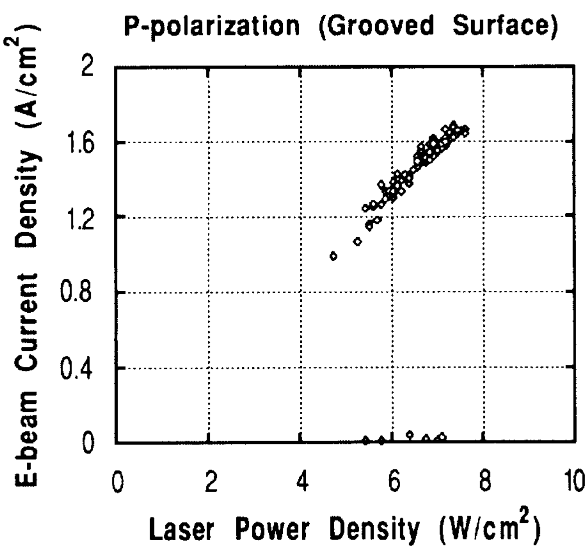

Fig. 4 (b) Laser power density v.s. e-beam current for the light of *P* -polarization using the *grooved* target.

IV. CONCLUSION

It has been shown that the quantum efficiency of a metal photocathode can be easily enhanced up to a factor of three simply by replacing a flat target with a grooved one. Unlike other enhance methods such as surface-plasma-wave method this method requires no resonance condition so that it can be adapted in the most of existing photo-injectors without many modifications.

V. REFERENCES

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