Behavior of a metal photocathode

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We report the behavior of a yttrium photocathode by rough and smooth surface. The utilized laser source was a KrF excimer, operating at 248 nm wavelength, 5 eV photon energy and 23 ns FWHM. The targets were tested in a vacuum at normal laser incidence and the anode-cathode distance was set to 5 mm. The measurements were performed after electric breakdowns between anode and cathode, induced under high laser energy and high accelerating voltage. This operation is made in order to increase the surface roughness. For rough cathode the maximum output current was 10.5 A, reached at 25 kV and 12 mJ laser energy; the maximum quantum efficiency (QE) value was 1.3×10^{-4}. Instead, for smooth cathode the maximum output current was 8.4 A, and the maximum quantum efficiency (QE) value was 7.0×10^{-5}, calculated in the same conditions. The photoelectric effect is very promising for getting easily electron beams of high current of low emittance employing low laser energy level. In fact, experimental results have confirmed that pulsed electron beams by photocathodes are characterized by emittances much better than those achievable by thermionic guns [1,2]. Consequently, these characteristics should promise the best background in helping high brightness electron beams.

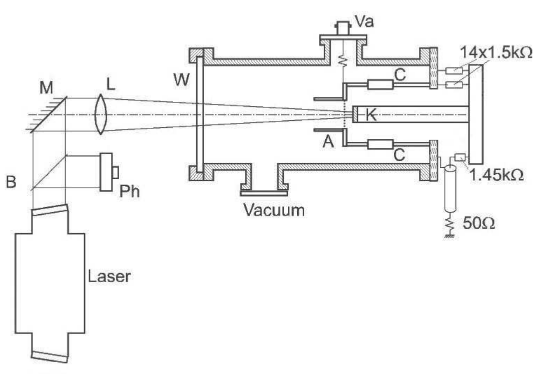

Figure 1. Experimental apparatus. M: mirror. B: beam splitter. Ph: photodiode. L: Lens. Va: high voltage. K: cathode. A: anode. C: capacitors.

The disadvantage of all conventional electron sources is their limited maximum current due theoretically to the space charge effect: the current I $\sim V^{3/2}$. It is noteworthy that the voltage increasing is responsible of the arcs which can occur in the accelerating gap, inhibiting the electron acceleration. The arcs are due to the plasma formation whose is responsible either the laser energy or the output current. Therefore, to get high extracted currents it is necessary to improve the cathode characteristics in order to avoid plasma in the accelerating gap and to supply high voltages.

The electron photoemission is a process governed by the modified Fowler-DuBridge equation by Bloembergen and Bechtel [3]. It contains, for the case $h\nu > \varphi$, with $h\nu$ the photon energy and φ the work function, the thermionic component:

$$J_0 = AT^2 exp(-\varphi/kT) \quad (1)$$

and the 1-photon process component:

$$J_1 \cong a_1 A I(t) T^2 (1-R)[\frac{1}{2}(\frac{h\nu - \varphi}{kT})^2 - \frac{\pi^2}{6}] \quad (2)$$

In the above equations I is the incident laser intensity, R is the target optical reflection, $A = 120A/(K^2 cm^2)$ is Richardson constant, T is the target temperature, a_1 is a quantum coefficient and φ is the metal surface work function.

Fig. 1 shows a sketch of the apparatus. A 100 cm focal length lens (L) was utilized to lead the beam onto the target. The cathodes were pure Y disks fixed on a conductor stem connected to the chamber by an insulating flange. The Y work function was 3.1 eV. The anode-cathode distance was 5 mm and the maximum accelerating voltage was 25 kV.

To diagnostic the current beam, it was necessary use a 100 Ω shunt to avoid reflections. The current was recorded at 1 and 0.001 Hz for 12 mJ laser energy and at 10kV accelerating voltage.

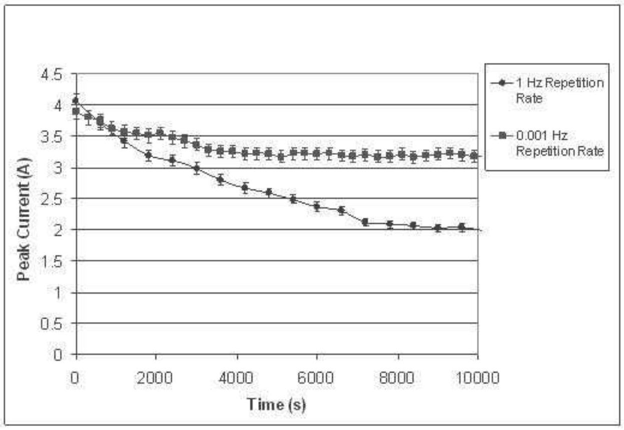

Figure 2. Temporal behavior of Y rough cathode.

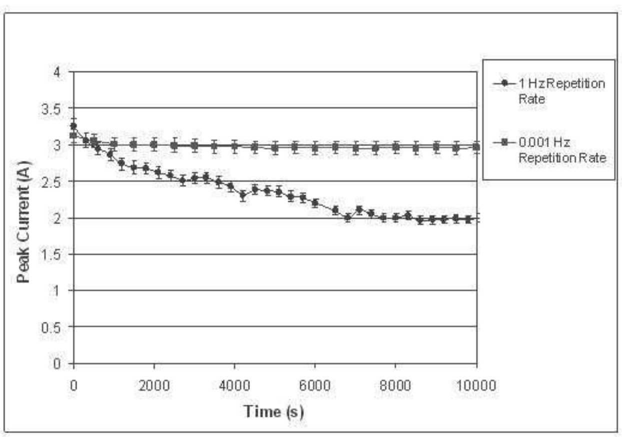

Figure 3. Temporal behavior of Y smooth cathode.

Fig. 2 and 3 show the temporal trend of the cathodes. Generally, the current for the rough cathode is more large than the smooth one. The higher rough cathode current is due to the high electric field present on its surface. The photoemission decreases on laser shot number. The behavior of the emission at 1 Hz is different from the 0.001 Hz one for both cathodes. The emission at 1 Hz is more market than the 0.001 Hz. This is due to the output current which modifies the surface for every laser pulse. The surface becomes smooth. In fact, after 900 laser pulses the current at 1 Hz for both cathode is similar pointing out that the surfaces morphology become very similar. The maximum output current was 10.5 A, reached at 25 kV and 12 mJ laser energy form the rough cathode. The maximum quantum efficiency (QE) value was 1.3×10^{-4}.

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