NEW ELECTRON SOURCE ASSISTED BY TWO LASERS

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Abstract

A new process of photoelectron emission assisted by two lasers was proposed recently to increase the quantum efficiency of metallic cathodes. We describe the test stand which is built to validate this concept.

We are developing a new gun-test stand to validate the hypothesis done about simultaneous actions of two laser beams on a metal photocathode to increase the quantum efficiency. A first laser producing high energy photons is directed on the cathode to extract electrons by photoelectric effect. But the quantum photoelectric yield of a metal is generally very low in the visible and the near-UV range, so that we have proposed to assist the action of the first laser by a second one. This laser, which corresponds to lower energy photons (Infra-red or Far infra-red) and high intensity (> 100 MW/cm²), is simultaneously directed on the cathode with grazing incidence. It is linearly polarized, normally to the surface. As shown on Figure 1, there are two supported actions of this second laser beam: to lower the potential barrier at the surface and to reduce the work function $\phi$ of the conduction electrons.

To test the validity of these hypothesis, a gun test stand is being built. This include the development of a set of measuring systems for the main electron parameters.

We expect a peak current density of about 200 A cm⁻² from this configuration and pure metal photocathodes such as Au ($\phi = 4.2$ eV) and Hf ($\phi = 3.6$ eV).

Electron emission diode

As shown on Figure 2, the emitting diode is placed in a vacuum chamber in which pressure can be lowered until 10⁻⁷ torr. The photocathode is constituted by a 2 cm² thin layer of metal deposited on a stainless steel substrate. The cathode is maintained by a handle and electrically insulated from the chamber. Its voltage

![Diagram of Electron Emission Diode](image)

Figure 1 - Potential energy $E_p$ and density $N_e$ of conduction electrons in a metal: (a) without external laser field and (b) when high-frequency laser inducing photo-electron emission is assisted by a low-frequency laser. $E_F$ and $E'_{F}$ are the Fermi level energies.
Figure 2 - 2 laser beams assisted photo-injector experimental apparatus

can be varied from 0 to -100 kV and its temperature can be adjusted from room temperature to approximately 1000 K, using a heating resistor. The cathode can also be cooled. The anode is at the earth potential (V = 0) and the electron beam is extracted through a hole with 6 mm diameter. The distance between the electrodes is adjustable from 5 to 15 mm. It has been estimated that for the 140 kV.cm\(^{-1}\) maximum electric field, the space charge limited current would reach 
\[ \approx 170 \text{ A.cm}^{-2}. \]

Lasers

The low-frequency photon source is a CO\(_2\) laser (\(\lambda = 10.6 \text{ \mu m}\)). Special NaCl optical elements were designed to obtain an uniform energy distribution on the cathode plane. The angle of the beam with the surface corresponds to near-grazing incidence and it is polarized by ZnSe plates at Brewster angle. This laser, constituted by an oscillator and seven amplifier stages, produces maximum peak intensity of \(I_{0} = 1 \text{ GW/cm}^2\) with 50 ns pulse duration. The other laser is a frequency-tripled Nd-Yag (\(\lambda = 353 \text{ nm}\)). Note that the corresponding photon energy is very closed to the Hafnium work function for instance. This laser beam illuminates the cathode either at a quasi-normal direction (\(\theta = 5^\circ\)) as represented on Figure 2, or at any other direction and specially at grazing incidence angle. This last situation favours the surface photoelectric emission as verified recently. CO\(_2\) laser pulse has 5 nsec duration and peak intensity can be varied from few kW.cm\(^{-2}\) to \(10 \text{ MW.cm}^{-2}\). To limit an excessive cathode heating, it seems to be adequate to limit this peak intensity to about \(1 \text{ MW.cm}^{-2}\). Later, this laser will be replaced by another one producing bursts of 200 psec micro-pulses at a repetition rate of 72 MHz/W, when N can be varied from 1 to 20.

The other laser beams are continuously monitored in time and energy.

Diagnostic of electron beam

It is realized by a series of adapted apparatus. In particular, in these experiments, real current is limited to 8.7 A and energy of electrons is lower than 140 keV.

Measurement of transverse emittance \(\varepsilon_{\perp}\) is done by a pepper-pot and a scintillating screen or by a magnetic lens associated with a transition-ray screen made of an Al or Ag sheet of 2 \(\mu\)m width (Figure 2).

The current intensity and charge are measured by use of a Faraday cup and adapted in impedance or by two Rogowski coils (Figure 2) close from the near of...
of anode and situated on both sides of the first magnetic lens which limits the electron beam divergence.

Finally, the electron energy distribution is determined by means of a magnetic spectrometer adjusted to the 100-150 keV bandwidth and associated to a wire-detector or a scintillating screen.

Conclusion

This experimental apparatus will be used to test new basic ideas to solve applied physical problems whose solutions are needed for the development of high-brightness laser.

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References


/4/ R. Dei-Cas et al., "A high brightness photo-injector for a free electron laser proposal", this meeting.