

PRELIMINARY RESULTS OF ADELE(*) EXPERIMENT

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Abstract

First outstanding results of ADELE experiment are presented. They concern the electronic emissions produced separately by a CO₂ and a tripled-frequency Nd-YAG laser on a gold photocathode. The data are analyzed in connection with the effective laser coupling with the metallic surface.

1 - Introduction

A gun-test stand built at C.E.B. [1] was used to validate the hypothesis suggested by one of us [2,3] about the simultaneous actions of two lasers on a metal-photocathode in order to improve the photoelectric quantum yield and therefore the photo-current intensity. From a previous experiment [4], it seems that it is possible to generate a significant reduction of the work function at the surface of a metal with a very high-peak-IR-laser intensity $I_{\omega} \gg 1 \text{ GW/cm}^2$. So, the classical photoelectric action of a visible radiation will be assisted by the IR-laser action. Because of their high thermal and stress resistances to the high-levels of radiative exposures [5], metal photocathodes can be competitive with semi-conducting materials. However, some experimental conditions described below have to be satisfied.

2 - Experimental set-up

As shown on the Figure 1 of ref. [1], the emitting diode is located in a large vacuum chamber, with various diagnostic devices. The pressure could be only lowered to 8×10^{-8} torr, but it will be improved to 10^{-9} torr in a next future. From the test of gold photocathodes with various substrates, we found that the more resistant to high irradiation is a system constituted by a $0.2 \mu\text{m}$ gold layer on a massive Ni piece. The cathode, insulated from the chamber is maintained by handle, its voltage varying down to -50 kV . The anode, at 5 mm from the cathode, is connected to the ground while the electron beam is extracted through a hole of 6 mm-diameter. Therefore, the applied electric field is limited to 100 kV/cm so that the space charge is less than 9 nC/cm^2 . A focusing-lens, with a supplied current $I_B = 0-1.5 \text{ A}$, is placed just behind the anode and limits partly the dispersion of the electrons. The photocurrent produced separately by each laser is detected with a 50Ω -Faraday cup of which the opening is limited by an arcing-ring. Because of the divergence of the electrons, it is possible to measure two correlated current intensities : one from the isolated disk in front of the cup and one from the Faraday cell. Their recordings are done with a Lecroy 9450 oscilloscope (350 MHz).

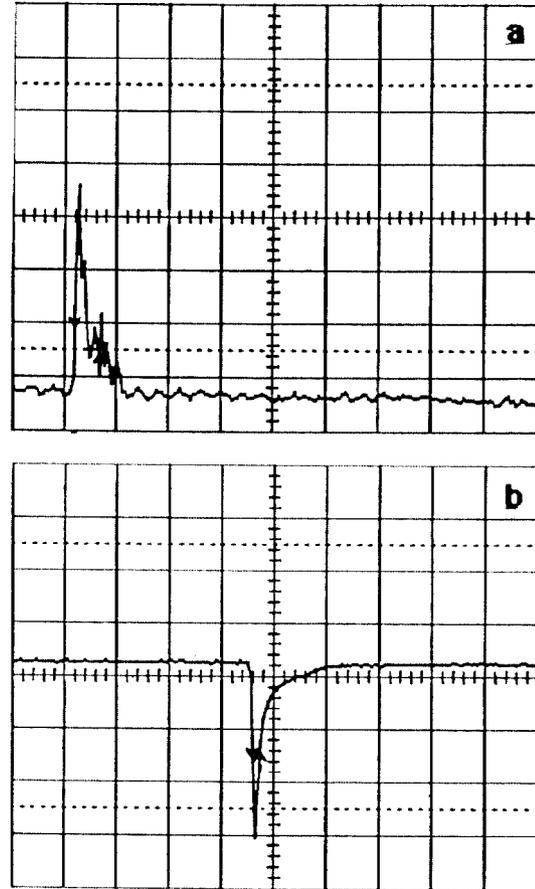


Figure 1 - Typical laser-pulses
of (a) CO₂ and (b) 3 ω Nd-YAG, Time/div 50 ns

The principal characteristics of the two laser beams are the following : the IR radiation, provided by a CO₂ laser ($10.6 \mu\text{m}$), is polarized so that its associated electric field E_{ω} is at right angle with the surface while the beam direction is at near-grazing angle ($\sim 85^\circ$). The pulse energy is limited to 0.5 J on the photocathode, the irradiated surface being $\sim 2 \text{ cm}^2$, the peak intensity is $\ll 50 \text{ MW/cm}^2$ i.e. $E_{\omega, \text{max}} \sim 20 \text{ kV/cm}$ (Figure 1a). The second radiating source is a tripled-frequency Nd-YAG laser emitting only few kW/cm^2 at 353 nm , during $\sim 7 \text{ ns}$ (Figure 1b). It illuminates the cathode at near-right-angle (5°), the spot diameter being for most of the experiments $\sim 0.9 \text{ cm}$ (Note that it varies with the laser energy). Also, the stability of the peak intensity is only $\sim 15 \%$.

3 – Main experimental results

We tested the good working order of our system by a preliminary series of experiments using principally the Nd-YAG laser. We first controlled that when no laser beam arrived on the photocathode, we observe no signal. The same situation was realized when the cathode was illuminated by the laser, with an interelectrode applied voltage $V_0 = 0$. Therefore, the electronic pulses, observed in all others situations are supposed to correspond to photoelectrons. The amplitude of the measured current intensity depends only on the focusing of the electron beam. So, for $i_B = 0$, the electrons are essentially collected by the arcing-ring, while for $i_B = 1.5$ A, they are collected by the Faraday cup. The both currents being recorded simultaneously (Figure 2), the maximum intensity produced by the 353 nm laser beam is ~ 36 mA, with a pulse duration ~ 6 nsec, that corresponds to an extracted charge ~ 0.2 nC (approximately 1/100 of the space charge density). As the electronic pulse duration is clearly smaller than the duration of the laser pulse, we think that such a current corresponds to a bi-photonic emission ($\hbar\omega \sim 3.4$ eV, $\Phi_{Au} \sim 5$ eV). The photoelectric sensibility is apparently high : $S_\omega \sim 3 \times 10^{-6}$ A/W. The laser pulse-repetition-rate being very low (< 1 per mn). We observe no destruction of the surface of material due to the laser interaction. But, as the multiphoton effect is typically non-linear –the peak current intensity depends on the peak laser density I_ω – we think that for $I_\omega \ll 100$ kW/cm² at 353 nm, it must be possible to produce a charge of some nC/cm².

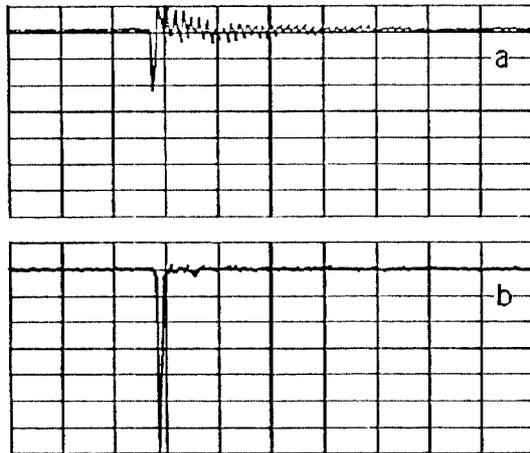


Figure 2 – Photoelectron current intensities produced by the 3 ω -Nd-YAG laser on a gold cathode measured from :
(a) the arcing-ring and (b) the Faraday cup
CH1 : 0.2V, CH2 : 0.2V and T/div 50 ns

Concerning the action of the CO₂ laser, we decided to limit the pulse laser energy on the photocathode to ~ 0.5 J because for higher energy a very rapid destruction of the surface was observed although the repetition rate was only 1 per 5 mn. We think that such a situation was due to the poor quality of the vacuum in the chamber and the presence of oil vapor traces. We are now putting right this situation.

When the diode is polarized to the higher voltage, typically : 100 kV/cm, any CO₂ laser pulse with an energy ~ 0.2 – 0.5 J, drags always the same electronic charge of

20 nC. This charge corresponds to the space charge density and the observed peak current is ~ 2 A (Figure 3). The CO₂ laser beam acts here as a release mechanism at the origin of the diode vacuum disruption and consequently leads to the transfer of all the charges present on the electrodes. Then, the coupling of the CO₂ laser beam with the surface of the cathode is a typical-field-coupling, while the one of the tripled-frequency Nd-YAG laser is a typical photon-coupling.

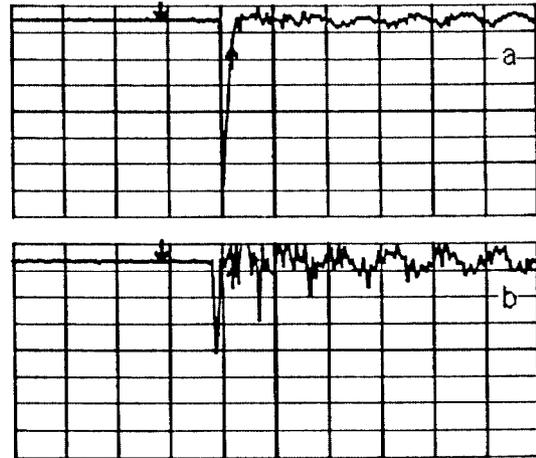


Figure 3 – Photoelectron current intensities produced by the CO₂ laser on a gold cathode measured from :
(a) the Faraday cup and (b) the arcing-ring
CH1 : 1. V, CH2 : 1. V and T/div 50 ns

For a polarization-voltage of the diode in order to 12 kV, no electronic emission is observed, comforting our hypothesis of a CO₂ laser-field action. Now, to increase the field effect of the CO₂ laser on the photocathode, while preventing any disruption of the diode, it is absolutely necessary to improve the cleanliness and to obtain a lower limit of the vacuum in the chamber. We think that a value close to 5×10^{-9} torr would be an acceptable condition.

4 – Conclusion

From the preliminary results reported here, the typical field and photonic-coupling of a CO₂ and a Nd-YAG laser respectively with a gold photocathode are consistent with our previous hypothesis. The ameliorations of experimental conditions and specially of the vacuum quality in the chamber must allow a rapid progress and provide a definitive confirmation of these first data.

References

- (*) ADELE is : "Assistance par DEux Lasers de l'Emission d'électrons".
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