#### HIGH EMISSIVITY PHOTOCATHODES

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# Summary

Studies of e sources triggered by laser light are under development in our laboratory. Beside photocathodes of normal size a special effort has been put on microemitters working in field emission conditions. New kinds of microemitters realized with the collaboration of BNL are under experimental study since July 1987. These emitters showed very high emissivity at low incident laser intensity in UV light ( $\lambda = 0.353 \mu m$ ). Quantity of charges above 20 nC have been obtained at photonic energies of 10<sup>-4</sup> J about. Experiments concerning these photocathodes in moderate (30 kV) and high (more than 100 kV) voltage configurations have been done and are here presented.

#### Introduction

The research of new microwave sources in S band and the realization of new e<sup>-</sup> sources led to important studies on laser switched photocathodes in many laboratories. Intense researches have been carried out on normal size photocathodes at  $SLAC^{(1)}$ ,  $KEK^{(2)}$ , LOS-ALAMOS<sup>(3)</sup>. Studies on cathodes of microscopical size have been done at LAL-Orsay<sup>(4)</sup>. BNL<sup>(5)</sup> and other laboratories have also started with similar programs.

The experiments on photocathodes of microscopical size, with emitting radius of less than 1  $\mu$ m, showed high photo emissivity in the three wavelengths : (1.06  $\mu$ m, 0.532  $\mu$ m, 0.355  $\mu$ m) when working in field emission conditions. Obtained results on single or arrays of needles have been already published. These results concerned carbone, niobium - titanium and tungsten microemitters.

New kind of microemitters have been realized by Brookhaven National Laboratory and tested at LAL. A presentation of the photocathodes, the experimental conditions and of the results is given below.

## II Photocathode description

In Figures 1 to 3 we show examples of the realized and tested microscopical emitters. These photocathodes were made with the integrated circuit techniques. All silicon ridge arrays were diffusion bonded to aluminium planchets. Each sample consists of 250 rows of 2.5 mm long with a separation of 10  $\mu$ m apart; row thickness is of about 0.5  $\mu$ m.

In a first step we characterized each sample in field emission regime. First tested sample was made of a ridge pattern which has been sputter coated with 750 A of tungsten (WSi). Then we tested another ridge pattern

which was coated with 500 A of PdSi. For this patern entire assembly was annealed at 400° C during 10 mm in argon to form PdSi layer over ridges [6]. Other sample made of highly n or p doped silicon are under tests.

## III Laser description

We used a trippled Nd : YAG laser, which consists of a mode locked oscillator by saturable absorbent. It produces a train of ps elementary pulses in different light wavelengths ( $l\omega$ ,  $2\omega$ ,  $3\omega$ ) with a chosen frequency modulation from 125 MHz to 3000 MHz at a rate of 10 Hz. A single optical amplifier allows the production of visible light with an energy of 8 mJ per burst and 3 mJ in UV light. Use of new colorant since 1987 allows the realization of stable 10 ps FWHM pulses. Fig. 4 shows an example of 3 pulses measured with a HADLAND IMACON 500 streak camera.

### IV Experimental results

The tests were made using two different vacuum cells. Produced photocurrents are measured on the cathode holder in the smallest cell (cell n°l) Fig. 5. This output allows a better knowledge of the emitted photocurrent pulses. In the second cell (cell n°2), produced photoelectrons are collected either on a polarized anode or on a Faraday cup.

Transmission light measurements showed that about 10% of the incident photons are reflected when entering the sapphire window of each cell. Light incidence angle on the photocathode was  $\theta \simeq 12^{\circ}$  in cell n°l and variable (roughly) from 20° to 90° in cell n°2 (Fig.6). Tested microcathodes were electrically characte tized in field emission regime by Fowler Nordheim plot before their irradiation by laser beam. Field emission threshold occurred in each cell at different potential values depending of the cathode anode distance. Typically it was for the WSi array of V = 28 kV for a cathode anode distance of  $\simeq 5$  mm in cell n°l and of V $\simeq 107$ kV in cell n°2 for a distance of 20 mm.

Average photocurrents were measured just below field emission threshold on an ammeter ; then pulsed photocurrents were observed using two different oscilloscopes with bandwidths of 1 GHz and 7 GHz respectively.

### IV.1 Obtained results with moderate high voltage (cell n°1

Using WSi sample at  $\lambda = 353$  nm with a photonic energy  $\varepsilon_1 = 10^{-4}$  J ± 20%, we observed in cell n°! the variation of the average emission with the D.C. potential (Fig. 7). All potential values were below the field emission threshold.

On this figure, we may notice an important enhancement of the photoemission just below the field emission threshold (FET).

In figure 8, variation of the emitted photocurrent vs photonic intensity is represented for a given HV. The important increase of the current may be tied principally to thermic behaviour. Pulse observation on 1 GHz scope showed a thermic tail. Increasing photonic energy to  $\epsilon_i = 10^{-3}$  J we noticed,

just below FET, a strong enhancement of the emission with 4.5  $\mu$ C : the corresponding pulses observed on a 1 GHz scope indicated a peak value of about 40 Amp for 100 ns ; the high rate of charges as well as the pulse enlargement indicates an important contribution of thermic effects. After some time, emission rate decreased in this region of the photocathode. Observation on a scanning electronic microscope showed local destruction on about 100  $\mu$ m by 2 mm (5% of the total area) (Fig. 9). XPS analysis showed, for this region, that tungsten was removed.

# IV.2 Obtained results with high voltage (cell n°2)

Tests were going on with this photocathode in cell  $n^22$ . FET were obtained for different cathode-anode distances. Breakdowns often occurred for potential values above 85 kV and weak photocurrents.

Photocurrent behaviour with incident light power and high voltage has been observed. On Figure 10, variation of pulsed photocurrent with optical power (in green wavelength) is showed for two values of the high voltage. Rapid increase of emitted photocurrent may be observed as before (figure 8).

### Conclusions

These photocathodes presented : high photoemissivity, good reproducibility of the photocurrents

with moderate laser energies (less than  $2.10^{-4}$  J), good mechanical stability and good behaviour to an exposure. Such photocathodes could be interesting candidates for laser driven RF guns. Some verifications on these photocathodes have to be done in LAL : precise measurement of the photocurrent pulse duration and emittance measurements.

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Fig. 1 - SiW array view by scanning electronic microscc



Fig. 2 - Enlarged view of SiW array



Fig. 3 - SiW microemitter



Fig. 4 - Light pulse observed on IMACON 500 streak-camera. Total duration of the three elementary pulses : 120 ps



Fig. 5 - Experimental cell nº 1



Fig. 6 - Experimental cell nº 2



Fig. 7 - Average emission variation with D.C. potential (cell n° 1)



intensity (cell n° 1)



Fig. 9 - Local destruction of the Siw array

