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REPORT ON MACHINE DEVELOPMENT

PROFILE MEASUREMENT IN THE LEAR TRANSFER LINE

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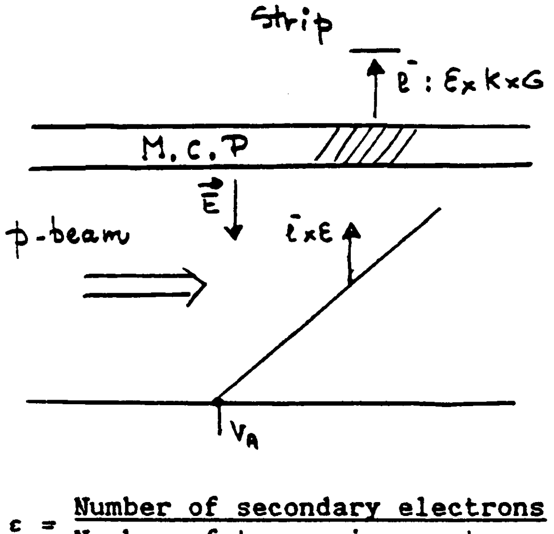
1. INTRODUCTION

The aim of the experiments was to check for the feasibility of profile measurements in the LEAR transfer line, and of the use of sensitive screens and vidicon cameras at very low intensities ($10^6 \rightarrow 10^3$ p/s).

Two machine developments have therefore been made end of 1986.

2. PRINCIPLE OF THE MCP PROFILE DETECTOR



In essence the detector uses the secondary emission created by the protons when traversing a thin metallic target foil. The secondary emission efficiency is defined as :

$$\varepsilon = \frac{\text{Number of secondary electrons}}{\text{Number of traversing protons}} = \frac{N_e}{N_p}$$

The electrons are accelerated toward a micro-channel plate (M.C.P) by an electric field. The M.C.P itself act as an electron amplifier with gain G. Due to geometrical considerations only a fraction K of the electron yield is amplified. In consequence the number N of electrons at the M.C.P output (for one incident proton is given by)

$$N = N_e \times K \times G$$

Electrons at the M.C.P output are collected by a set of 32 aluminium strip. The strips have a width d of 1 mm each and are spaced by 0.5 mm leaving therefore a gap of 0.5 mm between each foil. Therefore a correction factor k of 0.66 must be applied.

An integration of the current collected by each strip is provided. The integrator voltage is therefore :

$$V = e \cdot \varepsilon \cdot K \cdot k \cdot G \cdot \int_0^\tau \frac{1}{C} N_p (d,t)\, dt$$

where $e = 1.6\ 10^{-19}$ Coulomb   C the integrator capacitance (47 pF)

τ is the integration time.

If the number of protons passing through the foil is constant during the integration time (that is the case of an ideal spill).

$$V = \frac{\ell \cdot \varepsilon \cdot K_o \cdot G \cdot N_p \cdot d \cdot \tau}{C} \qquad (1) \qquad K_o = Kk$$

In principle V is proportionnal to the number N_p of protons passing through the foil over a surface equivalent to that of the corresponding grid.

The proton beam distribution, or profile, can thus be measured.

3. PHYSICAL SET-UP

The target foil and the M.C.P are installed in a vacuum tank with the following arrangement (fig. 1)

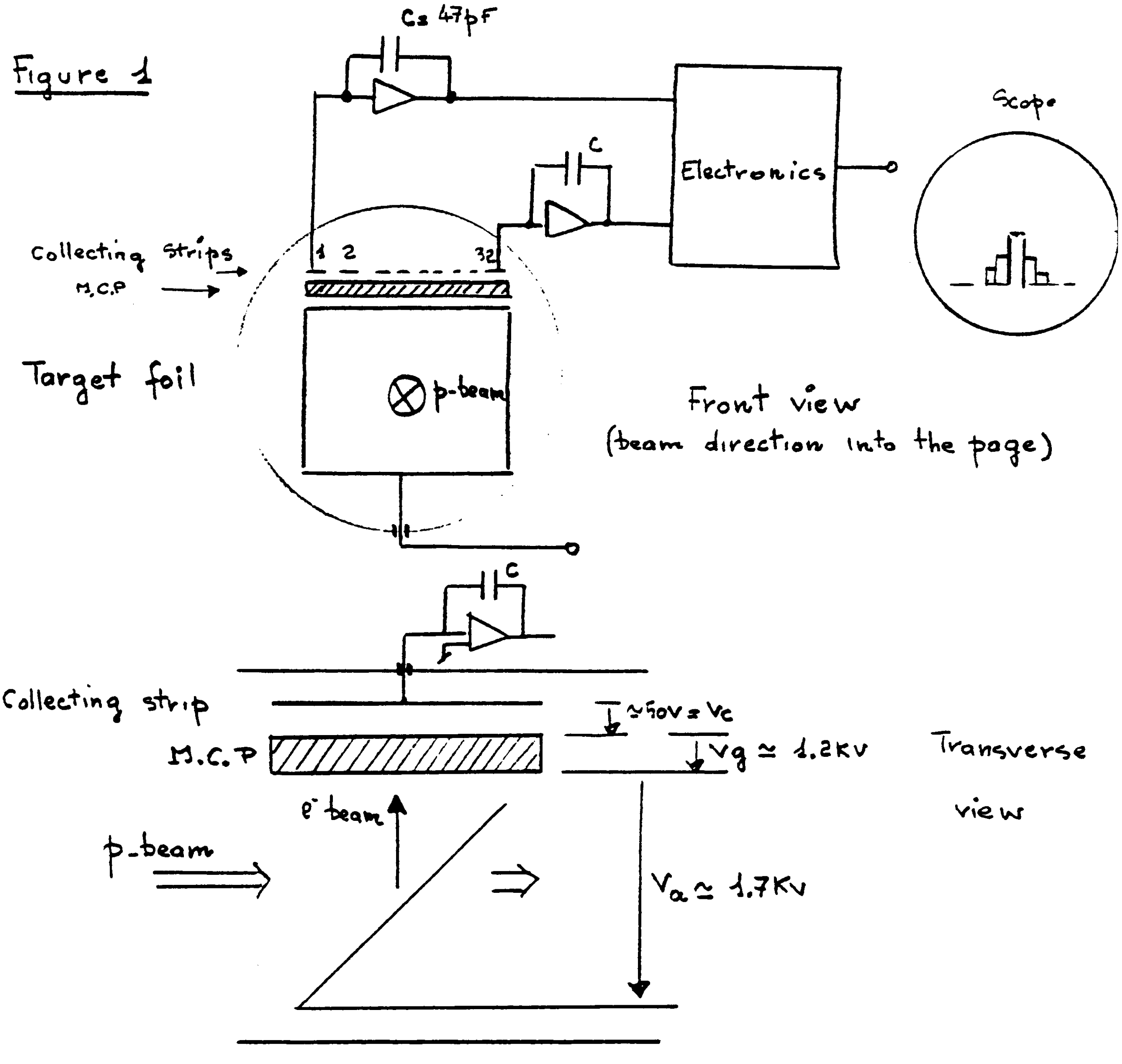
- The M.C.P type G25-70 has a diameter of 70 mm
- The foil consists in three successive layers (ref. 1).

300 Å CsI
600 Å Al
1000 Å $Al_2 O_3$

and has therefore a total thickness of 0.19 μm.

A similar type of sensitive layer, but much more thicker has been experimented at the SPS (ref. 3).

Figure 1



each voltages :

V_g : M.C.P gain voltage. $G = f(V_g)$

V_a : accelerating voltage

V_o : collecting voltage

can be adjusted.

The detector tank (except for the foil) and electronic has been already used at SPS (ref. 2).

The detector is installed at the end of the LEAR measurement line E5.

N_p, the number of extracted protons, is measured by another detector with a good accuracy.

4. EXPERIMENTAL MEASUREMENTS

The profiles appears on a scope as shown on photo 1. The ordinate corresponds to the integrator voltage output whereas the abscissa corresponds to the electronic scanning time (can be arbitrary adjusted).

Each horizontal step has therefore a "width" of 1.5 mm. In the present case the beam has a width of about 3 x 1.5 = 4.5 mm. However due to the absence of magnetic field the exact beam dimension must be about 1.5 mm less.

The maximum voltage amplitude will be referred as the "peak" in the following explanations.

4.1 Plateau

No magnetic field has been used. It will of course improve the profile measurement. However one must be sure that almost all the secondary electrons are collected.

Figure 2 shows the plot of the "peak" voltage as a function of V_a (V_g remaining constant). One sees that for $V_a \geq 1000$ V a plateau occurs showing that all electrons are reaching the corresponding strip.

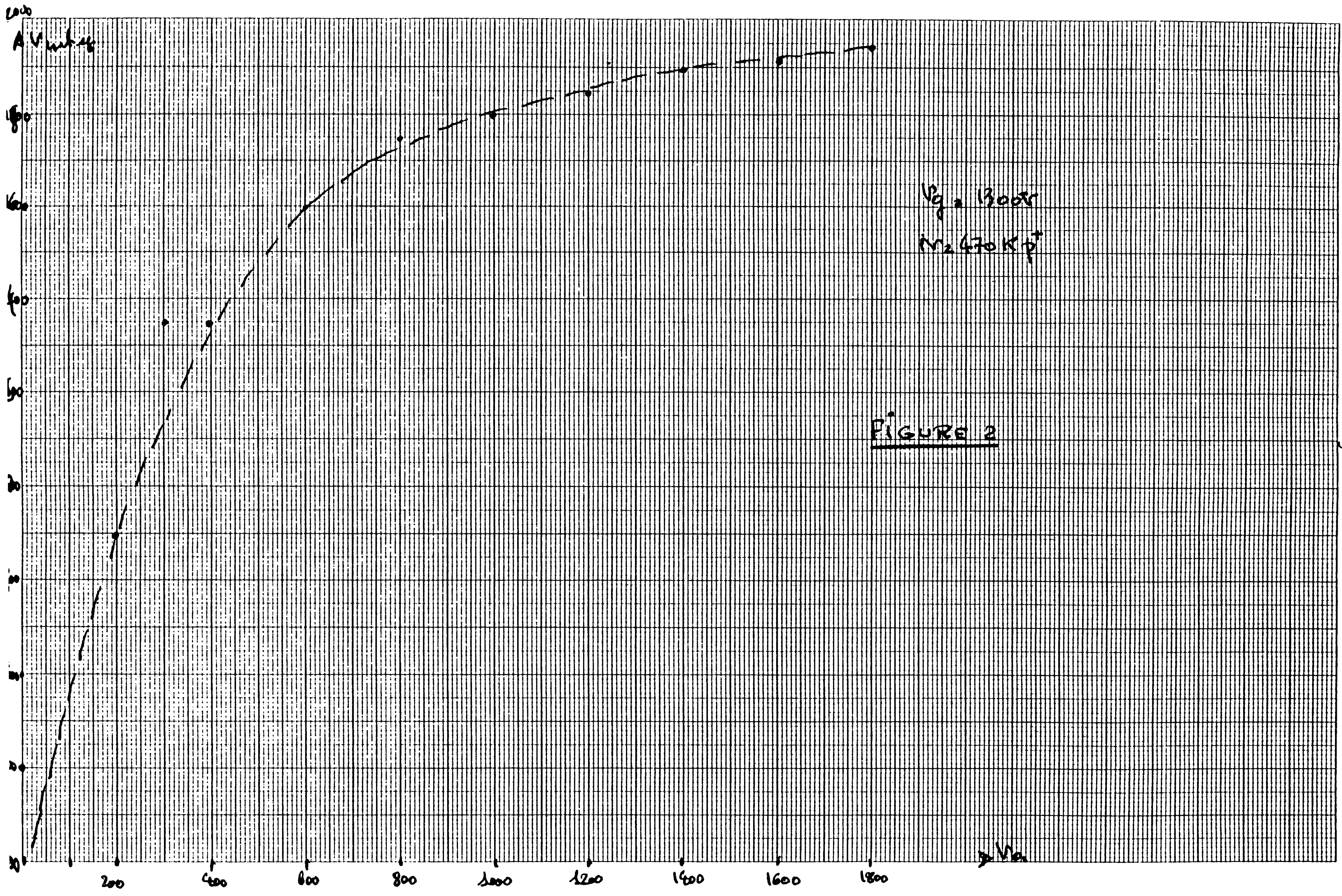

ΔV wh 4
2000
1800
1600
1400
1200
1000
800
600
400
200
200
400
600
800
1000
1200
1400
1600
1800
Va
Vg = 1300V
M = 470 K p+

FIGURE 2

4.2 Secondary emission efficiency

ε the secondary emission efficiency can be estimated from formula 1).

4.2.1 When the beam hits first the CsI side

The gain "G" of the MCP has been measured in laboratory (G = 3.5 10^3 at Vg = 1250 V, with an uncertitude of ± 20%).

$$\varepsilon = \frac{V \cdot C}{\ell \cdot K_o \cdot G \cdot \tau \cdot N_p} \qquad (K_o = 0{,}6 \times 0{,}6 = 0{,}36)$$

When using photo 1 (V = 2 x 0.5 + 1.5 = 2.5 V) or photo 2 or 3 one finds that ε = 1.8.

4.2.2 The same measurement made on the "$Al_2\ O_3$" side gives ε = 5% which is an agreement with the numbers already found at SPS

Linearity

A set of measurement has been made with different extracted intensity. The peak amplitude follows linearly N_p and the measured beam width does not change.

As it can be seen from photo 3 even with low intensities (N_p = 80.000) the detector is free of noise.

5. PRINCIPLE OF THE BTV PROFILE DETECTOR

A television camera is looking onto a light spot which is created by charged particles traversing a luminescent screen (ref. 4). Beam profiles can easily be obtained from these light spots. This has been due to the development of the SPS synchrotron light detectors (ref. 5, 6).

The MCP and the BTV-detector were installed one next to the other, so that the profiles are the same.

The facilities provided in the set-up allow a comparison of 2 different luminescent screens observed by a very sensitive SIT (Silicon Intensified Target). The target current gain can be varied by a factor 1600 by adjusting the photocathode accelerating voltage.

The profiles of a CsI-screen (being the most sensitive) are shown on photo 4.

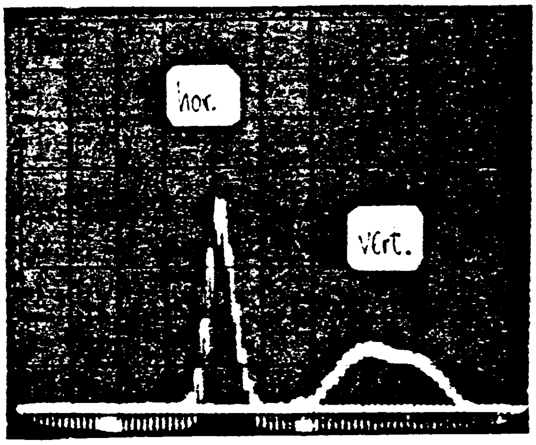


Photo 4

Horizontal and vertical profile measured with CsI-screen and intensity ~ 5 x 10^5 p/S

The gain of the tube was 160. The vertical scale corresponds to 100 mV/cm and the horizontal scale to 2.76 mm/cm. The total ellipse of the beam is approximately 21 mm^2 with a horizontal width of 3.1 mm (± 2σ). This compares well with the results of chapter 4 i.e. 4.5 mm for the same deviation. The CsI-screen was found to be about 50 times more sensitive than the well known red alumina screen.

With full gain profiles can be measured down to intensities of 2.5 x 10^4 p/S which corresponds to 48 p/mm^2 • 40 ms without any difficulties. For beam observation with a video monitor this intensity can still be reduced by a factor 5, such that 10 particles/mm^2 • 40 ms are observable with a SIT and CsI-screen.

6. CONCLUSIONS

These type of detectors, give in fact promising results what the MCP detector is concerned improvements have to be made on the electron collecting optics and in particular the use of combined and electronic magnetic fields should be envisaged but it was not the aim of the experiment.

References

1) Private communication from M. Claude Chianelli DPHNME CEN Saclay
2) SPS Improvement report N° 176 (1980)
3) SPS/ABM (in preparation)
4) SPS improvement report 187 (1981)
5) SPS improvement report 165 (1979)
6) Proc. XIth Conf. on High Energy - CERN July 7-11 (1980)

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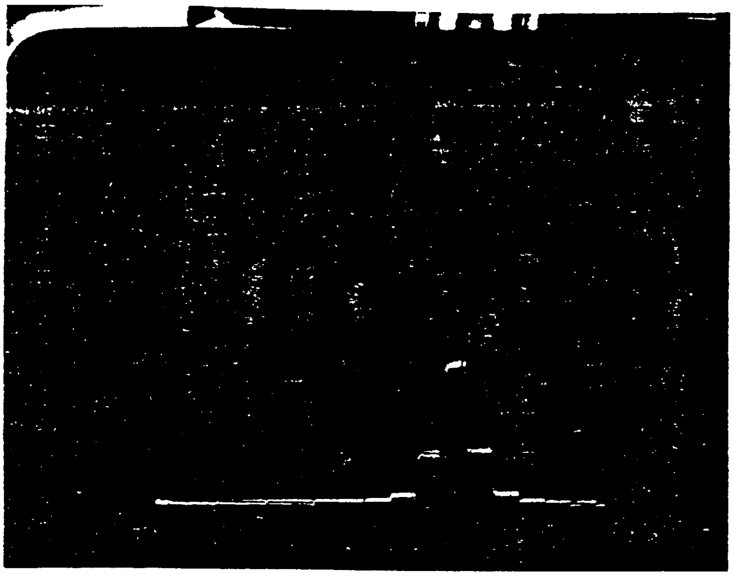

Photo 1

τ = 300 ms

0,5 V cm

N_p = 1,15.10^6 p

V_g = 1300 V

V_a = 1700 V

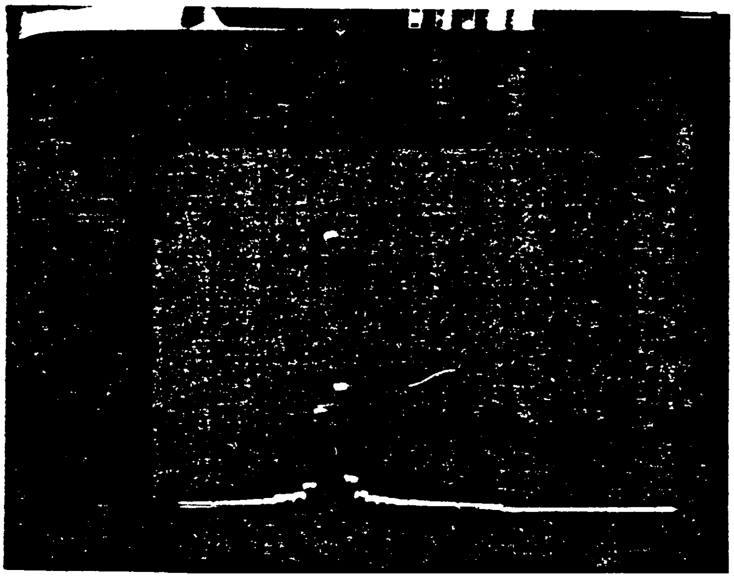

Photo 2

τ = 990 ms

1 V/cm

1,45.10^6 p

V_g = 1300 V

V_a = 1700 V

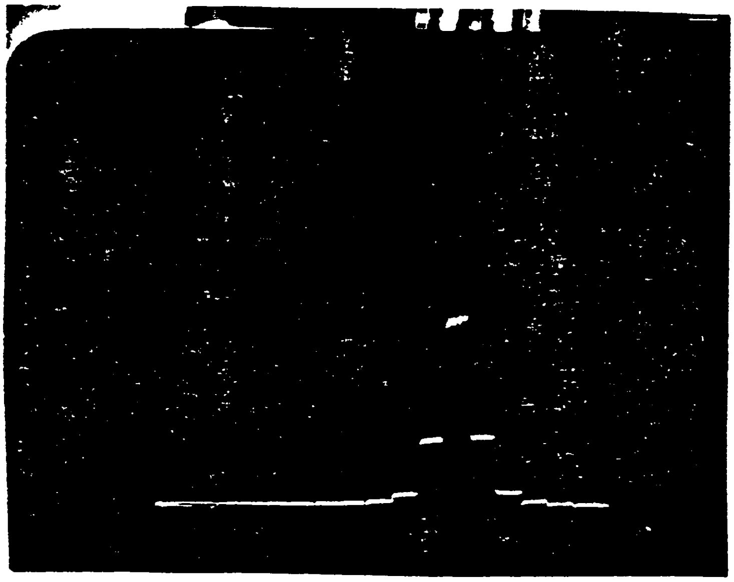

Photo 3

τ = 1 s

100 mV/cm

N_p = 8.10^4 p

V_g = 1300 V

V_a = 1700 V