HIGH POWER TEST OF GaAs PHOTOCATHODE IN RF GUN

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Abstract

A prototype of S-band RF photogun with GaAs photocathode has been build and tested at Novosibirsk. The main goal of this prototype is to check a possibility of long time operation for GaAs photocathode in a strong accelerating field of RF cavity. The first experimental results concerning dark current and lifetime of GaAs photocathode in NEA condition under high RF power are presented.

1 INTRODUCTION

Nowadays GaAs polarized electron source is the best available because it has intrinsic advantages in performance of intensity, quantum efficiency, degree of polarization compared with other type of polarized electron sources. Combining all these advantages with a significant interest to polarized electron beams which comes from a high energy physics, we have chosen a GaAs photocathode for our photo RF gun project. Unfortunately there was no experimental confirmation of possibility to use this cathode inside a high gradient cavity. In order to investigate a performance of GaAs photocathode in S-band RF gun the experimental bench was build in our laboratory. The detailed description of the installation can be found in [1].

2 EXPERIMENTAL RESULTS

2.1 GaAs photcathode with small quantum efficiency.

The first experiments started in autumn of 1997 with the bulk GaAs cathode activated to quantum efficiency about .01% - .05% on HeNe laser wavelength. It corresponds to positive electron affinity (PEA) regime probably. The aim of that run was to test all systems and measure cathode properties for different levels of RF power in the cavity. Dark current and lifetime were measured for the accelerating field strength up to 100MV/m. The detailed description of experiment and results can be found in [2]. In this experiment we did not observe any difference in GaAs photocathode (on the quantum efficiency level mentioned above) behavior in comparison with other types of photocathodes nor in dark current level nor in it's dependence on electric field strength. We observed decreasing of cathode lifetime up to 30 min in the field about 30MV/m which could be explained by vacuum worsening in the cavity due to dark current. When installation was opened we observed significant damage on the cathode surface.

2.2 GaAs photcathode with large quantum efficiency.

New cathode was installed at the end of 1997. After 50 hours of baking at 300°C pressure $2{\cdot}10^{-10}$ torr was established. Only ion pumps were used at this stage. Cathode was activated following usual "yo-yo" algorithm. Typical quantum efficiency on HeNe laser wavelength was 3%-5% that ensures that cathode surface is in negative electron affinity (NEA) condition. Lifetime was 7-8 hours in activation chamber and the same practically in the cavity with RF switched off. Typical dependence of quantum efficiency on time is shown in Fig.1.

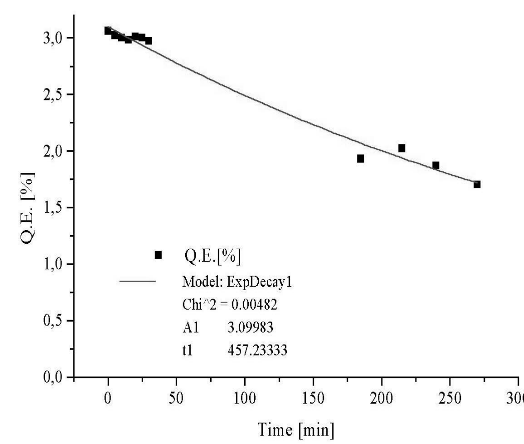

Figure1: The dependence of quantum efficiency of GaAs photocathode upon time measured in activation chamber.

Cathode was installed to the cavity after activation, RF power increased slowly step by step and dark current was controlled to prevent cathode damages observed in the previous experiment. Burst of dark current up to tens of nanoCoulomb was registered even for field strength on the cathode less then 10MV/m. Lifetime in this case was just several seconds therefore we reduced repetition rate of RF pulses to .5 Hz . Parameters of dark current pulse were measured digitized and stored in computer during each RF pulse. Photocathode was moved to activation chamber after each 10-15 pulses for measurement of quantum efficiency. Typical record of experimental run is shown in Fig.2.

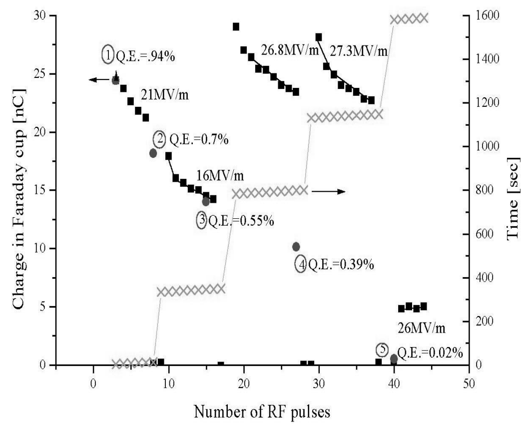

Figure2: Dependence of charge in Faraday cup and quantum efficiency upon number of RF pulses.

The dark current depends on quantum efficiency of the cathode and on the strength of RF field as seen in Fig.2. One can see from comparison of dark current curve with quantum efficiency measurements that dependence of dark current upon quantum efficiency is linear in the first approximation. Quantum efficiency drops exponentially with number of RF pulses therefore we can correct dark current data q_n multiplying it by coefficient $e^{n/Ne}$, where Ne can be calculated from dark current dependence upon number of RF pulses. This corrected data are shown in Fig.3.

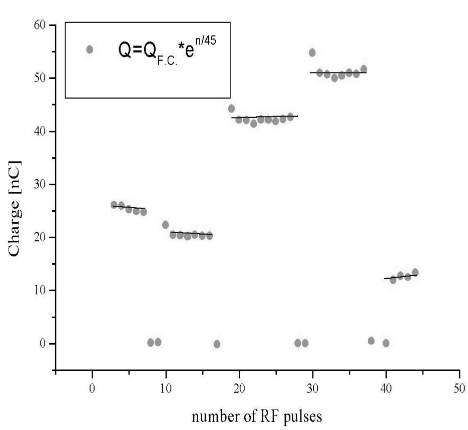

Figure 3: Corrected plot of dark current vs. number of RF pulses.

The dependence of dark current upon field strength on the cathode can be derived from corrected data. This dependence is shown in Fig.4 in Fowler-Nordheim coordinates.

In principle, Fowler-Nordheim low describes an autoemission from a metal surface, however experimentally measured dark current from semiconductor PEA photocathodes satisfies this low as well [2,3]. It is not true in our case as seen from Fig. 4. The linear fitting to experimental points gives slope opposite to one observed for metal surface and usual photocathodes. On closer examination one can see two branches shown by dotted lines in Fig.4, with normal and anomalous slope which probably coincide to PEA and NEA regimes of the photocathode respectively.

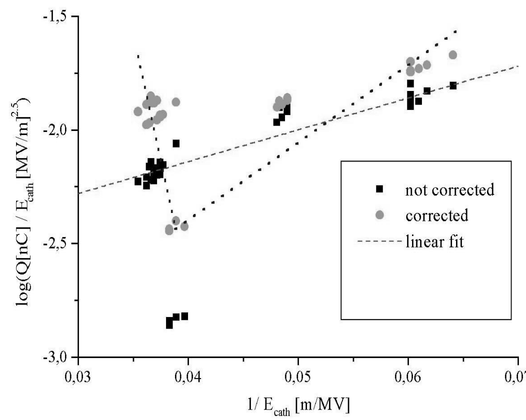

Figure 4: Fowler-Nordheim plot.

The results of another experimental run with larger number of pulses are shown in Fig.5,6.

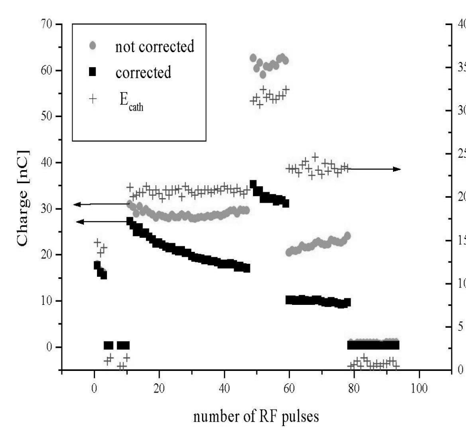

Figure 5: Dependence of charge in Faraday cup and quantum efficiency upon number of RF pulses.

These data were collected without interruption for quantum efficiency measurement. The same behavior of Fowler-Nordheim plot is observed.

3 CONCLUSIONS

The experimental results reported above allow making the following conclusions:

- GaAs photocathode can operate in a RF cavity with accelerating electric field strength up to 30MV/m without irreversible damages. After degradation due to bad vacuum conditions it can be activated again many times following usual procedure.
- Dark current from an activated to NEA cathode exceeds by 2 – 3 orders of magnitude dark current of PEA photocathode in a field of the same strength.

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- The dependence of dark current upon electric field strength from GaAs photocathode activated to quantum efficiency about 1% doesn't satisfy Fowler-Nordheim low

More experimental data are needed for further investigation of these phenomena. The main problem for experiment now is very short lifetime in the present variant of installation. The possible reason is intense gas desorbtion in Faraday cup which is very close to the cathode location. In order to improve situation we plan to increase distance from the cavity to Faraday cup and to place additional pumping between them.

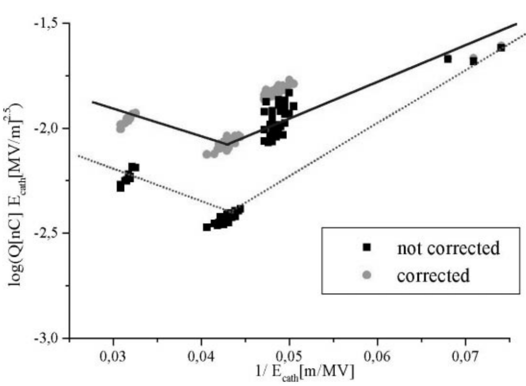

Figure 6: Fowler- Nordheim plot.

REFERENCES

[1] A.V.Aleksandrov et al, "A Prototype of RF photogun with GaAs photocathode for injector of VEPP-5", EPAC'96, Sitges, June 1996.

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[3] C.Travier et al, "CANDELA photo-injector high-power test.", NIM B89 (1994) 27-32.