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Influence of the Fringe Fields in Microchannel Amplifiers Design

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Abstract: Description of mathematical model for the fringe fields in photo detectors based on microchannel plates (MCP) is given. Normally the fringe field calculation requires complex and time-consuming computations using three-dimensional commercial codes. The original semi-analytic model suggested in the paper. This model is based on the mapping procedure for pre-calculated universal fringe field patterns for channels with specific values of the diameter and applied voltages. A fast algorithm can be used for metal channels with metal deposition on the edge and without it. Comparisons of numerical and experimental data are given. The dependencies of major device parameters vs. of applied voltage, pore size, and magnetic field magnitude have been studied.

Keywords: Photo Detector, Microchannel Plate, Numerical Simulation

1. Introduction

Microchannel amplifiers (MCA) are widely used in astrophysics, medical diagnostics, accelerator physics, and night vision devices. They have many advantages: compactness, high gain, work stability in radiation and in strong magnetic fields. MCA includes a photo cathode, one or more MCPs, anode system and circuits for the signal processing.

One of the earliest works devoted to a systematic study of microchannel amplifiers is the publication by A. Gest [1]. It suggests a semi-analytical model of secondary electron emission. More generous numerical models are considered in the publications by M. Ito [2] and other researchers. Full 3D model that takes into account photoemission, true secondary and backscattering components, fringe fields, as well as the saturation effect, was implemented in the code "MCS-3D" (Monte-Carlo Simulation) [3-5].

Microchannel plate is the main active element of the amplifier. Pores of MCP have a tilt angle with respect to the axis of the device. This leads to the appearance of three-dimensional fields of a complex structure in the vicinity of the input and output holes. Previously, these fields were computed using the commercial "COMSOL" code [6-9]. Since the pore diameter, their calibre (ratio of the length of the pore to its diameter), applied voltage and the pore angle are varied in the design of the amplifiers, the calculations result in an unjustified increase in the computational volume for each particular set of input data. Here an original fast algorithm which significantly reduces the computation time is presented. Theoretical background of MCA computer design is described in the monograph [10].

The numerical method of the MCA simulation is as follows. The electric fields in the gaps of the photocathode-MCP, between the plates, the MCP-anode, and also within the channels are considered one-dimensional. The exceptions are the regions in the vicinity of the inputs to and out of the channel, where the fields are calculated by a separate numerical algorithm of the method of integral equations [11-12]. For this reason, the trajectories of electrons from the photocathode to the anode are calculated analytically, and for secondary emission a semi-analytic model proposed by A. Gest [1] is used.

2. Fringe Field Numerical Simulations in 3D

Fringe fields at the entrance of MCP channels determine the photo electron collection efficiency. Fields at the exit of pores determine the angular distribution of secondary electrons and the gain factor as the cascades of those electrons produce the exponential grows of the current along the channel axis. These fields have a complex 3D structure. The electric fields at the ends of MCP pores were simulated using the multi-physic software COMSOL to study the photoelectron collection efficiency. The simulations show that in a highly-conductive environment, the electric field in the pore is directed axially inside the pore, having a gradual turn from the value in the resistive layer near the surface. In the simulations is assumed the relaxation time ε/σ is small enough for a thin resistive layer covered the MCP body of lead glass PbO_2. Figure 1 demonstrates the potential distribution and electric field in the MCP gap.

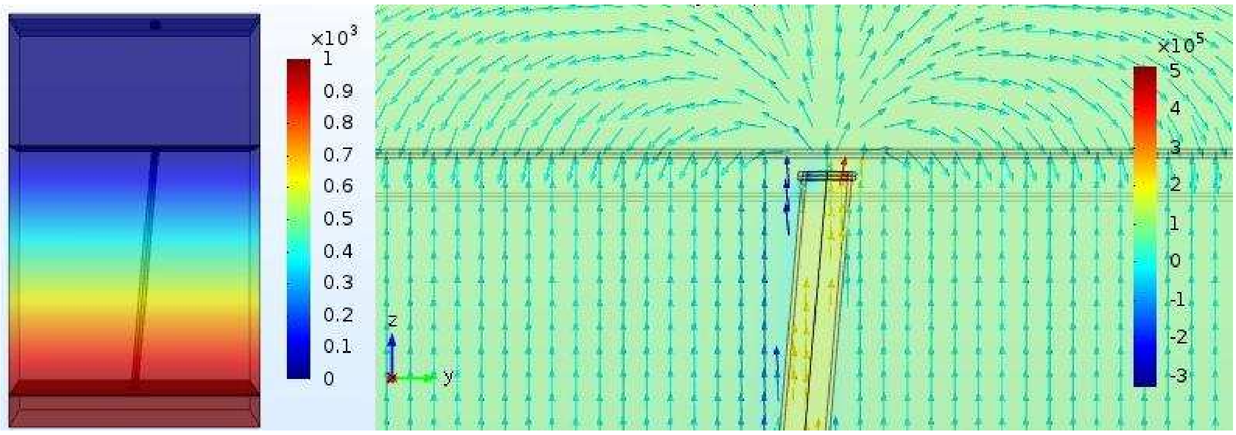

Figure 1. *Field distribution in the gap photo cathode (left), and the map of electric field (right).*

Calculations show the external field penetrated in the pore on the distance of two pore diameter; hence the pore diameter is the only dimensional parameter of the problem. Thus, for a given angle of inclination, it is possible to calculate the electric field intensity profiles along the channel axis and the angle of rotation of the field to the axis for a unit radius and a single applied potential. Then these profiles can be linearly scaled for arbitrary values of pore diameter and potential.

Figure 2a shows the fringe field profiles with no sputtering of metal at the channel ends, and 2b - with sputtering zone length of one channel diameter.

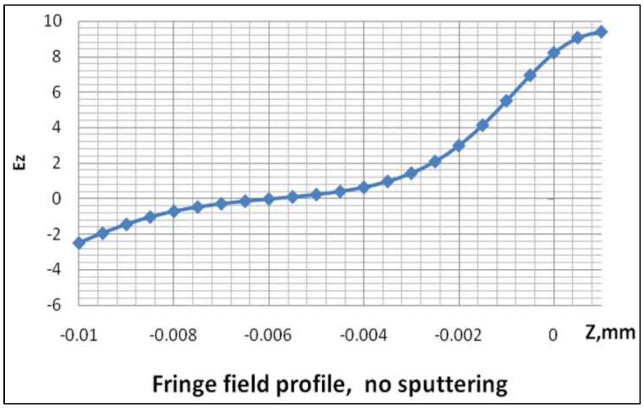

Figure 2a. *Fringe field Ez (z) for the channel with no sputtering.*

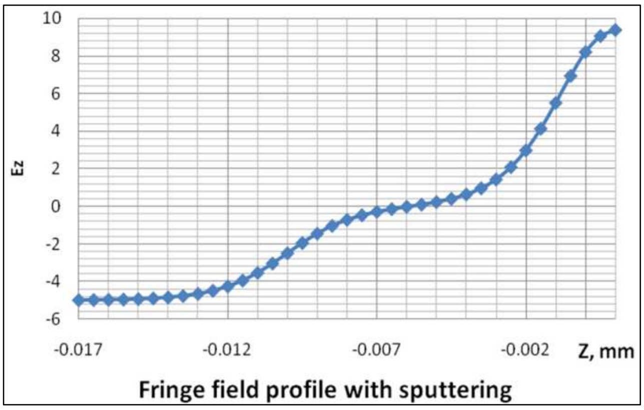

Figure 2b. *Fringe field Ez (z) for the channel with sputtering.*

3. MCP's Study with Taking into Account the Fringe Fields

Numerically studied properties of different MCP assemblies are presented in the Table 1. Since the parameters of photoemission and secondary electron emission are due to random collisions, to obtain smooth dependencies, several thousand calculations with random initial data for each point of the graph must be made. These massive calculations are performed on high-performance parallel computing systems or PC clusters. Figure 3 shows the fringe field effect for chevron pair 82015.

Table 1. *Parameters of the MCP assemblies.*

Type	Name	Channel diameter, µm	Calibr L/D	Tilt angle, degree	Interplate gap, µm
Single	89664	12.5	160	5	-
Chevron	74	6	50	5	100
Chevron	88353	7	40	13	100
Chevron	82015	10	40	5	100
Z-stack	418	7.5	43	5	100

The results for other MCPs demonstrate a good agreement between experimental data [8-9] and numerical calculations for pores with 5 degrees of tilt angle, and some divergence for 13 degrees angle in low gain range. Perhaps this is due to the complexity and low accuracy of gain measurements at low values, say, less than 10,000.

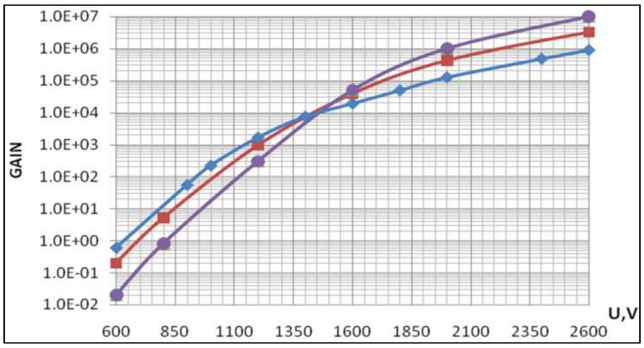

Figure 3. *Gain vs. applied voltage U for chevron 82015. Circles – experiment, diamonds – numerical data wirh no fringe fields, squares – fringe fields+sputtering.*

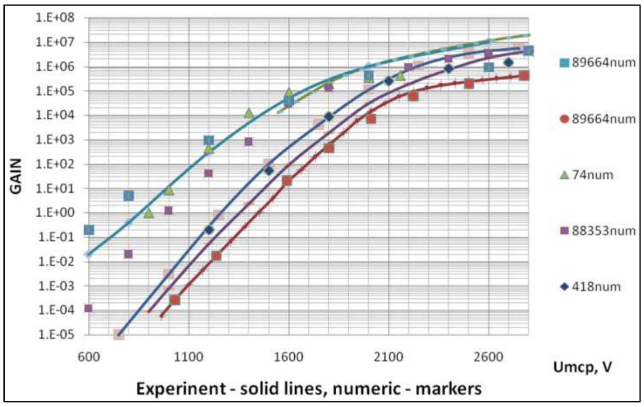

Figure 4. *Comparison of experimental and numerical data for different MCPs.*

4. Conclusion

Comparison of calculations and experimental data demonstrates a satisfactory agreement for the dependence gain vs. applied voltage for all studied MCPs. Modeling revealed the important role of fringe fields on the gain factor, timing resolution and on the photo electron collection efficiency. Suggested numerical model demonstrates a high computational speed in comparison with direct numerical calculations of three-dimensional electric fields.

Acknowledgements

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References

[1] A. J. Guest, A computer model of channel multiplier plate performance, Acta Electronica, 14 (1971) pp. 79-97. R. G. Lye, A. J. Dekker, Theory of secondary emission, *Phys. Rev. 107 (1957) 977-981.*

[2] M. Ito, H. Kume, K. Oba, *Computer analysis of the timing properties in micro channel plate photomultiplier tubes, IEEE Trans. NS-31 (1984) 408-412.*

[3] Z. Insepov, V. Ivanov, H. Frisch, Comparison of Candidate Secondary Electron Emission Materials, NIM B, 268 (2010) 3315-3320.

[4] V. Ivanov, Z. Insepov, S. Antipov, Gain and Time Resolution Simulations in Saturated MCP Pores, *NIM A, 52549 (2010) 02291-6.*

[5] Z. Insepov, V. Ivanov, S. J. Jokela, I. Veryovkin, A. Zinovev, H. Frisch, Comparison of Secondary Electron Emission Simulation to Experiment, NIM A, 52549 (2010).

[6] A. Barnyakov *et al*. R&D of microchannel plate phototubes. *NIM A, 567 (2006) 17-20.*

[7] A. Barnyakov *et al*. Investigation & development of microchannel plate phototubes. *NIM A, 572 (2007) 404-407.*

[8] V. Ivanov, A. Barnyakov, M. Barnyakov, V. Bobrovnikov, I. Ovtin. Numerical simulations of fast photo detectors based on microchannel plates. *J of Instrumentation, 12 (2017) P09024.*

[9] V. Ivanov, A. Barnyakov *et al*. Numerical simulation of fast photo detectors based on microchannel plates. *Int. Conf. "Instrumentation for Colliding Beam Physics", 28 Feb.–3 Mar., 2017, Novosibirsk, Russia.*

[10] V. Ivanov. Computational methods, optimization and synthesis in electron optics.- *Hmbg: Palmarium Academic Publishing, 2016.-525 pp.*

[11] V. Ivanov. Numerical solution of integral equations of the potential theory in electron optics. PhD Thesis, Computing Center of RAS, 1975, Novosibirsk, Russia.

[12] V. Ivanov. Computer Aided Design of Physical Electronic Devices. P. 1. Numerical methods of the field Calculations. Institute of Mathematics of RAS, Novosibirsk, 1986.-194 PP.