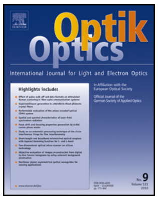
Optik 129 (2017) 1–7

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo



Simulation of resolution properties of microchannel plate

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ARTICLE INFO

Article history:
Received 14 August 2016
Accepted 18 October 2016

Keywords:
Resolution
Microchannel plate
Modulation transfer function

ABSTRACT

To improve the resolution capabilities of MCP, numerical simulation of the MTF of MCP has been made. Solving the electron trajectory equation, we obtain the potential distribution of MCP, and then obtain the electron trajectory in MCP. On this basis, a group of MTF curves are plotted by varying the tilt angle, the channel diameter, and the output end spoiling depth, individually. The simulation results show that in a moderate range a larger the tilt angle, a smaller the channel diameter, and a deeper the output end spoiling depth can improve the resolution of MCP significantly, according to the state of the art. Research on the effect of the above parameters on the resolution properties of MCP will provide a theoretical support for developing MCP with high resolution and further improving the resolution of image intensifiers.

1. Introduction

Microchannel plate (MCP) is the current-multiplying optical device frequently used in image intensifiers for intensification of the photoelectron image [1]. A most important parameters which determine the information content of the image on the screen of an intensifier is resolution. And a more objective evaluation method of the resolution of an optical or electron optical system is to use the concept of the modulation transfer function (MTF) [2,3]. In a channel image intensifier the resolution will be mainly determined by MCP. Therefore, the main factors determining the spatial resolution properties of MCP do merit concern.

In vacuum, electrons entering the channel at the low potential end will, on striking the wall, release secondary electrons. Under the influence of the electric field the secondary electrons will be accelerated down the channel before further interacting with the wall and releasing more secondaries. During this process, the transport properties of electrons will be determined by the structural parameters of MCP, such as the tilt angle, the channel diameter, and the output end spoiling depth, and thus the discrepancy of electron distribution on the screen is made. More importantly, this discrepancy affects the resolution of MCP and futher that of an image intensifier. However, so far most research into MCP has focused on its gain and noise characteristics [4–9], and relatively little attention has been paid to its resolution properties. Therefore, by solving the trajectory equation of electrons in MCP, the transport trajectory of these electrons are determined. Subsequently the electron distribution on the screen are obtained, and then the MTF curves are plotted. Simulation analysis of the effect of the tilt angle, the channel diameter, and the output end spoiling depth on the MTF of MCP are presented in this paper.

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http://dx.doi.org/10.1016/j.ijleo.2016.10.051
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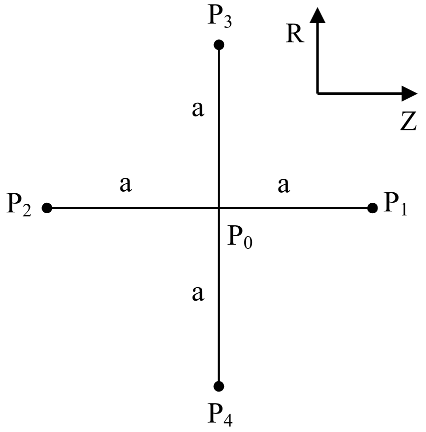
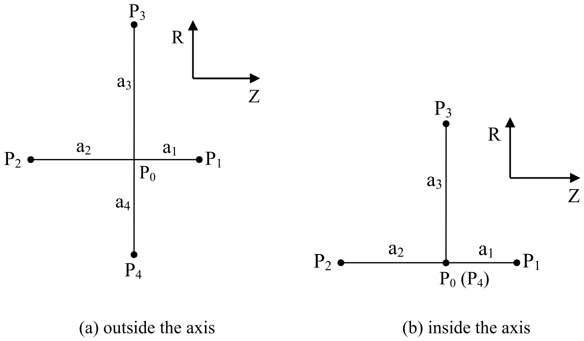


Fig 1. Schematic diagram of equidistant nodes.



(a) outside the axis (b) inside the axis

Fig. 2. Schematic diagram of unequidistant nodes.

2. Numerical calculation of MTF

2.1. Trajectory equation of electrons

It is assumed that the initial velocity and exit angle of electrons escaping from a photocathode are v_0 and θ, respectively. Additionally, R and Z are the radial coordinate and axial coordinate for electrons, respectively. And then the trajectory equation of electrons can be given by

$$\begin{cases} R = v_0 \sin\theta \cdot t \\ Z = v_0 \cos\theta \cdot t + \dfrac{eU}{2md} t^2 \end{cases} \tag{1}$$

where e is the electron charge, U is the voltage between the input and output electrodes of MCP, and m is the electron mass.

2.2. Potential distribution of MCP

To calculate the potential distribution of MCP, it is necessary to divide the field of MCP into many small meshes, and regard each mesh as a discrete node. Using finite difference method, we can transform a partial differential equation into a difference equation. Next, according to the relationship between a mesh node and adjacent nodes and boundary conditions, the approximate potential of discrete mesh nodes is determined by multiple iterations until within a limit of allowable error.

In a region of potential changed greatly, mesh nodes should be subdivided for reducing the truncation error. Simultaneously, the region of the electron transport should also be subdivided so that large errors cannot be introduced into the calculation of the electron trajectory. Here, it includes two cases for an electron field of MCP, i.e., equidistant nodes (Fig. 1) and unequidistant one (Fig. 2).