Sub-Millimetric Vacuum Electron Gun Design and Characterization

A. Leggieri[1], G. Ulisse[1], F. Di Paolo[1], F. Di Paolo[1], A. Di Carlo[1]

[1]University of Rome "Tor Vergata" - Department of Electronic Engineering, Rome, Italy

Abstract

Introduction
This paper presents the design of an electron gun that could be employed for vacuum tubes operating in the THz range.

One of the main difficulties in the realization of THz vacuum tube is the design and the realization of the electron gun. Since the dimensions are quite small (few millimeters) a Multiphysics (MP) approach is necessary in the electron gun design in order to study the effect of the multiple influencing factors.

The current level and beam dimensions, chosen for the electron gun design, are consistent with vacuum devices already studied in the THz frequency range [1-4].

In order to start the developing of MP models for these devices, a Particle Tracing (PT) simulation, based on COMSOL Multiphysics®, for a vacuum Electron Gun (E-Gun) has been performed. PT simulation in a MP ambient can be extended to a Thermal and Structural Mechanics simulation.

Use of COMSOL Multiphysics®
The electromagnetic field is altered by the particles presence, determining a two-way coupling between the particles and field; it thus is necessary to solve for the particles and fields simultaneously, by coupling a Charged Particle Tracing (CPT) and an Electrostatic (ES) Interface, using a time dependent analysis [5].

In the ES Interface, the anode and the cathode electric potential are specified.

In the Inlet node of the CPT module, in order to simplify the particle emission by neglecting the statistical behavior, the electrons are intended as released from the cathode boundary only on its normal direction (y) with an initial velocity determined by the design initial potential energy of the electrons. Since the cathode current density is constant in time, the charge release is represented by a sequence of short pulses with width Δt. The number of charge per release corresponds to a bi-linear relation dependent by the design cathode current, the elementary charge of the electron, the pulse width Δt and a Charge multiplying factor n.

The electric force node has been added in order to specify the Electric Force via the Electric Potential computed by the ES Interface.

The Particle-Field Interaction node has been added, specifying the electric potential computed by the ES Interface and the factor n.

In order to include the Coulomb interaction force between charged particles to the total force, the Particle-Particle Interaction node has been added.

Results
By solving a time dependent analysis on the described device, the following results have been obtained:

-Particle Energy: Maximum energy reached by the particle is W = 10.41[KeV].
-Particle velocity: Maximum speed reached by the particle is v = 6.06·107[ms^-1].
-Particle cross sectional position: The particle spot has been described by using the Poincare Map.
-Beam Waist: the beam waist is located close to the anode interface at a distance from the cathode d = 6.0[mm] and it has a radius r = 0.1[mm].
-The cathode current density, terminated the initial transient is stable around J = 2[A·cm^-2].

All these values are conform with the academic expectations for the analyzed device.

Reference

[1] A. Di Carlo et al, “The European project OPTHER for the development of a THz tube amplifier,” International Vacuum Electronics Conference, pp. 100 - 101, 2009.
[2] Kenneth B. K. Teo et al, “Microwave devices: Carbon nanotubes as cold cathodes,” Nature, 437, 2005.
[3] J. Tucek, D. Gallagher, K. Kreischer, R. Mihailovich, “A compact, high power, 0.65 THz source,” International Vacuum Electronics Conference, pp. 16 - 17, 2008.
[4] G. Ulisse, F. Brunetti, A. Di Carlo, "Study of the influence of transverse velocity on the design of cold cathode based electron guns for THz devices" IEEE Transactions on Electron Devices, Vol. 58, Iss. 9, pp. 3200-3204, 2011.
[5] COMSOL Particle Tracing Module Users Guide, Version May 2012, COMSOL 4.3.
[6] COMSOL AC/DC Module Users Guide Version May 2012, COMSOL 4.3.

Figures used in the abstract

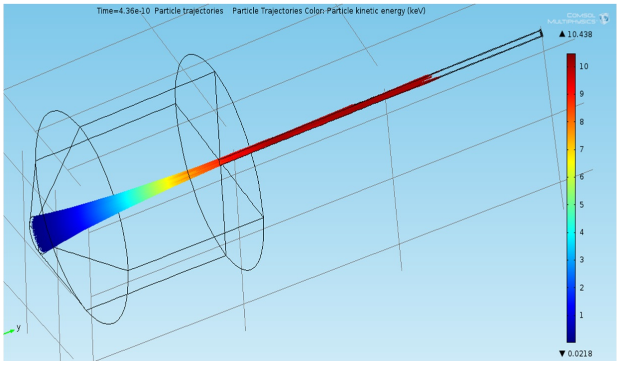

Figure 1: Electron Energy

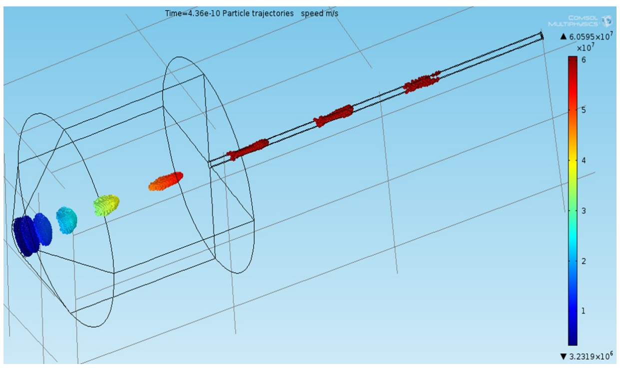

Figure 2: Electron Speed

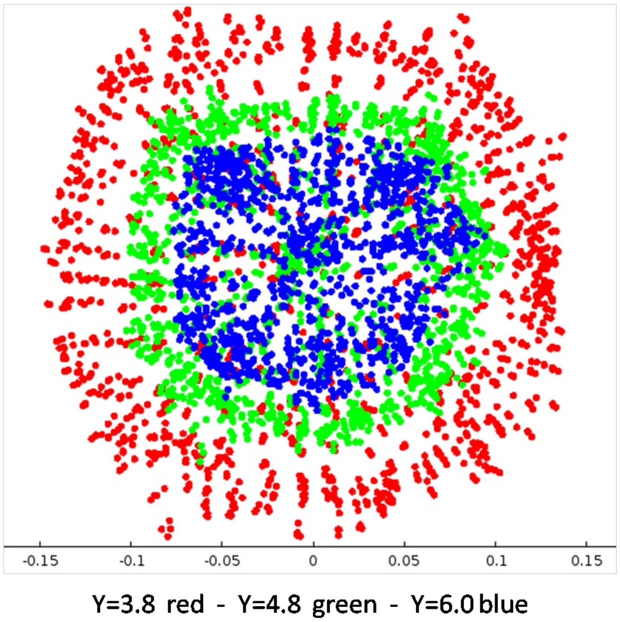

Figure 3: Electron Spot

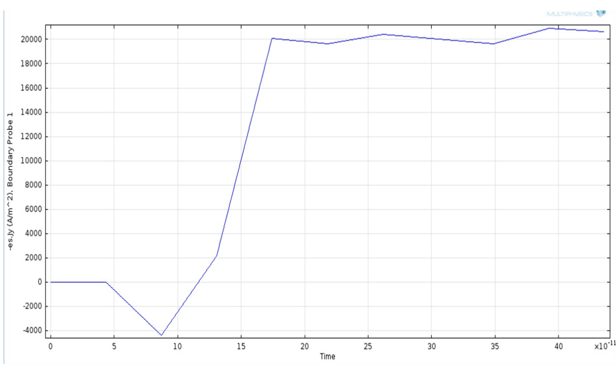

Figure 4: Cathode Current Density