Key-Holes Magnetron Design and Multiphysics Simulation

A. Leggieri[1], F. Di Paolo[1], D. Passi[1]

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

Abstract

Introduction
This paper describes the COMSOL Multiphysics® (MP) simulation of an 8 Key Holes resonant cavity Magnetron, which undergoes thermal-structural effects due to the cathode heating. The proposed study involves Thermal Stress (TS), Eigen-frequency (EF) and Particle Tracing (PT) analysis based in a COMSOL Multiphysics® (MP) simulation.

Magnetrons are well known and often utilized High Power (HP) Radiofrequency (RF) Vacuum Tube (VT) oscillators. In order to generate high power signals, they employ thermoelectric cathodes which can reach very high temperatures, necessary to produce enough surface charge density [1]. The signal frequency depends on particular electrodynamics conditions and the structure shape, which is characterized by a set of resonant cavities. The system of coupled cavities must resonate at a particular frequency. This feature requires an accurate Eigen-frequency analysis.

In order to estimate the motion of the electrons within the anode cathode interaction space, a PT simulation is mandatory and an electrostatic (ES) simulation allows to set the excitation field and to estimate the interaction between these fields and the space charge effect due to the presence of electrons.

Due to the high temperatures reached by the cathode, thermal expansion of the main structure can occur, with consequent stresses and strains that can produce enough displacements of the cavities geometry. This alteration can vary the resonant frequency of the coupled system and the electron motion, so consequently modify the output signal frequency and amplitude, causing a decrease of the performance.

A Multiphysics approach is necessary in order to study the effect of these multiple influencing factors.

Use Of COMSOL Multiphysics®
An eight key holes X-Band Magnetron operating in π mode, with copper anode and tungsten cathode, has been characterized using COMSOL Multiphysics®. Thermal Stress (TS) stationary analysis has been employed to determine the temperature and the deformation due to the cathode heating, at the thermal steady state [2].

In order to perform the EM analysis on the structure deformed by the TS interface, the Moving Mesh (MM) dedicated interface has been used [3]. The EMW interface has been employed to perform an accurate stationary analysis, considering the losses of the anode and cathode surfaces of the Magnetron[4]. The ES interface has been employed to set the critical magnetron voltage[5]. The CPT interface has been used to set the critical induction field and to give the rules on how calculate the particle trajectories[6].

ES and CPT are employed in a fully coupled time dependent analysis. The temperature computed by the TS has been linked in the EMW and ES interface.

Results
The resonance and particle trajectories alterations due to the thermal-structural working condition, have been studied, obtaining a complete characterization of the proposed device.

An Eigen-frequency analysis, a computation of the electric field resonant modes and particle trajectories have been performed, considering the thermal-structural modifications induced by the cathode heating to the entire structure.

The electric field power density of the resonant normal modes with related Quality factors and Energies have been plotted together with the Particle trajectories and electrostatic operative field.

Reference

[1] James Benford, John A. Swegle, Edl Schamiloglu, “High Power Microwaves”, second edition, 2007.
[2] COMSOL Structural Mechanics Module User’s Guide Version : May 2012 COMSOL 4.3.
[3] COMSOL Multiphysics User’s Guide; Version: 2010 COMSOL 4.3
[4] COMSOL RF Module User’s Guide Version : May 2012 COMSOL 4.3.
[5] COMSOL AC/DC Module Users Guide Version May 2012, COMSOL 4.3.
[6] COMSOL Particle Tracing Module Users Guide, Version May 2012, COMSOL 4.3.

Figures used in the abstract

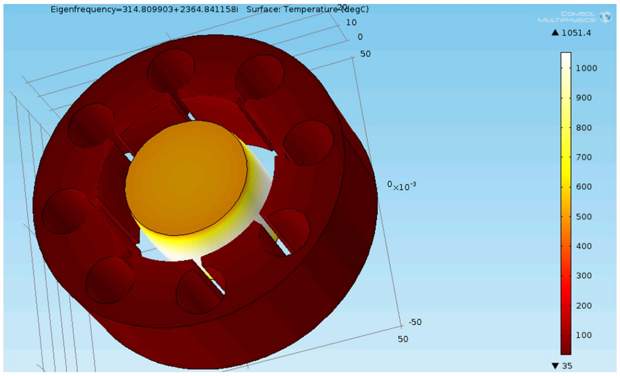

Figure 1: Temperature

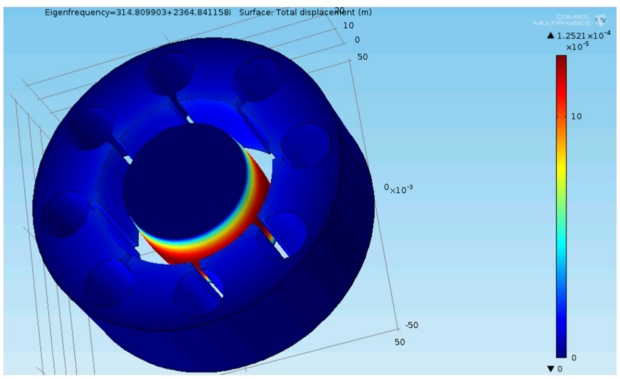

Figure 2: Displacement

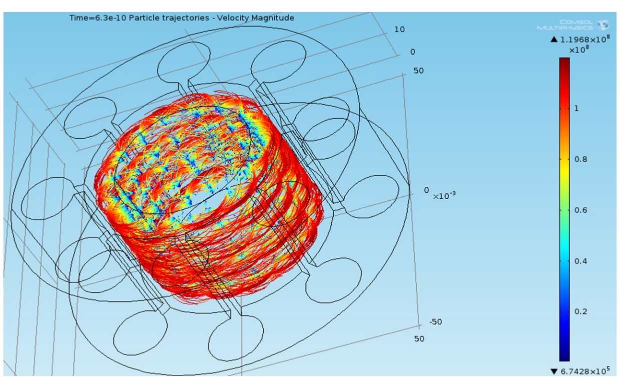

Figure 3: 3d particle tracing

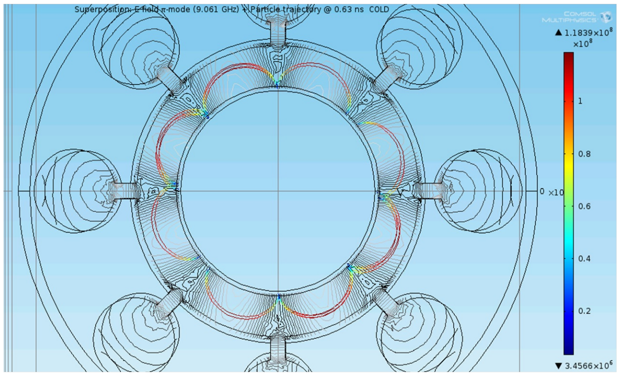

Figure 4: Cross section of a short particle tracing scrap over resonant electric field