Virtual Prototype of a Dielectric Window for High-Power Microwave Tubes

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Abstract

This paper describes the virtual prototype of a Dielectric Window (DW) for high-power microwave vacuum tubes. The proposed DW has been designed by considering the thermo-mechanical effects due to the joule effect and the thermal contact with the tube.

The proposed device is a pill-box-type vacuum DW with alumina ceramics. This DW consists of a Rectangular Waveguide (RWg) to Circular Waveguide (CWg) transitions with a ceramics disk in the middle of the CWg. The DW is designed in order to avoid dissipations and oscillations and the maximum power transfer between RWg and CWg, according to [1].
During the DW operation, multiple physical effects occur.

The Joule effect is induced by the electromagnetic power dissipation of the microwave which cross the device. Moreover, since the device is connected to a HPM Tube, it experiences a further temperature increase, due to the thermal contact with the tube, which have a controlled constant temperature over its surfaces.

These multiple effects induce some alterations of the electromagnetic behavior of the DW and, for this reason, they have been taken into account in the proposed design technique. The resulting virtual prototype shows a negligible decrease of the electromagnetic performance while these multiple physical factors exerts their effects over the DW operation. The proposed design is based on modeling in the COMSOL Multiphysics® environment.

This study investigates the in-frequency behavior of the DW, in order to improve matching and transmitting conditions. Design formulas are provided and computer aided design techniques are proposed.

The scattering parameters and the surface currents have been evaluated by setting a certain power input in the Electromagnetic Waves (EMW) interface [2].

The Joule effect has been computed by linking the surface current density to the Joule Heating and Thermal Expansion (JHTE) interface and the temperature alteration induced by the contact with the tube has been introduced by a boundary condition in the same interface [3].

Meshes have been moved by the Moving Mesh (MM) interface [4] so that a deformed mesh

configuration has been obtained, based on the displacement calculated by the JHTE interface. These multiple effects have been introduced in a subsequent electromagnetic analysis performed by the EMW on deformed meshes and storing temperature information from the JHTS. A substantial strength of the DW performances have been noted during the thermo-mechanical working operation.

Reference

1. Alberto Leggieri, Alessia Ciccotelli, Giuseppe Felici, Davide Passi and Franco di Paolo: “Tuned Window for Standing Wave Linear Accelerators”, Progress In Electromagnetic Research Symposium, Guangzhou, 2014.

2. COMSOL RF Module User’s Guide Version: November 2013 COMSOL 4.4.

3. COMSOL Structural Mechanics Module User’s Guide Version: November 2013 COMSOL 4.4.

4. COMSOL Multiphysics Reference Manual, Version: November 2013 COMSOL 4.4.

Figures used in the abstract

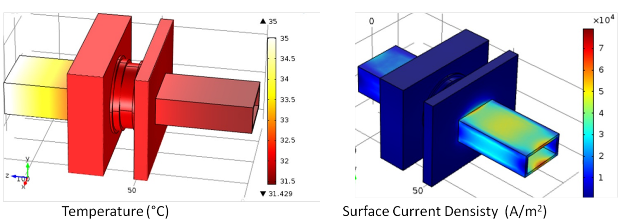

Figure 1: Temperature and Surface Current Density. The electromagnetic energy, traveling in the Window induces dissipation and Joule Heating

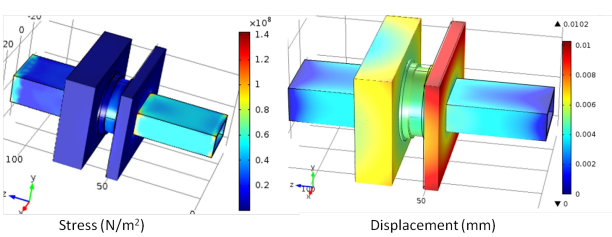

Figure 2: Thermomechanical Stress and Displacement. The thermal expansion induces compressive forces with consequent stresses and displacements.

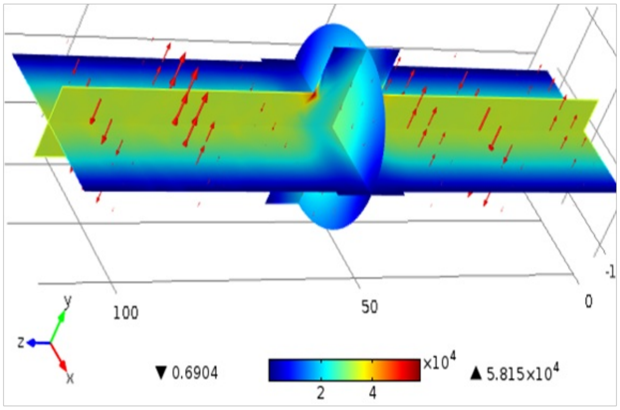

Figure 3: Electric Field distribution in Thermo-mechanical operating condition

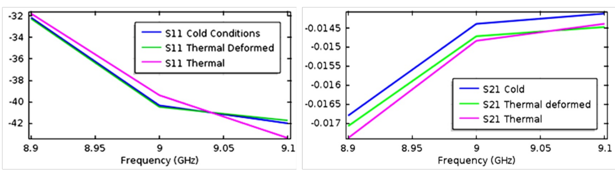

Figure 4: Scattering Parameters Magnitude in cold condition (Cold), by considering only thermal alteration of the conductivity (Thermal) and by considering the whole Thermomechanical conditions (Thermal Deformed). Note how the designed shape, when deformed compensates the degradation due to the thermal alteration of the conductivity.