COMSOL Aided Design of an Extraction Pipe for the Electron Beam From a Plasma Focus Device

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Abstract

Introduction: The electron beam emitted backward by Plasma Focus devices is being investigated as a radiation source for IORT (Intra-Operative Radiation Therapy) applications [1]. A Plasma Focus device is being developed to this aim. The electron beam is driven through an electron pipe made of stainless steel to impinge on a 50 µm brass foil, where conversion X-rays are generated [2]. Use of COMSOL Multiphysics: Electromagnetic forces in the Plasma Focus device have to be investigated to understand their influence on the electron beam produced by the extraction tube (Figure 1). The peculiarity of the phenomenon is related to the time scale involved, of the order of microseconds, requiring the capability of EM field analysis with frequencies around 100 kHz. Different materials for the extraction tube have to be investigated for clinical applications, to determine the optimum material under two constraints: metal tubes are barred by electrical safety reasons, and on the other hand shielding of the beam against the electromagnetic field is needed to prevent undesired deflections of the electrons. The AC/DC Module in COMSOL is being used to simulate the electromagnetic field in the extraction tube to determine the optimum material.
Results: For different frequencies and different materials, graphs of the magnetic field norm vs the z-coordinate have been extracted using COMSOL's Cut Line feature. These graphs (Figure 2) show that at working frequencies (100 kHz-1 MHz) the magnetic field cannot penetrate in the extraction tube zone (from 0 to 100 mm) when the material used is stainless steel or stainless steel covered by a delrin coating, while a full delrin tube is permeable to the magnetic field. Conclusion: When using an extraction tube made of delrin, the magnetic field can penetrate the tube walls modifying the trajectory of the electron beam and thus making it impossible to generate X-rays. On the other hand, using stainless steel as material, the electron beam trajectory is unaltered; however metal surfaces cannot be brought in contact with human tissues, especially in radiotherapy applications. For this reason a delrin coating has been developed to surround the extraction tube.

Reference

[1] M. Sumini, A. Tartari, D. Mostacci, E. Ceccolini, F. Rocchi, G. Cucchi, M. Roson, M. Martignon, M. Ciocca, A. Facoetti, R. Orecchia, 2010. Physical and radiobiological characterization of extremely high dose per pulse X-ray beams produced by a Plasma Focus device for IORT. In: Proceedings of the 6th International Conference of the International Society of Intraoperative Radiation Therapy, Scottsdale, AZ, USA. Oct. 14-16, 53, 2010.
[2] E. Ceccolini, F. Rocchi, D. Mostacci, M. Sumini, A. Tartari, Monte Carlo Simulation of the Conversion X¬-Rays from the Electron Beam of PFMA-3, AIP Conf. Proc. 1412, 79-85 (2011).

Figures used in the abstract

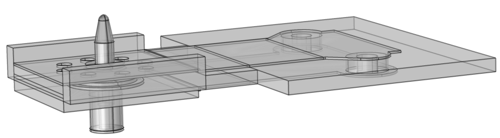

Figure 1: Plasma Focus COMSOL Multiphysics modeling.

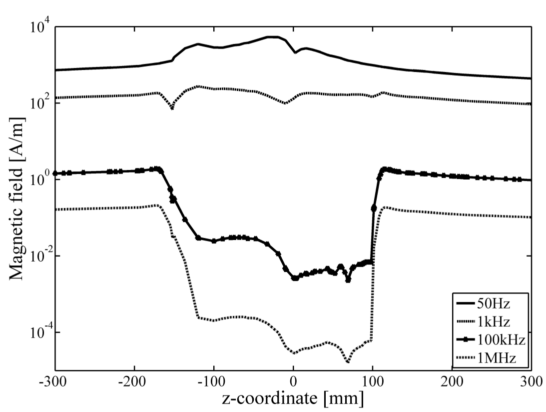

Figure 2: Magnetic field for different frequencies: extraction tube made of stainless steel.