

MODELING MICROWAVE/ELECTRON-CLOUD INTERACTION

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Abstract

Starting from the separate codes BI-RME and ELOUD or PyELOUD, we are developing a novel joint simulation tool, which models the combined effect of a charged particle beam and of microwaves on an electron cloud. Possible applications include the degradation of microwave transmission in tele-communication satellites by electron clouds; the microwave-transmission techniques being used in particle accelerators for the purpose of electron-cloud diagnostics; the microwave emission by the electron cloud itself in the presence of a magnetic field; and the possible suppression of electron-cloud formation in an accelerator by injecting microwaves of suitable amplitude and frequency. A few early simulation results are presented.

MOTIVATION

Electron multiplication on surfaces exposed to either an oscillating electromagnetic field or to a pulsed electric field gives rise to the phenomenon of multipacting, which can significantly degrade the performance of radiofrequency devices operating in high-vacuum conditions. These include, for example, components for satellite telecommunication like waveguide filters but also accelerating cavities for particle accelerators. In both examples, the electron multiplication can result in a quasi-stationary “electron cloud” inside the devices perturbing their performance.

Though studies of electron multipacting in microwave devices as well as of beam-induced multipactor in particle accelerators have both been ongoing separately for several decades already [1, 2, 3, 4], little is known about the simultaneous interaction of an electron cloud with both microwaves and a particle beam [5, 6]. This lack of knowledge has so far prevented the proper interpretation of microwave transmission measurements which have been applied in several accelerators afflicted by an electron cloud. A related phenomenon is encountered in satellite-based telecommunication systems, which nowadays suffer from the problem of an electron-cloud build up interacting with the microwave field used to transmit information.

MODEL

In the associated oral contribution at ELOUD12 we have outlined the model applied to describe the interaction between electrons and microwaves. Differently from [7],

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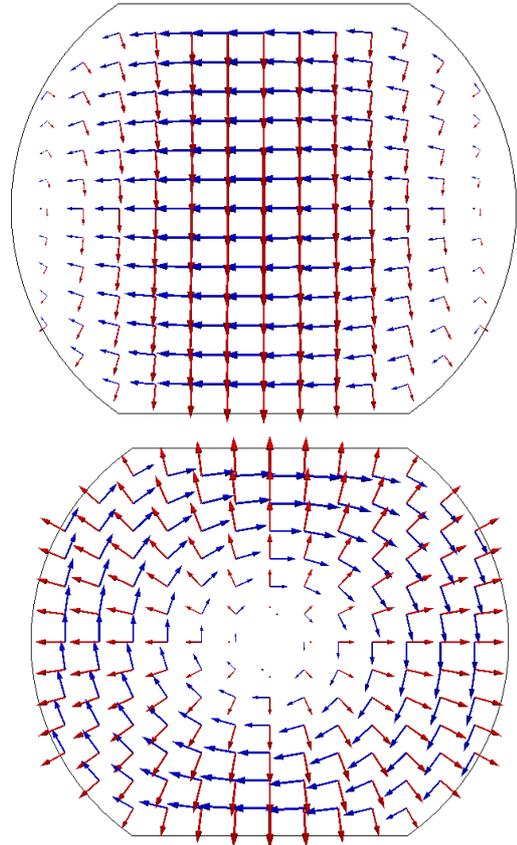


Fig. 1: First TE (top) and TM (bottom) mode of LHC beam pipe. The red arrows represent the transverse electric field, the blue ones the transverse magnetic field.

the modelling is based on time-domain Green functions describing the radiation of a single electron represented as a point charge. Using the modal expansion representation of the involved Green functions, we are able to take into account the exact boundary conditions of the devices, e.g. waveguides or cavities.

EXAMPLE RESULTS

Figure 1 shows the example of the LHC beam pipe representing the transverse electric (red arrows) and magnetic field (blue arrows) of the first TE and TM mode, respectively. The modes are computed using the BI-RME algorithm [8].

In Fig. 2 the example of a single electron under multipactor regime between two parallel plates separated by 0.2 mm is depicted. The electric field, driving the electron,

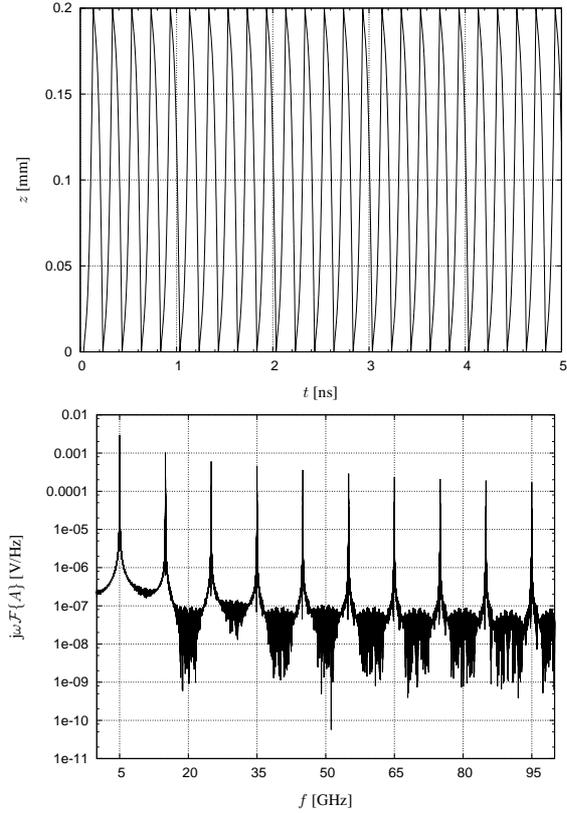


Fig. 2: Multipacting electron (top) and the associated radiated electric field spectrum (bottom) inside a parallel-plate waveguide of height 0.2mm. Simulation parameters: RF frequency: 5 GHz; RF voltage: 70 V, initial velocity of electrons: 2 eV.

oscillates at 5 GHz. The upper figure shows the position of the electron, the lower one the part of the radiated electric field density related to the time-derivative of the vector potential A . The spectrum includes all harmonics that are odd multiples of the fundamental one and are generated by the moving electron.

The model developed is useful for microwave diagnosis of devices prone to microwave breakdown due to multipacting. The upper picture of Fig. 3 shows the evolution of the electron density for the case of the parallel plate waveguide of Fig. 2 applying the model of [9]. The blue curve represents the electron density, the red one the associated radiated electric field contribution from the time-derivative of the vector potential A . There is a clear correlation between the two curves. The lower part of Fig. 3 is an example from the LHC beam pipe. The space charge build up was simulated with PyELOUD [10] (blue curve). Based on the electron trajectories the radiated electromagnetic field has been computed (red curve). Again, a correlation of the two curves can be observed.

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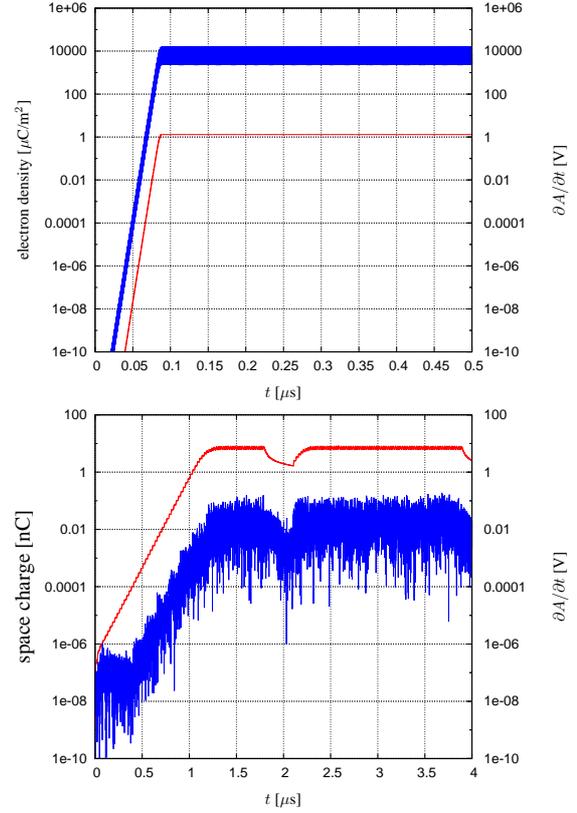


Fig. 3: Example of an electron cloud build-up inside the parallel plate waveguide of Fig. 2 (top) and in the LHC beam pipe. The red curve represents the electron density (top) respectively the space charge (bottom). The blue lines are the associated time derivatives of the vector potential A , thus the electric field.

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