Electromagnetic Modeling of Field Emitter Cathodes Inside an L-Band RF Gun at Fermilab Using COMSOL®

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Abstract

Field-emitter (FE) electron sources offer significant advantages over photocathode and thermionic sources due to their ability to be operated without the need for an auxiliary laser system or a heating source. While FE cathodes have been traditionally used in DC environments, we explore electron beam generation from carbon based FE cathodes inside an L-band RF gun at Fermilab, where significantly higher current electron beams are possible owing to high extraction RF electric fields (nominal) on the order of tens of MV/m. In this regard, we present electromagnetic modeling using COMSOL®'s RF module, of the RF gun to understand the electric field profile, eigenfrequencies and field enhancement at the FE tips inside the gun. The field profile and eigenfrequency variation with respect to the considered cathode geometries and position offsets, along with Q-factor studies are presented. Some of the numerical results are compared, where possible, to experimental measurements for validation. Finally, we briefly discuss the future implications of the current work with regards to integration with dedicated charged particle tracing programs and possible multiphysics studies.