Name: **Njomza Ibrahimi**
Email: njomza.ibrahimi@univ-pau.fr
Supervisors: Laurent Pécastaing and Marc Rivaletto
Partners/Funding: E2S/UPPA
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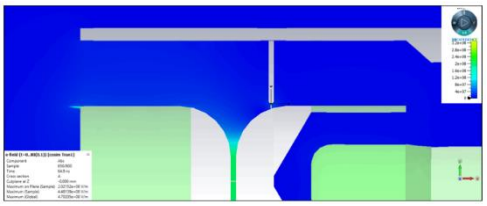
Subnanosecond pulsed power technology for bio-medical and defense domains

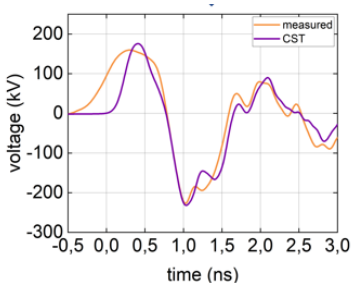
Context

This thesis focuses on the use of subnanosecond pulsed power technology for biomedical and defense applications. As part of a major effort into developing a contactless technology, first we determined conditions of the applied PEFs (number of pulses, strength, pulse repetition frequency) able to produce electropermeabilization of biological cells. To perform this study an experimental arrangement based on a detailed 3-D numerical modeling, was used to study biomedical effects imposed by subnanosecond pulsed electric fields (PEFs) [1]. As a second step forward, we report the proof of concept on the design, realization, and experimental validation of a novel contactless subnanosecond PEF exposure system for cells electropermeabilization. For future studies a monopolar and a bipolar pulse forming lines (PFL) for bio-medical and defense applications were designed based on advanced 3D numerical modelling analysis. Related to that, a 3D electromagnetic co-simulation model was developed with the aid of CST MW and DESIGN Studio which integrates the transient switching devices and other circuit elements in the 3D EM model and comprehensively studies the EM behaviour of the system. This thesis also covers a lot of aspects concerning the measurements techniques based on 3D modelling used in pulsed power domain which can serve as a calibration method or monitoring technique for future pulsed power systems.

Main Results

In the framework of the first part of the thesis, preliminary biological results reported are very encouraging, showing that trains of 5000 to 50 000 pulses applied at a pulsed repetition frequency of 200 Hz (maximum PRF) can efficiently induce E. Coli electropermeabilization. Related to the second part of the thesis which evolves the contactless technology, the developed contactless PEF exposure system allows the generation of electric fields applied to the biological sample having the amplitude of 170 kV/cm being focalized in the center of the sample covering an area of 28 mm^2. The third part of the thesis confirms the performance of the designed and tested M-PFL and B-PFL resulting on voltage pulses of 300 kV and less than 1 ns duration for the M-PFL and up to 500 kV peak-to-peak amplitude and a FWHM of around 1.5 ns for the B-PFL.





[1] N. Ibrahimi, L. Vallet, F. Andre, L. Ariztia, M. Rivaletto, A. de Ferron, B.M. Novac, L.M. Mir, L. Pécastaing, A subnanosecond pulsed electric field system for studying cells electropermeabilization, *IEEE Transactions on Plasma Science*, DOI : 10.1109/TPS.2020.3034286, November 2020