RF Emission Spectra in Laser-Plasma Acceleration of Protons

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Abstract

The acceleration of protons and ions by highly intense, ultra-short laser pulses is a very active field of experimental and theoretical research. From laser-plasma interactions the emission of a strong electromagnetic pulse (EMP) has often been reported as a side effect. It potentially interferes with, or even may cause damage to, electronic devices such as particle detectors inside or outside the vacuum system. A better understanding of the sources of rf emission may be highly relevant for several practical aspects including efficient EMP suppression.
We have used the RF module of COMSOL Multiphysics® to model the essential components of a complete experimental setup for laser-proton acceleration and to identify the major sources of EMP. The basic example of a cylindrical cavity representing the principal vacuum vessel allows for reproducing the fundamental modes (which can be readily compared to analytical solutions) as well as higher modes. Several parts of the vacuum system have then been added to the setup to study the appearance of corresponding eigenfrequencies.
In addition to the cavities, internal components act as microwave antennas. Those elements which are most likely to transfer electric currents due to the emission or absorption of charged particles, like the target holder, have been implemented in the simulated compound. Even with simplified geometries their resonant frequencies contribute significantly to the overall rf spectra. Further, modulations of the cavity spectra due to interference with the internal parts have been observed as well.
At high frequencies (in our case, at 1.0-2.5 GHz) the density of simulated modes increases strongly, making it necessary to evaluate quantitatively the contribution of single modes to the overall EMP amplitudes. COMSOL Multiphysics® offers two distinct definitions of quality factors corresponding to each eigenfrequency. Their adequacy as weighting factor for a complete spectral representation has been studied.
The simulated EMP spectra compare reasonably well to experimental data. Our results will be applied as an analysis tool for laser-plasma interactions from different targets.

Figures used in the abstract

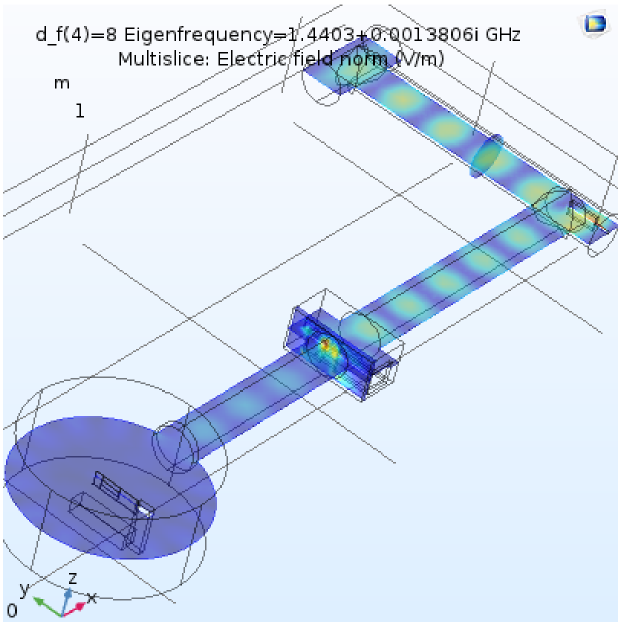

Figure 1: Example of higher resonant mode of the simulated vacuum system.