Analytical and numerical analysis of the plasma evolution in air generated by nanosecond laser pulses

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Laser-induced breakdown (LIB) is a well-known phenomenon which leads to plasma generation and rapid production of a large amount of free electrons. The influence of electron gain and loss processes on the breakdown is of significant interest in a wide field of research and industrial applications across science and technology. Because of that, it is important to describe the evolution of the plasma properties, especially the density of free electrons, with regard to variations of the experimental conditions via both analytical and numerical methods. An analytical solution to the rate equation for the free electron density induced by nanosecond pulses in the air is presented and verified via numerical simulations. Here, the rate equation includes both the net gain of the electron density due to the joined effect of multi-photon and the cascade ionization processes, while the loss processes are expected to take place due to diffusion out of the focal volume, recombination, and attachments. The effective contribution of each of the abovementioned physical processes to the breakdown phenomenon is examined by studying the time evolution of the electron density (Fig. 1(a)) in terms of the laser pulse intensity (Fig. 1(b)).

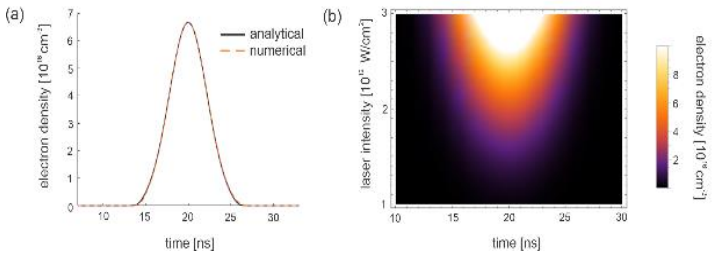

Figure 1. (a) Comparison between the analytical and numerical solution for the free electron density, (b) Free electron density as a function of time and laser intensity.

Good agreement between the numerical and analytical results at atmospheric conditions has been achieved, indicating the validity of the analytical solution to the proposed model. Based on this result, in our further work, we will experimentally validate the proposed analytical and numerical approaches.

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