Femtosecond laser excitation of dielectric materials: Understanding thin-film ablation and looking for THz emission

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The investigation of ultrashort-pulse laser excitation of dielectric materials is both interesting and relevant. While the relevance is clear from several demonstrations in a variety of material-processing applications, the fundamental interest lies in the fact that such investigations provide insight into the fundamental mechanisms of material excitation. Electrons are promoted from the valence to the conduction band by strong-field excitation, and the generated carriers can subsequently interact with the light, acquiring kinetic energy and when this energy is high enough, collisional processes may generate additional free carriers.

In this presentation, we will discuss recent results from combined experimental and modeling investigations in our group. We recently developed a material-excitation model that combines a description of the basic excitation processes in the so-called multiple-rate-equation (MRE) model with light propagation obtained from a direct solution of Maxwells equations (in one dimension) [1]. This model allowed us to interpret the results of laser-ablation experiments carried out on thin (~1 micron) Al_2O_3 films. The ablation is found to originate from the regions of constructive interference inside the film, thus giving rise to ejection of multiple layers from the sample in steps corresponding to the distance between interference maxima [2].

We are currently setting up an experiment to investigate the predicted emission of THz radiation from short-pulse excited dielectrics. We recently showed that carrier transport in highly excited dielectric materials can explain an experimentally observed transient birefringence, reported in Ref. 3. Our simulations predicted that the difference in electron- and hole mobilities leads to the fast build-up of a strong electric field (the Dember field), and, in addition to the transient birefringence, THz emission would be an experimental signature of this process [4]. We hope to be able to present the first results from the ongoing THz experiments at the conference.

References:

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