Excitation dynamics in silicon using two-dimensional Three-Temperature Model

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Study of laser processing of semi-conductors such as silicon has numerous applications in nano-structuring and fabrication industry. Since the interaction involves complex areas of physics, numerical modeling proves to be useful in understanding the physics of the process. Based on the density-dependent Two-Temperature model (nTTM) [1], we developed a one-dimensional Three-Temperature model (1D-3TM) and studied the laser-excitation process and damage in silicon [2]. The model was found to be reasonably consistent with experimental data [3] for damage threshold in silicon. In the present work, we extend 1D-3TM to a two-dimensional 3TM (2D-3TM). The purpose of the study is to understand the transverse flow of energy on the surface of the film. The ablation threshold and dynamics related to the damage process can be better understood with a 2D-model, which calculates the electron and lattice dynamics on the surface of the film, in addition to the dynamics within the film which was calculated in the 1D model. Figure 1(a) and 1(b) show the electric field profile and evolution of lattice temperature and how the field intensity and temperature vary with film depth and time. In case of 2D-3TM, we can further study the field profile and the temperature evolution on the surface of the film as shown in fig. 1(c) and 1(d) respectively. The surface gradients of field intensity and the lattice temperature are more well defined, an important advantage of intense femtosecond pulses in material processing. Thus, we can use 2D-3TM to study the effect of laser spot size on the damage threshold and also compare the dynamics within the silicon film with the dynamics on the surface.

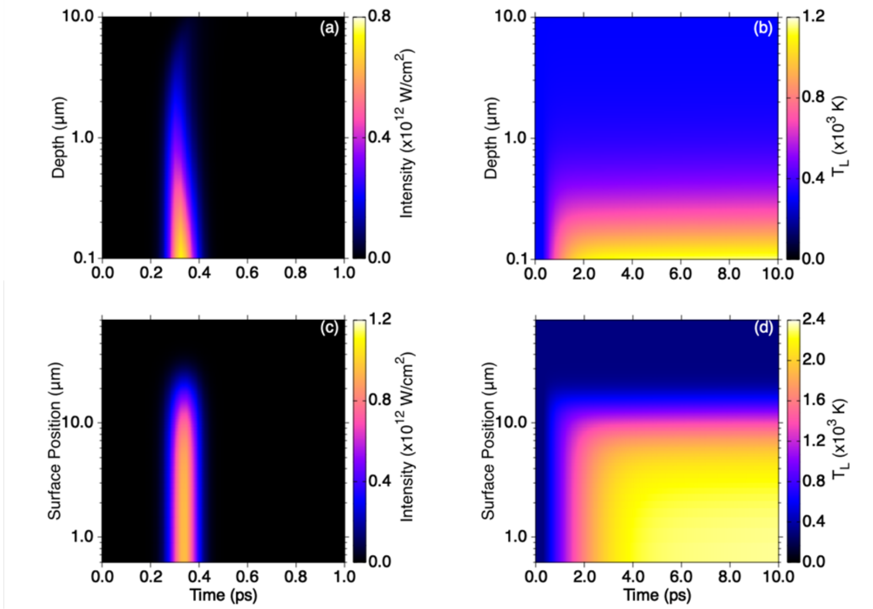

Fig.1: Spatial and temporal profiles of (a) field intensity and (b) lattice temperature (T_L) varying with the depth of film, (c) field intensity and (d) T_L varying on the surface of film.

References:

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2. P. Venkat and T. Otobe, *Applied Physics Express*, **15(4)**, 041008 (2022).

3. P. Allenspacher et al., *Proc. SPIE*, **4932**:358, 2003.