Energy Deposition in Femtosecond Laser Inscription

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Femtosecond (fs) laser inscription has recently become a versatile technology in manufacturing of photonic devices [1]. We address the problem of energy absorption of the focused femtosecond laser pulse in the process of laser inscription. The distribution of the absorbed energy in the bulk of the transparent material is crucial in sculpturing the inscribed photonic structures. It ultimately depends on a complicated balance of competing physical effects such as diffraction dispersion, self-focusing, Multi-Photon Absorption (MPA), plasma resistive absorption, and plasma defocusing.

We focus our attention on absorption dynamics since it eventually leads to permanent modification of transparent material by means of fs inscription. A comprehensive review is presented of numerical, analytical and experimental results on energy deposition. We compare different inscription regimes corresponding to loose and tight focusing and discuss crucial importance of different effects for laser beam confinement. For example, self-focusing is a primary mechanism of the spatial beam localization in loose focusing geometry while in case of tightly focussed beam it is primarily down to the lens focusing.

We show analytically that in the small energy limit the absorbed energy E_{abs} scales with the initial pulse energy E as E_{abs}~E^K where K is the order of MPA. The influence of plasma on the absorption threshold is also studied and compared to that presented in [2]. We show that the plasma absorption which is a major contributing factor in energy deposition for all the focusing geometries kicks off when the laser beam fluence $F=E/R^2$ exceeds the threshold $F_{cr}=E_g/\sigma$, where E_g is a gap energy and is the cross section of inverse Bremsstrahlung. It is curious that the macroscopic laser fluence has to exceed the threshold expressed in microscopic terms.

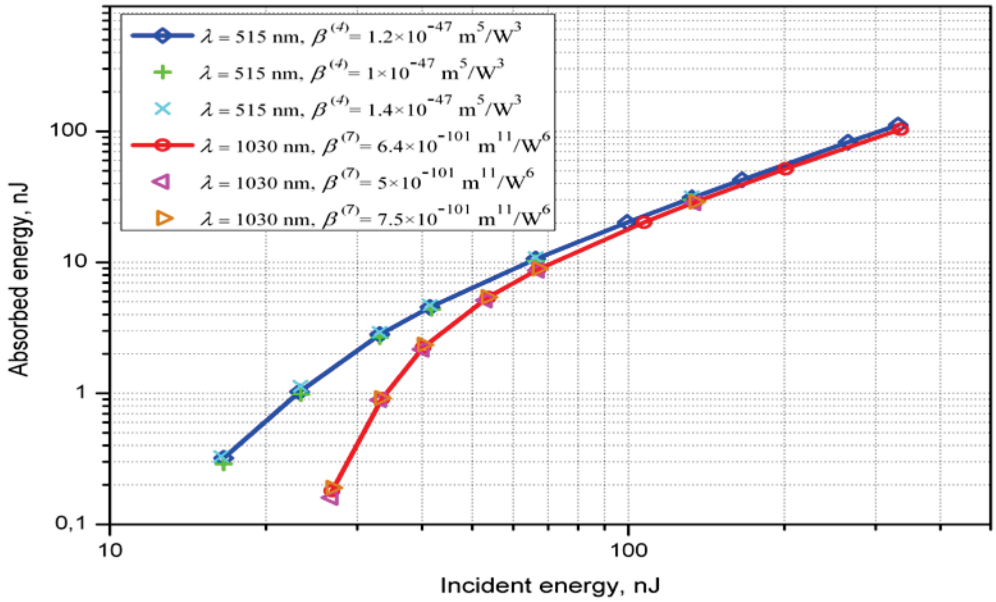

Fig. 1. Absorbed energy versus input energy for different orders of MPA.

For specific analysis we have performed a comparative numerical study of femtosecond laser inscription for fundamental (1030nm) and second harmonic (515nm) of Yb-doped laser. The dependencies E_{abs} (E) for different wavelengths are presented in Fig.1. We have analyzed the absorption efficiency for different orders of MPA in terms of instant heating resulting from recombination of electron-hole plasma left behind the fs pulse. It turns out that while lower order MPA is more efficient in terms of absorbed energy, higher order MPA leads to inscription of more compact structures.

References

[1] R.R. Gattass and E. Mazur, "Femtosecond laser micromachining in transparent materials", Nature Phoytonics *2,* 219 (2008).

[2] L. Berg, S. Skupin, R. Nuter, J. Kasparian, and J.-P. Wolf, "Ultrashort filaments of light in weakly ionized, optically transparent media", Rep. Prog. Phys. **70**, 1633 (2007).