Enhancement of the confinement of energy deposition in the interaction of Bessel beams with dielectrics

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Transparent materials such as glass and sapphire are ubiquitous in modern technology. They are used for consumer electronics, substrates for microsystems, microchips, encapsulation. Infrared ultrashort laser pulses are a useful tool for precision micro and nanomachining of transparent dielectrics since they allow for energy deposition within the bulk of the material, in the 3 dimensions of space. However, the general case of Gaussian beam focussing reveals to be in general very difficult to control when the objective is to deposit inside the material the high densities of energy that are necessary to reach void formation over long distances. This is because of the complex spatio-temporal distorsions undergone by Gaussian pulses in the filamentation regime where both Kerr effect and nonlinear ionization play a dominant role. Bessel beams have been successfully used in a variety of applications where long and thin modifications are required [1]. One example is stealth dicing of glass, where in a first illumination step, a series of nanochannels is created by a sequence of ultrafast laser pulses (one channel per pulse) and in a second step, a mechanical, thermic or chamical stress allows for cleaving along the plane defined by the series of nanochannels [2,3]. The illumination process can be as fast as several meters per second.

In this context, the nanochannel formation is a critical control parameter. We will report on several strategies to increase the channel length for cutting much thicker glass [4], decrease the channel diameter and increase the efficiency for channel drilling. Specifically, we demonstrate that double pulse illumination and high focussing angles drastically enhance the capability for channel formation [5]. Transmission measurements show that this is due to enhanced confinement of energy in comparison with single pulses. Our results show the relevance of nanomachining with high repetition rate bursts of pulses.

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