Nanoscale modification of glass via micro-explosion using ultrafast Bessel laser pulse

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1. Introduction

In the framework of laser-induced micro- and nanoscale material modification, we present results on ultrafast Bessel beam-glass interaction, inducing extended length scale material modification on single-shot basis. The possibility of high-level energy localization using non-diffractive Bessel beams has been shown using chirped pulses and moderate focusing conditions, drawing attentions in the fields of nonlinear optics and large volume material processing [1, 2]. Here, we show how ultrashort Bessel laser pulse interacts with fused silica glass in a tight focusing geometry and the follow-up material relaxation over a broad range of temporal domain i.e. ns - μs. The consequence of such interaction in terms of ultimate material transformation will be discussed.

2. Experimental arrangement and results

The laser pulses (800nm, 50fs, Gaussian spatial profile) delivered from a Ti:Sapphire laser system were first transformed into zero-order Bessel pulses using axicon lens and suitable magnification system (Fig. 1(a)). The generated Bessel pulse (750nm core size) was exploited for studying the Bessel-glass interaction dynamics. A typical permanent modification in glass using single Bessel pulse is shown in Fig. 1(b), depicting both increased (black part) and decreased (white part) refractive index modified zones. In the present case, as verified using scanning electron microscopy, the decreased index modified zone is indeed a void, which can be potentially used for photonic and fluidic applications. The extended scale (i.e. few hundred microns long) nature of material modification using Bessel pulse was exploited for deep drilling and simultaneous multi-layer processing applications.

In order to control the material modification characteristics, the excitation and relaxation pathways were tracked using time-resolved optical microscopy techniques (sub-μm spatial and ns temporal resolution). Indeed, we observed unique relaxation pathways corresponding to different permanent modifications. We observed pressure wave at few ns after laser excitation, indicating the occurrence of micro-explosion due to high pressure. As evident from left photo of Fig. 1 (c), the void-like domain was evolved over few hundred ns [3]. i.e. It's different from the earlier observation, which attributes the void formation to shock-rarefaction phenomena. In the case of positive index modification, although the heat transport is clearly visible (right photo of Fig. 1 (c)), the structural phase evolves in a different way, resulting in a dense phase of matter, and advocating the role of molecular kinetics for final material phase.

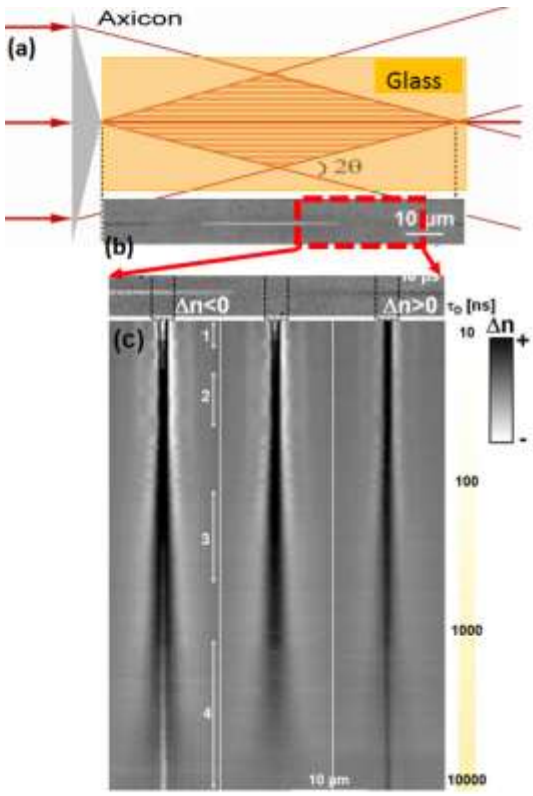

Figure 1 Bessel beam induced material modification. (a) Schematic diagram of Bessel beam generation and interaction with glass. (b) Typical material modification using single Bessel pulse. (c) Structural evolution of laser excited regions.

3. Conclusions

Ultrafast Bessel beam-glass interaction phenomena and resulting nano-scale material modification were studied. Extended scale voids in fused silica glass were produced using single Bessel pulse and their formation dynamics was tracked using time-resolved microscopy technique, revealing the signs of emergence of void via micro-explosion on a rather slow time scale i.e. few hundred nanoseconds.

References

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