Fused silica improvement for high energy laser applications

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In more than 100 years of fused silica development [1] not only the optical properties of this optical material had to become always better, also the optical applications using it grew more and more ambitious. Where, in 1960, only transmission and thermal resistance were of importance for ruby laser flash lamps, today laser optics have to face quite more challenges. Laser fusion projects require high energy fluences and short pulse systems have to deal high intensities.

The most sensitive optics in this kind of systems are in the final focusing assembly at 3ω or behind the optical pulse compression. Commercial bubble specifications as DIN58927 with bubble class 0 (no bubbles > Ø80µm) are not enough. Laser fusion systems aiming for a goal of no bubbles > Ø10µm or even better to reduce the effect of wave front distortion and/or damage the optical material due to intensity spikes. A patented, very unique refining process enables the removal of bigger bubbles in fused silica to provide high performance optical material.

In the direct flame fusion process for manufacturing fused silica, the raw material features high frequency gradients in the optical homogeneity. Sharp gradients affect the ability to focus the laser beam. In the shear region of the refining process, sharp gradients are washed out.

Laser damage at 1ω and 3ω is not just influenced by the coating performance and the surface finishing quality, also laser absorption in the bulk material contributes to the performance of the system [2]. Therefore, depending on the application wavelength, low OH or hydrogen doped fused silica have to be used to minimize heating and focus shift.

For material supplier, it is not only a challenge to provide an optics >Ø500mm ensuring all above described properties. The challenge is to reproduce them in a high volume to be able to build systems with hundreds of beams and thousands of optical elements. This is only possible by producing to the requested specifications and not alone by material selection.

Tighter tolerances forced as well the development of metrology. High resolution bubble and homogeneity measurements are fundamental to proof the tight specifications. Optics designers require the raw material data to be able to simulate the laser propagation in their systems.

References

[1] Nürnberg, F., Kühn, B., Rollmann, K., Proc. SPIE 10014, 100140F (2016).
[2] Nürnberg, F. and Kühn, B., Proc. SPIE 9632, 96321R (2015).