CO2 laser ablation leads a novel path to customized continuous fused silica surfaces

February 25 2020, by Zhang Nannan

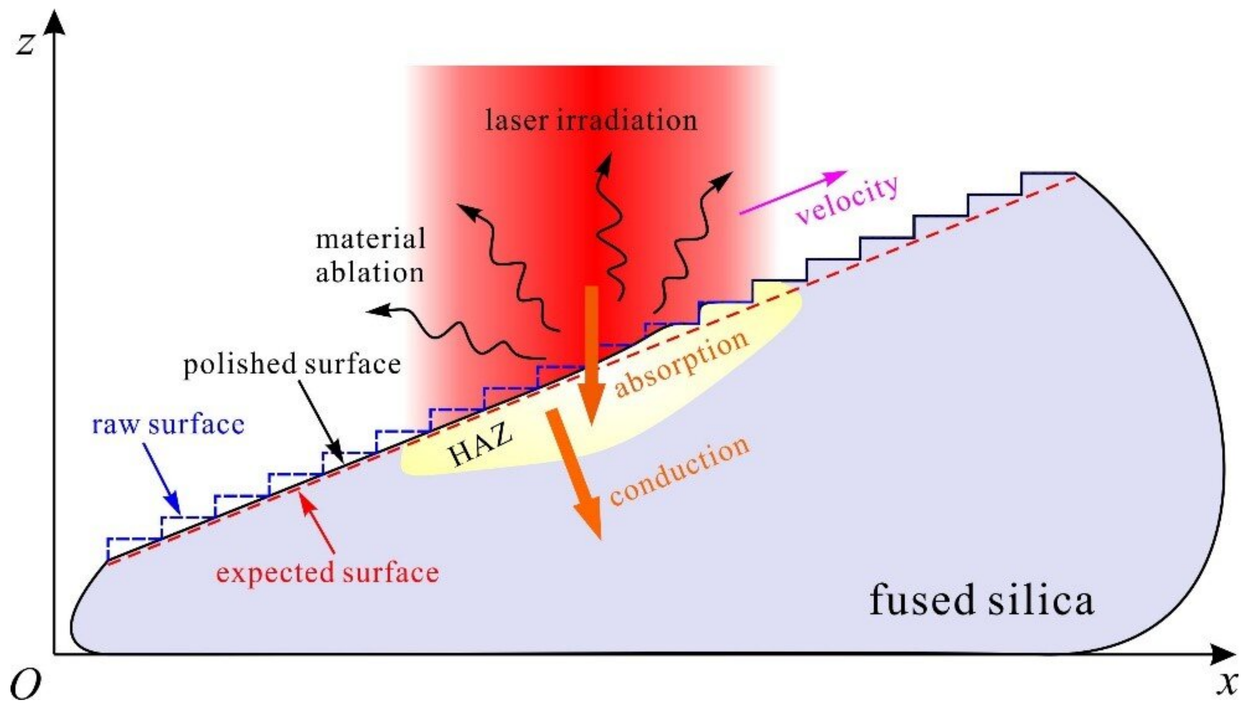

Figure 1. Schematic diagram for 2-D numerical model of CO_2 laser ablation. Credit: SIOM

Fused silica is a significant material for numerous applications in optics and photonics owing to its excellent optical performance. The processing of fused silica with pulsed CO_2 laser ablation offers the opportunity of converting an arbitrarily etched stepping structure into a continuous one. However, the achievement of continuous optical surfaces with the highest precision by laser-pulse ablation requires a balance of several parameters.

In order to rapidly obtain the optimum parameters for state-of-art polishing, a research group from Shanghai Institute of Optics and Fine Mechanics (SIOM) of the Chinese Academy of Sciences (CAS) has recently developed a numerical model based on the finite-element method for predicting the morphological evolution of a stepping structure on fused silica under different CO_2 laser heating conditions. Their findings were published in Materials.

In the experiment, the simulation focused on the non-explosive laser ablation with laser intensity in the regime of ~0.1-1MW/cm^2, where material removal by evaporation dominated, and uncontrollable melt displacement and ejection were avoidable. Thus, the critical temperature of surface recession was the vaporization threshold of fused silica at normal atmospheric pressure.

According to Hertz-Knudsen-Schrage formula, the velocity of surface recession could be calculated from the absorbed laser irradiation, the density of the material and total change of enthalpy required to volatilize the material. Furtherly, the comprehensive surface deformation of a stepping structure on fused silica could be calculated under different parameters based on the finite-element method.

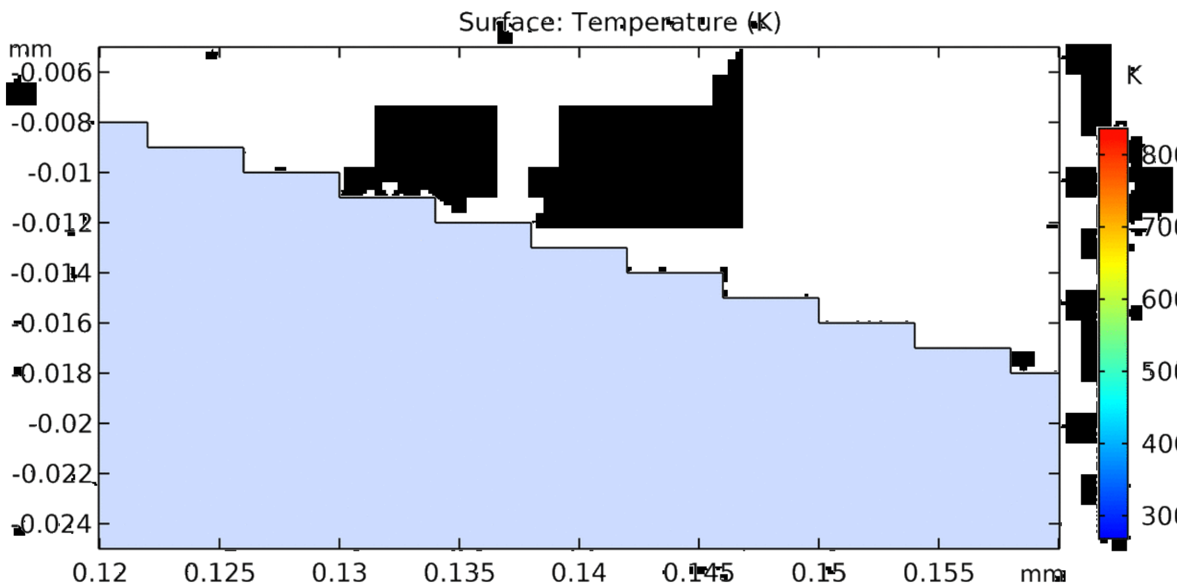

Figure 2. Morphological evolution and temperature profile during the ablation process. Credit: SIOM

Comparatively, it was preferable to acquire a polished profile that was closer to the expected one with less material loss. Using the numerical model, the researchers obtained the optimum parameters for polishing the stepping structure on fused silica after a comparison of the predicted surface morphologies under different heat conditions.

Adopting the optimized parameters acquired from the numerical model, a typical cone-shaped stepping structure with a diameter of 2 mm and a slope angle of 10.4° was processed via CO_2 pulsed laser ablation experimentally. The morphology of the processed structure was observed and characterized, and the measurements were in good agreement with the predicted values.

These results indicate that the numerical model can simulate morphological modification of CO_2 laser ablation with a high degree of reliability. It could further be used to optimize processing parameters for customizing continuous fused silica surfaces, which could facilitate industrial manufacturing of freeform optics.

More information: Li Zhou et al. Numerical and Experimental Investigation of Morphological Modification on Fused Silica Using CO2 Laser Ablation, *Materials* (2019). DOI: 10.3390/ma12244109

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