Picosecond laser machining of Borofloat®33 glass

Krystian L. Wlodarczyk and Duncan P. Hand

Heriot-Watt University, Riccarton, Edinburgh, EH14 4AS, UK

Corresponding author: Krystian L. Wlodarczyk, Email: K.L.Wlodarczyk@hw.ac.uk

Borofloat®33 is an inexpensive borosilicate glass which is characterised by excellent thermal, optical, and chemical properties. Therefore, it has found use in many different areas such as optics, chemistry, micro-electronics, photo-voltaics, and bio-technology. In this work, we investigate picosecond laser machinability of this attractive glass at three different laser wavelengths: 343, 515, and 1030nm, showing that the highest glass removal rate is achieved at the 515 nm wavelength.

Experimental results

Figure 1 shows the surface damage threshold of Borofloat®33 glass when machined by 6 ps laser pulses. The results are presented for two different laser wavelengths (λ = 343 and 515 nm) and for a different number of laser pulses. This graph does not show the surface damage threshold of Borofloat®33 glass when machined using the 1030 nm laser wavelength, because at this wavelength the laser-induced damage was observed either inside glass or on the exit (back) side surface.

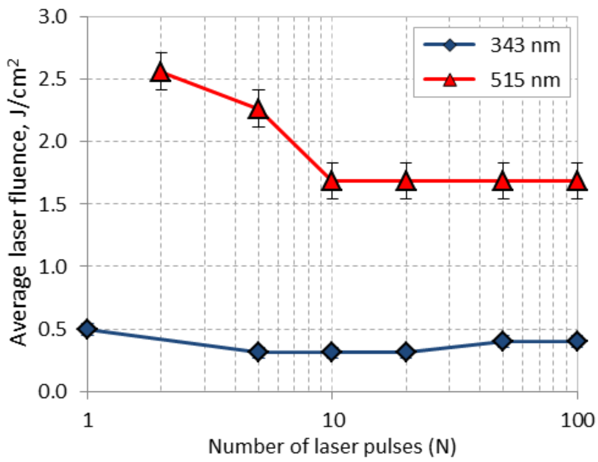

Figure 1. Surface damage threshold of Borofloat®33 glass determined at λ = 343 and 515 nm.

In this work, we measured the ablation depth of Borofloat®33 glass, when machined by a moving laser spot at the pulse repetition rate of 1 kHz, and studied the impact of the laser beam overlapping and the number of laser passes on the glass removal rate. All these experiments have been performed at λ = 343 and 515 nm. Figure 2 shows the linear dependency between the number of laser passes and the ablation depth in Borofloat®33 glass. Although this linear dependency was observed for both λ = 343 and 515 nm, these results show clearly that a higher removal rate is achieved at the 515 nm wavelength. Using the longer wavelength and maintaining the rest of laser machining conditions unchanged, i.e., the average laser fluence and the laser beam overlap, it is possible to increase the removal rate of Borofloat®33 glass by approximately 20%. This approach allows us to generate deeper structures without increasing the laser processing time. This is very important aspect in terms of making holes, blind-holes, and micro-channels in this glass. An example of the structure generated at λ = 515 nm is shown in Figure 3. Each square within this structure was machined at the same values of the average laser fluence and the laser beam overlap, but using a different number of laser passes. The average surface roughness of the squares was measured to be approximately 0.55µm, whereas the depth of the outside and middle square was 13 µm and 39 µm, respectively.

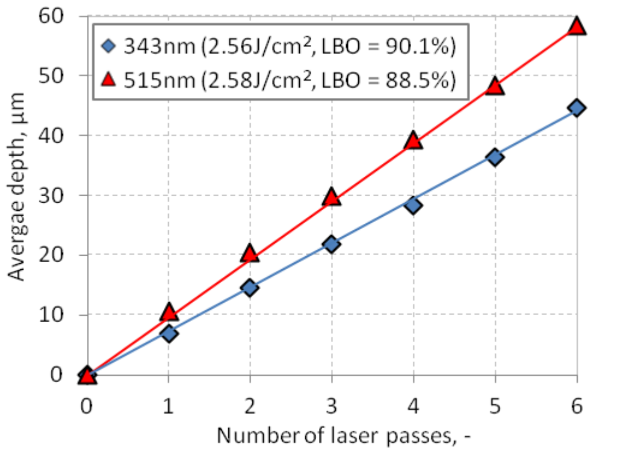

Figure 2. Average ablation depth at different number of laser passes. Results obtained at λ = 343 and 515nm, for similar values of the average laser fluence and the laser beam overlap (LBO).

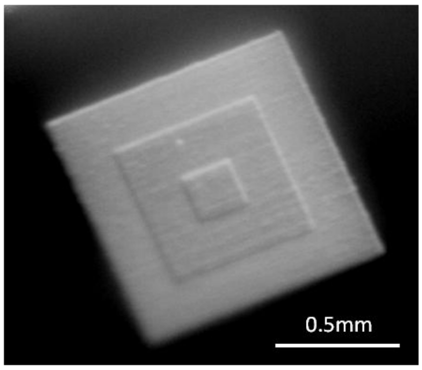

Figure 3. Structure machined in Borofloat®33 glass with a picosecond laser at λ = 515 nm, F = 3.55J/cm², and LBO = 88.5%.

Our research has also shown that picosecond laser micro-machining of Borofloat®33 glass does not provide satisfactory results at λ = 1030 nm, even though the average laser fluence and the laser beam overlap are increased to 5.2 J/cm² and 94%, respectively. The areas machined at this wavelength have found to have damage (fractures) inside the glass and very often on the exit (back) side surface.

Presenter

Krystian L. Wlodarczyk graduated with a PhD degree in 2011. Currently, he is a Research Associate within the High Power Laser Applications group at Heriot-Watt University where he works on a project involving adaptive optics for laser micro-machining applications.

E: K.L.Wlodarczyk@hw.ac.uk