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Ultrashort pulsed laser micromachining of glass using an interlaced laser beam scanning method

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Modern industrial high average power ultrashort pulsed lasers are capable of producing femtosecond and/or picosecond pulses with very high pulse repetition frequencies (PRFs), even in the MHz range, with pulse energies high enough to machine metals and glass. This suggests that such lasers should provide high process throughput. Unfortunately, laser machining at very high PRFs does not always lead to improved process throughput because laser-induced heat in a workpiece often causes its overheating, uncontrolled melting, oxidation, bending or even cracking. The simplest method to avoid these unwanted effects is to reduce the PRF and the laser beam scanning speed, but of course this also reduces process throughput and overall efficiency. A partial solution is to equip a laser system with a high-speed laser beam scanning unit that allows the laser beam to move with a high speed, thereby maintaining appropriate pulse overlap at an increased PRF. Another solution is to split the output laser beam into an array of less powerful beamlets by using, for instance, a diffractive optical element. This method enables processing of multiple areas on the workpiece simultaneously.

In this paper, we present a very simple method that increases process throughput without modifying the laser machining system. By changing only the laser beam scanning strategy, from "sequential" to "interlaced" (compare Figure 1 (a) with (b)), we were able to almost double the removal rate of borosilicate (Borofloat®33) glass, as shown in Figure 1 (c). The effect of this easily-implemented change on process throughput and machining quality will be presented for different PRF values and pulse overlaps, two pulse durations and two laser wavelengths. In this work, we also used a high-speed camera to record the picosecond laser micromachining of glass for both the sequential and interlaced scanning methods. The videos helped us to understand the mechanisms that lead to the machining improvement demonstrated with the interlaced approach.

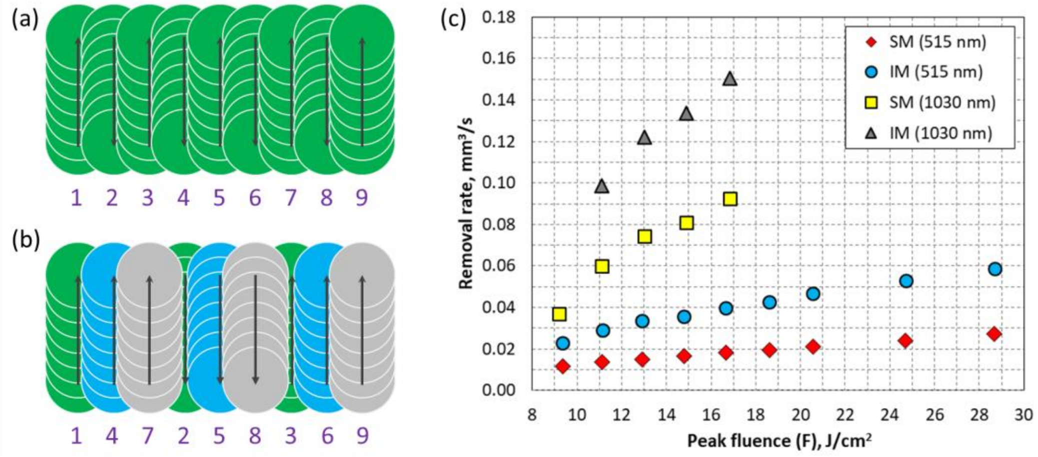

Figure 1. Illustration of two laser beam scanning methods: (a) sequential method (SM) and (b) interlaced method (IM). Removal rate of borosilicate (Borofloat®33) glass obtained by using a picosecond (Trumpf TruMicro 5x50) laser is shown in (c). These results are presented for different values of laser fluence, two laser beam scanning methods and two laser wavelengths (515 nm and 1030 nm). The glass samples were machined using a pulse overlap of 90% and pulse repetition frequency of 100 kHz. The laser spot diameters were 24 µm for λ = 515 nm and 40.8 µm for λ = 1030 nm.

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