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High speed UV femtosecond machining

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Abstract

High power femtosecond UV lasers up to 40 W contribute to increase the application range of ultrafast laser processing, by the use of new materials such as functionalized polymers or organic materials. From the user perspective, dealing efficiently with high average power levels and high pulse repetition rates, e.g. in high speed scanners, requires an increase in the pulse modulation speed as well as free triggering in order to synchronize the laser pulses with scanner or axes positioning, and ultimately with the application. The challenge in femtosecond lasers is then to maintain the inversion level constant through the entire amplifier chain, and hence the output pulse energy, for any user profile. With this issue solved, the user can adapt the laser pulse period or repetition rate to the variation of speed in case of complex movements in order to maintain a constant fluence on the sample.

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Frequency conversion to the ultraviolet spectral region is typically required to improve laser processing of organic materials or material compositions, e.g. for OLED-based displays. High power UV femtosecond lasers are therefore extremely promising for high efficiency and high-quality laser processing of polymer-based materials tolerating only very low heat affected zones. Femtosecond lasers are today delivering output powers of more than 100 W in UV, thus allowing the use of up to 50 W UV fs laser in industrial conditions. The laser architecture is based on high-power hybrid fiber-/crystal [Hönninger *et al.* 2018] femtosecond lasers and consists of a fiber-based seed module with a 40-MHz broadband passively mode-

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locked oscillator, a pulse picker, and fiber amplifier stages. The fiber-base enables for ultrashort femtosecond pulse generation thanks to its wide emission bandwidth. The pulses from the seed module can be compressed to a pulse duration on the order of 250 fs. The high power laser platforms are based on Yb:YAG crystals in a slab-geometry for superior thermal management. This amplifier platform has been scaled up to 200-W average power. Pulses as short as 350 fs are obtained (fig. 1)

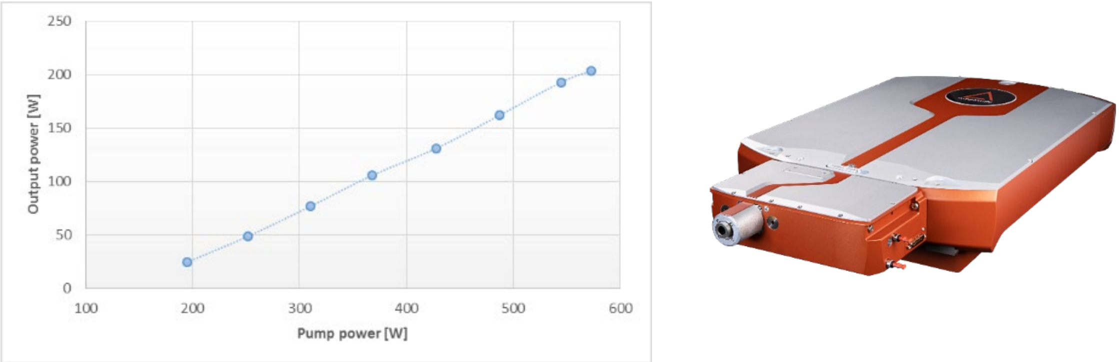

Fig. 1. Tangor high power laser system, delivering up to 200 W of IR at the amplifier output and 50 W of UV with the frequency conversion module.

The key challenge is to translate the available power into high throughput machining and still maintain the high quality and precision that makes femtosecond laser processing so unique. Combining the powerful femtosecond laser with fast scanning systems or multi beam shaping are two promising strategies to increase productivity. A major improvement for high speed processing will be the reduction of dead times during processing caused by acceleration and deceleration phases of moving axes or scanner mirrors. Being able to exploit these phases for laser processing requires free triggering of the laser output pulses, more likely than operating the laser at a constant pulse period or repetition rate. The realization of more complex shapes, e.g. curved shapes, requires also such free trigger options in order to maintain constant pulse overlap and to obtain best processing quality. We have developed a femtosecond laser that allows free triggering by the user with a timing jitter as low as one oscillator period (FemtoTrig®). This low timing jitter results in a positioning precision of typically less than 1 µm which is an excellent value for typically employed focusing conditions with spot sizes in the range of 10 to 30 µm. A challenge in this context of "free triggering" is to maintain the output pulse energy constant at the desired level because the laser amplifiers are continuously pumped and hence the stored energy may vary when the time intervals between amplified pulses change.

We have addressed this challenge via an innovative laser control concept. As an example, we show in Fig. 2 a user case where the pulse period is modified after each shot over the beam movement. The laser control system follows the user define pattern, and the average energy of each spot is maintained.

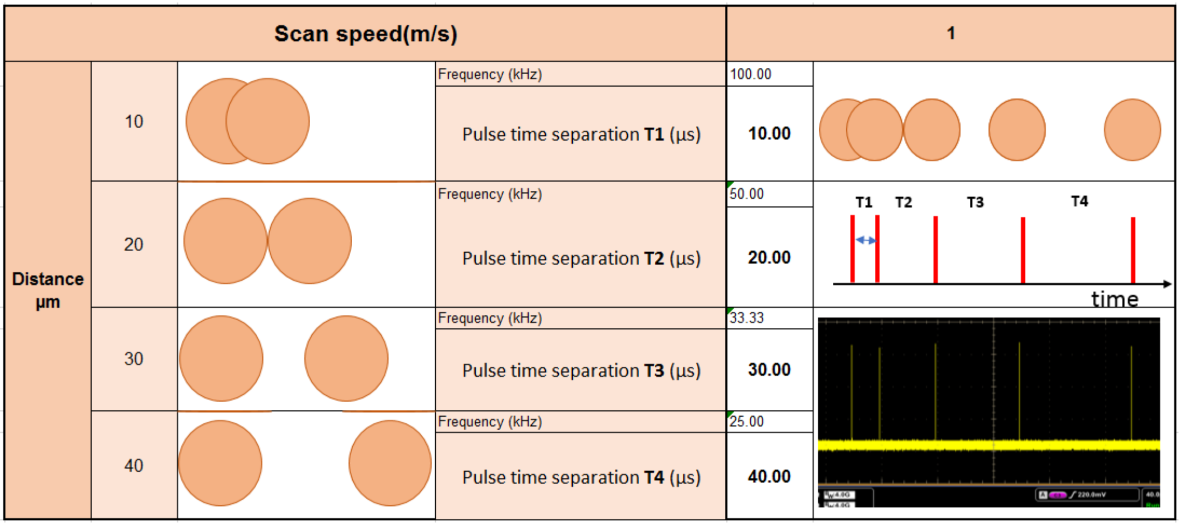

Fig. 2. user defined pattern of 5 spots (diameter of 20 µm) combined for a linear beam movement (scan speed of 1 m/s). The measured screen shot (yellow) correspond to the desired laser control pattern (red).

As an example, the method illustrated in Figure 2 is applied for the irradiation of a polymer (PET film) for several values of the scanning speed (1 m/s, 3 m/s and 5 m/s). Figure 3 shows that the positioning and shape of the spot is maintained.

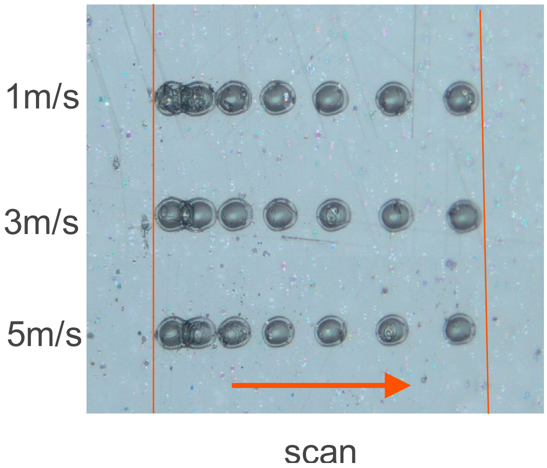

Fig. 3. Example of using the FemtoTrig® function to maintain the same spatial pattern of spots while varying the scan speed

References

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