

ENHANCED PCD ABLATION WITH THE ICEFYRE® FS IR200 FEMTOSECOND LASER USING BURST-MODE OPERATION

In our earlier study on femtosecond laser micromachining of polycrystalline diamond (PCD) [Application Focus 50: *Polycrystalline Diamond Machining with Femtosecond Bursts*], we demonstrated the advantages of burst-mode operation using the Spectra-Physics® Spirit® 1030–100 laser system. Those results showed that dividing a high-energy pulse into multiple lower-energy sub-pulses within a burst can significantly enhance material removal rates while maintaining excellent processing quality. Specifically, we reported a twofold increase in ablation rate when using a 9-pulse burst compared to single-pulse operation, highlighting the efficiency of burst-mode machining for ultrahard materials.



Figure 1. Spectra-Physics IceFyre FS IR200 high energy industrial femtosecond laser.

Building upon those findings, we have now extended our investigations to evaluate the performance of the new Spectra-Physics IceFyre FS IR200 laser (Figure 1), a next-generation femtosecond system offering higher average power and hence enhanced throughput for industrial applications. The laser provides pulse energy of $>200 \mu\text{J}$ and average power of $>200 \text{ W}$ at a wavelength of 1030 nm

and $<500 \text{ fs}$ pulse duration, with TimeShift™ burst mode operation capability, making it ideally suited for high-throughput, precision material processing applications.

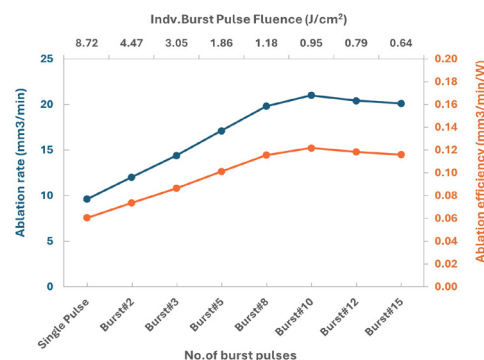


Figure 2. Material removal rates achieved with the IceFyre FS IR200 laser system, illustrating the performance gains from burst-mode compared to single-pulse operation.

Using similar experimental conditions to those described previously, we characterized the volumetric ablation rate achieved with the IceFyre FS IR200 laser. The new results, summarized in Figure 2, show a peak material removal rate of $>21 \text{ mm}^3/\text{min}$, representing a substantial increase in throughput compared to the earlier generation laser system. The data clearly demonstrates that burst-mode operation continues to provide significant benefits for ablation efficiency at higher power levels. Consistent with the previous study, we again observe approximately a twofold increase in ablation rate when using 10 burst pulses compared to single-pulse exposures.

The burst-fluence optimization approach, in which the optimal fluence for a process is revealed by implementing additional burst sub-pulses instead of reducing the incident (single) pulse energy, has again proven valuable.

By effectively managing the energy distribution within each burst, optimal fluence is maintained at the workpiece, enabling higher removal rates without compromising surface integrity or introducing thermal effects. The resulting excellent quality and large volume ablation are evident in a digital camera macro photo of the processed sample (Figure 3).

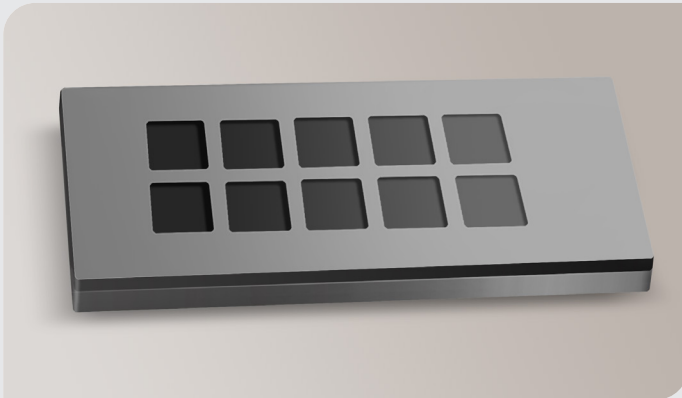


Figure 3. Pockets milled in polycrystalline diamond (PCD) using IceFyre FS IR200 laser.

Further, the simplicity of applying the laser's full average power while at the same time pinpointing the ideal processing fluence has great value – both in reducing process development time as well as instilling confidence in the final result – given that no additional adjustments to focus spot size or pulse repetition frequency are required.

In summary, the combination of higher average power and optimized burst-mode operation with the IceFyre FS IR200 enables exceptional material removal rates of $>21 \text{ mm}^3/\text{min}$, further validating the burst approach as a key strategy for next-generation ultrafast micromachining of ultrahard materials.

Thus, burst mode more than doubled the ablation efficiency, and did so while using far less energy per pulse. This supports the idea that ultrashort pulse burst processing allows more controlled, efficient energy delivery by splitting a high-energy pulse into smaller, more manageable sub-pulses.

PRODUCT

Product: IceFyre FS UV50 and IR200 Lasers

IceFyre FS UV50 is the highest-performing UV femtosecond laser on the market, providing >50 W of UV output power, >50 μ J pulse energy, and pulse widths of <500 fs at high repetition rates up to 3 MHz. IceFyre FS IR200 delivers high average power (>200 W) and high pulse energy (>200 μ J) with a wide repetition-rate range from a single shot to 50 MHz in the infrared. High average power (>200 W) and high pulse energy (>200 μ J) combined with high repetition rates up to 50 MHz push femtosecond micromachining applications to the highest levels of throughput at the lowest cost-of-ownership.

The IceFyre FS platform delivers exceptional versatility for optimal process performance. It offers flexible burst-mode operation with adjustable repetition rates, pulse-on-demand (POD) and position-

synchronized output (PSO) triggering, and TimeShift programmable pulse capability for flexible burst-mode operation.

Building on MKS' deep experience and technology, the patent-pending IceFyre FS lasers pass extensive environmental qualification testing to ensure high reliability and a low cost-of-ownership. Fully automated and computer controlled, the laser exhibits exceptional stability in power, beam parameters, and beam pointing during 24/7 operation to deliver high precision and reproducibility for demanding applications.

	IceFyre FS UV50	IceFyre FS IR200
Wavelength	343 $\pm$ 2 nm	1030 $\pm$ 6 nm
Power	>50 W @ 1 MHz and 1.25 MHz	>200 W @ 1-50 MHz
Maximum Pulse Energy	>50 μ J @ 1 MHz	>200 μ J @ 1 MHz
Repetition Rate Range	Single Shot to 3 MHz	Single Shot to 50 MHz
Pulse Width, FWHM	<500 fs	
Pulse-to-Pulse Energy Stability	<2% rms	
Power Stability (after warm-up)	<1% rms over 8 hours	
Spatial Mode	TEM ₀₀ (M ² <1.3)	
Polarization	>100:1, vertical	
Beam Diameter at Exit	5.0 mm $\pm$ 0.5 mm	4.0 mm $\pm$ 0.5 mm
Beam Divergence (full angle)	<0.20 mrad	<1.0 mrad