

PULSECORE Technology for Faster High-Quality Micromachining

Iradion's **Advanced Laser Control** Offers New Standards in Productivity and Quality



Nanosecond DPSS Lasers - An Efficient Solution for Manufacturing Companies

Nanosecond diode-pumped solid-state (DPSS) lasers are well established in industrial laser applications like cutting PCBs, marking ID cards, trimming electrical resistors and many more. Users enjoy the compact laser designs as well as the efficiency and longevity of the laser heads. This makes them easy to integrate and a cost-efficient solution due to low operational costs. From a more application-related point of view, these lasers combine high peak powers at a high beam quality to guarantee the best process results.

The flexibility of usage is not limited to the mentioned applications but all applications have one thing in common: quality and throughput are essential criteria of process qualification in industrial usage. Nevertheless, productivity and quality are often opposing requirements, and a compromise needs to be evaluated. Laser manufacturers face this challenge by scaling up the average laser power to increase productivity, but this approach can have a negative impact on the process result. The increased heat input overheats the material, particularly when the absorbed laser radiation is limited to a small processing area. Additionally, the investment costs are directly linked to the available laser power, which means that lasers become more expensive with increasing power levels.

In contrast to this method, Iradion's PULSECORE technology offers a solution to improve throughput and processing quality by simply controlling the pulses in the right way. This way, the energy of each pulse can be used effectively to ensure high processing quality in the fastest possible way without increasing the costs caused by higher power lasers.

Iradion's **PULSECORE** Technology at a Glance

Within the laser, controlling the pulses means to control three aspects the duration of each pulse, the amount of energy in each pulse and the time between the pulses. Pulse energy and pulse repetition frequency are parameters for optimizing process results, in particular, if they can be controlled during processing.

PULSECORE technology is a further development in Q-switch control, which enables individual modulation of pulse energy for each pulse.

The internal control of the Q-switch in our DPSS lasers enables the fastest and most flexible as well as the most precise adaption of pulse energy at the highest pulse-to-pulse stability, which positively affects ...



PROCESS SPEED



MANUFACTURING QUALITY



PROCESS FLEXIBILITY

The further development of the existing Q-switching technology stabilizes processing in narrow process windows or enables new laser processes. In the following sections, some use cases will be described, focusing on four aspects: high-speed pulse energy switching, smart pulse energy control, first pulse control and advanced pulse-to-pulse stability.

Fast Pulse Energy Switching



Smart Pulse Energy Mode



First Pulse Control



Pulse-to-Pulse Stability



Fast Pulse Energy Switching Accelerates High-Speed Processing

Besides the first pulse control, the PULSECORE technology accelerates laser processes in which the pulse energy needs to be changed frequently and significantly. For these applications, pulse energy stability and, in particular, speed and precision of pulse energy control are essential abilities of the laser source. In the following, the benefit of PULSECORE technology is shown using the marking process of passports or ID cards as an exemplary application.

In ID card and passport marking, as can be seen in figure 1a, every single laser pulse is used to create one pixel of a letter or an image. Every pixel requires a specific pulse energy to create the desired grey scaling or color. A complete card is processed via a pattern containing hundreds of thousands of pixels, but such a number of pixels requires high processing speeds to manufacture in a cost-efficient way. Consequently, the laser source needs to be able to adjust the pulse energy at high speeds, precisely set the pulse energy to the desired value and avoid any fluctuation in pulse energy to achieve the desired quality. In figure 1b, the comparison of pulse energy adjustment with and without PULSECORE technology is shown. To create the contrast, the pulse energy is adjusted to the grey scaling distribution. The finer the approximation by the laser, the better the quality of the processing results. By being able to switch the energy in a faster manner (red bars), the approximation is more precise compared to a standard laser mode (black dashed bars). Assuming high-speed processing, the standard configuration will not be able to precisely follow the distribution because the switching time for the pulse energy adjustment is too slow. The result is packages of pixels with the same grey scaling. By controlling the Q-switch in an optimized way, the switching time can be considerably reduced to follow the distribution even at higher speeds.

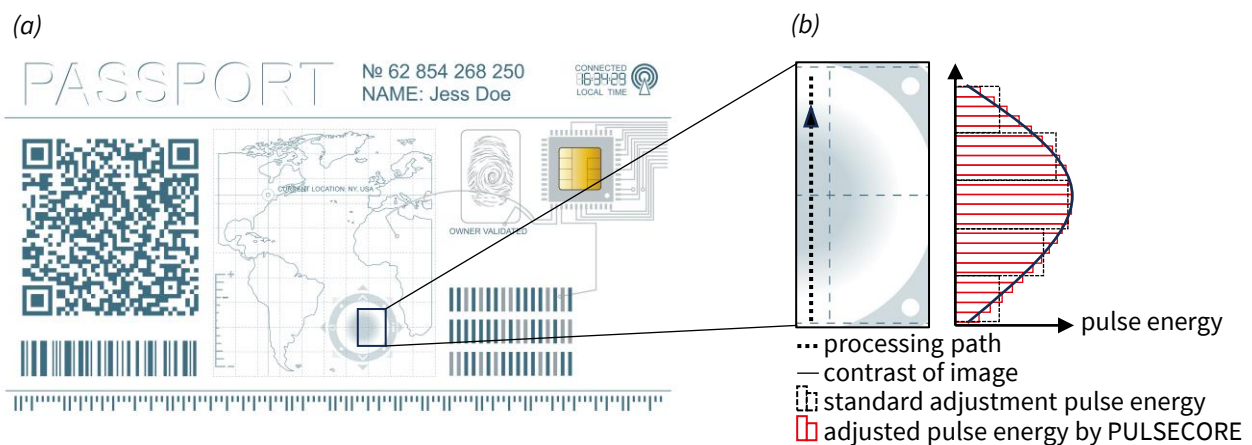


Fig. 1. Example of marked passport (a) and schematic comparison of pulse energy adjustment with and without PULSECORE technology in order to improve the processing quality

Each pulse can be modulated individually, which makes any AOM obsolete. Consequently, an advanced performance, achieving up to 256 different steps in grey shading, can be realized by a simplified and robust laser design. Furthermore, changing the pulse energy within the full laser range does not require any compromises in processing speed. Additionally, a typical pulse-to-pulse stability of 1% at 1064 nm and 532 nm as well as 2% at 355 nm offers stable processing in areas with a similar contrast.

To sum up, by using PULSECORE technology, laser users benefit from the following aspects:

**SIGNIFICANT INCREASE IN
PROCESSING SPEED** ↑

**PULSE-TO-PULSE STABILITY
DOWN TO 1%**

**PROCESSING QUALITY
WITH 256-BIT CODING**

Smart Pulse Control for High-Quality Processing

In laser material processing, the velocity of the laser beam often changes during processing due to the dynamic limitations of beam deflection or kinematic systems. The laser spot can easily be moved on a line, but precisely following a curved trajectory can be challenging. Therefore, the speed of the laser spot often needs to be reduced compared to straight-line processing. Consequently, the overlap of the pulses will vary if the laser emits laser pulses with a constant repetition rate. When the laser beam operates at high speeds, the pulses will only slightly overlap or will even be separated; at low speeds, the positions of consecutive pulses converge. For many applications, this is a state that cannot be tolerated because quality is negatively influenced by the inhomogeneous heat input into the material.

At Iradion, we solve this problem by adapting the laser's pulse repetition rate to the relative speed of the laser beam compared to the workpiece. For this, the laser receives the current state of velocity data of the beam deflection or kinematic unit and calculates as well as adapts the pulse repetition rate during processing. The result is a constant pulse overlap during the entire processing time. In contrast to many other nanosecond DPSS lasers, the pulse energy and the pulse duration can be kept at a constant value at the same time, independent of the repetition rate. This enables laser users to achieve the highest process stability.

In figure 2a, an exemplary coding process on an electronic component is shown to highlight the benefit in quality and process speed. For the marking process, a galvanometer scanner was used to deflect the beam. The resulting quality and processing speed significantly depend on the control of the laser, as shown in figure 2b. In typical standard control modes of nanosecond DPSS lasers, the marking speed is limited to a certain value to achieve an acceptable quality. In the example shown, it is 1.6 m/s. Up to this value, the quality is quite good. Only some slight melt creations are visible because no significant speed variations occur. The process does not require the adaption of the laser's repetition rate at this speed.

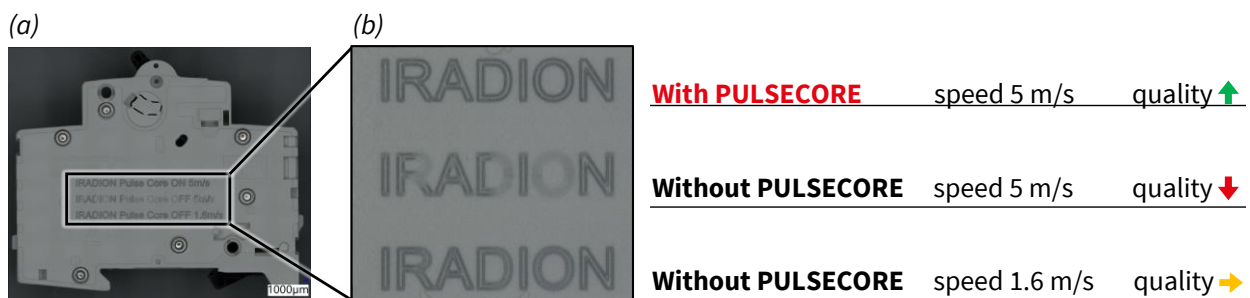


Fig. 2. Marking on an electronic component (a) and comparison of quality and process speeds with and without PULSECORE technology (b)

If a higher productivity is required, this is not the case anymore. When further increasing the processing speed to 5 m/s, the quality is negatively influenced when using the standard control mode. This is a result of limited dynamics of the scanner. To maintain the marking geometry, the processing speeds need to be reduced particularly in curved sections of the trajectory. Without adjusting the repetition rate, the material is overheated and melted. After re-solidification, the contrast is quite low.

By using the PULSECORE technology, both advantages can be combined: an excellent contrast can be achieved at 5 m/s. At every marking section, the repetition rate is adapted to the spot velocity, and the heat input is constant within the entire processing area. Consequently, no melted areas occur and the marking contrast is completely homogeneous even at high speeds of the laser spot. Skywriting, which is often necessary for quality reasons, can be eliminated, saving process time and costs.

In literature, further examples are shown in which the processing quality can significantly be improved by adapting repetition rate. This ability is particularly important for applications in which ultrashort pulsed lasers are used. One example is the cutting of thin sheet metals or foils if the cutting trajectory is not straight, but curved.

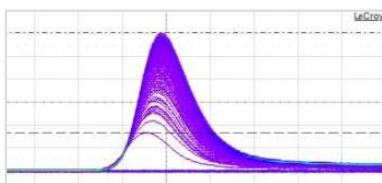
To sum up, the following potentials can be unlocked:

PROCESS ACCELERATION	PROCESSING QUALITY	USEFUL FOR SCANNER-BASED
UP TO 3X	↑	AND FIXED-OPTICS SYSTEMS

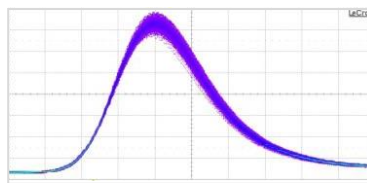
First Pulses Controlled

For many applications, manufacturing quality usually suffers from the uncertainty in pulse energy distribution when emitting the first pulse using a DPSS laser. Deviations in pulse fluence and peak power occur depending on the charging state of the laser crystal, as shown in figure 3. Particularly in free-running mode, these deviations are significant, which negatively affects the manufacturing quality. Even standard first pulse control implementation can reduce this effect, but usually does not eliminate pulse energy deviations.

free running mode



standard first pulse control



smart PULSECORE technology

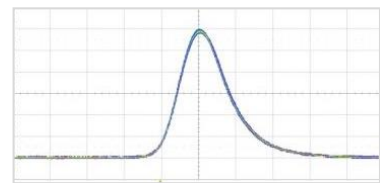


Fig. 3. Comparison of first pulse behavior of DPSS lasers in different operation modes

By using our smart PULSECORE technology, the Q-switch is precisely controlled to regulate the energy state of the laser crystal. As a result, every pulse has the same pulse energy. Pulses that can damage the component to be processed are eliminated. This can be seen in figure 4, exemplifying the improvement of the processing quality by PULSECORE technology at the starting point and when skywriting – generally speaking, whenever the laser is switched on. The pulse energy control stabilizes the production quality to achieve uniform processing results starting with the first pulse.

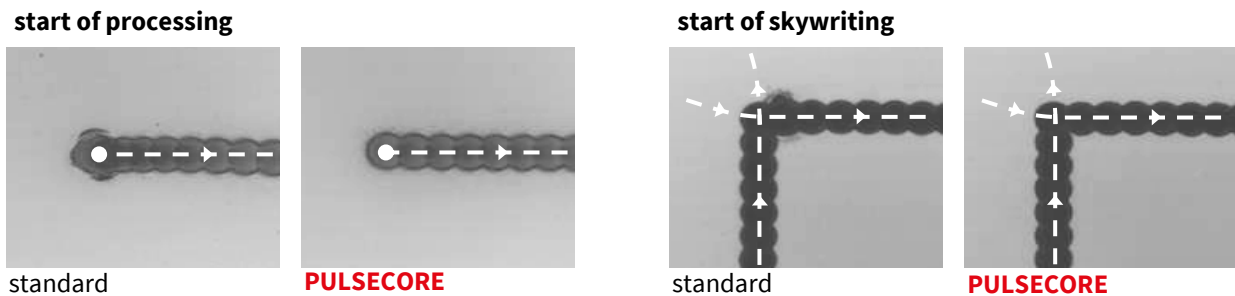


Fig. 4. Improvement of manufacturing quality when using PULSECORE technology at the start of processing

Relevant laser applications for first pulse control:

MARKING **ENGRAVING** **SCRIBING** **DECOATING**

Whenever Pulse-to-Pulse Stability Matters

Laser processes with narrow process windows or on sensitive materials require an excellent pulse-to-pulse stability of the laser source. In this field of applications, a high pulse-to-pulse stability can have two effects: improving the manufacturing quality or even enabling the laser processes. The stability value is one of the key specifications usually listed in the datasheet of the laser's manufacturer and quantifies the measured fluctuation in pulse energy of a defined number of consecutive pulses. In many industrial laser applications, these fluctuations cannot be tolerated due to quality variations of the processing result.

Resistor trimming is one exemplary application that requires that kind of laser ability (see figure 5a). During the trimming process, the coating of every single resistor is laser-ablated by one laser pulse (see figure 5b) to adjust the exact resistance in real-time during circuit testing with a precision of down to 0.05%. The ablation trajectory can vary, but the ablation depth is always adapted to the thickness of the coating. The goal is to completely remove the coating from the ceramic base material on the desired trajectory, otherwise ageing effects shift the resistance of the resistor over time. Therefore, variations in pulse energy are not allowed to achieve a constant ablation depth.

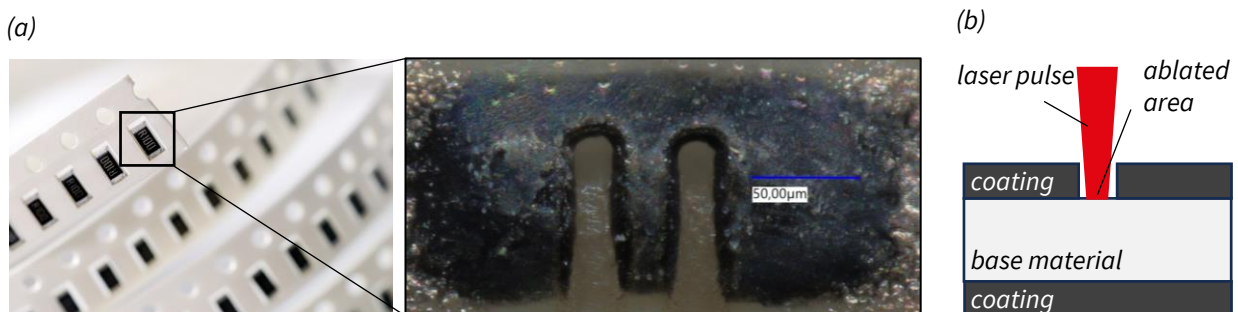


Fig. 5. Stripes of micro-resistors and trimmed precision resistor (a) as well as schematic description of laser processing (b)

Other processes in which the pulse-to-pulse stability of a laser does matter are ID card marking or silicon wafer marking. In ID card marking, all written letters or numbers usually need to have exactly the same contrast. The contrast is directly controlled by the pulse energy, which means that variations in pulse energy would directly affect the homogeneity of the marking on the workpiece. Pulse-to-pulse stability matters!

In wafer soft and deep marking, the geometry of every marked dot of a code is tolerated down to the sub-micrometer level. Small changes in pulse energy will result in another marking geometry, which can influence the complete manufacturing chain in silicon wafer processing.

Examples of applications where pulse-to-pulse stability is crucial:

RESISTOR TRIMMING

ID CARD MARKING

WAFER MARKING

Iradion – a **Leading** Supplier for Innovative Nanosecond DPSS Lasers

Applications with the highest demands on pulse energy control and stability have been our core business for over 10 years. Our PULSECORE technology offers advanced solutions for semiconductor, microelectronics, or micromachining industries. We are collaborating with globally renowned machine builders to offer the highest quality standards for laser-based manufacturing.

For More Information, Please See the Following **Links or QR Codes**

**Latest Nanosecond DPSS Laser
with built-in PULSECORE Technology**



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