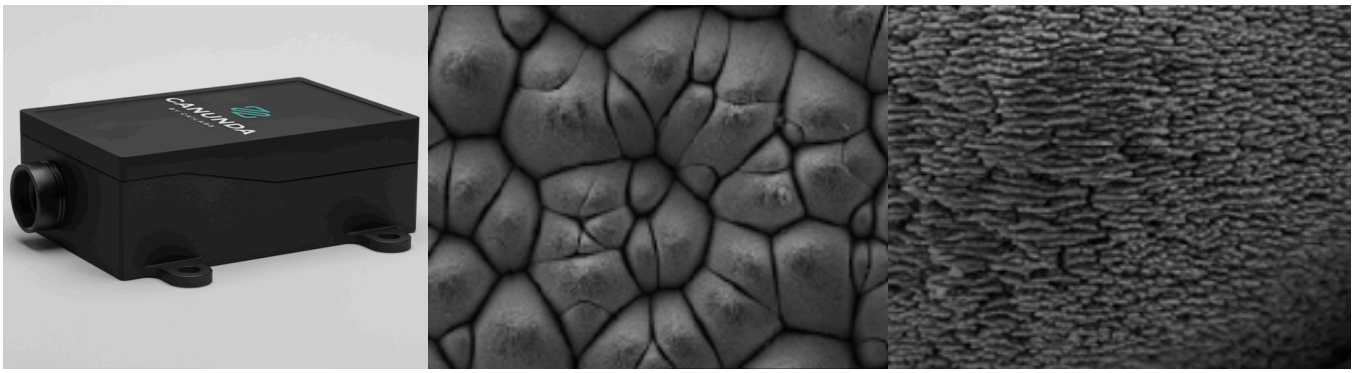
CANUNDA

CASE STUDY

CANUNDA-PULSE enables fast surface texturing by line top-hat beam shaping with femtosecond laser



The partner's issue

ALPhANOV, a research center developing various laser processes, is investigating new techniques for enhancing the speed and efficiency of laser surface functionalization. In particular, they needed a rugged and efficient beam shaper, able to work with femtosecond lasers, to optimize energy delivery and increase the performance of generating so-called Laser Induced Surface Structures (LIPSS).

The CANUNDA-PULSE solution

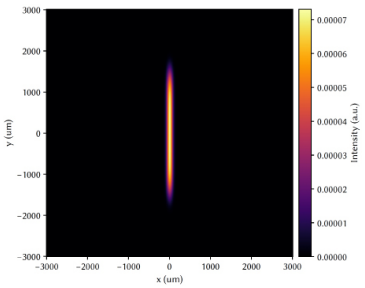
Cailabs' CANUNDA-PULSE is a beam shaper based on our patented, efficient and flexible Multi-Plane Light Conversion (MPLC) technology.
Completely reflective by design, it was conceived to handle high-energy femtosecond pulses with **great stability**. It is able to produce a high-quality line top-hat for quickly and efficiently generating surface structures.

New trends for improving laser surface structuring processes

Founded in 2007, ALPhANOV is a non-profit organization located in Bordeaux, France, seeking to boost innovation through collaboration between research and industry. ALPhANOV has an expertise in laser processes and micromachining and it is investigating, developing and characterizing laser surface functionalization, among other processes.

Surface functionalization (or texturing) by laser allows you to create effects or give new properties to the surface of a material, by generating micro or nano structures with laser irradiation. For example, surfaces can be made hydrophobic, hydrophilic, antibacterial, have light-trapping properties, etc. This process is primarily confronted with one main challenge: in order to be commercially viable, the process needs to be **fast and efficient** in order to minimize the processing costs.

One key solution for boosting the process speed is the use of laser beam shaping for optimizing laser energy deposition. In particular, shaping a laser beam into a line shape allows irradiating a larger area than with a conventional Gaussian beam in the same number of pulses. This leads to dramatically faster processing rates. Moreover, by optimizing the energy distribution to have a homogeneous "top-hat" distribution in the length of the line, you have a consistent energy deposition on the material, which is key to generating highly homogeneous surface structures.



Intensity profile of a line top-hat beam

Need for an adapted, rugged and precise beam shaping technology

The more conventional beam shaping technologies (SLMs, DOEs, ROEs, etc.) have limitations. They typically present a limited depth of field, are sensitive to misalignment and beam defects, and are usually unable to handle high-power and high-energy lasers. This prevents their use on an industrial scale, especially with industrial setups such as galvo-scanner and f-theta lenses. Additionally, conventional beam shaping technologies are transmissive (transparent) optical components. This causes them to be confronted to certain undesirable phenomena when working with high-power/high-energy ultra-short pulse lasers, such as pulse duration increase, further preventing their use on an industrial scale.

ALPhANOV
Optics & Lasers Technology Center

cailabs
SHAPING THE LIGHT

Cailabs' solution: CANUNDA-PULSE, a reflective beam shaper

The solution proposed to ALPhANOV is CANUNDA-PULSE, a laser beam shaping module specifically designed for Ultra Short Pulse (USP) laser requirements and tailored to micro-machining constraints. It is based on Cailabs' proprietary beam shaping technology, the Multi-Plane Light Conversion (MPLC), which passively shapes the phase and amplitude of a laser beam through successive reflections on phase masks.

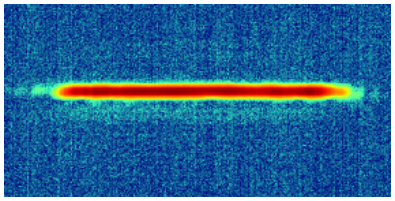
The reflective design of this beam shaper allows it to **withstand higher energy** pulses and **higher average powers** from the input laser. This makes it suitable for demanding material processing use. It can also be used to avoid many undesirable phenomena such as pulse broadening, making it a **perfect, stable and robust solution** to work with Ultra-Short Pulse lasers for industrial processing. Moreover, a unique and patented technology was developed in order to ensure the CANUNDA-PULSE module would be compatible with beam instabilities: **mode cleaning**. This technology compensates all USP laser output beam fluctuations that usually deteriorate shaping with these lasers in order to maintain a perfect shape on material, even for long and intense operating times.

CANUNDA-PULSE, an ultrafast laser beam shaper

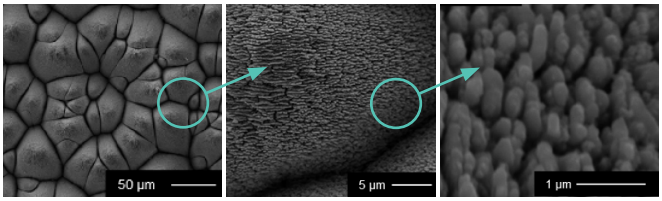
Line top-hat beam shaping for surface blackening

A CANUNDA-PULSE beam shaper was installed at ALPhANOV in order to produce a 600 µm x 30 µm line (aspect ratio of 20). The energy distribution was controlled in order to give a top-hat energy distribution over the length of the line and a Gaussian energy distribution over the width. The beam shaper was used with the Tangerine HP femtosecond laser from Amplitude Systèmes (35 W, 2 MHz, pulse duration < 350 fs) and was integrated in **a galvo scanner and f-theta** (f=100 mm) setup in order to quickly irradiate steel samples. On the sample, the beam was used to generate surface structures with light-trapping properties through Laser Induced Periodic Surface Structuring (LIPSS), giving a deep black coloring on the surface. **Reflectivity < 5%** was measured experimentally.

As CANUNDA-PULSE controls the phase of the laser beam, the line shape was preserved for **over 6 mm**. This made it easy to position the sample. The energy homogeneity over the length of the line enabled an **energy variation of no more than +/- 10%** and allowed generating highly homogeneous surface structures. The **pulse duration was preserved** in auto-correlation measurement. Overall, using the line beam shaping we were able to parallel process instead of serial process with a Gaussian beam. This enabled a **repetition rate reduction by a factor of 20**. This paves the way for high-speed processing of large areas, decreasing femtosecond laser surface structuring costs.



Intensity profile (log scale) of the line produced by the CANUNDA-PULSE module



Laser Induced Periodic Surface Structures Generation by femtosecond laser and Multi-Plane Light Conversion beam shaping

Cailabs: beam shaping made easy

Cailabs is a leading provider of innovative solutions designed to enhance performances of laser-based systems for many applications, such as research, optical telecommunication and material processing.

With the CANUNDA product line, we develop and manufacture a range of robust and easy to integrate light shaping components improving the quality and speed of laser processes. From additive manufacturing and metal welding and cutting with high-power lasers, to transparent material processing and micro-processing with USP lasers, CANUNDA products by Cailabs will provide you with a perfect beam shaping solution.

> *"The implementation of beam shaping strategies, which allows the use of all available power from the latest generation of femtosecond laser sources (hundreds of W), opens up great possibilities for the exploitation of MPLC technology in the industrial fields."*
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> **G. Mincuzzi (ALPhANOV) et al.**
> https://doi.org/10.1117/12.2546609

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