Beam shaping for large part texturing with kW femto-second lasers

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Jean-François Morizur
jf@cailabs.com
A few words about Cailabs
We develop, manufacture & sell innovative optical components

Unique technology (MPLC) and expertise in beam shaping

48 + employees (18 PhDs)

20 + patent families

16.6 M€ raised
“We shape light for you”
We solve problems related to complex beam shaping

MPLC technology

- Improve laser material processing
- Future-proof fiber infrastructure of LANs
- Invent the optical networks of the future
- Ensure the reliability of lasercom
- Integrate tailored optical solutions

Cailabs inside
Multi-Plane Light Conversion (MPLC):

- Succession of spatial phase profiles and propagation
- Passive beam shaping
- Reflective implementation
- Multiple modes / beams
➢ What are some of the key challenges of USP laser processing?

➢ How can complex beam shaping help tackle these challenges?

➢ Brief summary of process results
➢ What are some of the key challenges of USP laser processing?

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➢ Brief summary of process results
Yield is core to cost-effectiveness of large part texturing
Example: laser thin film removal

Laser thin film removal is ablation over a small thickness
- highly localized and selective (5 to 100 µm focused USP laser spot)
- without damaging its substrate

Applications range from small surfaces (micro-electronics) to large areas (solar cells)

Process yield has a direct impact on cost-effectiveness in some critical applications

Images credit to Lasea
Yet trying to increase yield creates its own set of challenges
From the input (laser stability) to the processing spot

**Yield improvements** usually come from …

- **Energy / Power** increase
- **Scanning speed** increase
- **Beam splitting**

These create **4 main types of challenges**:

- Input stabilization
- Shaping to maintain process quality
- Splitting to deliver the right amount of energy
- Power handling

*Images credit to Amplitude and Lasea*
What are some of the key challenges of USP laser processing?

How can complex beam shaping help tackle these challenges?

Brief summary of process results
MPLC provides access to a wide range of shapes

A high resolution succession of phase plates enabling:

• A free form high quality beam shaping to the limit of diffraction
• A managed phase for a preserved depth of field
• A preserved pulse duration
• An integration compatible with industry equipment

Interferences with Gaussians vs with top-hat beams

Catalog USP Top-Hat

Catalog USP Bessels
MPLC can be leveraged for mode cleaning

Concurrent implementation of two functions: **beam shaping and mode cleaning**

MPLC
HG00 → Square Flat Top
HGnm extracted for n+m>0

Input
Output

Injection
Mishaped input beam

Output
To target material

Filtered Output
To beam blocks / photodetectors

All beam drifts and imperfections handled: tilt, shift, defocus, ellipticity, astigmatism etc.
MPLC can be used for beam-splitting with low chromaticity

A high quality beam splitting:

- ± 2% homogeneity (std dev)
- Compatibility with industry equipment
- No chromatic effect
Reflective nature of MPLC makes multi-kW handling possible

Beam shaping at up to 16kW

- Complex beam shaping
- Reduced focus shift with reflective design
- Depth of field preserved
- Loss < 1%
- Fully integrated!

Water-cooled Collimating Module

Standard LLK-D fiber Input = TRUMPF TruDisk 16002

MPLC Custom Module amplitude and phase control

Water-cooled Focusing Module

Target Shape
➢ What are some of the key challenges of USP laser processing?

➢ How can complex beam shaping help tackle these challenges?

➢ Brief summary of process results
Laser thin film removal demonstrates splitting

Process of decoating:

• Molybdene decoating over steel
• Single pass decoating
• Line parallelism impacted by material intrinsic non-homogeneity

Results enabling an immediate yield increase of a factor of 9!

Paper number: 11270-25

Confocal microscopy
Laser thin film removal demonstrates splitting

Process of decoating:

Decoating sample
Laser Induced Periodic Surface Structure demonstrates shaping + stabilization

LIPSS generation:
• With a Line Top-Hat
• A morphology of highest quality
• Reflectivity < 5%

At a constant average power, get the same quality as a gaussian beam by processing at 100kHz instead of 2MHz enabling an immediate yield increase of a factor of 5

Paper number: 11268-47
Laser Induced Periodic Surface Structure demonstrates shaping + stabilization

LIPSS generation:
Penetration tests in steel at high power demonstrate high-power handling.

**Preliminary Process Results** on stainless steel thick sheets:

- **10 kW**
  - 0.8 m/min
  - Depth: 13.1 mm

- **16 kW**
  - 0.4 m/min
  - Depth: 24.2 mm

Without protective gaz shield

Paper number: 11273-17
Penetration tests in steel at high power demonstrate high-power handling

**Preliminary Process Results** on stainless steel thick sheets:
To sum it up: MPLC can help achieve yield improvements

A « simple » increase in laser power is not necessarily enough anymore to achieve process yield improvements

Complexe beam shaping, and MPLC in particular, can help mitigate some of the most critical issues blocking yield increase

- Input stability, beam shape on material, splitting

Process improvements demonstrating these features are presented this week:

- 11270-25 Splitting
- 11267-10 Shaping
- 11273-17 High-power handling, shaping
- 11266-36 Stabilization, shaping
- 11268-47 Stabilization, shaping
Partners wanted!

Looking for

- **Application labs** with novel challenges
- **End-users** or **system integrators** with quality / yield challenges
- **Laser manufacturers** who would like to increase laser stability or explore new use-cases
- **High-power fiber manufacturers** to explore USP fiber delivery architectures

Get in contact

- [www.cailabs.com](http://www.cailabs.com)
- [jf@cailabs.com](mailto:jf@cailabs.com)
- Booth number: 4386
Thank you for your attention!