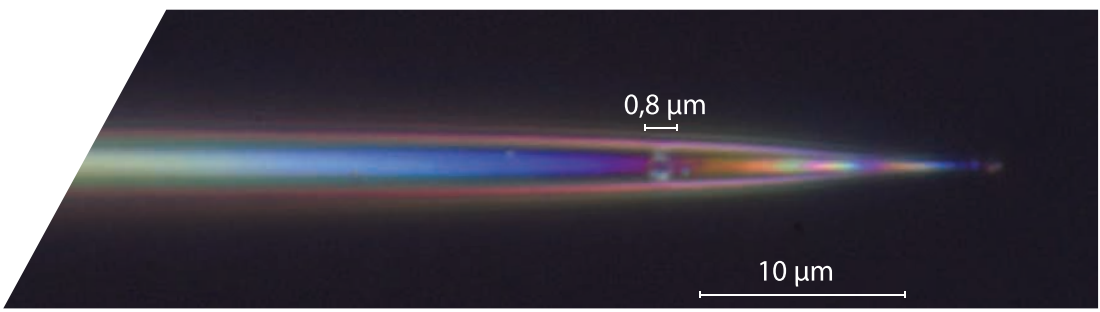
Workshop of Photonics



LASER MICROMACHINING SOLUTIONS AND TECHNOLOGIES

2017

Workshop of Photonics

Workshop of Photonics® is all about ultrashort pulsed lasers micromachining.

We develop instruments and solutions for laser micromachining tasks. From feasibility studies to customized optical modules and from electronic devices to laser machines.

Our services are targeted to industrial and academic customers.

Our key competencies:

- Feasibility studies on femtosecond laser micromachining
- Development of custom femtosecond laser micromachining workstations and optical modules
- Laser system automation software

Our competence growth is inspired by culture of open innovations and partnership with the Lithuanian laser sector companies and worldwide partners.

Workshop of Photonics is constantly working on projects connecting scientific inventions with the industrial needs.

Academic partners

CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY

SWINBURNE UNIVERSITY OF TECHNOLOGY

UNIVERSITY OF Southampton

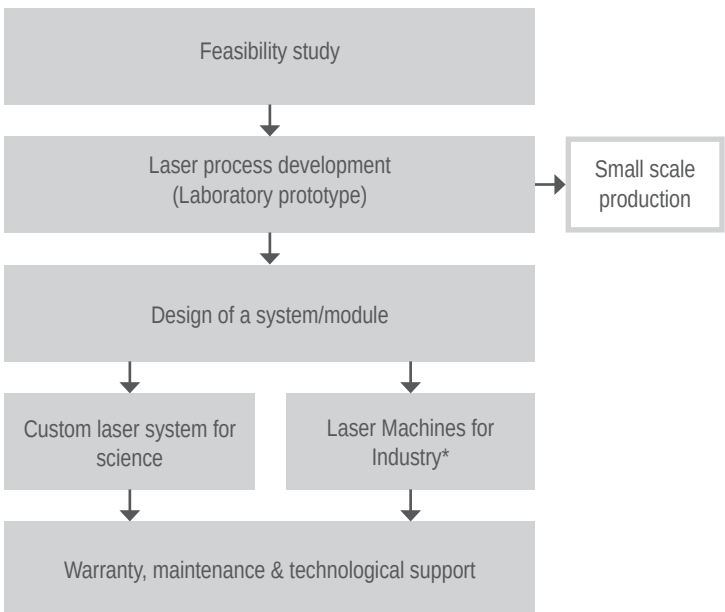
CONTENT

SERVICES

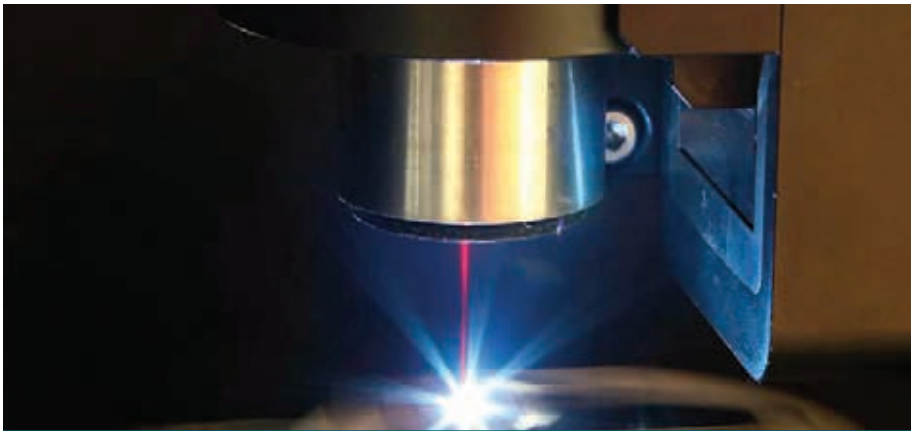
Workshop of Photonics cooperation with customer usually starts with a demand to perform a specific micromachining task.

The first step is a feasibility study which means that our company prepares samples for a customer to showcase achieved results and prove feasibility of laser processing. Regarding customer requirements it may lead to a small scale production if this is only a one time request. For a more demanding customer feasibility studies would lead to a laser process development - the solution how to prepare the samples would be developed together with a customer.

Pinnacle of the cooperation with the customer is designing and manufacturing custom system for a laser micromachining task. It is a customer's choice how far to go down the steps of cooperation with Workshop of Photonics.



* In partnership with manufacturing machinery producers



Feasibility study in action

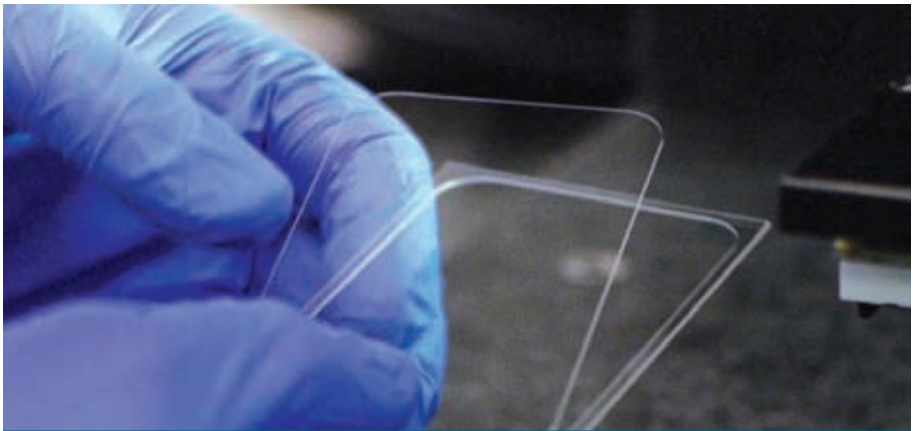
Feasibility Studies

The essence of feasibility study is to demonstrate that customer's problem can be solved using ultrashort pulsed laser micromachining technology and that it has advantages over competing technologies.

Workshop of Photonics laboratories are fully equiped and ready to process various materials with femtosecond and picosecond lasers in order to achieve desired results.

Feasibility studies are performed in following steps:

- Detailed task description
- Samples
- Processing
- Evaluation of results
- Preparation of report
- Feedback from customer



Self breaking of glass after laser cutting process

Laser Process Development

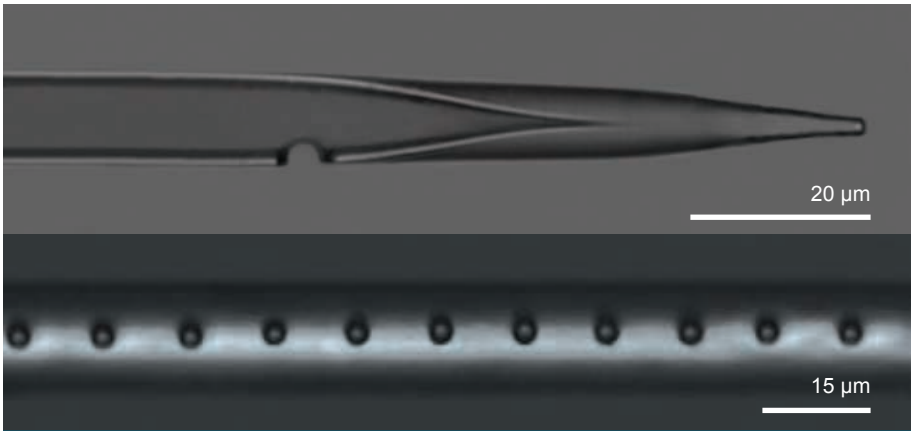
Most of laser micromachining applications are not as straightforward as for example marking. Majority of them require development that takes weeks and even months.

Not only different laser parameters have to be tested but also various beam shaping and focusing solutions.

A typical approach for a comprehensive process development contains following steps:

- testing of different wavelengths in order to explore light-material interaction
- testing of different focusing conditions
- selecting and testing most suitable positioning solution
- determining what is required for repeatability and required speed of process
- optimizing software functionality for convenient process control

Every customer is welcome to contact us with specific micromachining tasks. We are committed to develop a micromachining process. If a task is more demanding, we are ready to involve our academic partners in search of a solution.



Small scale production examples

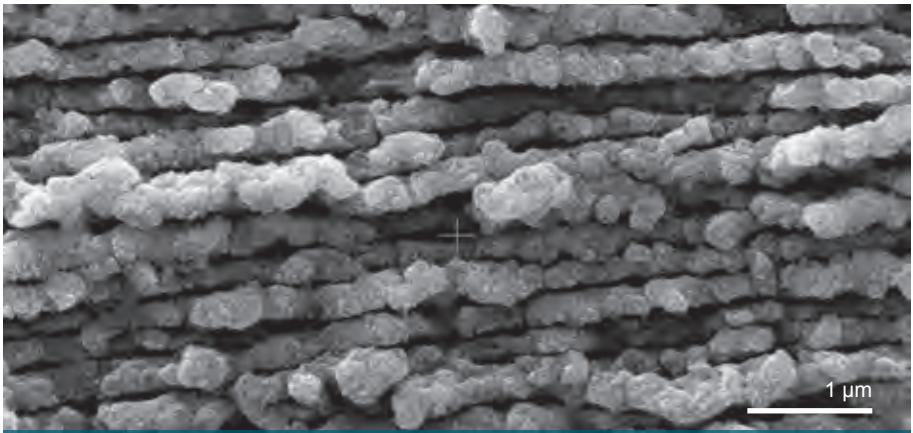
Small Scale Production

Laser micromachining technologies are perfect solution for specific tasks in material processing. High accuracy, great repeatability, high speed and ability to fabricate difficult objects with submicron resolution are just few advantages of laser proccesing.

However, if purchasing laser micromachining workstation is not the option at the moment, consider using our laser job shop services. Our laser laboratories are equipped with several laser workstations, using femtosecond and picosecond laser pulses.

We are also able to access laboratories of our partners if different laser capabilities are required for your specific purpose.

A small batch of articles may be fabricated in our laser laboratories according to your requirements.



Surface micro/nano structuring developed in cooperation with Swinburne University

Joint Research Projects

Workshop of Photonics have already participated in several joint research projects using laser technologies with partner companies aiming to develop interdisciplinary products and technologies. Combining our knowledge and abilities with our partners, we are able to put advantages of several scientific fields into a whole.

Our team is open minded, eager to broaden their knowledge, and also interested to get more experience in various fields. Our laboratories are fully equipped with laser micromachining workstations.

Results of joint research projects using laser technologies:

- S-waveplate
- FemtoLAB MPP

Let us know if there is a prospect for joint research projects using laser technologies – we are ready to become your successful partner.

PRODUCTS

Laser micromachining system for laboratory FemtoLAB

Micromachining Workstation for Laboratories

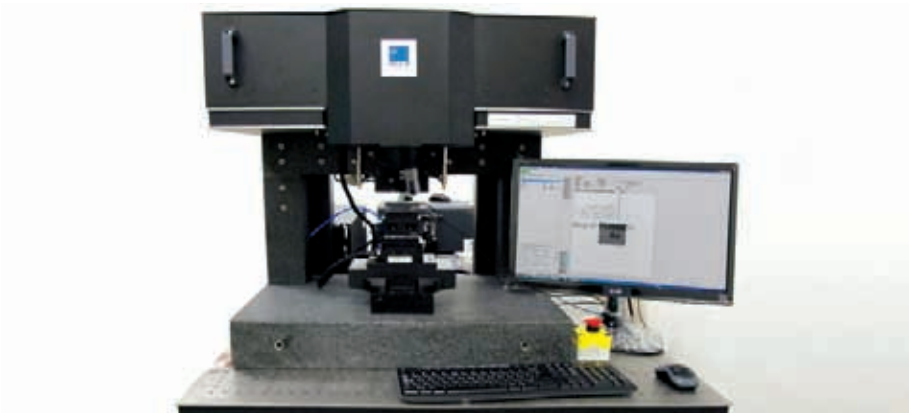
Workshop of Photonics develops customized laser micromachining workstations - devices that fully meet customer's requirements in laboratories for scientific research or R&D centers.

System configuration is carefully selected based on customer requirements.

Main components:

- Laser source
- Sample positioning system
- Beam delivery and scanning unit
- Laser power and polarization control
- Software for system control
- Machine vision
- Sample holders and special mechanics
- Sample handling automation (optional)
- Optical table
- Enclosure
- Dust removal unit

We provide a custom solution for every laboratory. A proven flexibility of FemtoLAB concept allows to further expand and upgrade the system when new requirements arise.



Femtosecond laser micromachining system for laboratories

FemtoLAB

FemtoLAB is a femtosecond laser micromachining system for scientific laboratories. Equipped with high accuracy linear positioning stages, high performance galvanometer scanners and versatile micromachining software SCA, FemtoLAB becomes an entire laser laboratory on an optical table.

Features:

- Custom design
- End user selected laser source
- Efficient beam delivery and power control
- Highest quality optical components
- High accuracy positioning stages
- Additional non-stadard equipment can be integrated on request

Specifications:

- Pulse duration: from 200 fs to 10 ps
- Repetition rate: from 1 kHz to 1 MHz
- Average power: up to 20 W
- Pulse energy: up to 2 mJ
- Wavelengths: 1030 nm, 515 nm, 343 nm, 258 nm, 206 nm
- Positioning accuracy: ±250 nm
- Travel range: from 25x25 mm to 300x300 mm (larger on request)

Applications:

Surface micro and nanostructuring, engraving, drilling, refractive index modification inside bulk of material, selective layer removal, cutting brittle materials, scribing transparent material, waveguide fabrication, other applications upon request.

FemtoLAB-MPP workstation for multiphoton polymerization

FemtoLAB-MPP

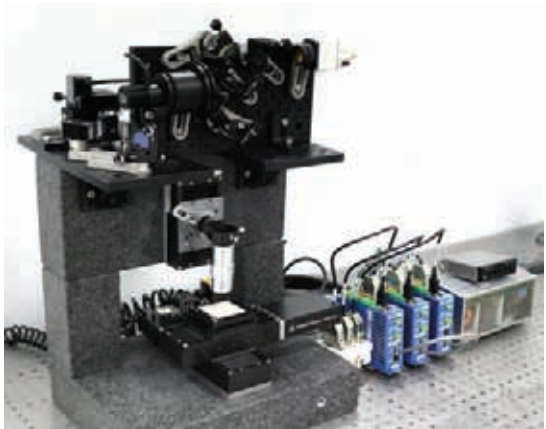
FemtoLAB-MPP workstation is optimized for multiphoton polymerization (MPP) technology.

System layout and design is similar to standard FemtoLAB which can also be used for MPP application after minor modifications.

For rapid fabrication we recommend to have synchronized movement of scanner and positioning stages.

Features:

- High resolution 3D additive manufacturing
- Rapid prototyping
- Machine vision solution for samples recognition
- Commercially available photoresists
- Wide range of wavelengths with additional OPA



Micromachining system FemtoLAB-KIT

FemtoLAB-KIT

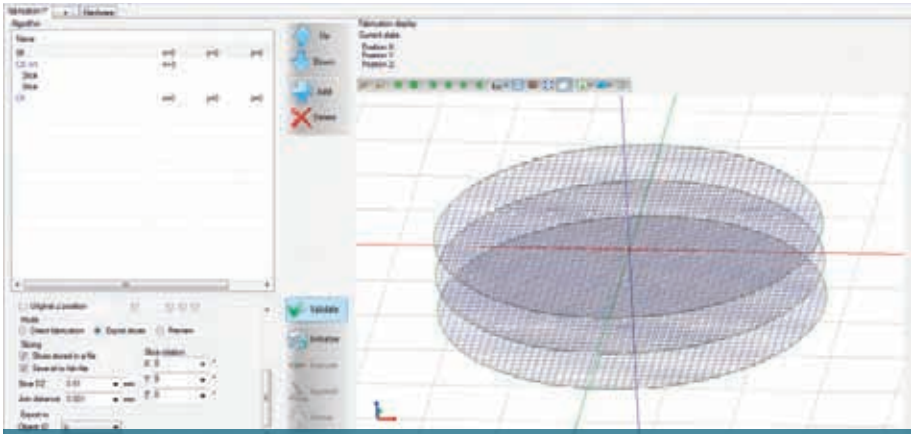
FemtoLAB-KIT is a unique micromachining system which can be installed next to customer's laser source. Depending on laser specifications this system can become a universal tool for micromachining of different materials. Machine vision and user friendly software allows to perform various micromachining tasks.

Features:

- XYZ high accuracy sample positioning
- Beam delivery and shaping for selected wavelengths
- Control of entire system through single-window software
- Easily extendable, custom design

Applications (depends on customer's laser):

- Surface micro- and nano-structuring
- Selective ablation
- Micro-drilling
- 3D direct laser writing
- Refractive index modification
- Dicing and cutting
- Multiphoton polymerization (MPP)



Cross-hatched shape prepared for 2.5D fabrication

Laser Micromachining Software SCA

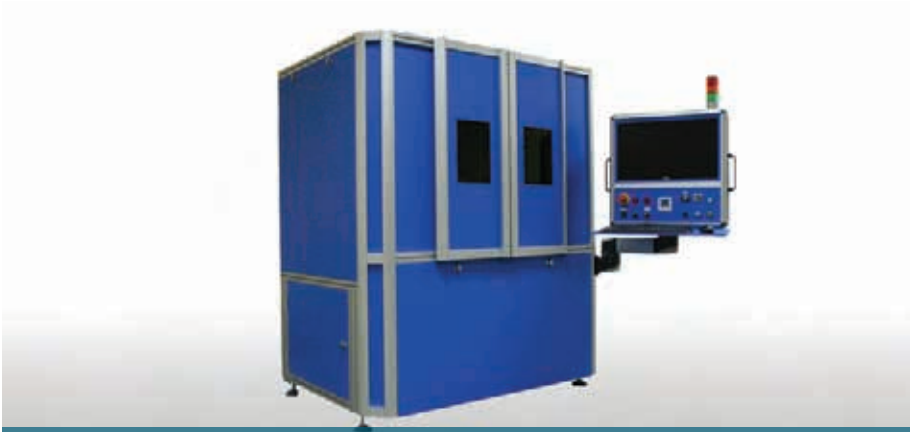
SCA software makes fabrication tasks easy to write and fine-tune. It is customizable to fit special requirement of scientific or industrial applications. Laser micromachining software SCA is essential part of laser systems and is not sold separately.

Key benefits:

- Eliminated need to work with G-code
- WYSIWYG interface
- Convenient input of fabrication algorithms and mathematical commands
- Direct control of hardware: laser, positioning stages, galvanometric scanners, power attenuators and power meters, polarization rotators, machine vision and other dedicated peripheral devices

Features of the software:

- DXF, PLT, STL, BMP, SVG, AI file format import
- Data import from TXT or XML files
- Slicing and hatching of 3D object for 2.5D fabrication
- Digital and analog I/O control
- Fabrication preview window
- Camera view in superposition with fabrication preview
- Machine vision (MV) module for sample position detection



Femtosecond laser micromachining system FemtoFAB for industry

Micromachining Workstation for Industry

FemtoFAB is a laser workstation designed for specific industrial process. Configuration is selected and carefully tuned according to a specific application. System is protected by Class 1 equivalent laser safety enclosure and controlled through advanced SCA engineer software window.

Features:

- High process speed – up to 300 mm/s (more on request)
- Fabrication of complex objects with submicron resolution
- Precise object positioning with submicron accuracy
- High-performance galvanometer scanners
- Pulse density control
- Synchronization of laser pulses with moving object in space and time domains
- Unique software interface for control of all integrated hardware devices

Specifications:

- Pulse duration: from 200 fs to 10 ps
- Repetition rate: from 1 kHz to 1 MHz
- Average power: up to 20 W, pulse energy: up to 2 mJ
- Wavelengths: 1030 nm, 515 nm, 343 nm, 258 nm, 206 nm
- Positioning accuracy: ±250 nm
- Travel range: from 25x25 mm to 300x300 mm (larger on request)

Applications: Ceramics scribing, drilling of various materials, sapphire cutting, through glass via (TGV) drilling, drilling of optical fibers, birefringent pattern fabrication, other applications upon request.

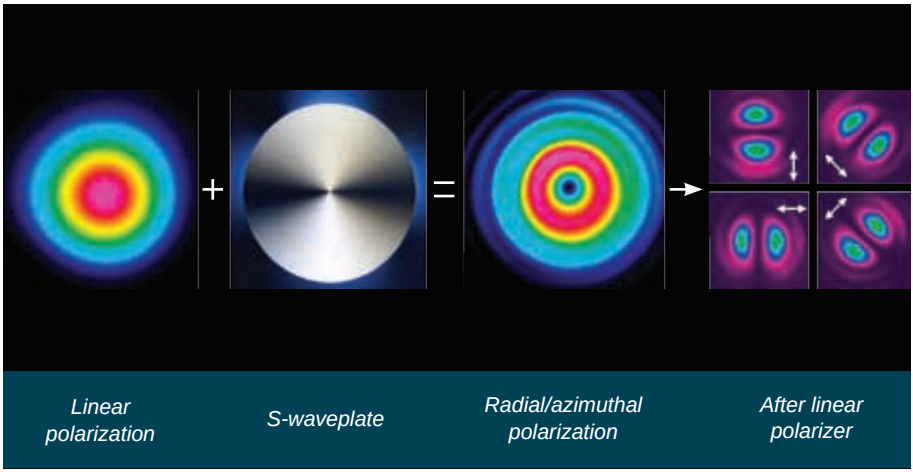
S-waveplate fabricated for 632 nm, clear aperture 8 mm. Cross polarized light photo

S-waveplates

S-waveplate is a super-structured waveplate which converts incident linear polarization to radial or azimuthal polarization. S-waveplate can also be used to convert incident circular polarization to a beam carrying optical angular momentum. Product is unique for its high damage threshold at least 100 times exceeding alternative liquid crystal devices. S-waveplate is fabricated inside UVFS bulk.

Features:

- Converts linear polarization to radial or azimuthal polarization
- Generates optical vortex (if incident polarization is circular)
- High damage threshold
- 50-90% transmission (dependable on wavelength, AR coatings
- applicable)
- Large aperture possible (up to 15 mm; standard 6 mm)
- No segment stitching

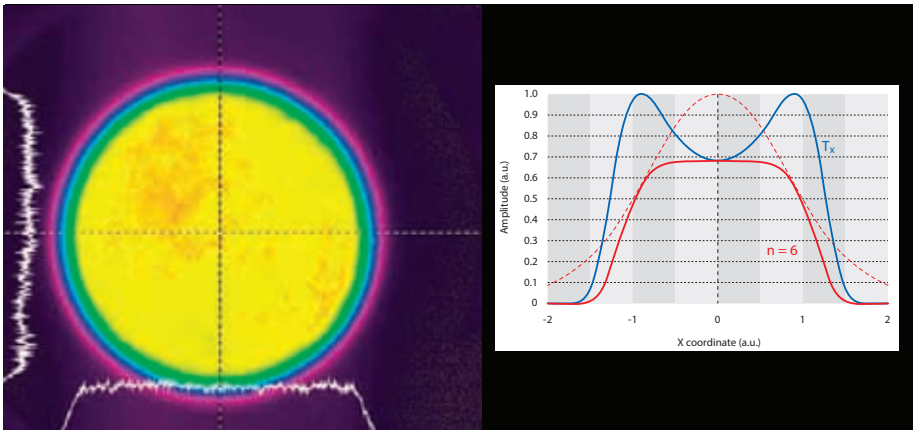


Incident Gauss beam. S-waveplate in cross-polarized light. Radial/azimuthal polarization intensity distribution after passing S-waveplate. Radial polarization intensity distributions at different polarizer angles (white arrows show polarizer transmission axis).

Standard S-waveplate models are available for 1030 nm, 515 nm, 800 nm and 1550 nm wavelengths. Dielectric anti-reflection coatings can be applied on both converter sides to further increase converter transmission. Custom wavelength (from 400 nm to 2000 nm) converters are available at request.

Applications:

- STED microscopy
- Micromachining
- Microdrilling high-aspect-ratio channels
- Generate cylindrical vector beams
- Multiple particle trapping
- Micro-mill driven by optical tweezers
- Intracavity element to generate radial polarization
- Photonic spin Hall effect observation
- Realization of polarization evolution on higher-order Poincaré sphere
- Engineering of novel optical material
- Addition and subtraction of optical orbital angular momentum
- Hybrid classical-quantum communication



Flat-top intensity distribution after converter and graph of functions

One-dimensional initial Gaussian function (dashed red line), 6-th order super-Gaussian function (solid red line) and calculated transmission function TX (blue solid line).

Spatially Variant Waveplate for Flat-Top Conversion

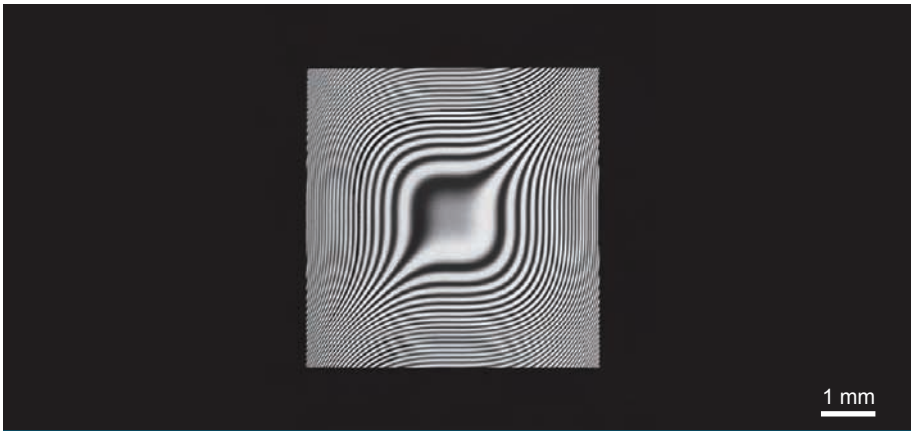
Combination of a spatially variable waveplate and a polarizer acts as a spatially variable transmission filter and can be used to transform an initially Gaussian beam to a flat-top beam. It is a spatially variable phase retardation plate inscribed inside bulk of fused silica glass by femtosecond laser pulses. Combination of a spatially variable waveplate and a polarizer acts as a spatially variable transmission filter (patent pending) and can be used to transform an initially Gaussian beam to a flat-top beam with efficiency of more than 50% of initial laser power. Converter allows for on-the-fly adjustment of the beam shape from flat-top to a shape with a dip in the middle. Converter is compatible with high power ultrashort lasers.

Features:

- Conversion of Gaussian beam to a flat-top beam
- High damage threshold
- Conversion efficiency up to 60% (wavelength dependent)
- Large aperture (up to 15 mm; standard is 6 mm)

Applications:

- Laser micromachining
- Laser pump shaping



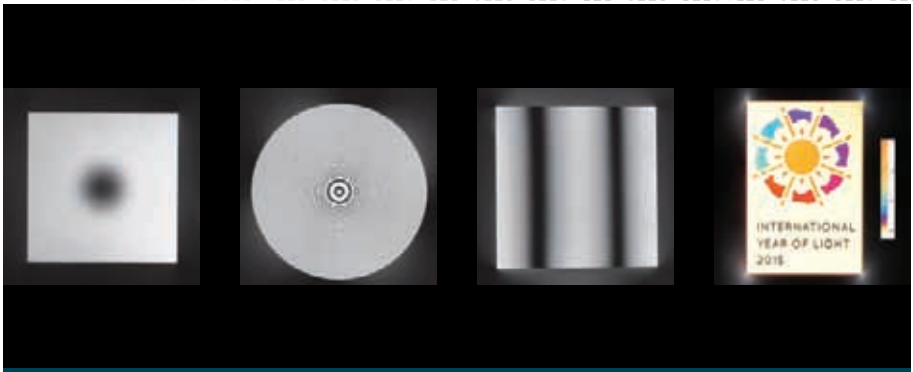
Airy beam converter in cross polarized light

Features:

- Clear aperture from 2 mm to 15 mm
- Wavelength range from 400 nm to 2000 nm
- Substrate size 25.4 mm
- Substrate thickness 3 mm

Orientation of induced nanogratings orientation is always perpendicular to laser beam polarization that is used for writing, therefore it is possible to fabricate predefined fast axis distribution patterns. Other patterns, such as Fresnel lens, “soft” aperture, Dammann gratings, flat-top and Airy beam converters, sinusoidal phase and fork-shaped gratings can be easily realized using this technology.

SVRs have a very broad range of applications from material processing to spinoptics in plasmonics.



Spatially variable waveplate examples (from left to right): apodizing aperture, Fresnel lens and sinusoidal phase grating (shown in cross polarized light)

Custom Space Variant Retarders

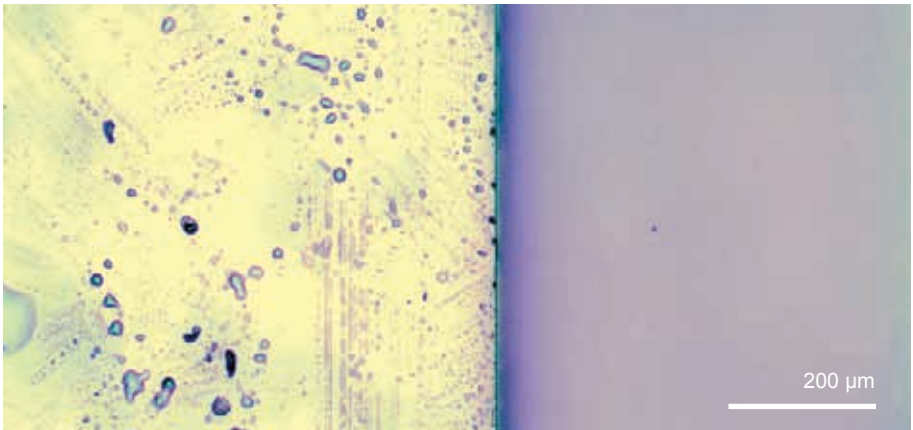
Space variant retarders (SVR) fabrication is based on inscription of selforganized nanogratings inside fused silica glass using a femtosecond laser. Rapid prototyping enables adaptation of every element to the specific needs of end user (fast axis and retardance distribution, structure clear aperture, substrate shape and thickness) without high additional development costs.

SVRs are spatially variable retardance plates which enables tailored control of spatial polarization also for high power lasers. SVRs embedded in bulk of fused silica glass have high damage threshold which is at least 100 times higher than that of liquid crystal devices.

Features:

- Wavelength range from 400 nm to 2000 nm
- Half-wave or quarter-wave converters available
- Size from 1 mm to 15 mm
- Transmission from 30% to 90% (* wavelength dependent)
- Custom fast axis and retardance patterns

TECHNOLOGIES



Tempered glass 0.55 mm thickness, 42 µm DOL. Top view

Laser Technology for Cutting Glass and Sapphire

Workshop of Photonics has developed a state of the art glass and sapphire cutting technology to meet new challenges arising from new materials and requirements. Our technology enables dicing glass or sapphire from 30 µm to 1.3 mm thick with process speed from 100 mm/s to 1000 mm/s. Straight and curved cuts can be performed in the same step.

Technology was tested on a variety of glass and sapphire samples provided by various suppliers.

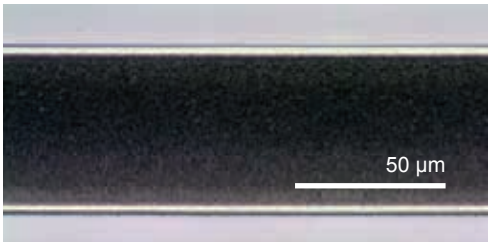
Processing parameters:

Process is optimized for each type of glass/sapphire that is used. Processing window is quite wide and can be set up easily according to these parameters:

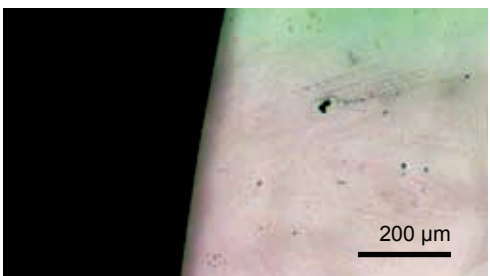
- Straight and round cut trajectories
- Thickness of tempered glass: 0.3 – 1.3 mm
- DOL of tempered glass: 10 – 80 µm
- Thickness of non-tempered glass: 0.03 – 1 mm
- Thickness of sapphire: 100 – 760 µm
- Speed of cutting (tested): 200 mm/s
- Speed of cutting (extrapolated): 800 mm/s
- Cut surface roughness: Ra<1 µm

Different processing parameters might be developed for specific inquiries.

Laser Cutting Examples

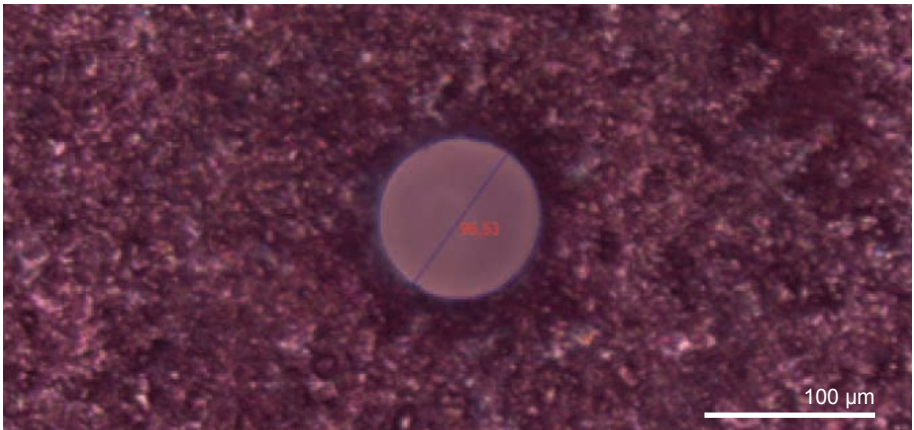


Tempered glass 0.55 mm thickness, 42 µm DOL. Side view



Sapphire 0.325 mm thickness. Top view

Sapphire 0.1 mm thickness. Side view



100 µm hole in ruby disc

Laser Micro Drilling

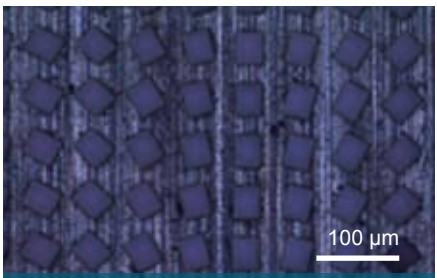
A solution has been developed at Workshop of Photonics that enables machining of holes with controlled (positive, zero, negative) taper in various materials at high drilling speed, good surface quality and a wide range of diameters (tens of micrometres to millimetres). Both transparent and absorbing materials can be drilled using femtosecond laser technology.

For reliable controlled taper drilling the depth to diameter ratio of 8:1 has been demonstrated so far, but every material has it's own limitations and possibilities. Single point drilling or usual helical path drilling can produce holes of much higher aspect ratios than 6:1 (usually limited only by ablated material evacuation from extremely deep narrow holes) with typical taper angles of 4 deg. per side. Limited depth wells can also be machined with good bottom and sidewall quality depending on material and hole geometry.

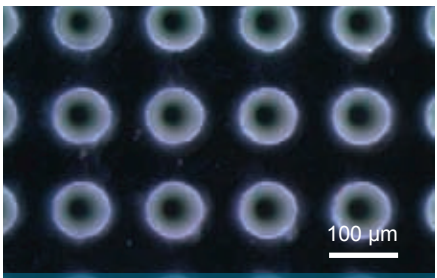
Materials tested at Workshop of Photonics currently include but are not limited to:

- Polyimide
- Ruby
- Sapphire
- Schott AF32 glass
- Soda-lime glass
- Fused silica
- Various steels (stainless, chromium steel, plain carbon steel)
- Molybdenum alloy
- Hard ceramics (alumina, silicon nitride, CBN, others)

Laser Micro Drilling Examples

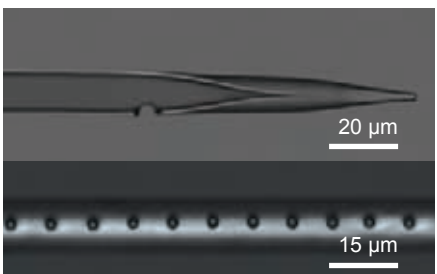


Square holes in SiN

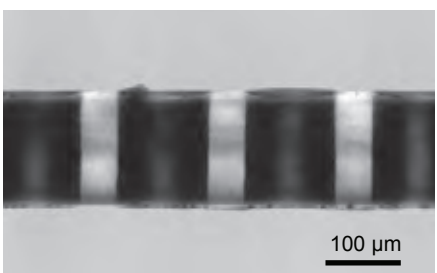


Matrix of holes in sapphire

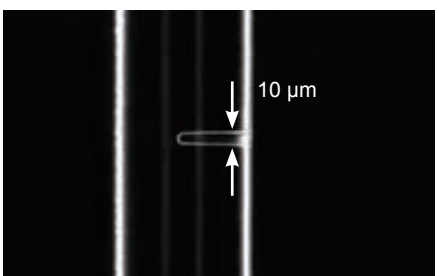

150 µm borosillicate glass, 900 holes



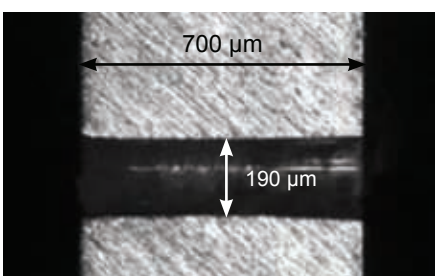
Glass tube drilling



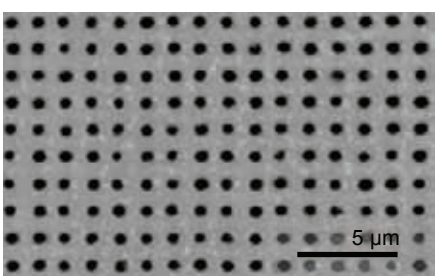
Holes in stent wall



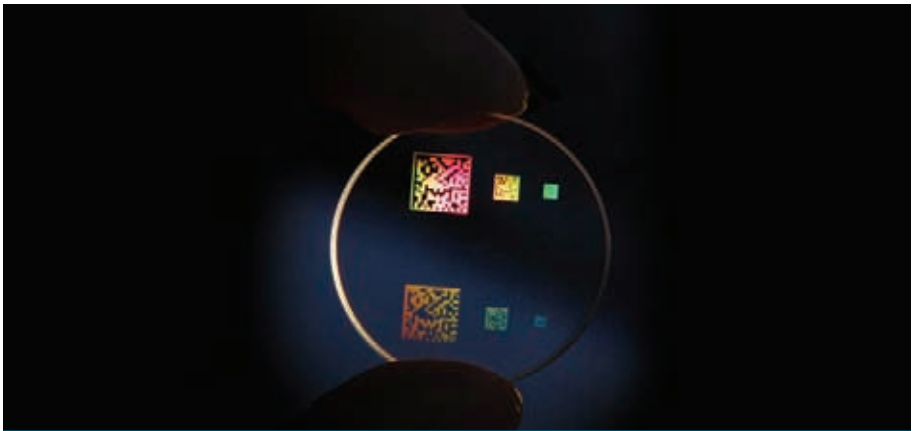
Fiber drilled to the middle



Fuel nozzle drilling



Steel foil micro drilling



Sapphire bulk marking

Laser Micro Marking

Laser marking on the surface of various materials allows to create logos, images, text, bar codes, security and identification marks or any other plane objects on the surface of many materials with micrometer precision. Laser marking of organic materials leaves no signs of burning and no heat affected zones. High positioning accuracy and precise control of the process makes marking feasible in highly flammable environments.

Laser marking features:

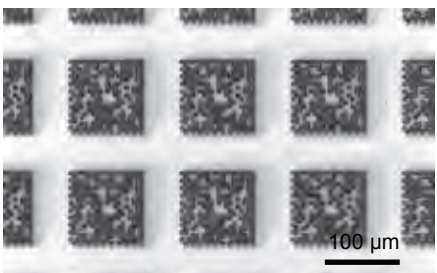
- High contrast
- High durability
- Colourful structures available
- Very small or no cracks near markings
- No heat affected zones
- High positioning accuracy

Main advantage of laser marking inside transparent materials is that information (serial number, logos, images, bar codes, security and identification 2D/3D marks) can be written directly inside the object by making refractive index irregularities without damaging the surface.

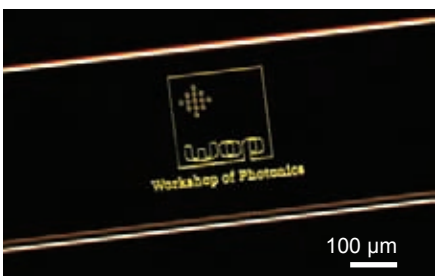
Laser Micro Marking Examples

Marking inside contact lens

Glass bulk marking



Datamatrix

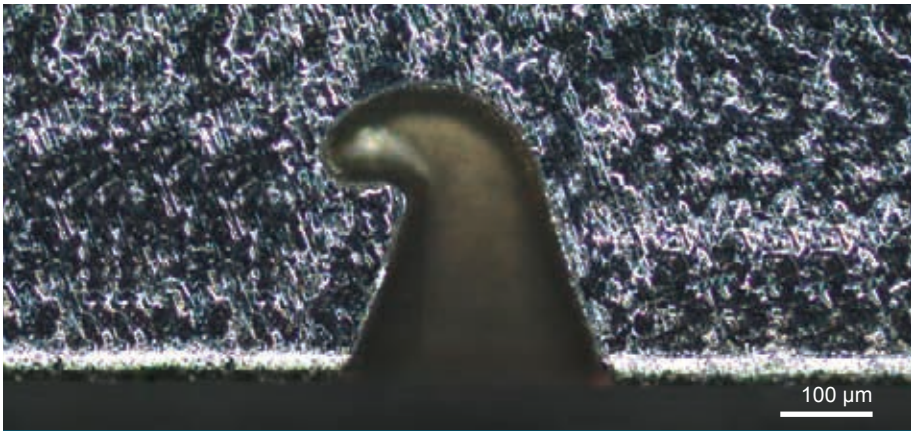


Fiber inside marking

Colourful metal marking

Metal marking

Hair marking



Metal surface structuring

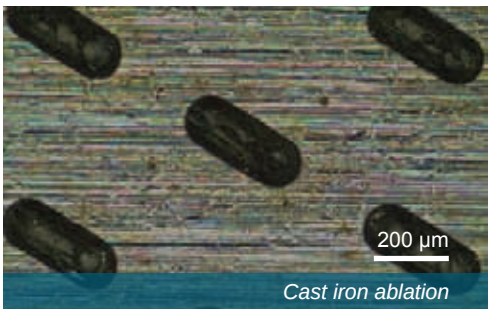
Laser Surface Structuring

Laser surface structuring can be applied to enhance various properties of surfaces or even induce new properties that material does not possess by itself, for example:

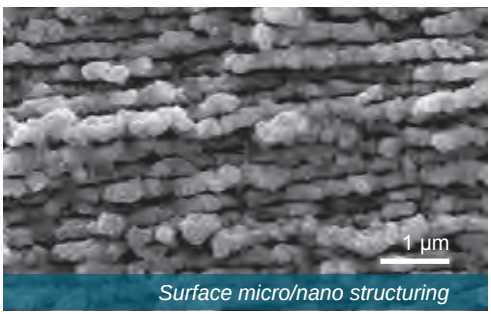
- Friction reduction/lubricant retention
- Diffractive structures for optical applications
- Micromolds for micro/nano feature replication
- Roughness modification
- Hydrophobicity/hydrophilicity
- Marking

Using femtosecond lasers surface structuring can also be performed on a variety of transparent materials.

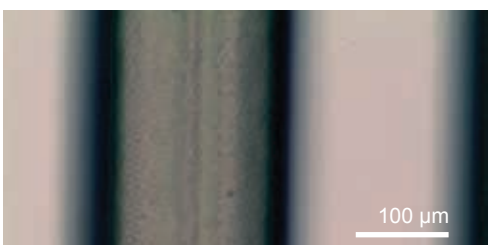
Laser Surface Structuring Examples



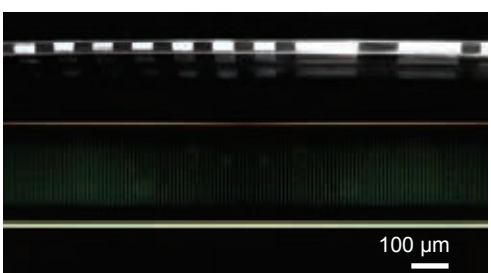
Cast iron ablation



Surface micro/nano structuring



Metal surface structuring
(bottom surface of groove)



Optical fiber volume fabrication

Chrome ablation from glass substrate

Selective Laser Ablation

Selective laser ablation today is the most common industrial application of the lasers, because of high processing speed and high quality of processed area. Small portions of metal layers can be precisely removed without any damage to the substrate using femtosecond laser pulses. Depth and geometry of ablation may vary, therefore it is suitable for variety of applications.

Selective laser ablation of materials features:

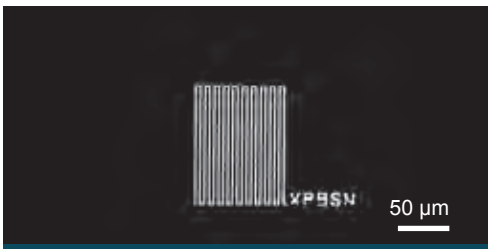
- High speed laser processing
- No signs of burning
- No heat affected zones
- High positioning accuracy
- High quality
- Micron resolution

Applications of selective laser ablation of metal layers:

- Lithography mask production
- Beam shaping elements
- Optical apertures
- Diffractive gratings

However, hard material ablation (e.g. polycrystalline diamond (PCD) and sapphire) is a challenging task even for lasers. Except femtoecond lasers. Femtosecond laser pulses allows to bypass not only the hardness of materials, but also very high thermal conductivity which may lead to burned regions if other methods are used.

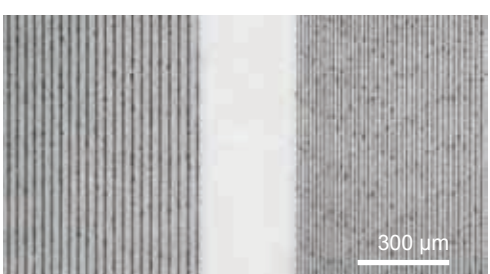
Selective Laser Ablation Examples



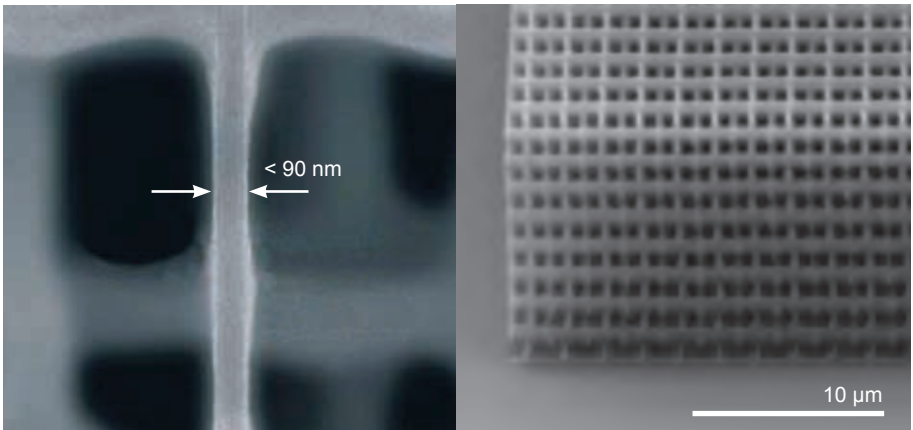
Au layer ablation without damaging MgO substrate

Titan coating selective ablation

Ablation of polycrystalline diamond (PCD)



Texturized sapphire surface



Example of 3D microstructure

3D Additive Manufacturing

3D additive manufacturing, or multiphoton polymerization (MPP) is a unique technology for 3D structuring of micron scale objects with nanometer resolution developed with Vilnius University Laser Research Center. Femtosecond laser beam is focused inside a drop of photoresist polymer and desired pattern is “written” precisely. After photoresist is washed away the fabricated microstructures remains on the substrate.

Features:

- Writing resolution: 200 nm – 10 µm
- Variety of polymers available
- Transparent 3D objects fabrication

Variety of photoresist materials with required features can be chosen:

- No structural distortions
- Certain wavelength absorption
- Refractive index matching

Precise and controllable self-polymerization

Standard direct writing is able to make repeatable structures as small as 200 nm, though by employing self-polymerization effect, the smallest lines can be around 90 nm.

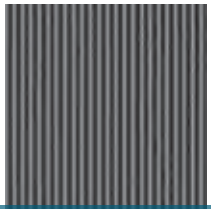
Identical structures can be fabricated by direct laser writing process but in order to save time and work for large area patterning stamping technique can be used.

3D Additive Manufacturing Fabrication Examples

Conventional minimized optical components

Lenses

Prisms

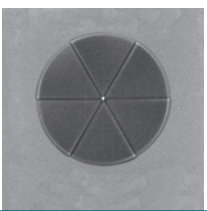


Gratings

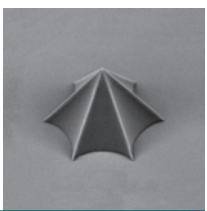
Axicons

Free form 3D elements

Spiral phase plates

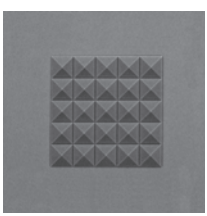


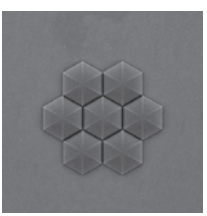
Segmented phase plates



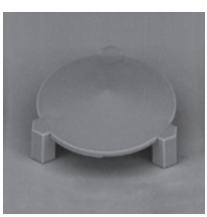
Fresnel lenses fraxicons

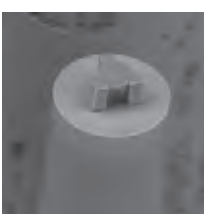
Arbitrary shape arrays of the micro optical components with 100 % fill factor

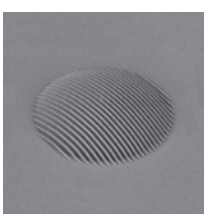


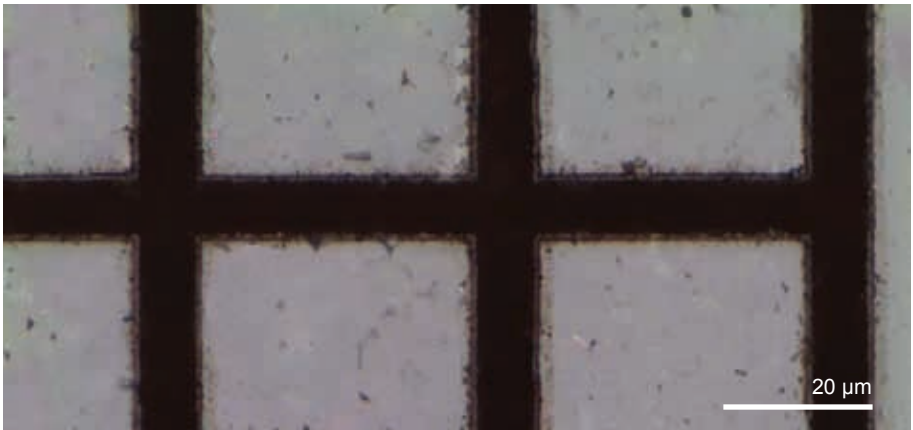


Complex shaped, multi-functional and integrated µ-optics in a single fabrication procedure.









Scribed cermics. Top view

Laser Micro Scribing

Ultrashort laser scribing shows the best results for heat sensitive materials fabrication. Ablated grooves seem to be homogeneous, and the wall of the groove least affected, when using special technology developed especially for this kind of materials.

The fabrication features:

- No heat affected zones and melting layers
- Grooves of less than 15 µm widths and more than 25 µm depth
- No overshooting in intersections
- Better than 0.5 µm accuracy within 40 mm area
- Fabricating up to 9 samples without any operator interference
- Controlling the fabrication process for up to 24 hours long and maintaining needed accuracy, compensating beam and mechanical drift within 0.5 µm.

NOTES

Participation in Exhibitions

LASER World of PHOTONICS CHINA

14-16 March, 2017, Shanghai, China, Stand N1.1507

LASER World of PHOTONICS

26-29 June 2017, Munich, Germany, Stand B3.511

MICRO | NANO | MEMS 2017

26-27 September 2017, Birmingham, United Kingdom

formnext

14-17 November 2017, Frankfurt, Germany

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