LASER MICROMACHINING SOLUTIONS AND TECHNOLOGIES 2019
Workshop of Photonics® is all about ultrashort pulsed lasers micromachining.

We develop instruments and solutions for ultrashort laser micromachining tasks. From feasibility studies to laser micromachining workstations and state of the art technological solutions.

Our services are aimed at industrial and academic customers.

**Company core competencies:**

- Feasibility studies on femtosecond laser micromachining
- Development of custom femtosecond laser micromachining workstations and optical modules
- Laser system automation software
- Small scale production (job shop) in the area of laser micromachining

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

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

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**Academic partners**

- VILNIUS UNIVERSITY OF TECHNOLOGY
- SGSTN TECHNOLOGISTAS UNIVERSITETAS
- SWINBURNE UNIVERSITY OF TECHNOLOGY
- CENTER FOR PHYSICAL SCIENCES AND TECHNOLOGY
- UNIVERSITY OF SOUTHAMPTON
- STUDIORUM UNIVERSITY OF LITHUANIA

We are a proud member of

- LITHUANIAN LASER ASSOCIATION
- EPIC
SERVICES

Feasibility Studies
Laser Process Development
Small Scale Production
Glass Processing Services
Joint Research Projects

PRODUCTS

Micromachining Workstation for Laboratories FemtoLAB
FemtoLAB-MPP
FemtoLAB-KIT
Laser Micromachining Software SCA
Micromachining Workstation for Industry FemtoFAB
S-waveplates
Space-Variant Waveplate for Flat-Top Conversion
Custom Space-Variant Retarders

TECHNOLOGIES

Glass and Sapphire Processing
Laser Micro Drilling
Laser Micro Marking
Laser Surface Structuring
Selective Laser Ablation
3D Additive Manufacturing
SERVICES

The cooperation between Workshop of Photonics and customer usually begins with a request to perform a specific micromachining task.

The first step is a feasibility, this which means that our company prepares samples for a customer to present the achieved results and prove the feasibility of laser processing. If a result of a feasibility study is acceptable for a customer, Workshop of Photonics can offer a small scale production. A small batch of articles may be fabricated in our laser laboratories according to customer requirements. However, if a customer needs a complete setup or machine which could execute the same task at customer’s site - Workshop of Photonics can develop a custom optical module or laser workstation for a specific task.

* In partnership with manufacturing machinery producers
Feasibility Studies

The objective of a feasibility study is to demonstrate that customer’s problem can be solved using ultrashort pulsed laser micromachining and that it is more advantageous than over competing technologies.

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

Feasibility studies are performed in the following steps:

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

Most of the 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 includes the following steps:

- testing of different wavelengths in order to explore the light-material interaction
- testing of different focusing conditions
- selection and testing the most suitable positioning solution
- determination of repeatability requirements and required process speed
- optimization of the software functionality for convenient process control

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

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

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

We also have access to 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.

We offer small-scale production services of:

- Glass cutting
- Fiber processing
- Drilling of various materials
- Other on demand
Since 2003 we have been carrying out extensive research in the field of ultrashort laser micromachining. By now we have accumulated an extensive experience in glass and various brittle materials ultrashort pulse laser micromachining for industry-compliant services. High accuracy, great repeatability, high speed and ability to fabricate difficult objects with submicron resolution are just a few advantages of our offered laser processing services.

We have gathered significant knowledge base in developing unique laser processing methods and created production ready facility in Lithuania, therefore can confidently say - our high throughput and yield glass processing services are perfect for small-scale production.

Laser glass cutting process is optimized for each type of glass that is used. We can process up 2.5 mm thickness glass (thicker under the demand) and perform straight and curved cuts. We can meet the exact specifications for a variety of industries, being able to use wet etching assisted process if minimal feature size is required.

Our fabrication methods can be easily customized for different types of glass, being a one of the best solutions available in today’s market to meet your unique needs.
Arrays of arbitrary shaped holes (1 mm thickness glass)

**Variety of glass types:**

- Corning Eagle XG glass
- Schott D263T borosilicate glass
- Hoya SD2 glass
- Gorilla Glass
- Other (Borofloat33, AS87, etc.)

Specific glass grade can be selected by customer and tested in Workshop of Photonics laboratory prior order.

**Features:**

- ≤ 200 mm x 200 mm wafer size
- ≤ 2.5 mm thickness substrates
- Minimal or no post-processing is needed
- Low chipping <20 µm is achieved
- Aspect ratio up to 1:100
Joint Research Projects

Workshop of Photonics has already participated in several joint research projects using laser technologies with partner companies aiming to develop interdisciplinary products and technologies. By combining both our and our partner knowledge and abilities, we are able to merge 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 you are interested in joint research projects using laser technologies – we are ready to become your successful partner.
PRODUCTS
Micromachining Workstation for Laboratories FemtoLAB

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 if new requirements arise.

Applications:

- Surface micro and nanostructuring
- Engraving
- Drilling
- Refractive index modification inside a bulk of the material
- Selective layer removal and ablation
- Dicing and cutting
- Scribing transparent material
- Waveguide fabrication
- 3D direct laser writing
- Multiphoton polymerization (MPP)
- Other applications upon request
FemtoLAB is a femtosecond laser micromachining workstation 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-standard 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)
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 a 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
- Infinite field of view (IFOV)
- User friendly software SCA

Specifications:

- Writing resolution: 200 nm – 10 µm
- Wavelength: 780 nm
- Repetition rate: 100 MHz
- Pulse duration: < 100 fs
- Average power: > 50 mW
- User friendly software SCA
FemtoLAB-KIT

FemtoLAB-KIT is a solution for laboratories and R&D centers, which already have a laser source, but do not have a complete solution for various laser micromachining tasks. Configuration is selected and carefully tuned according to a specific application.

Features:

- XYZ high accuracy sample positioning
- Beam delivery and shaping for selected wavelengths
- Control of the entire system through single-window software
- Easily upgradeable, custom design
- Additional non-standard equipment can be integrated on request
Laser Micromachining Software SCA

SCA software allows for an easy writing and fine-tuning of fabrication tasks. It is customizable to fit the special requirements of scientific or industrial applications. Laser micromachining software SCA is an 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:

- Import of DXF, PLT, STL, BMP, SVG, and AI file formats
- 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
Micromachining Workstation for Industry FemtoFAB

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 processing 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 time and space
- 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)
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. The 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 the incident polarization is circular)
- High damage threshold
- 50-90% transmission (depends on wavelength, AR coatings can be applied)
- Possibility of a large aperture (up to 15 mm)
- No segment stitching

Applications: STED microscopy, micromachining, microdrilling high-aspect-ratio channels, generation of cylindrical vector beams, multiple particle trapping, optical tweezers driven micro-mill, intracavity element for generation of a radial polarization, photonic spin Hall effect monitoring, implementation 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.
Space-Variant Waveplate for Flat-Top Conversion

Combination of a space-variant waveplate and a polarizer acts as a space-variant transmission filter and can be used to transform an initially Gaussian beam to a flat-top beam. It is a space-variant phase retardation plate inscribed inside bulk of fused silica glass by femtosecond laser pulses. A combination of a space-variant waveplate and a polarizer acts as a space-variant transmission filter (patent pending) and can be used to transform an initially Gaussian beam to a flat-top beam with the 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% (depends on wavelength)
- Large aperture (up to 15 mm; standard is 6 mm)

Applications:
- Laser micromachining
- Laser pump shaping
Custom Space-Variant Retarders

Space-variant retarders (SVR) fabrication is based on the inscription of self-organized nano-gratings 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, clear aperture, substrate shape, and thickness) without high additional development costs.

SVRs are space-variant retardance plates that enable tailored control of spatial polarization for high power lasers as well. 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
- Aperture size from 1 mm to 15 mm
- Transmission from 30% to 90% (depends on a wavelength)
- Custom fast axis and retardance patterns

Orientation of induced nano-gratings is always perpendicular to laser beam polarization that is used for inscription, 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.
TECHNOLOGIES
Glass and Sapphire Processing

Workshop of Photonics accumulated an extensive experience in ultrashort pulse laser micromachining of glass and various brittle materials for industry-compliant services.

Laser cutting (scribing) process is optimized for each type of glass that is used. We can process glass with a thickness of up to 1.5 mm (thicker under the demand) and perform straight and curved cuts. We can meet the exact specifications for a variety of industries, being able to use wet etching assisted process if a minimal feature size is required.

The roughness of a cut surface Ra<1μm, processed parts are smooth and minimal or no post-processing is needed. Low chipping <20 μm is achieved for most materials, as well as no debris on the rear and front surface. Therefore, our high throughput and yield processing services are perfect for small-scale production services.

Our processes can be easily customized for different types of glass, being a number one solution available in today’s market to meet your unique needs.
Glass and Sapphire Processing 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
- Sapphire Laser Cutting
Laser Micro Drilling

Workshop of Photonics developed a solution 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.

In case of a reliable controlled taper drilling the depth to diameter ratio of 8:1 has been achieved so far, but every material has its 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 a 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)
Examples of Laser Micro Drilling

- Square holes in SiN
- Matrix of holes in sapphire
- 150 μm borosilicate glass, 900 holes
- Glass tube drilling
- Holes in stent wall
- Fiber drilled to the middle
- Fuel nozzle drilling
- Steel foil micro drilling
Laser Micro Marking

Laser marking with micrometer precision allows creating logos, images, text, barcodes, security and identification marks or any other plane objects on the surface of many materials or inside a bulk of transparent materials. 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 possible in highly flammable environments.

**Laser marking features:**

- High contrast
- High durability
- Colourful structures are possible
- 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, barcodes, 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

Marking inside of a fiber

Colourful metal marking

Metal marking

Hair marking
Laser Surface Structuring

Laser surface structuring can be used 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

With the use of a femtosecond laser, 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**
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:

- Production of lithography masks
- Beam shaping elements
- Optical apertures
- Diffraction gratings

Hard material ablation (e.g. polycrystalline diamond (PCD) and sapphire) is a challenging task even for lasers. However, femtosecond laser pulses allow defeating 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

- **Titan coating selective ablation**

- **Ablation of polycrystalline diamond (PCD)**

- **Texturized sapphire surface**
3D Additive Manufacturing

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

Precise and controllable self-polymerization

Standard direct writing can 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, a stamping technique can be used.
3D Additive Manufacturing Fabrication Examples

Conventional minimized optical components

<table>
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<tr>
<th>Lenses</th>
<th>Prisms</th>
<th>Gratings</th>
<th>Axicons</th>
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Free-form 3D elements

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<tr>
<th>Spiral phase plates</th>
<th>Segmented phase plates</th>
<th>Fresnel lenses fraxicons</th>
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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.
Participation in Exhibitions

nano tech 2019
International Nanotechnology Exhibition & Conference
Jan. 30 - Feb. 1, 2019, Tokyo, Japan, Stand 4V-21

LASER World of PHOTONICS CHINA
March 20 - 22, 2019, Shanghai, China, Stand W4.4707

LASER World of PHOTONICS
June 24 - 27, 2019, Munich, Germany

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