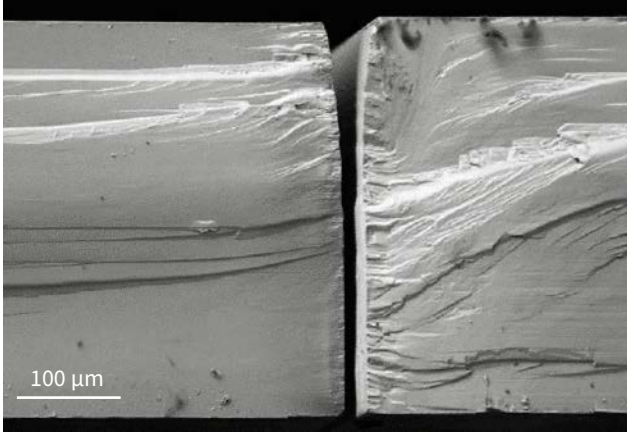


# EXAMPLES OF INDUSTRIAL APPLICATIONS

## Brittle & highly thermal-sensitive material cutting



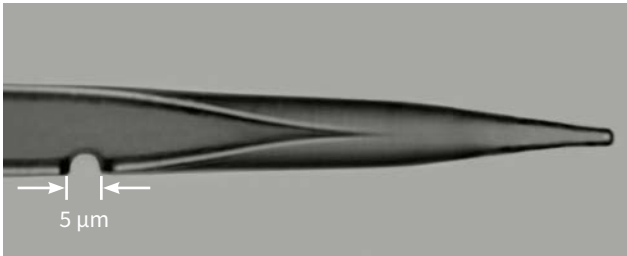
Multi-pass cadmium tungstate cutting. No cracks. All thermal trace effects eliminated. Source: Micronanics Laser Solutions Centre.

## Stainless steel stent cutting



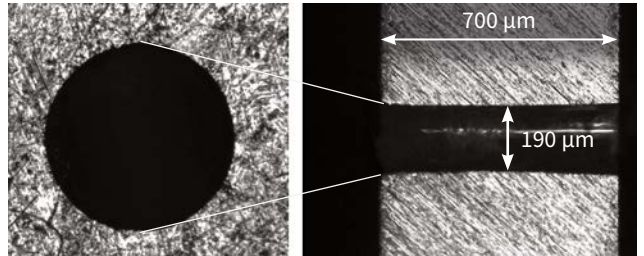
Stent cut using CARBIDE laser. Source: Amada Miyachi America.

## Glass needle microdrilling



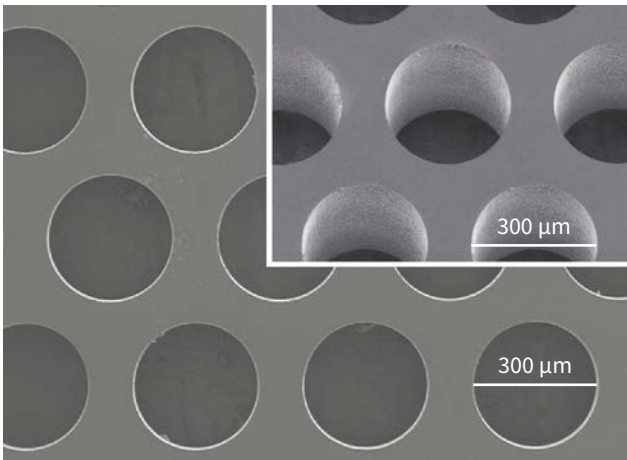
Glass needle microdrilling. Source: Workshop of Photonics.

## Steel drilling



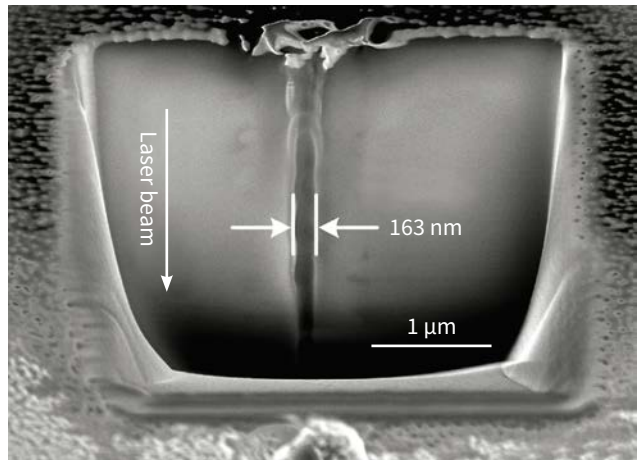
Taperless hole microdrilling in stainless steel alloys. Source: Workshop of Photonics.

## Various type glass drilling



Various glass drilling. Source: Workshop of Photonics.

## Nanodrilling of fused silica



Longitudinal section of a single void. Source: "Ultrashort Bessel beam photoinscription of Bragg grating waveguides and their application as temperature sensors", G. Zhang, G. Cheng, M. Bhuyan, C. D'Amico, Y. Wang, R. Stoian. Photon. Res. (2019).

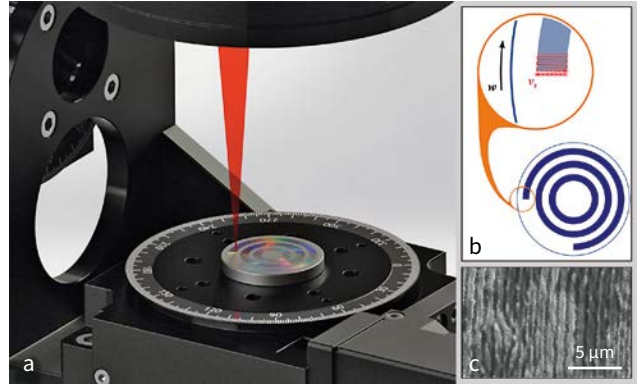
### Milling of complex 3D surfaces



3D milled sample in copper. Zoom in SEM image.

Source: "Highly-efficient laser ablation of copper by bursts of ultrashort tuneable (fs-ps) pulses", A.Žemaitis, P.Gečys, M.Barkauskas, G.Račiukaitis, M.Gedvilas. Scientific Reports (2019).

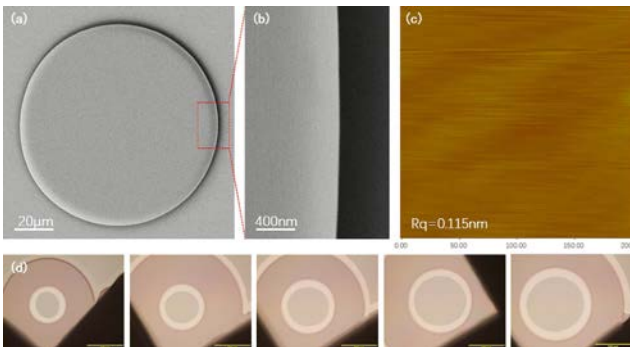
### Friction and wear reduction



(a) Schematic of the laser treatment, (b) laser patterning strategy, (c) SEM image of induced LIPSS.

Source: "Tribological properties of high-speed uniform femtosecond laser patterning on stainless steel", I.Gnilitskiy, A.Rota, E.Gualtieri, S.Valeri, L.Orazi. Lubricants (2019).

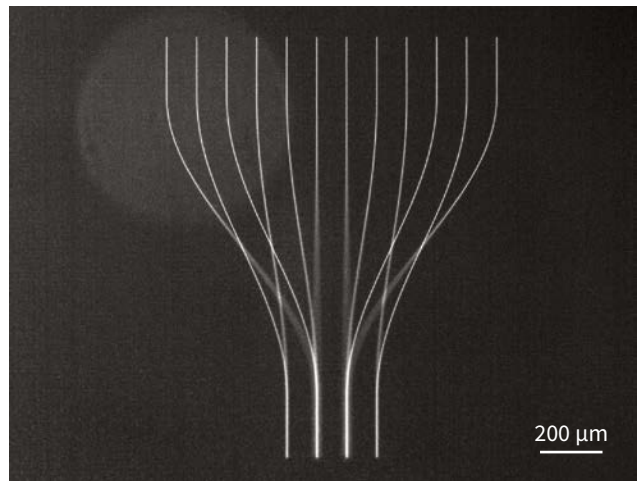
### Selective Cr thin film ablation



Cr thin film ablation for creation of  $\text{LiNbO}_3$  micro-disk resonator. (a,b) SEM images, (c) AFM image of micro-disk wedge, (d) optical images of micro-disk resonators with different diameters.

Source: "Fabrication of crystalline microresonators of high quality factors with a controllable wedge angle on lithium niobate on insulator", J.Zhang, Z.Fang, J.Lin, J.Zhou, M.Wang, R.Wu, R.Gao, Y.Cheng. Nanomaterials (2019).

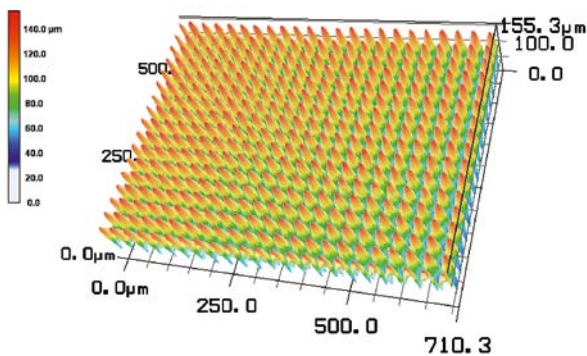
### 3D waveguides



3D waveguides fabricated in fused silica glass.

Source: Workshop of Photonics.

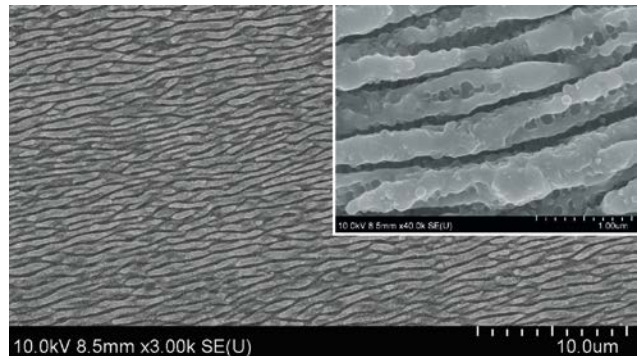
### Terahertz broadband anti-reflection structures



Fabricated moth-eye 3D profile, taken by laser scanning microscope.

Source: "Terahertz broadband anti-reflection moth-eye structures fabricated by femtosecond laser processing", H.Sakurai, N.Nemoto, K.Konishi, R.Takaku, Y.Sakurai, N.Katayama, T.Matsumura, J.Yumoto, M.Kuwata-Gonokami. OSA Continuum (2019).

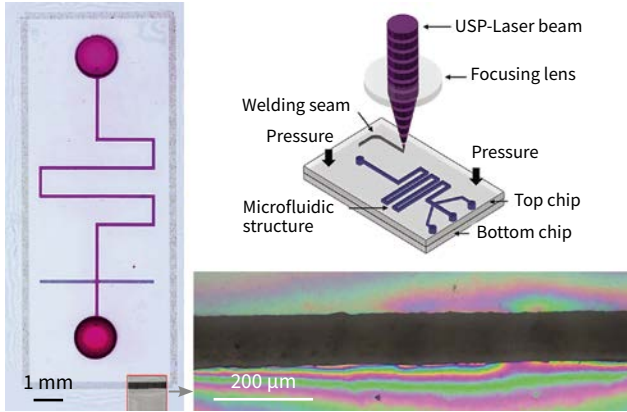
### Surface-enhanced Raman scattering (SERS) sensors fabrication



SEM image of the Ti-6Al-4V (TC4) surface after irradiation with progressive laser scan.

Source: "Large-scale fabrication of nanostructure on bio-metallic substrate for surface enhanced Raman and fluorescence scattering", L.Lu, J.Zhang, L.Jiao, Y.Guan. Nanomaterials (2019).

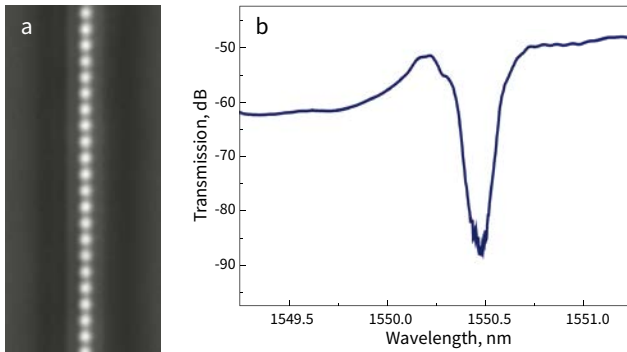
## Lab-on-chip channel ablation and welding



Welding of transparent polymers for sealing of microfluidic devices. Top view on a sealed microfluidic device (left), welding seam (bottom right).

Source: "A new approach to seal polymer microfluidic devices using ultrashort laser pulses", G. Roth, C. Esen and R. Hellmann. JLMN-Journal of Laser Micro/Nanoengineering (2019).

## Bragg grating waveguide (BGW) writing



(a) First-order Bragg gratings inscribed in waveguide, (b) Resonant spectral transmission of inscribed BGW.

Source: "Ultrashort Bessel beam photoinscription of Bragg grating waveguides and their application as temperature sensors", G. Zhang, G. heng, M. Bhuyan, C. D'Amico, Y. Wang, R. Stoian. Photon. Res. (2019).

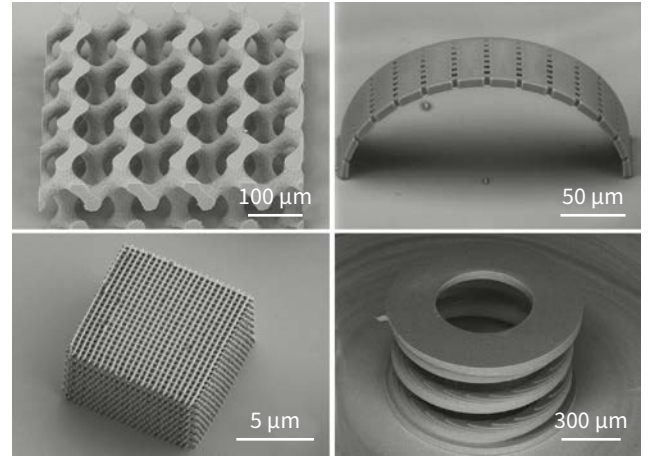
## Birefringent glass volume modifications



Form induced birefringence-retardance variation results in different colors in parallel polarized light.

Source: Workshop of Photonics.

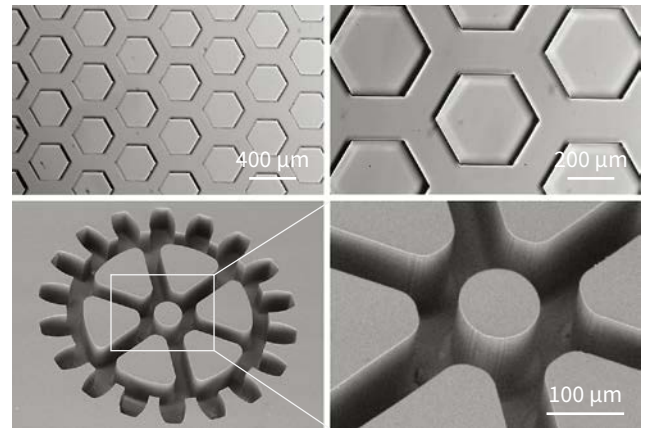
## 3D micro printing using multi-photon polymerization



Various 3D structures fabricated in SZ2080 polymer using multi-photon polymerization – nanophotonic devices, microoptics, micromechanics.

Source: Femtika.

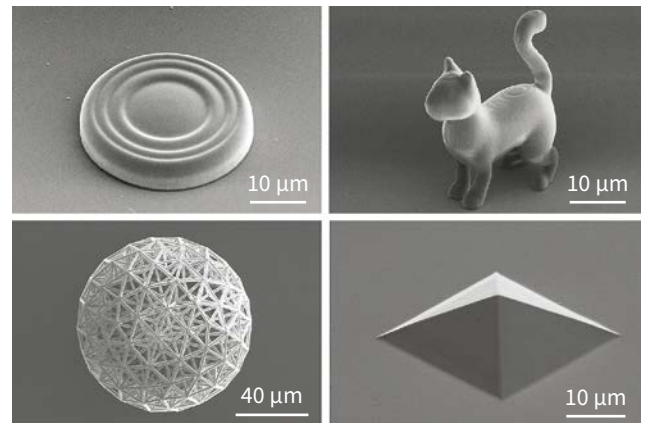
## 3D glass etching



Various structures fabricated in fused silica glass.

Source: Femtika.

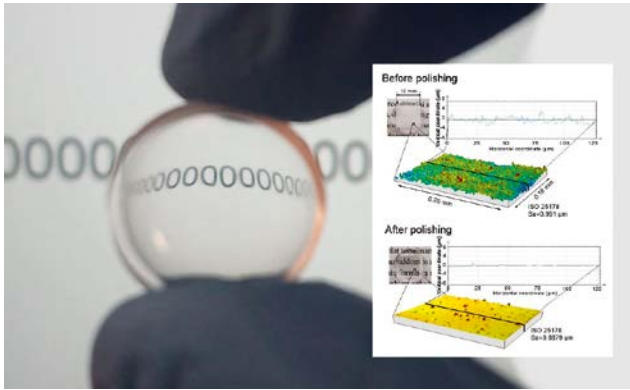
## 3D multi-photon polymerization



Various 3D structures fabricated in SZ2080 polymer using multi-photon polymerization.

Source: Workshop of Photonics.

## Polymer polishing



Polished curved surface and surface roughness measurements before and after polishing with GHz BiBurst.

Source: “Micromachining of Transparent Biocompatible Polymers Applied in Medicine Using Bursts of Femtosecond Laser Pulses”, E. Kažukauskas, S. Butkus, P. Tokarski, V. Jukna, M. Barkauskas, V. Sirutkaitis. *Micromachines* (2020).

## QR code marking



High contrast QR codes markings on various samples. Size 3 × 3 mm. Sky-writing mode enabled.

Source: Light Conversion apps lab.

## Color center creation

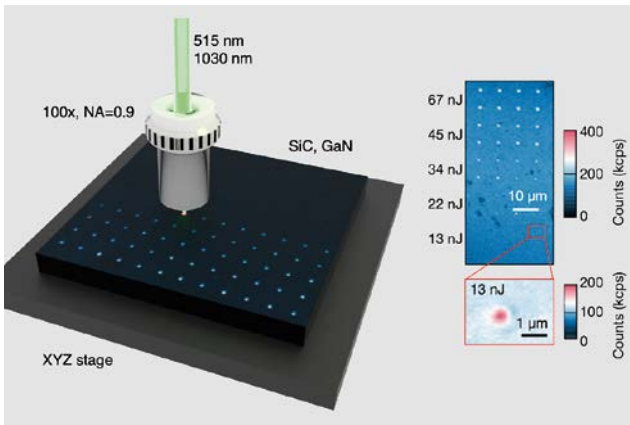
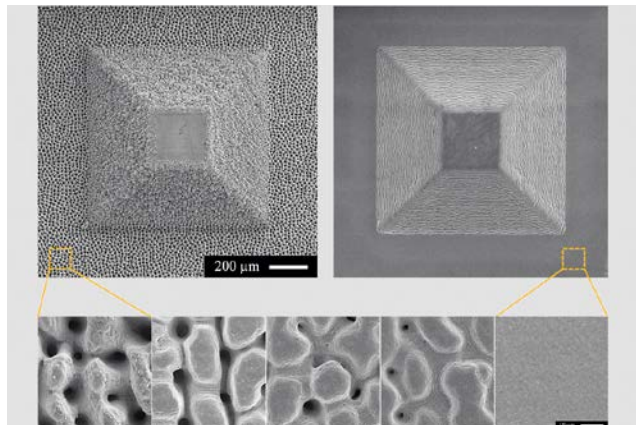


Illustration of the laser writing of color centers (left), silicon carbide containing arrays of laser-written color centers (right).

Source: “Color Centers Enabled by Direct Femto-Second Laser Writing in Wide Bandgap Semiconductors”, S. Castelletto, J. Maksimovic, T. Katkus, T. Ohshima, B.C. Johnson, S. Juodkazis. *Nanomaterials* (2020).

## Stainless steel surface polishing



SEM image collage of structures ablated in stainless steel, before and after laser polishing. Typical micro-cone structure (bottom, left) and smoothing with GHz burst mode (right).

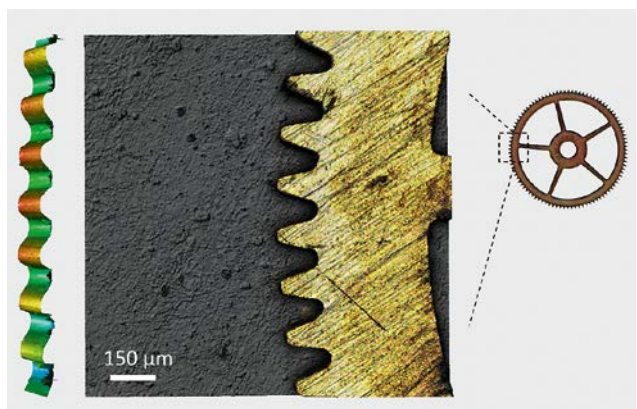
Source: “High-quality surface treatment using GHz burst mode with tunable ultrashort pulses”, D. Metzner, P. Lickschat, S. Weißmantel. *Applied Surface Science* (2020).

## Glass cutting



Example of glass cutting. Source: Citrogene.

## Precision parts cutting from brass



Example of gear cut from brass. Source: Lasea.