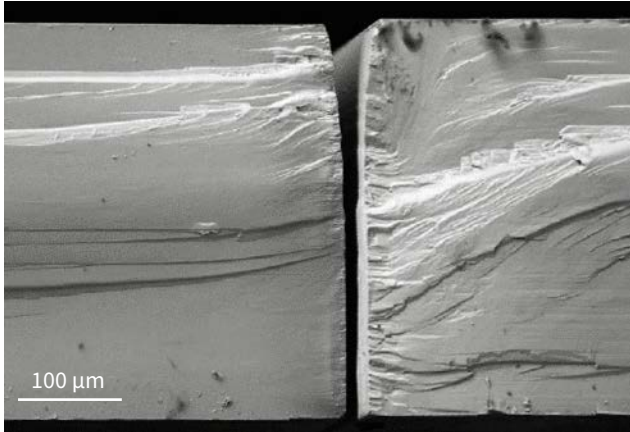


# EXAMPLES OF INDUSTRIAL APPLICATIONS

## Brittle & highly thermal sensitive material cutting



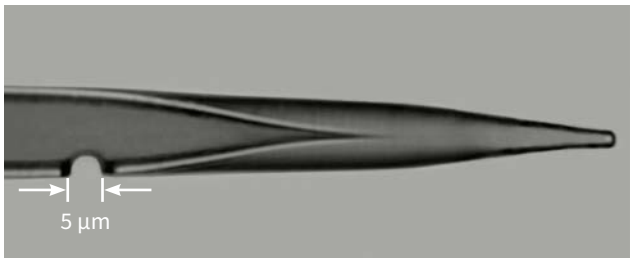
Multi-pass, cadmium tungstate cutting. No cracks. All thermal trace effects eliminated. Source: Micronanics Laser Solutions Centre.

## Stainless steel stent cutting



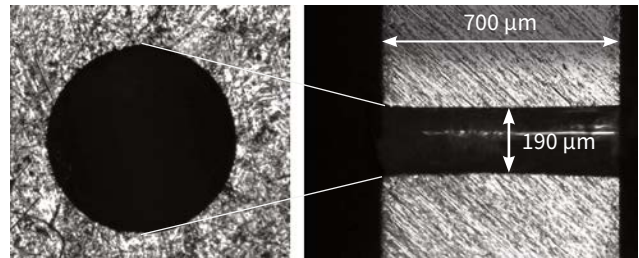
Stent cut using CARBIDE laser. Source: Amada Miyachi America.

## Glass needle microdrilling



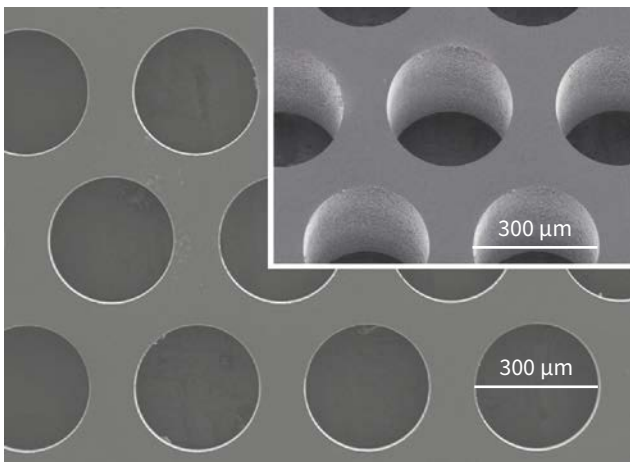
Glass needle microdrilling. Source: Workshop of Photonics.

## Steel drilling



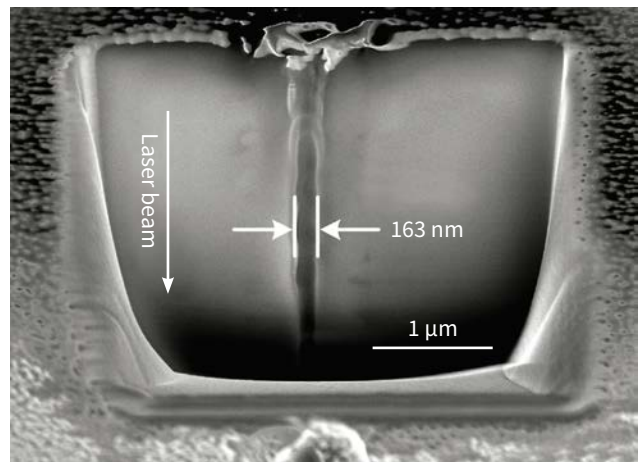
Taperless hole microdrilling in stainless steel alloys. Source: Workshop of Photonics.

## Various type glass drilling



Various glass drilling. Source: Workshop of Photonics.

## Nanodrilling in fused silica



Longitudinal section of the 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).

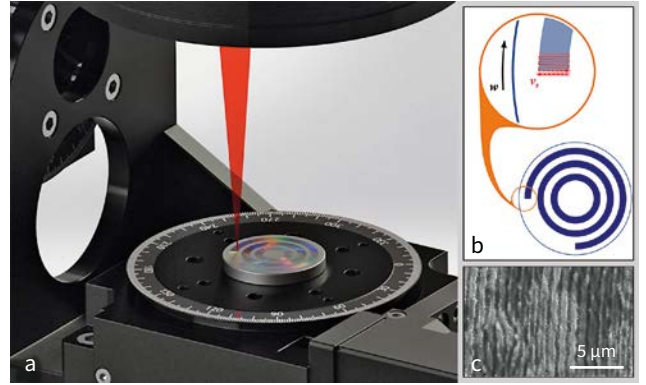
### Milling of complex 3D surfaces



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).

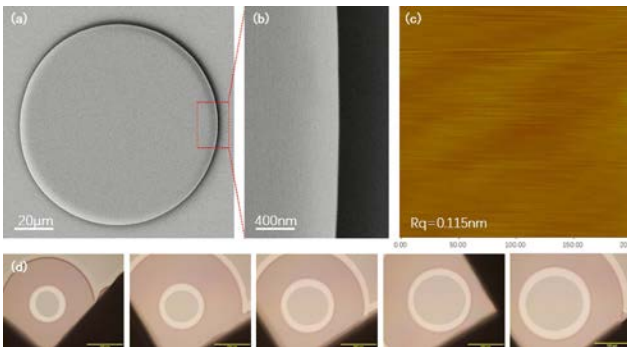
### Friction and wear reduction



(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).

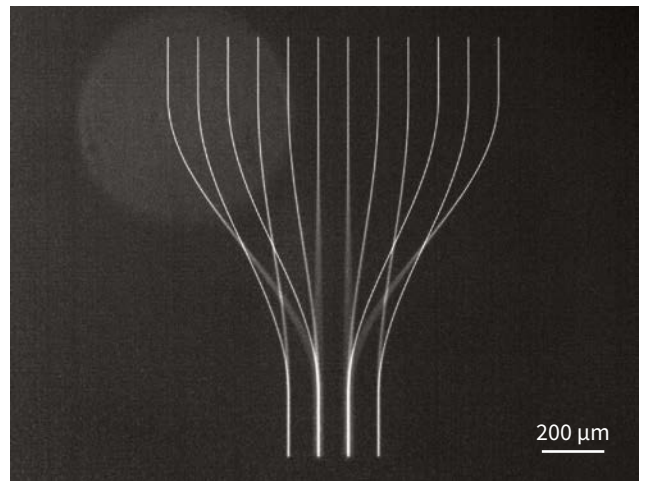
### Selective Cr thin film ablation



(a) SEM image of a fabricated  $\text{LiNbO}_3$  micro-disk resonator, (b) close up view, (c) atomic force microscope (AFM) image of micro-disk wedge, (d) optical microscope image of micro-disk resonator 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).

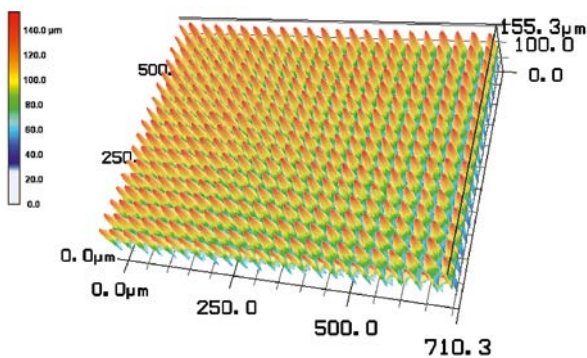
### 3D waveguides



3D waveguide fabricated in fused silica glass.

Source: Workshop of Photonics.

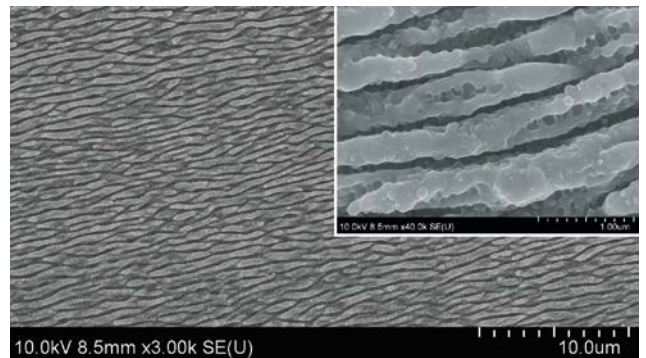
### Terahertz broadband anti-reflection structures



Fabricated moth-eye 3-D profile image, 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).

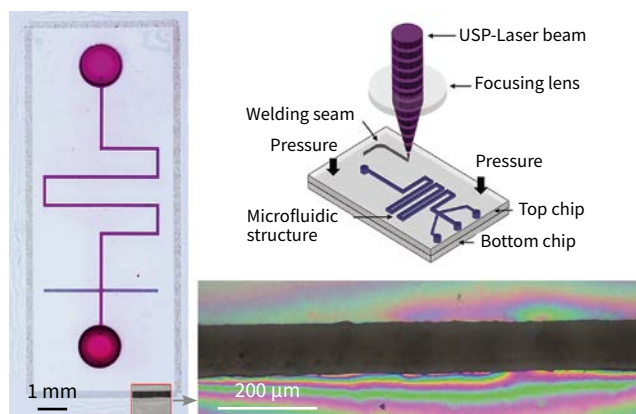
### Surface-enhanced Raman scattering (SERS) sensors fabrication



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

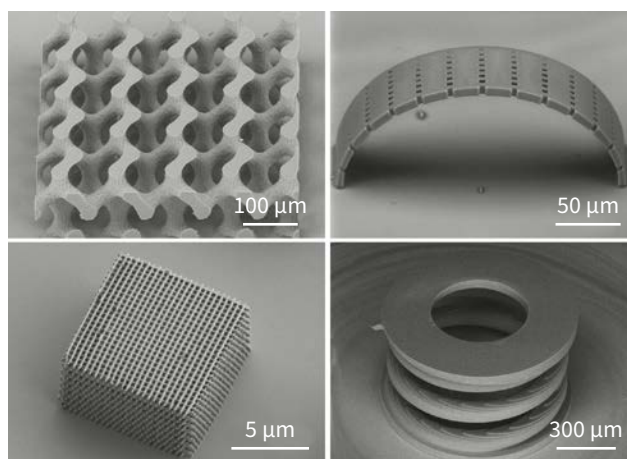
## Lab-on-chip channel ablation and welding



(a) Welding of transparent polymers for sealing of microfluidic devices, (b) COC welding seam (c) top view on a sealed microfluidic device.

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).

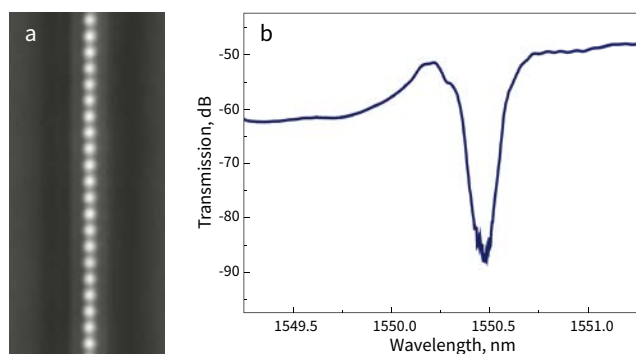
## 3D micro printing using multi-photon polymerization



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

Source: Femtika.

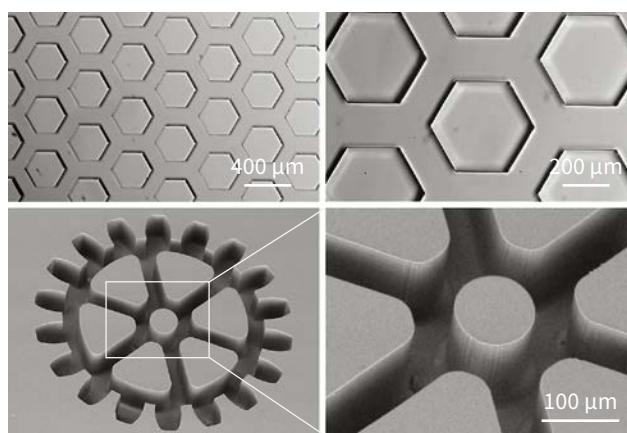
## Bragg grating waveguide (BGW) writing



(a) first-order Bragg gratings inscribed in written 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).

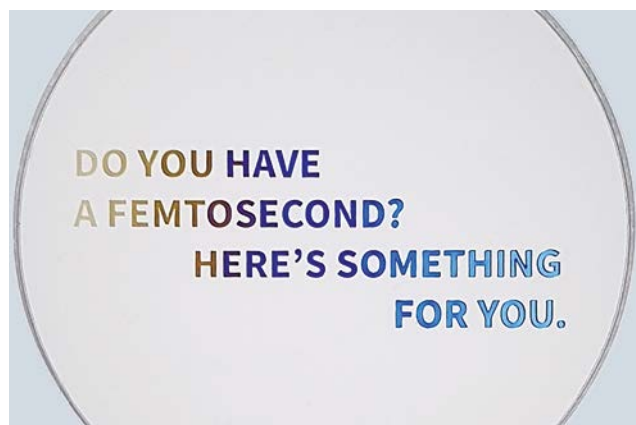
## 3D glass etching



Various structures fabricated in fused silica glass.

Source: Femtika.

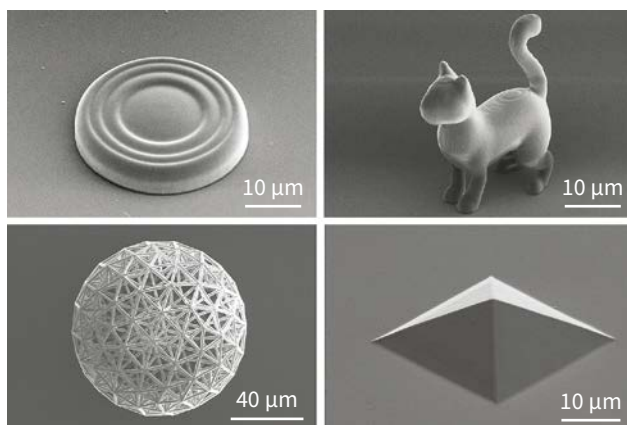
## Birefringent glass volume modifications



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

Source: Workshop of Photonics.

## 3D free shape multi-photon polymerization



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

Source: Workshop of Photonics.