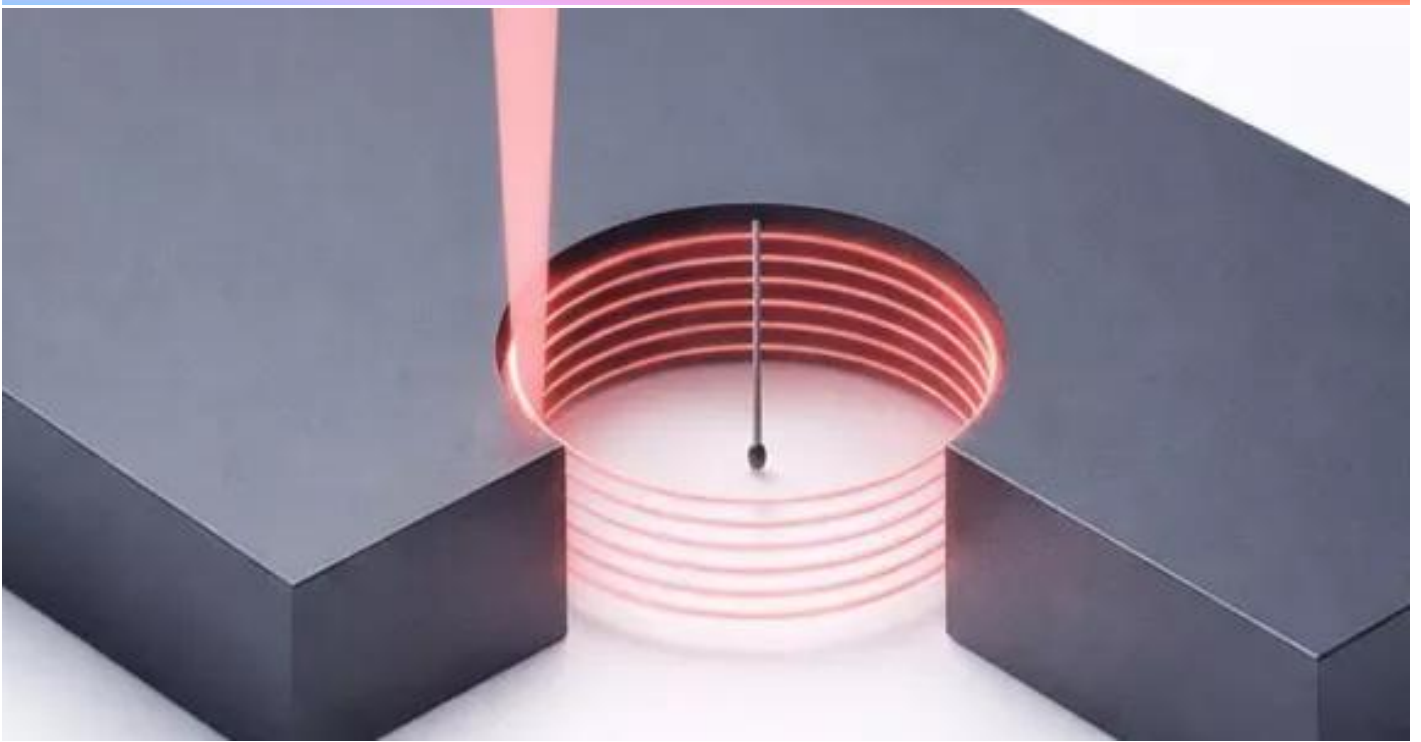




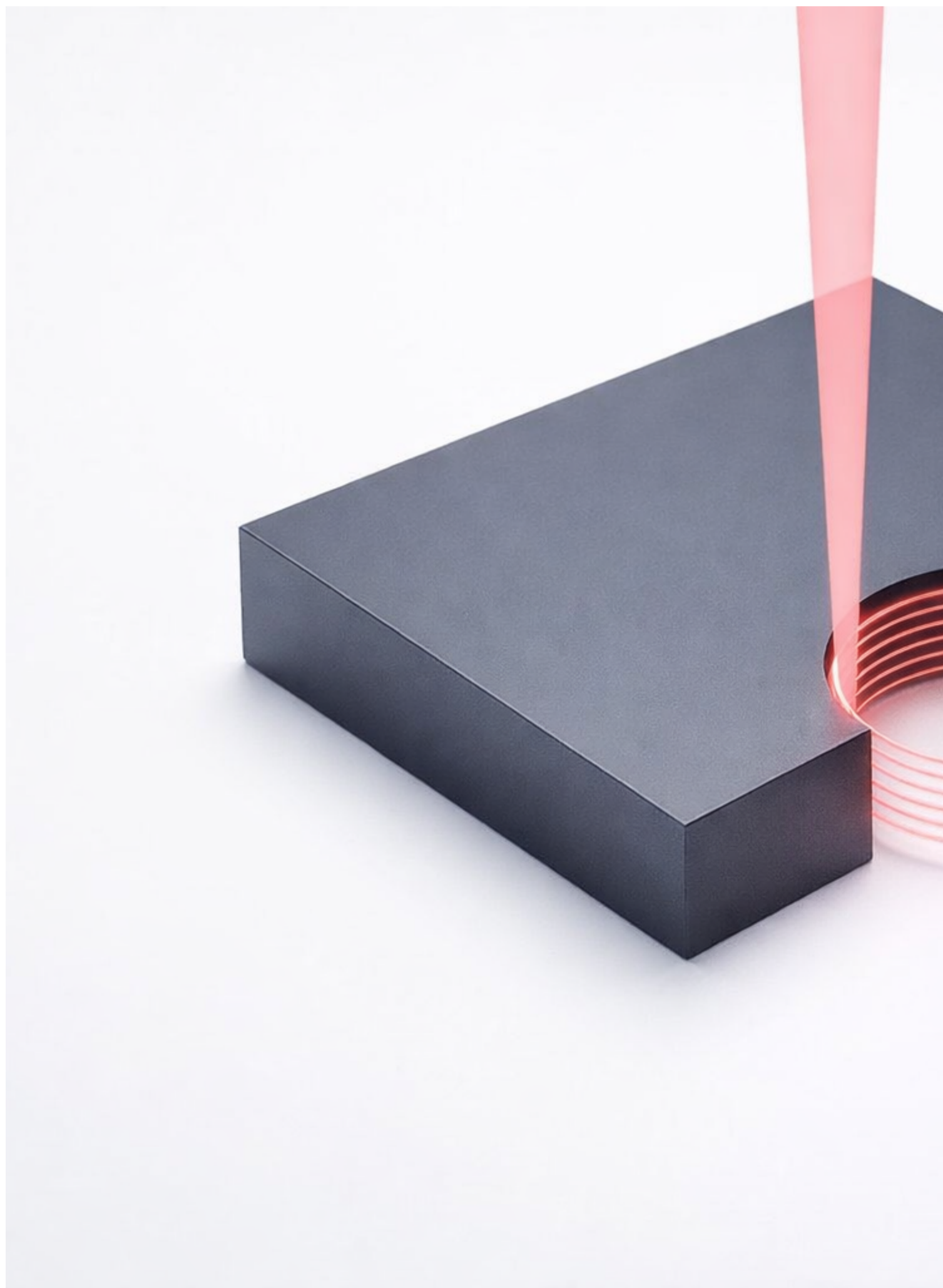
Femtosecond laser processing for glass and ceramics

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High-precision machining without heat effects, approaching industrial maturity

Precise machining of glass and technical ceramics remains challenging with conventional methods. This article explores how femtosecond laser processing enables cutting, drilling, and surface structuring with minimal thermal impact. It explains the underlying principles, highlights practical examples in glass and ceramic components, and reviews the applications where the technology is moving from research towards industrial use.

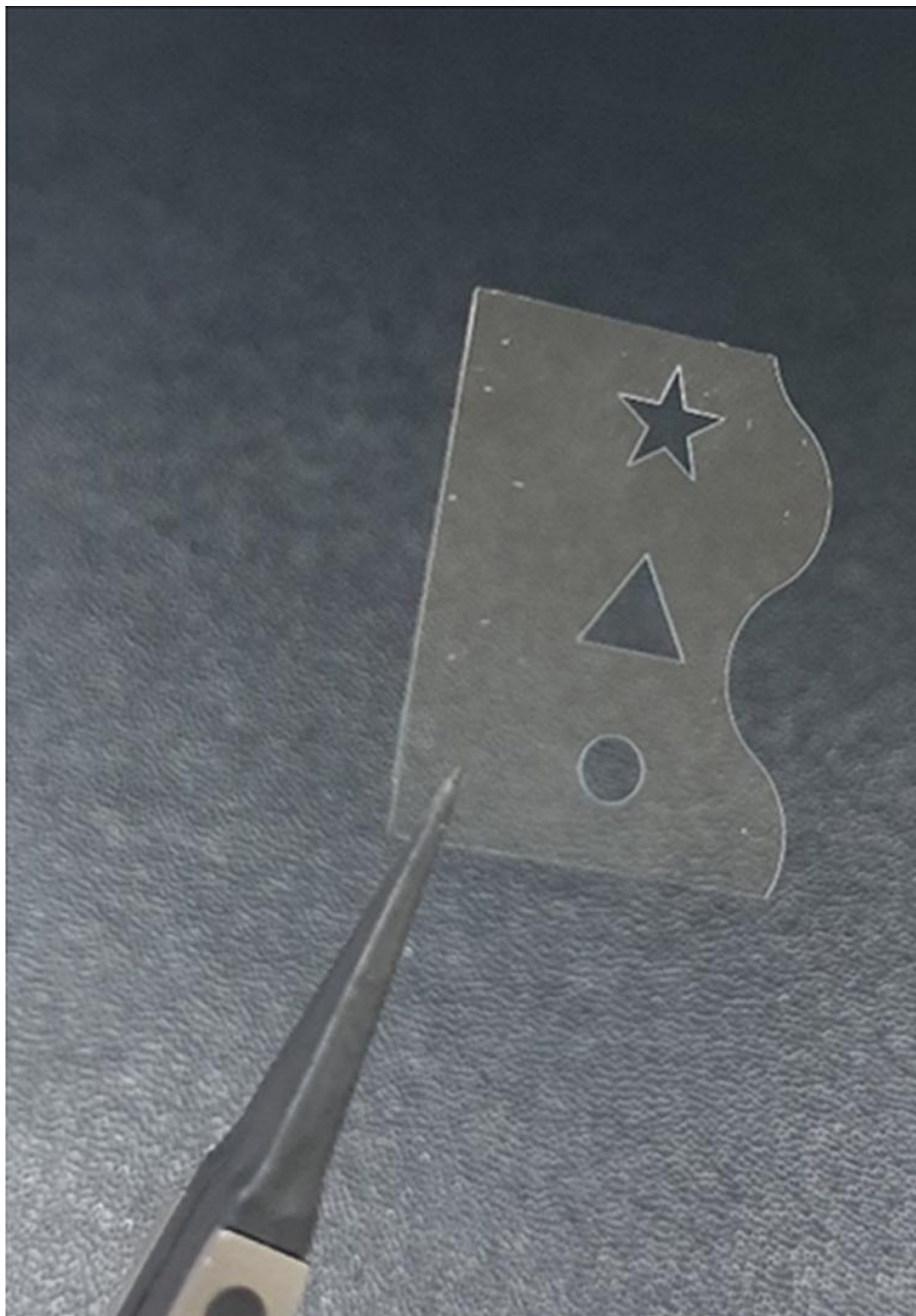


Femtosecond laser processing: a practical approach to a persistent problem

Glass and technical ceramics, such as alumina, zirconia, or silicon carbide, are indispensable in industrial applications today. They are used as carriers, guides, nozzles, sealing rings, sensor housings, or optical components. These materials excel in wear resistance, chemical inertness, and temperature stability, but they are also notorious for being difficult to machine. Mechanical machining with diamond tools or grinding wheels is slow, costly, and limited in design freedom. In addition, there are risks of cracks and microfractures, which can compromise the structural integrity of the component.

For companies processing precision components in glass or ceramics, this remains a barrier to automation and product optimization. The need for finer structures, tighter tolerances, or integrated functionality is growing, but conventional machining techniques are reaching their limits.

In this context, femtosecond laser processing (fs processing) offers an alternative. Thanks to extremely short pulses with high peak powers, material is removed with minimal heat input. This “cold” interaction makes it possible to work with high precision, without the typical thermal damage or microcracks associated with traditional techniques. What was once an experimental method is now becoming an industrial tool: reliable, reproducible, and compatible with production environments.



How does femtosecond laser processing work on brittle materials?

When a femtosecond pulse hits a transparent or ceramic material, nonlinear absorption occurs. Due to the high intensity of the beam, local ionization and plasma ablation arise, even if the material is normally transparent to the laser wavelength. The energy is delivered so quickly and locally that the material vaporizes before heat can spread.

This has three key advantages:

1. **Minimal thermal damage**

Edges and bore walls remain sharp and free of melt zones or cracks. This reduces the need for post-processing such as polishing.

2. **Very fine details possible**

Spots of only a few microns and precise depth control make it possible to create small holes, slots, and complex shapes, even in hard, brittle materials.

3. **Surface texture as a by-product**

Under certain conditions, self-organizing nano-ripple structures (LIPSS) form, which can influence surface tension, friction, or light absorption of the processed surface. [1,2]

Glass processing: more than just cutting

Femtosecond lasers are already operational today in many applications involving technical glass. For example, they are used for drilling and cutting technical glass types such as borosilicate, ground glass, or strengthened glass for sensors, protective windows, or optical plates. Small through-holes, slots, or complex contours are produced with high edge quality and minimal chipping.

Surface functionalization is another application. As with metals, micro- or nanostructures can be applied to glass surfaces to create water-repellent, anti-fog, or dirt-repellent properties. Think of sensor windows or covers for outdoor use, which acquire functional properties without additional coatings. [3]

Thanks to the flexibility of the laser beam, different zones on the same component can be processed with different parameters: for example, adding mounting holes in one part of a glass plate and surface structures in another.

Precision ceramics: cutting, structuring, strengthening

The same advantages apply to technical ceramics, which are often used in demanding applications:

- **Alumina and zirconia**

These materials are used in wear parts, pump components, positioning elements, and sealing rings. Femtosecond lasers make it possible to create precise openings, slots, or chamfers without compromising structural strength.

- **Ceramic substrates**

In electronics, alumina and similar substrates are often provided with small vias, recesses, or

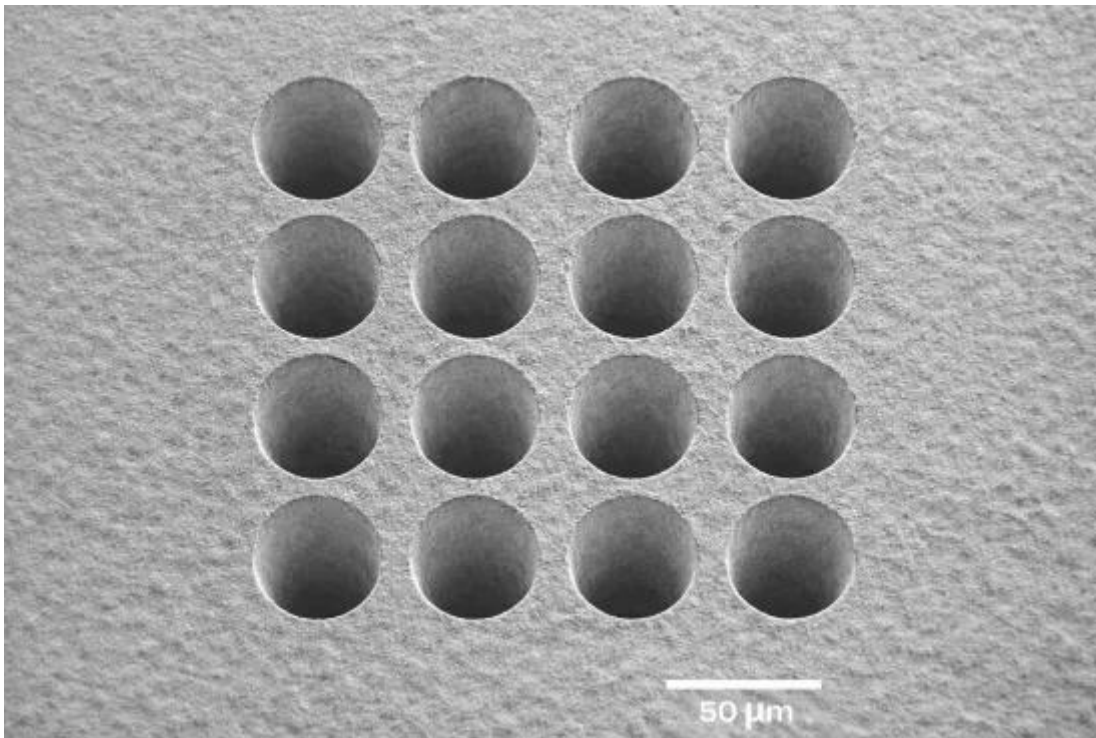
channels. Fs processing allows these structures to be produced contactlessly and with high repeatability, without mechanically stressing thin plates.

- **Nozzles and openings**

For gas dosing, liquid distribution, or microdosing, exact and clean openings in ceramics are crucial. The laser enables complex outlet shapes or local chamfers, which can improve flow behaviour or reduce clogging, while maintaining wear resistance.

- **Light surface structuring**

By applying microgrooves or dimples, sliding properties or lubricant film formation can be optimized [4]. This approach originates from metal applications and is now also being applied to standard ceramics.



Femtosecond lasers
for inspection

Industrial maturity and further optimization

Today, the focus of femtosecond laser processing is not on disruption, but on optimization:

- **Increasing productivity within existing power classes**

Smarter scanning strategies, beam shaping, and optimization of pulse overlap allow existing systems to work faster without loss of quality.

- **Standardization and parameter libraries**

As more companies adopt the technology, parameter sets for standard materials such as alumina or borosilicate are becoming better documented and reproducible. This lowers the entry barrier.

- **Combining shaping and functionalization**

There is growing interest in using the same laser both to shape and to tune surfaces. A sealing ring with a lightly textured sealing zone, or a sensor window where both openings and

surface structures are created in a single process: the combination of machining and surface modification is being used increasingly often.

A technology with a future

Femtosecond laser processing is no longer a futuristic promise, but a practical reality. For glass and ceramic components that are often produced at the limits of what is possible, this technology offers a robust solution. Companies processing complex, precise, or multifunctional parts can integrate new shapes and functions thanks to fs lasers, without compromising material quality or reliability.

This article was created in the context of the [BBBC project FEMTOFUNC](#), with support from the FOD Economie.

Interested in shaping biomimetic surfaces and exploring their industrial potential?

Through the FEMTOFUNC project, Sirris demonstrates how femtosecond laser texturing enables functional, sustainable and circular surfaces. We invite you to engage, gain inspiration and discover how this clean technology opens new opportunities in design and manufacturing.

[Discover the FEMTOFUNC project](#)

Are you facing machining challenges in glass or technical ceramics?

Contact our expert Felipe Baroni to discuss your application and evaluate how femtosecond laser processing can add value in your production context.

[Contact us](#)

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