Flexible microdrilling for test electronics

For microdrilling diverse holes in electronics test rig components, **ULTRASHORT PULSE LASERS** offer notable advantages over mechanical drilling. A new system approach now makes microdrilling and ablation possible even in polymers and ceramics, and with enormous geometric flexibility.

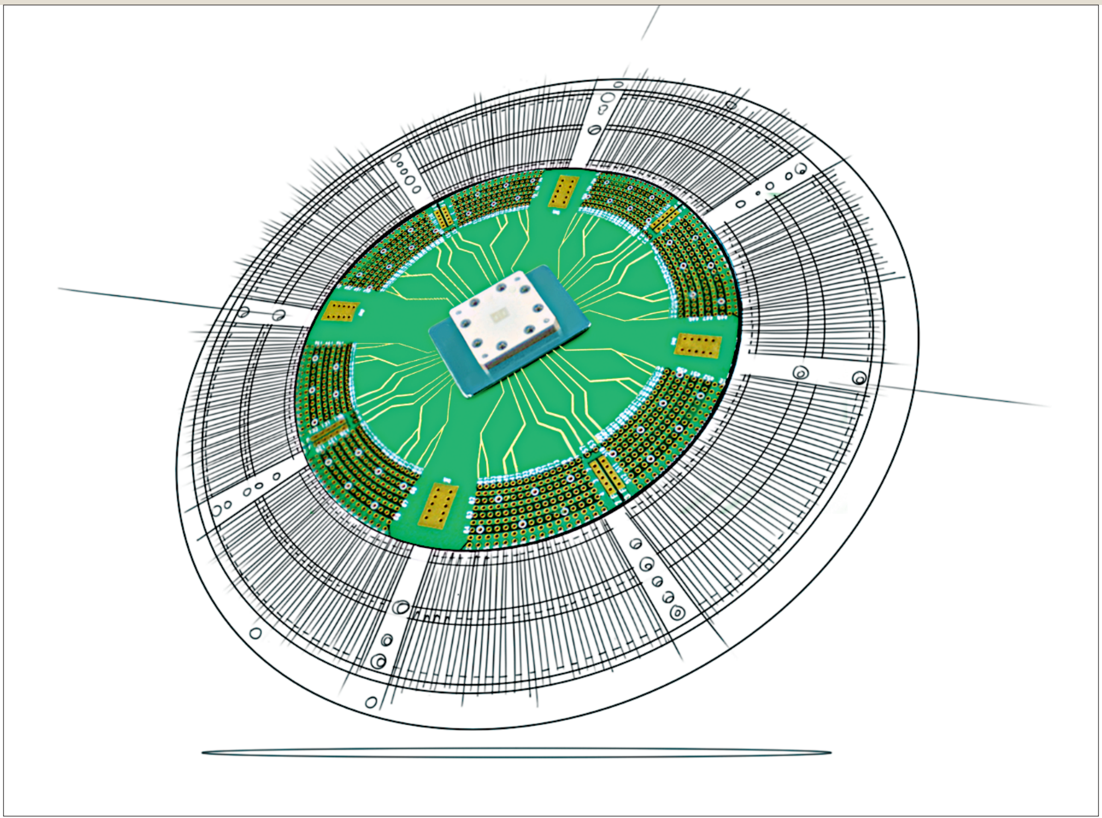

Figure 1. A ›probe card‹ for electronics testing contains large numbers of complex micro-bore holes

PATRICIA HAMMERS-WEBER AND UDO HEINZEL

The electronics industry's growing requirements are one major factor driving advances in laser micromachining systems. In particular, difficult-to-handle materials such as polymers and ceramics need to be processed with higher contour fidelity, tightest tolerances and high aspect ratios. Plus, the electronics industry's endless quest for miniaturisation requires ever smaller connectors on semiconductor devices. Accordingly, the rigs used for testing electronics – known as ›probe cards‹ – need to be ever smaller, too **(Figure 1)**.

A critical component in these probe cards is the ›guide plate‹. It consists of a mechanically-stable substrate with thousands of micro-bore holes, through which the probe card's contact pins must be inserted safely and precisely to later establish proper contact with a semiconductor device's connectors. Suitable substrate materials are hard or soft ceramics.

›Advanced probe cards‹ demand not only smaller geometries with tighter tolerances, but also rectangular holes – which makes mechanical drilling no longer sufficiently precise. In contrast, lasers deliver repeatable bore quality and advanced hole geometries, accompanied by much shorter process times.

USP lasers for nonconductors

Hard, nonconductive materials can't be processed via EDM (Electrical Discharge Machining) methods, whereas ultrashort pulse (USP) lasers are particularly well-suited for microdrilling. For this, the Puchheim, Germany-based company Scanlab

Figures: Posalux (1), Scanlab (2)

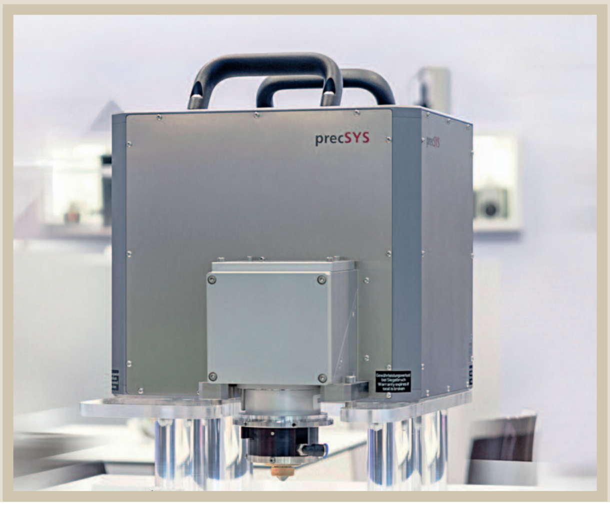

Figure 2. ›Precsys‹ 5-axis scan system from Scanlab

supplies a 5-axis scan system called ›Precsys‹ **(Figure 2)**. When coupled with a femtosecond laser, it processes diverse materials such as metals, polymers or ceramics without considerable thermally affecting the substrate. Additionally, it machines highly sensitive materials such as nitinol, and produces cuts that are burr-free, e.g. for timepiece gears, with edge tolerances of less than 0.3° **(Figures 3a and 3b)**.

System design for laser micromachining

The Switzerland-based company Posalux develops systems such as the ›Femto Mono‹ **(Figure 4)** for laser micromachining. Here, the company and Busch Microsystems jointly designed xy-stages made of granite to ensure a solid machine structure. Based on this, particularly careful consideration was given to the laser source, the optical beam path and tool-handling kinetics. Additionally, the interplay of

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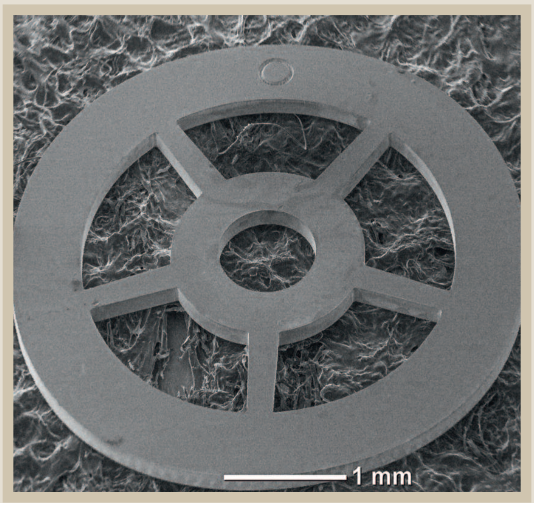
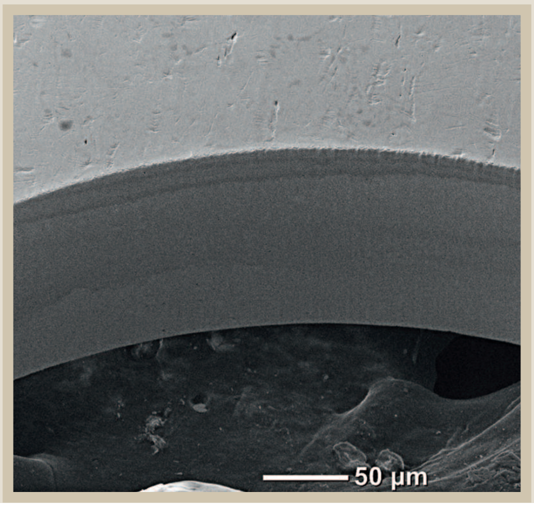
Posalux relies on these basic technologies:

- µ-Machining and PCB (Printed Circuit Board) for drilling, milling, etc.
- SACE (Spark Assisted Chemical Engraving)
- EDM (Electrical Discharge Machining)
- Femto-Laser





Figures 3a and 3b. Left: timepiece gear cut from strip material (Maillechort); right: image section from figure 3a

the components, including cooling, was studied and optimised. The Precsys scan system, equipped with industrially suitable interfaces, was likewise integrated by Posalux into its machine, at both the hardware and software levels. An intuitive user interface supports operators in loading the bore image, arranging its parameters and scanning the workpiece surface. Freely definable hole geometries facilitate processing and positioning in the µm range.

During the machine's development, a critical role was played by precise and highly dynamic beam deflection for guiding the laser spot on the workpiece. For this, Posalux chose to integrate Scanlab's Precsys 5-axis micromachining subsystem, with its robust construction, user-friendly operation and included ›Drillcontrol‹ software interface. This subsystem also guides the laser beam in x, y and z machine coordinates with simultaneously superimposed, adjustable angles of incidence (positive and negative). And it allows fabrication of micro-cavities with high aspect ratios.

In pure 3-axis laser processing of materials, particularly at higher aspect ratios, the conical beam path (caustic) hinders formation of vertical walls. In contrast, the Precsys can set the beam on a revolving circular course during processing, allowing extension of the bore entrance side to form sharp edges and ideally vertical (cylindrical) walls. And even negatively conical bore contours are possible. In addition to circular shapes, elliptical, rectangular and line-shaped geometries can be reliably fabricated. This scan system was specifically designed for series production.

The Precsys is equipped with an ›automatic fine adjustment‹ feature that stabilises the beam from the laser to the working field. This is accomplished via a sensor in the system that detects positional and angular deviations from the ideal target beam path and shows this in the Drillcontrol software. If the laser beam entering the Precsys were to deviate from a user-specified target setpoint, e.g. due to laser-pointer fluctuations or thermal fluctuations,

Figure 4. Machine layout of ›Femto Mono‹ for laser micromachining

Figures: Posalux

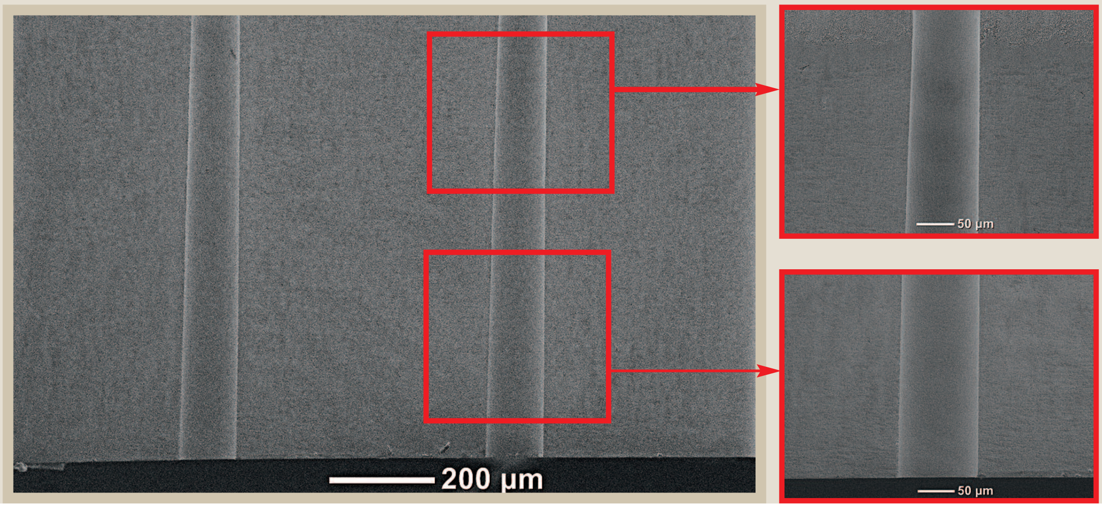


Figure 5. SEM (Scanning Electron Microscope) images of an injector bore hole, entrance diameter = 90 µm, exit diameter = 105 µm in a 1 mm thick wall

then the user could issue a software command that initiates re-adjustment. This automatic fine adjustment then completes in less than half a minute and thus guarantees long-term process stability without elaborate cause analysis or manual alignment work.

The Precsys process observation port acquires real-time data from the process zone that can be used, for example, to monitor processing results before proceeding to the next process step.

Practically everyone is drilling

A similar machining process can be applied for automotive for the injector holes, with an entrance diameter of 90 µm and exit diameter of 105 µm in a 1 mm thick wall (diameter-to-depth ratio: 1:10) **(Figure 5)**. Likewise achievable are diesel injector control passages, with diameters up to 60 µm and a diameter-to-depth ratio of 1:10.

When micromachining a probe card or test engineering rig for electronics, unprecedented demands are placed on scanners. For process

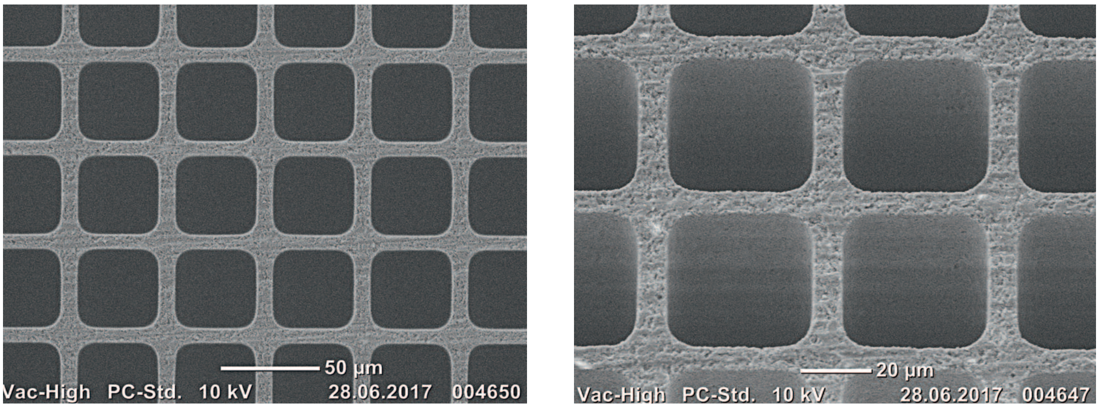


Figure 6. Square bore holes with an edge length of 40 µm, a 50 µm raster and an Si_3N_4 substrate

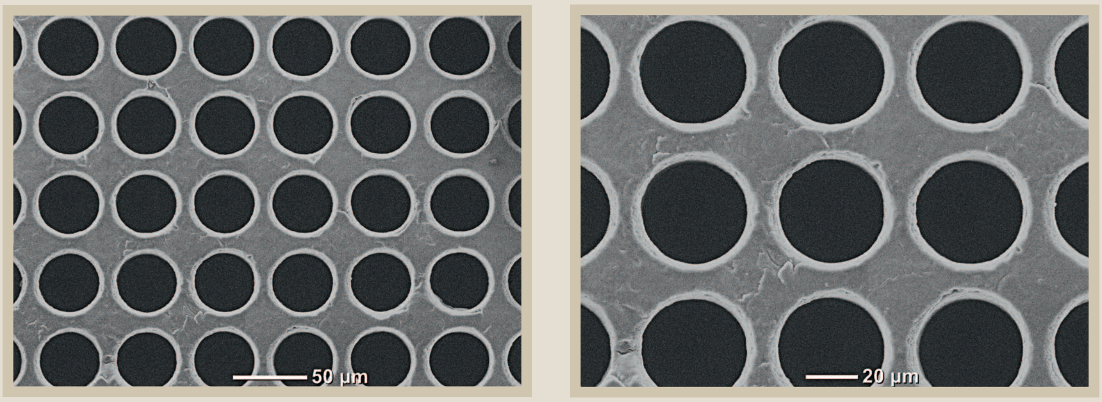


Figure 7. Round bore holes with a diameter of 40 µm and a 55 µm raster in an S1000 polymer substrate

reliability within the Precsys subsystem's image field, round or rectangular holes with diameters and edge lengths up to 40 µm need to be fabricated while maintaining a 50 µm raster.

Figure 6 depicts processing of a rectangular bore matrix (10 × 10) in Si_3N_4 ceramic within the Precsys image field. The square's edge length is 40 µm, with a 50 µm raster, resulting in 10 µm thick walls. The connecting radii of the four corners were measured at ≤ 5 µm. Here, process times of 1.2 s per bore hole were achieved in a 250 µm thick substrate.

Figure 7 shows a 10 × 10 bore matrix in an S1000 polymer substrate with a material thickness of 350 µm. The bore holes have a diameter of 40 µm, the raster is 55 µm and the process time was 2.5 s per bore hole.

The ›Swiss Cross‹ in **Figure 8** is surrounded by 2,000 square holes in a polymer (PPS) substrate with a thickness of 350 µm. Each square bore hole has an edge length of 40 µm and a wall thickness of 15 µm, resulting in a 55 µm raster. The first 100 square holes (10 × 10 matrix) were bored in one operation within the Precsys image field. Then the stage was repositioned to precisely bore the next 100 holes. In the example, this was performed 20 times over an area of approximately 7.5 mm².

Figure 9 shows a section of the upper left corner of figure 8. Note the seamless transition between individual matrices. This requires ±1 µm of precision for both workpiece and process positioning, which sums to ±2 µm positioning precision within the machine's working area.

As these examples prove, this highly integrated machine design delivers a controlled process with dependable quality. Its system-specific calibration also enables array processing in an image field 2.5 mm in diameter, allowing fabrication of consecutive rectangular bore holes even beyond the optical axes without the need for workpiece re-positioning. This can noticeably slash both process times and cost. ■ MI110540

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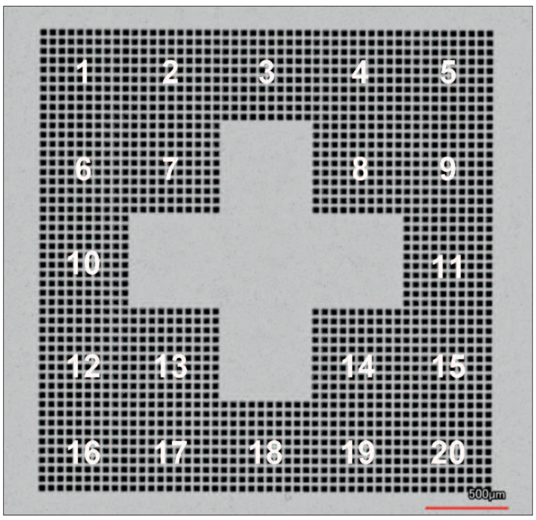

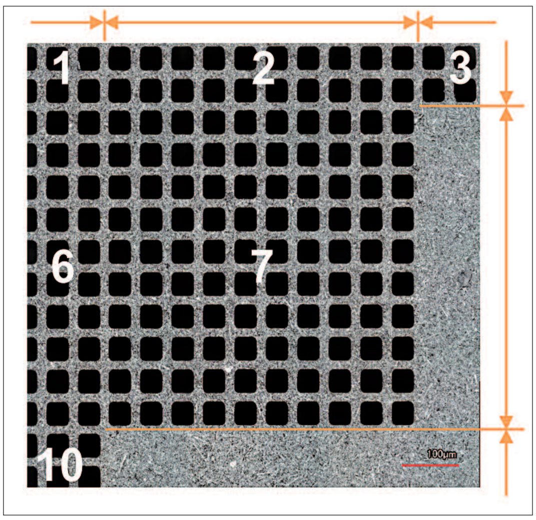

Figure 8 (left). Swiss Cross, surrounded by 2,000 square bore holes with an edge length of 40 µm and a 55 µm raster in 350 µm thick PPS

Figure 9 (right). Section from upper left corner of figure 8: zoomed view of transition area for six matrices

Figures: Posalux