5-axis micro processing

The precSYS micromachining sub system enables ultra-short-pulsed laser micro processing of flexibly variable geometries, e.g. fabrication of positively/negatively conical or ideal cylindrical, round or elliptical drill holes with high aspect ratios. The precSYS combines leading-edge high-end scan technology, integrated control, embedded PC and user-friendly software. This enables laser micro processing with ultimate dynamic performance and precision.

Its graphical user interface facilitates straightforward creation and testing of micro-processing jobs. precSYS’s robust, innovative construction ensures maximum dependability in industrial applications. Its compact, modular design and specially adapted hardware and software interfaces allow easy, optimal integration into customer-specific laser machines and networked production environments (industry 4.0). precSYS offers observation ports for process-monitoring and beam-monitoring add-ons.

SCANLAB ensures time-efficient system alignment and precise system operation thanks to factory default settings and calibration, as well as an optional automatic fine-adjustment package.

Key advantages:
• User-friendly creation of micro-processing operations with 3D visualization
• Flexible USP processing with defined variable angle of incidence
• Maximum dependability and stability for highest precision
• 515 nm variant for even more precise laser processing
• Speed-independent contour fidelity thanks to innovative control algorithms
• Designed for usage in industrial serial production
• Ethernet and EtherCAT control interfaces
• Highly integrated solution with embedded PC
• Ultra-precise pre-calibration and alignment software
• Optional automatic fine adjustment (system monitoring)
• Comprehensive on-site customer service

Typical applications:
• Drilling
• Ablation
• Structuring
• Cutting

Typical industries:
• Automotive
• Electronics
• Textiles
• Medical technology
• Precision engineering
**Principle of Operation**

precSYS lets you 3D-position the focal spot onto workpieces with precise tracking of angles of incidence (AOI). You can simultaneously vary progression of focal motion, angles of incidence and laser intensities etc.

High-end scan technology with small mirror rotation angles and low moving masses ensure highly dynamic processing with trepanning or precession frequencies up to 500 Hz (30 000 rpm). The system works without any rotary optics.

Advanced digital encoders, control algorithms and application-optimized servo control enable contour-true, speed-independent processing with maximum precision. The system is servo-regulated for stable positioning at precession frequencies up to 500 Hz. Specially conceived for USP precision processing, the optical path is polarization-maintaining and accommodates pulse energies up to 300 µJ.

**System Design**

Active water cooling of beam-guidance components (including galvo axes) and of spatially separated electronics makes the system robust against load-dependent temperature fluctuations. Moreover, the system’s innovative beam guidance provides suitability for up to 50 W lasers. A sealed, gas-purged optical beam path (overpressure) guarantees optimum cleanliness even in harsh industrial conditions – thereby enhancing system service life and processing accuracy.

**Innovation**

precSYS is the first stable, purely-galvo-based 5-axis micromachining sub system for ultra precise series-production processing. This new technology is patent-pending.
Flexible Processing
Due to precSYS’s possibility to position the laser beam in 5 axis (x, y, z, α, β), it offers highest flexibility for process development.

Circular, elliptical or linear trajectories can be defined in 2D or 3D (examples are shown in the lower left figure). For any geometry, the incidence angle will be controlled as specified during trajectory motion. Thus, precSYS can precisely execute trajectories suitable for drilling, cutting or ablation with defined laser beam tilting.

For example, precession drilling – in contrast to typical trepanning and spiral drilling – allows processing with a helically moved and simultaneously tilted laser beam, e.g. to practically eliminate beam-caustic effects at entry edges. In this way, the precSYS’s high precession frequencies even enable production of deep bore holes with high aspect ratios and vertical walls at one-second intervals.

A similar effect can also be exploited when structuring or cutting walls with vertical or negative-tapered defined profiles.

High-precision processing is possible with the full +/- 7.5° range of incidence angles in circular image fields up to 2.5 mm in diameter. Typically employed pulse lengths are in the USP range of 250 fs – 25 ps. In addition, markings can be created within an image field of up to 5 mm in diameter.
DrillControl software

An intuitive graphical user interface (GUI) with 3D job visualization helps you easily create and simulate processing jobs. Communication between DrillControl or system control and DrillServer occurs over Ethernet with TCP/IP or via the EtherCAT interface. Factory calibration enables description of laser motion directly in metric units within precSYS’s cartesian image field coordinate system.

The software depicts processing steps in 3D and enables straightforward job programming, as well as varying the diverse process parameters.

Job designer
- Definition of process sequences with visualization of the 3D laser path
- Management of process jobs on the precSYS system (embedded PC)
- Comprehensive simulation and testing possibilities
- Parameter relationships displayed as lists and diagrams
- No job size limitation
- Control of up to 10 digital and 2 analog outputs with freely definable ramps for setting additional parameters (e.g. laser power or process gas pressure)
- Diagnostics panel (galvo status, galvo temperature, etc.)
- Software-based adjustments
  - aligning the focal plane to the precession plane
  - global offsets, scalings and rotations for the laser focus path
  - characteristic curves for adjusting the laser power control parameters

Functionality for Production
- Additional user interface for production operation
- Easy management of one or several systems via one software
- Remote control via Ethernet or EtherCAT for integration in system control (PLC): Simple protocol for defining, selecting and running jobs (job definition via XML including validation) and for parameter adaption for compensating workpiece tolerances (e.g. offsets)

* Certain system components (e.g. lasers, electrically-switchable gas valves, motorized polarization plates, motorized beam expanders) are typically not provided by SCANLAB.
Options

Beam conditioning components
- For adapting the entrance beam’s diameter and divergence, as well as adjusting circular polarization within the image field
- Alternatively as beam conditioning unit without housing and gas purging

Extraction unit
An optional extraction unit can be installed at the process-gas nozzle tip for constant extraction of ablation particles from the process zone.

Components for optical process monitoring
SCANLAB offers a precSYS-matched camera objective with optional color filters for an observation wavelength of 880 nm ± 10 nm (Observation also possible at other wavelengths) and attachments to increase resolution. Additionally, customer-supplied components can be installed at the process observation port.

Automatic Fine Adjustment
precSYS’s factory-precalibrated beam position measurement unit can be used for monitoring the system’s beam position. If the beam position exceeds the application-specific tolerance limit, then the software can be used to readjust the beam back to its original zero position by the system-internal five galvo axes.

Advantages:
- Beam position stabilization close to the working field minimizes deviations along the beam path from laser to workpiece
- Lastingly reproducible process results without complicated effect analysis and manual readjustment
- Beam position monitoring via maintenance software program
- Automatic readjustment of beam position and angle via the DrillControl software (regulation via system-internal galvo axes)
- Supports precSYS alignment during commissioning and servicing

Further customer-specific solutions on request.
precSYS 5-axis material processing enables machining of fine geometries in the sub-millimeter range with high aspect ratios and quick process times, using ultra short pulsed laser beams. Typical micro applications are ablation, structuring, drilling and cutting.

precSYS’s high-end scan technology and innovative calibration facilitate dynamic, highly-precise traversal of defined paths throughout the entire 2.5 mm circular working field. Fabrication is also possible outside the optical axis. Thus, no XY translation stage is needed for workpiece positioning while processing bore-hole arrays in the image field. You can assign individual jobs to each specific bore hole, i.e. for processing with individual parameter settings.

Helical processing with defined laser beam tilting allows fabrication of high quality bore-hole entries and exits that are clean-cut, burr-free and molten-free. This enables creation of – for example – precise positive-conical (V-shaped) and negatively conical (Λ-shaped) or ideally cylindrical (II-shaped) bore wall contours with high aspect ratios.

precSYS lets you execute not only 3D geometries, but also 2D marking. In addition to processing of circular, elliptical or linear laser motion paths, you can also easily mark text with various fonts and font sizes in a 5 mm circular working field (e.g. for labeling during process development). In addition, more complex geometries such as ellipses or squares with perpendicular edge contours can be fabricated. For example, figure 7 shows a 4 x 4 square array in ceramic with 30-µm side lengths and a 1:10 aspect ratio. Thanks to factory pre-calibration, the squares are precisely positioned within the image field to maintain a defined 10-µm wall thickness across the entire array.

When the required geometry exceeds the image field of 2.5 mm in diameter, supplementary external axes can be employed below the precSYS for workpiece guidance. Figure 9 shows a cutting application where segments with vertically-contoured walls were cut out of a 200-µm-thick brass.
component. The wall quality is characterized by homogenous, defect-free surfaces with sharp edges.

**Quality**
The high quality, dependability and industrial suitability of SCANLAB’s scan solutions are the result of long-standing experience in developing and manufacturing galvanometer scanners and scan systems. SCANLAB scan heads have been deployed by industry in large quantities for many years. Each individual scan head earns approval for customer delivery only after first passing the SCANcheck endurance test.

**Customer Service**
This highly integrated system features a product-specific customer service:
- Local support for precSYS commissioning by an experienced service technician
- On-site maintenance and repairs
- Comprehensive training for efficient usage of software and performance of maintenance work
- Installation of software updates
- Remote servicing and error diagnostics (remote interface)
- Technical support via phone service

200-µm bore holes in steel – compared to a human hair, fabricated with fixed workpiece position, without an XY translation stage (SEM image)

Detail of a 4 x 4 square hole array in ceramic - Square geometry: 30 µm x 30 µm - Depth: 300 µm, Aspect ratio: 1:10 - Perpendicular wall contour - Corner-rounding radius: < 4 µm - Wall thickness: 10 µm (SEM image)

200-µm bore holes in 300-µm thick steel (entrance side), fabricated via workpiece positioning with an XY translation stage (SEM image)

Cutting application with perpendicular cutting edge contour in 200-µm thick brass (SEM image)

Marking pattern for labeling - Characters: 0.5 mm font size, SimpleStraight3 font - Circle diameters: 0 mm, 0.1 mm, 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm, 2.5 mm
## Specifications (preliminary data for precSYS 515)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wavelength</strong></td>
<td>1030 nm or 1064 nm 515 nm (Standard) 515 nm (min. focus diameter)</td>
</tr>
<tr>
<td><strong>Clear aperture at entrance</strong></td>
<td>4 mm 4 mm 4 mm</td>
</tr>
<tr>
<td><strong>Typical entrance beam diameter (1/e²)</strong></td>
<td>2 mm 2 mm 2.5 mm</td>
</tr>
<tr>
<td><strong>Typical focus diameter in image field (1/e²) for M² = 1.2</strong></td>
<td>20 µm 10.2 µm * 8.2 µm *</td>
</tr>
<tr>
<td><strong>Minimum focus diameter in image field (1/e²) for M² = 1.2</strong></td>
<td>15 µm 8.2 µm * tbd</td>
</tr>
<tr>
<td><strong>Typical convergence angle of focused beam (full opening angle at 1/e² level)</strong></td>
<td>0.08 rad 0.08 rad 0.1 rad</td>
</tr>
<tr>
<td><strong>Maximum angle of incidence (AOI)</strong></td>
<td>± 7.5° ± 7.5° ± 7.0° *</td>
</tr>
<tr>
<td><strong>Trepncing / precession frequency (for max. AOI and Ø 100 µm)</strong></td>
<td>≤ 650 Hz (39 000 rpm) ≤ 650 Hz (39 000 rpm) ≤ 650 Hz (39 000 rpm)</td>
</tr>
<tr>
<td><strong>Typical pulse energy</strong></td>
<td>≤ 300 µJ ≤ 65 µJ ≤ 100 µJ</td>
</tr>
<tr>
<td><strong>Typical average power</strong></td>
<td>≤ 50 W ≤ 50 W ≤ 50 W</td>
</tr>
<tr>
<td><strong>Typical pulse length</strong></td>
<td>250 fs – 25 ps (up to cw) 250 fs – 25 ps (up to cw) 250 fs – 25 ps (up to cw)</td>
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<tr>
<td><strong>Objective focal length</strong></td>
<td>75 mm 75 mm 75 mm</td>
</tr>
<tr>
<td><strong>Effective focal length</strong></td>
<td>25 mm 25 mm 25 mm</td>
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### Working field size (diameter, depending on nozzle opening)

- **Precission processing**: ≤ 2.5 mm ≤ 2.5 mm ≤ 2.5 mm
- **Marking**: ≤ 5 mm ≤ 5 mm ≤ 5 mm
- **Maximum focus range in z direction**: ± 1.0 mm ± 1.0 mm ± 1.0 mm
- **Maximum focus speed in z direction**: 10 mm/s 10 mm/s 10 mm/s
- **Theoretical position resolution in xy image field**: 17 nm < 20 nm < 20 nm
- **Repeatability in image field**: ≤ 0.5 µm ≤ 0.5 µm ≤ 0.5 µm
- **Theoretical resolution of incidence angle**: 2 µrad 2 µrad 2 µrad
- **Focus polarization (after beam conditioning)**: circular circular circular

### Observation port wavelength

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<th>Precission processing</th>
<th>Marking</th>
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<td>680 nm ± 10 nm; 1200 nm - 1400 nm</td>
<td>≤ 2.5 mm</td>
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<tr>
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<td>≤ 5 mm</td>
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### Axes

- 5 factory calibrated axes (x, y, z coordinates and 2 incidence angles α, β)

### Power supply requirements

- 30 V – 33 V, max. 6 A

### Data and control interfaces

- Ethernet (DrillControl, remote interface for PLC/machine control, XML job definitions), EtherCAT, external job start/stop trigger
- 2-bit digital output
- 8-bit digital output (PLC)
- Two 12-bit analog outputs (0 ... 10 V) with freely definable ramp profiles
- Job Busy output

### Cooling

- water, 25 °C

### Purge gas (for optical beam path)

- nitrogen, synthetic air (other gas types on request)

### Process gas

- freely selectable, max. 6 bar, 1 mm process gas nozzle opening

### Replaceable protective glass (for fast-replacement drawer)

- yes

### Software

- DrillControl (graphical user interface), DrillServer (on embedded PC)

* Certain system components (e.g. lasers, electrically-switchable gas valves, motorized polarization plates, motorized beam expanders) are typically not provided by SCANLAB.

** Deviation of diameter and roundness over 6 hours operation load (for AOI = -7.5° ... 7.5°; Ø 0.09 mm ... 0.3 mm; f = 50 Hz ... 650 Hz; z = -1 mm ... +1 mm)

*** Other nozzle openings are optionally available if needed.

* valid for lasers with a spectral bandwidth < 1.5 nm