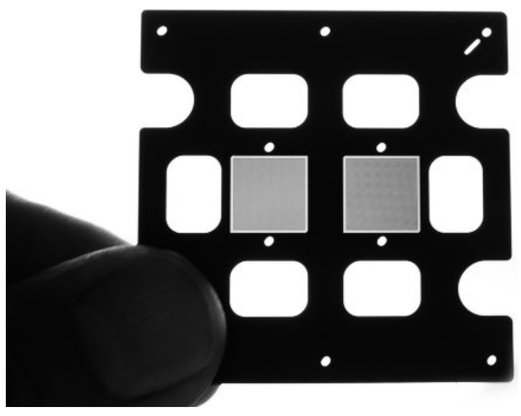
SWTW26-54

High Density Laser Drilling in Semiconductor Test Hardware: Evaluating the Trade-Off Between In-House Capability and Outsourced Manufacturing



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BACKGROUND

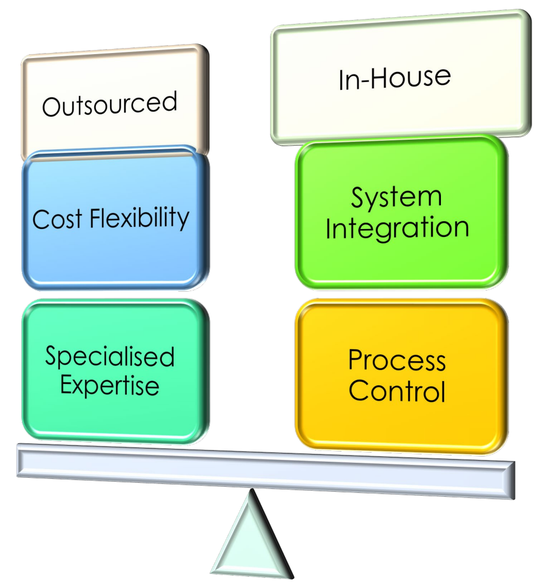
As semiconductor test hardware continues to evolve toward higher probe densities and tighter pitch requirements, laser drilling has become a critical manufacturing process for components such as **probe card guide plates**, **ceramic substrates**, and **interposers**.

Technical Challenge - Sub-50 µm drilling introduces increased:

- Process sensitivity and variability
- Control of laser pulse duration and energy
- Risk of taper, debris, and thermal damage

Current Manufacturing Reality

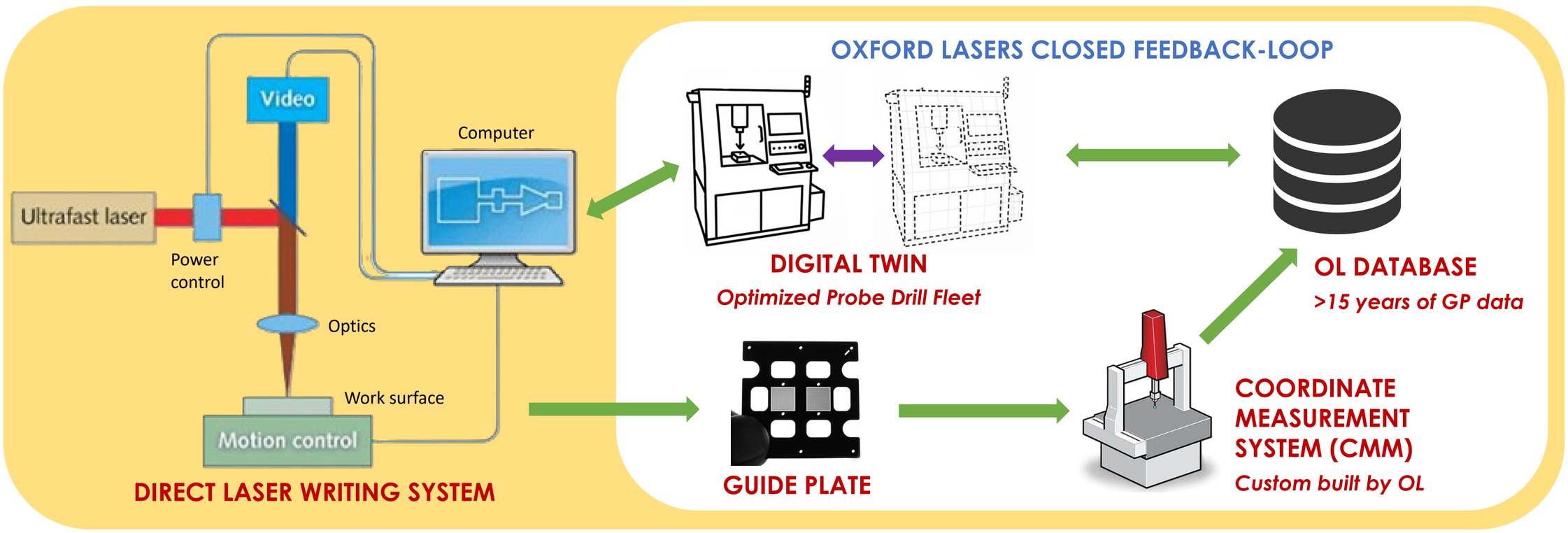
- Ultrafast lasers enable high-quality micro-features
- Achieving consistent results requires:
  - Significant capital investment
  - Process expertise and optimization
  - Sustained equipment utilization



When should sub-50 µm laser drilling be developed in-house or outsourced from specialized suppliers?

LASER DRILLING PROCESS CONSIDERATIONS

Specialized laser micromachining companies incorporate laser drilling tools, advanced metrology, and automated process optimization. In Oxford Lasers, this is complemented by a **unique database**, **automated measurement system** and **closed feedback-loop**, represented below.



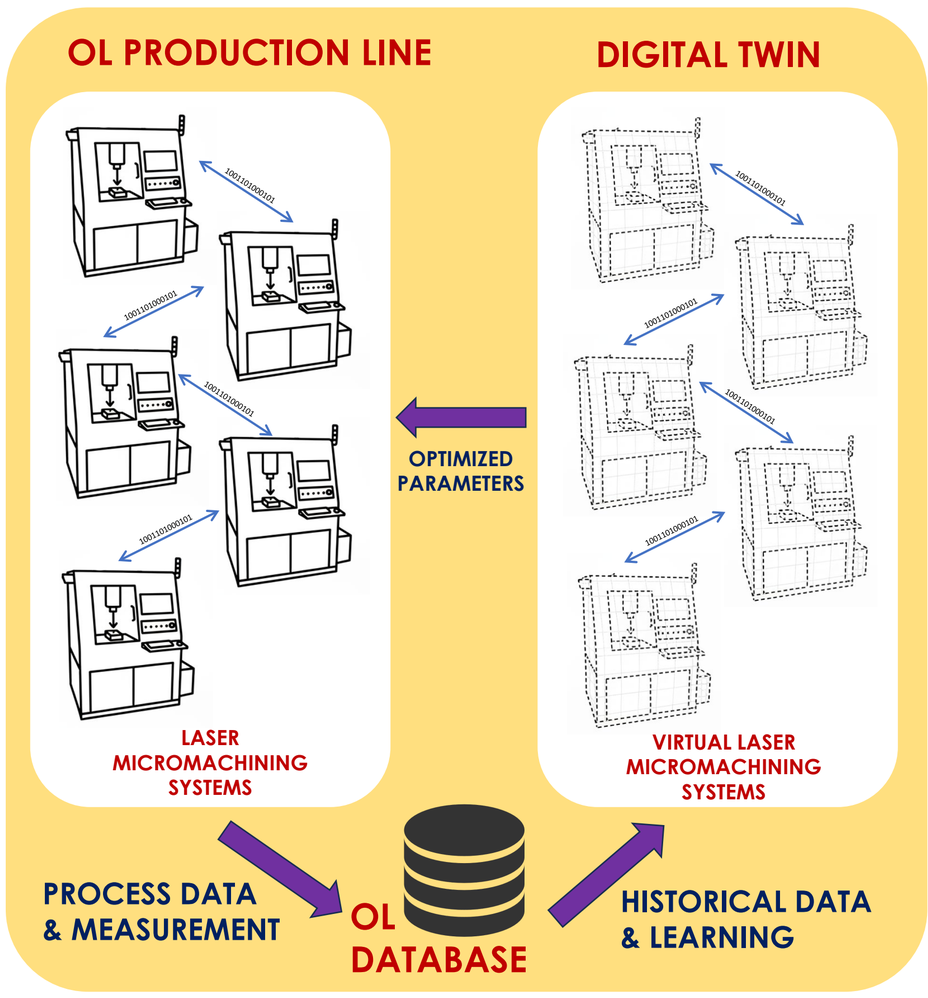
Key Considerations for In-House vs. Outsourced Laser Drilling	
1. CLOSED-LOOP DATA-DRIVEN PROCESS CONTROL IN LASER DRILLING	Precise laser control, automated inspection, digital twin optimization and metrology feedback assists with **first-time-right processing** for new designs.
2 . FEATURE REQUIREMENTS & LASER PARAMETER KNOWLEDGE	Sub-50 µm features require tight control of geometry and laser parameters, increasing process sensitivity and needed **equipment flexibility & knowledge**.
3. PRODUCTION VOLUME STABILITY & INVESTMENT	Ultrafast laser **return on investment** relies on high sustained volumes to offset cost; however process drift can quickly degrade yield and impact profitability.
4. DESIGN ITERATION FREQUENCY	**Faster cycles (<6 weeks)** between design, drilling, and testing require speed, responsiveness, reachability and flexibility from all stakeholders

1. CLOSED-LOOP DATA-DRIVEN PROCESS CONTROL IN LASER DRILLING

Delivering consistent sub-50 µm features at very high hole counts requires more than fixed recipes. A closed-loop workflow such as Oxford Lasers' uses metrology data and feedback to continuously tune drilling parameters, improving uniformity and reducing variation across builds.

- **Vast process memory:** Oxford Lasers' Database of 200M drilled holes across production programs with 12 TB of process and metrology data
- **Rich traceability:** Geometry, positional error, and system conditions recorded for every hole
- **Real-time visibility:** Monitoring of tool health, and drilling status
- **Improving over time:** Historical data drives parameter refinement
- **Digital Twin Optimization:** Enables simulation-based capability planning and parameter optimization prior to production

Result: Predictive optimization and first-time-right processing that shorten development cycles and increase yield and consistency.



2. FEATURE REQUIREMENTS & CORRESPONDING LASER PARAMETER KNOWLEDGE

Sub-50 µm features require tight control of geometry and laser parameters, significantly increasing process sensitivity and the need for flexible equipment and process knowledge.

Key process variables and knowledge:

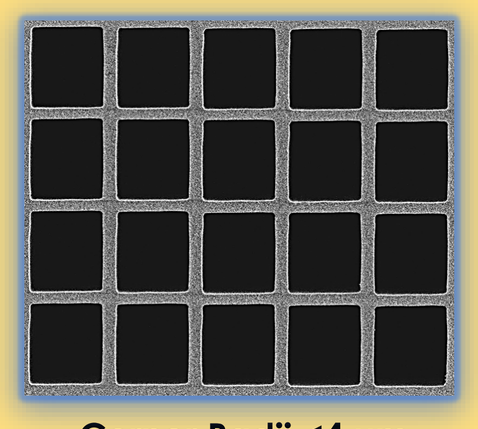
- Pulse duration
  - Nanosecond
  - Picosecond
  - Femtosecond
- Laser Wavelength
- Optics configuration
- Beam shaping
- Motion control
- Repetition Rate

Oxford Lasers experience:

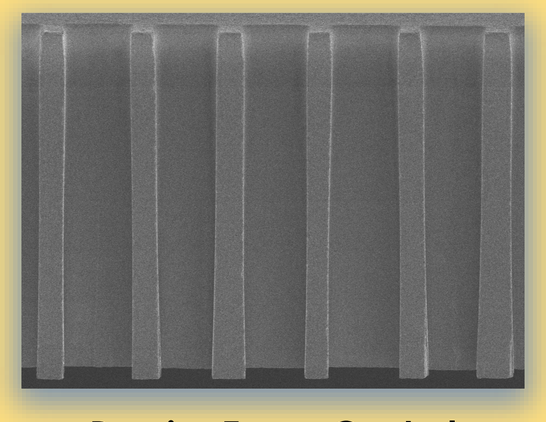
- Extensive micromachining applications including semiconductor, aerospace, pharmaceutical industries
- Emerging applications of through Glass Vias (TGV)/ glass interposers.
- Container Closer Integrity Testing (CCIT) applications with calibrated ~2 µm ±1 µm micro holes in ~1mm thick glass
- Process insight is further optimized by high-speed and bright event laser imaging capability
  - Detailed observation of laser-material interactions using OL **FireBIRD** Laser Illumination System ➡️

These requirements highlight the importance of accumulated process knowledge and capability, which must be considered when evaluating in-house development versus outsourcing.

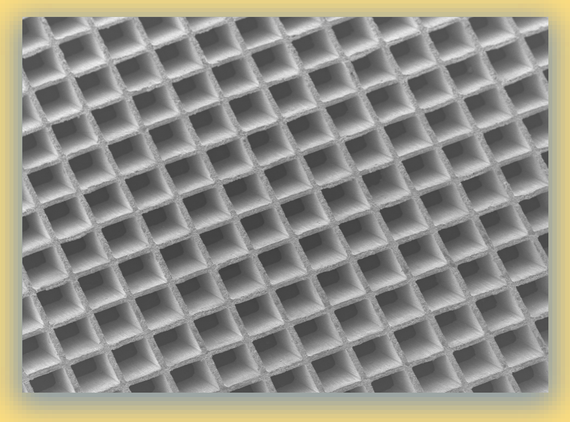
Sub 50 µm Oxford Lasers Ceramic Guide Plate Examples:



Corner Radii <4 µm

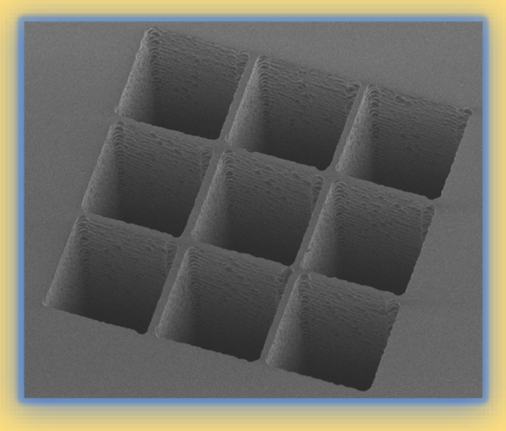


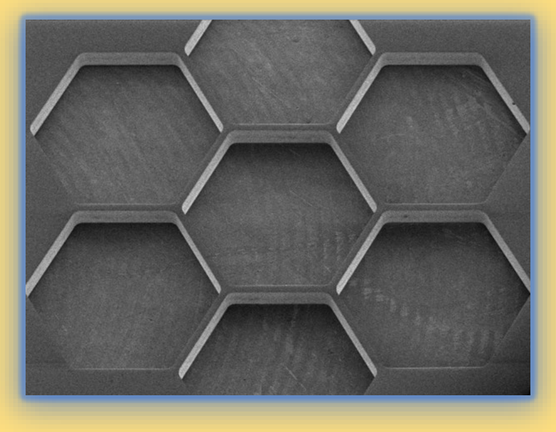
Precise Taper Control



6 µm web width

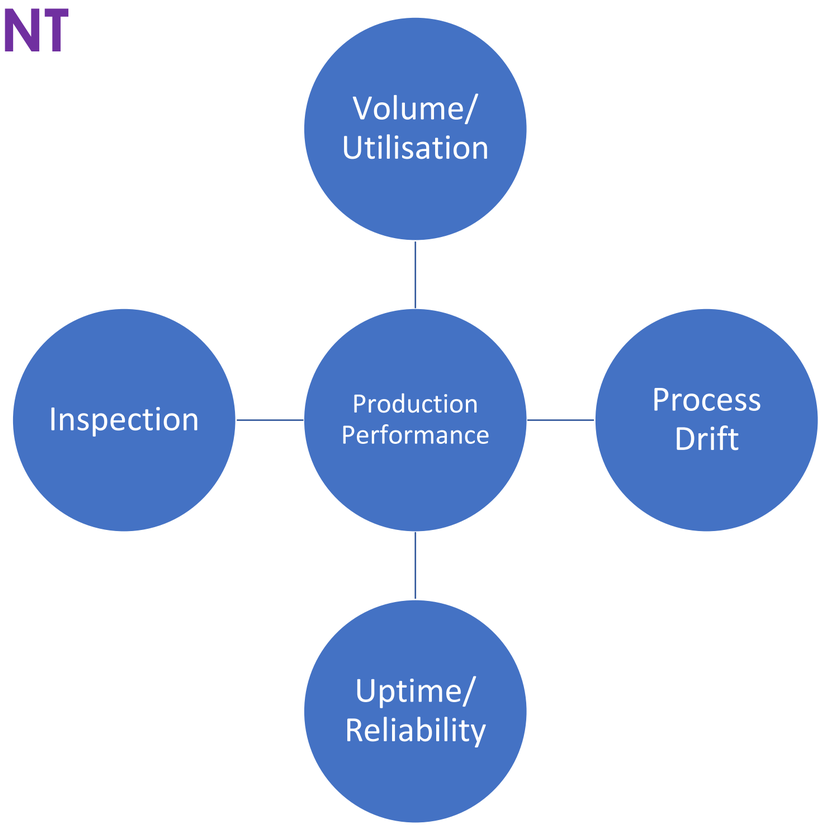
Drilling and Selective Laser Etching in Borosilicate Glass





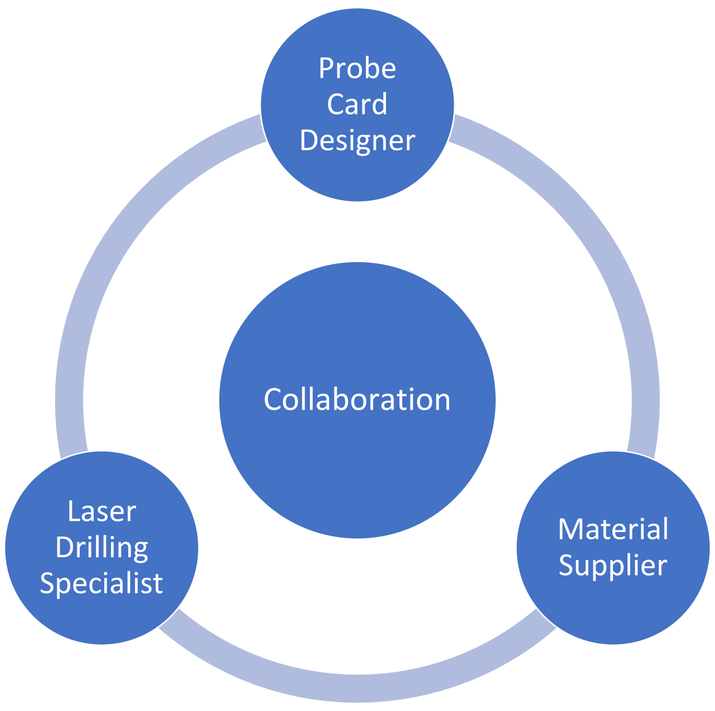
3. PRODUCTION VOLUME STABILITY & INVESTMENT

- Achieving **return on investment** requires sustained production volumes and high equipment utilization
- Process variation and drift of positional error can impact yield requiring **constant monitoring** and corrective action
- System uptime and reliability influence overall productivity and cost efficiency
- Production must support both baseline and peak demand requirements
- Inspection and metrology are required to maintain consistency and detect process drift



These factors directly influence the decision between in-house capability and outsourcing.

4. DESIGN ITERATION FREQUENCY



- Probe card development cycles are accelerating, with design-to-test timelines often **<6 weeks**
- Rapid iteration requirements influence the choice between **in-house** and **outsourced**
- **In-house** capability is often perceived to offer faster turnaround and control however speed depends on responsiveness, collaboration and process capability across all stakeholders

Design iteration delivery time is therefore driven by stakeholder collaboration, process knowledge and responsiveness rather than manufacturing location alone.

SUMMARY

- Process capability at sub-50 µm probe card assembly components are driven by accumulated data, experience, and predictive optimization, not just equipment ownership
- The decision between in-house and outsourced laser drilling involves trade-offs between:
  - Capital investment, utilization, and cost
  - Process control, yield stability, and expertise
  - Development timelines and responsiveness
- In-house capability offers control, but requires **significant investment** and time to develop
- Outsourced providers with **vast databases** & extensive knowledge offer established capability, high utilization, process knowledge and advanced technologies such as digital twins, which companies can use to reduce development time by up to 50% through virtual prototyping
- **Close collaboration across the supply chain** is critical to achieving optimal performance

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