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“The personalization process of a gate array”, Lasarray S.A., brochure (ca. 1990)
“Display application test patterns on chrome mask after etching and resist stripping”, HIMT Archives
“Photomask”, HIMT Archives (1997)
“SEM photo of photoresist structures, exposed by a DWL”, HIMT Archives (ca. 1997)
“Grayscale lithography with the DWL 66”, Fraunhofer Institute, Jena
“Example of drill hole”, HIMT Archives, presentation (2002)
“Test exposures of contact pads with the LSA 600”, HIMT Archives (2006)
“‘Cityscape’ – laser milling with the LAM66”, HIMT Archives (1999)
“Personalized ASICs”, IMS Chips (Institut für Mikroelektronik Stuttgart), presentation (2015)
“A microfluidic device written by the MLA”, CMi EPFL Center of MicroNanotechnology (2015)
“Nanoscale contacts”, Bojun Cheng, ETHZ

Background image: “Fan-out demo pattern with 1 µm line width in 500 nm AZ 1505, exposed with DWL 2000 GS with WM I, detailed image”, HIMT Archives

Back flap: “Working on the MaskWrite 1550”, HIMT Archives (ca. 1997)

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CONTENT

Chapter 2

THE EARLY YEARS 1984-88

In the early years, the company developed a variety of systems for different markets: the LPM (Line Profile Measurement), the LTS (Laser Tomographic Scanner) and CLSM (Confocal Laser Scanning Microscope), as well as AWIS, a wafer inspection system, and the first Heidelberg Instruments laser lithography systems LLS (Laser Lithography System) and LPS (Laser Pattern System).

2.1. Confocal Imaging

The history of the early Heidelberg Instruments years is marked by an emphasis on not one, but several types of tools utilizing the laser scanning technology.

The confocal principle was of particular importance to several of the resulting products. Much of the research in the founders' labs and institutes had centered on increasing optical resolution and generating high-contrast optical images, and both these parameters can be achieved and optimized by confocal imaging. In confocal imaging, a pinhole in the beam path only lets light from a narrow focus area pass and blocks out all surrounding out-of-focus light. Importantly, a second pinhole in front of the detector blocks out any residual out-of-focus light, making sure that only the light from the focus point reaches the detector, which creates the sharpest image of this point. The focus spot – the fact that a laser was used was new at the time – is scanned across the sample at a certain depth of focus at a time. Images can therefore be recorded at different depths in the sample by varying the focal plane on the microscope. The principle can be seen in Figure 2.1-1.

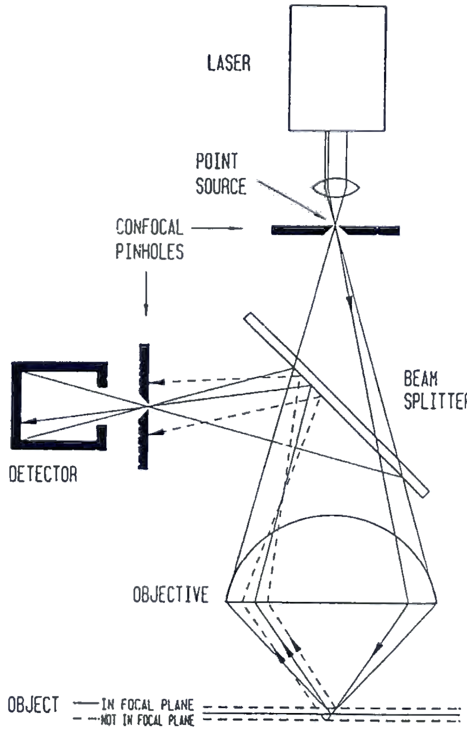


Figure 2.1-1 *The principle of confocal imaging, central to so many of the early Heidelberg Instruments systems: this schematic representation and the explanation are taken from a product description of the Laser Tomographic Scanner, approximately 1988. "In a confocal optical scanner, a point-like light source is focused to a point of the object under examination. The object point illuminated by the laser reflects part of the incident light. The reflected light is registered by a point-like detector. The point-like detector is realized by a very small diaphragm (…). Only such light which originates from the focal plane of the imaging optical system can pass through the diaphragm and reach the detector."*

This technique in combination with a new type of image analysis allowed the creation of whole 3D maps as well as a vertical image slice of the sample – a cell, for instance – from the resulting data points. The Heidelberg Instruments expertise in electronic image analysis processing therefore played a critical role in the application of this technique.

The expectation was that instruments based on confocal imaging would have a clear performance advantage over the standard optical tools of the time. This was true for medical imaging, with special emphasis on the laser scanning ophthalmoscope, as well as depth profiling of critical structures in integrated circuits and VLSI (very-large-scale integration) structures. All Heidelberg Instruments systems – the ophthalmoscope, the confocal microscope, the wafer inspection system, the line profile measurement system, and the laser lithography systems – were based on the company's wealth of knowledge and experience in their core technologies of laser scanning microscopy and electronic image processing and thus all drew from one and the same specialized expertise, with the lithography system the only one that did not rely on the confocal principle.

Although the different evolving products were closely related in concept and design, their specifications and applications were very different. This unfortunately soon made it difficult to clearly position the company and its products in the various markets.

2.2. AWIS – the Automatic Wafer Inspection System

In 1985, work started on the first projects: the Automatic Wafer Inspection System AWIS, the LSM (Laser Scanning Microscope, later known as CLSM), and the opthalmoscope.

Soon after the foundation of Heidelberg Instruments, the company had won a contract with Siemens within their Superchip project (which started at almost exactly the time when Heidelberg Instruments was founded) to develop both a laser lithography system and an automatic on-line test system for semiconductor wafers to inspect chips for faults during manufacturing. The project ended in 1987 and resulted in the AWIS, but also the LPM and the LLS (see below).

The AWIS was a fully automatic wafer inspection station which could carry out critical dimension measurement and micro inspection, comparing the wafer to the design data and carrying out die-to-die inspection. The original specifications called for a smallest error of 0.5 µm to be detectable, with a pixel size of 0.2 µm. The system featured a fast laser scanner and highly accurate mechanical positioning of the wafer by means of a stage and interferometer. The optical scanner was realized with a polygon mirror, very expensive at the time and difficult to handle. Each polygon facet triggered the following step. The system used a multiprocessor concept to control the stage and the data processing, involving an ASIC (application-specific integrated circuit) to detect errors.

The AWIS however was not successful as a product, as both optical and electronic resolution were insufficient and did not meet the specifications required by Siemens, with 1 µm optical resolution and pixel size not even being enough to detect errors of 1 µm size. When the Siemens project ended, Heidelberg Instruments initially tried to continue the development on its own, however had to come to the conclusion that the overall concept – based on the changing requirements of the market at that time – was not viable anymore.

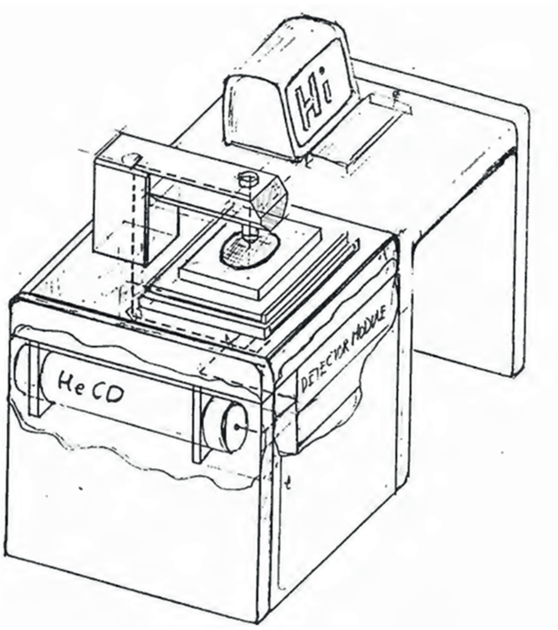


Figure 2.3-1 *Early project stage line drawing of the LPM Line Profile Measurement system*

2.3. LPM – the Line Profile Measurement System (1987)

This system also came about through the cooperation with Siemens in the framework of research on the “Superchip”. In 1987 the first LPM system was installed at Siemens.

The “Line Profile Measurement system” (LPM) was essentially a laser scanning microscope, however specifically developed for process control in microstructure manufacturing, including wafers, masks, and reticles. The principle of confocal laser microscopy was used to measure critical dimensions in the sub-micron range. The system was created following the construction of the AWIS and a project outline from the time reveals that the LPM built on the development of the AWIS and utilized some of its modules. The algorithms to measure line width and line center position with sub-pixel resolution are still used in the DWL systems today.

Chapter 10

THE HALLS OF ROHRBACH SUED

The new production facility which opened in 2002 ("Halle 3") was the first building to be planned, built, and owned by the company, and it represented a significant growth in production capacity. It was, however, only one part of the story of the Heidelberg Instruments building situation in Rohrbach Sued which altogether involved five halls and which deserves its own chapter.

10.1. The “Old Halle 2”

Originally, when the company had first moved there in 1994, the production department had been based in the souterrain of the headquarters (“Halle 1”) in Tullastrasse 2. After a couple of years, this space was no longer sufficient and around 1998 or 1999, part of the workforce moved to a different building at the other end of the street, in Tullastrasse 20. There the company had rented part of a big hall, a space that was designated “Halle 2” (Figure 10.1-1).

Figure 10.1-1 *The Old Halle 2, which around the turn of the millennium was used for the assembly of PCB systems and very large systems (image shows the entrance to Heidelberg Instruments’ part of the building on Hatschekstrasse).*

Figure 10.1-2 *The Interior of the Old Halle 2 featuring party tents (1999)*

The Heidelberg Instruments Halle 2 featured a number of “boxes” (a “box” came to denote a unit (cubicle or large room) where a machine would be assembled). Smaller systems frequently were assembled in the tried and tested party tents (Figure 10.1-2). A particularly useful attribute of Halle 2 was the fact that the office spaces were located directly next to the production hall, so that the trip from the desk to the machine was super quick.

It was later known as the “Old Halle 2” because there was to be a new hall with the same name several years later.

Figure 10.1-3 *December 2002 – Christmas party in the old Halle 2 (one of the “boxes” – production units – can be seen in the background on the right-hand side)*

10.2. Extension of “Halle 1”, the Headquarters

In 1999, the company growth was also reflected in the physical growth of the company’s headquarters: the building in Tullastrasse 2 (Halle 1), which originally consisted only of one floor above street level (plus the souterrain), was extended vertically, adding an entire second story on top (Figure 10.2-2 shows the construction in progress). This brought the overall floor area of the building to 1200 square meters. Most of the employees who joined later may not even have known that the second floor (consisting of a generous open-plan office space, plus a small kitchen and a large meeting room) had not always been there.

Figure 10.2-1 *Halle 1 in 1999 before building work started on the first floor*

Figure 10.2-2 *The construction of the second story on the building in Tullastrasse 2*

Until 2021, this building served as the registered company headquarters of Heidelberg Instruments and housed the company's administration, the mechanical workshop, the PAL (Process and Application Laboratory), Sales and Marketing, Service, and Documentation.

The extension to Halle 1 was just the beginning in fact for the construction work surrounding Heidelberg Instruments facilities – soon it would be joined by an entirely new building.

Figure 10.2-3 *In June of 1999, the workforce gathered on the steps of Tullastrasse 2 before embarking on a company trip.*

10.3. "Halle 3" – a Brand-New Production Building

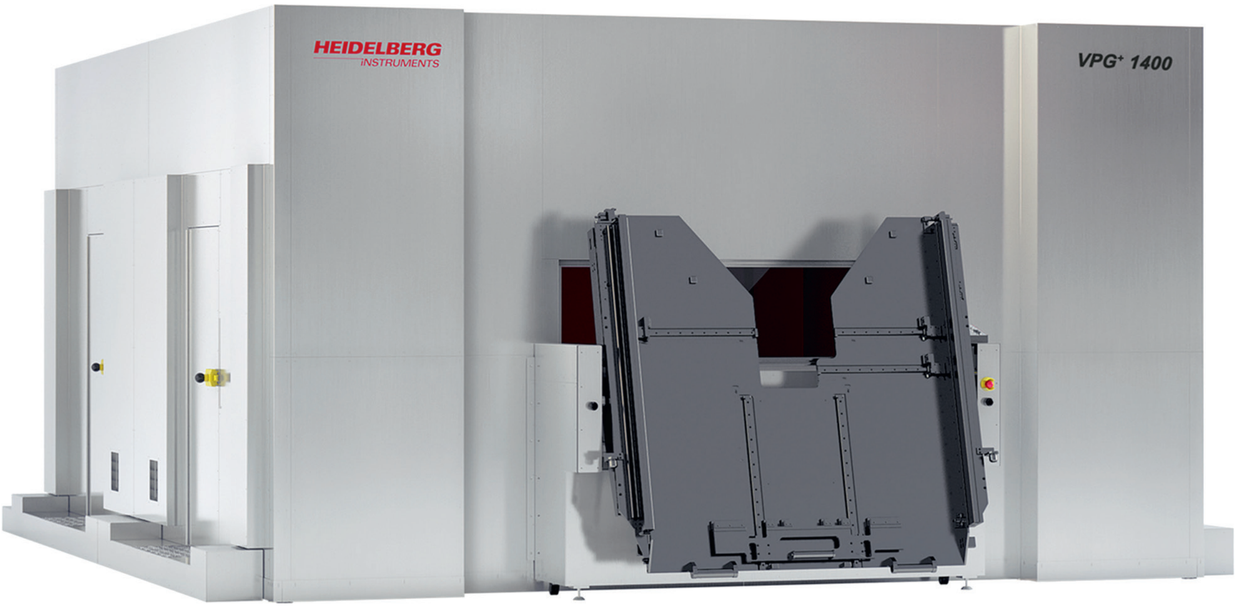
An interesting anecdote shows that to some extent the decision to build a new dedicated production facility evolved from the fact that a piece of land had already been obtained for a different purpose. The number of employees had continued to increase. This in turn meant that the company had to provide a correspondingly large number of parking spaces. There were only a handful of those in front of the building in Tullastrasse, so an empty piece of land around the corner was purchased and designated a parking area for Heidelberg Instruments employees. When sometime later the realization grew that the production space was at its full capacity, the idea was born to use that very plot of land to build a made-to-measure production facility for Heidelberg Instruments Mikrotechnik.

In the middle of May 2001, construction started on the new production facility. This was a memorable moment in company history, being the first ever time that Heidelberg Instruments planned and built a building to fit its specific requirements and needs. It was located on Englerstrasse, just around the corner from the company headquarters, about 3-5 minutes' walk away. The construction site was set back somewhat from the actual road, behind the first row of buildings, where the ground dropped a little. The five-story building was constructed with the help of prefabricated reinforced concrete parts and cost around EUR 3 million. The topping-out ceremony was held in August of 2001 (Figure 10.3-1).

area, were re-released at the same time, consisting of VPG^{+} 200 and 400, and VPG^{+} 800, 1100, and 1400. A few individual systems optimized for emulsion applications have also been produced (VPG^{+} 800 E).

The VPG^{+} 1400 (seen in Figure 20.1-2) is the largest Heidelberg Instruments system that is still in production today, designed for applications in the display industry such as touchscreens, flat panel LCDs, and AMOLED screens. In addition to its impressive, particularly powerful flowbox with four independent clean air and cooling systems it features a differential interferometer and advanced panel pitch optimization to prevent mura effects.

Figure 20.1-2 *The VPG^{+} 1400, the largest Heidelberg Instruments system still in production*



20.1.3. The ULTRA (2018)

The ULTRA was designed specifically to address the requirements of photomasks for the semiconductor industry, called reticles. The market surveys forecast high growth rates for reticles including laser written “mature” photomasks with relatively coarse features and low specifications.

The VPG (and VPG^{+}) had always been optimized for photomask production, however specifically those photomasks with minimum features between 1 µm and 4 µm, therefore addressing the market of chip packaging, MEMS, or flat panel displays (FPD). For those applications, the critical dimension (CD) and position accuracy do not underly such demanding specifications as they do in the semiconductor industry.

If a system based on VPG technology was to conform to semiconductor industry standards, a number of key components had to be completely redesigned. This included the optical modulator, the chuck, and the objective lens, which had been used already with great success in the VPG^{+} HR. The optical modulator used was the new version of the GLV, customized for Heidelberg Instruments, much faster than the previous versions, and supported by a newly developed interface board to handle the higher data flow. To avoid any thermal expansion, the ULTRA substrate chuck was no longer built from granite, but from Zerodur™, a material which exhibits zero thermal expansion, and which had been first used in the VPG HR. The chuck’s surface was optimized to avoid trapping of dust particles and to improve the

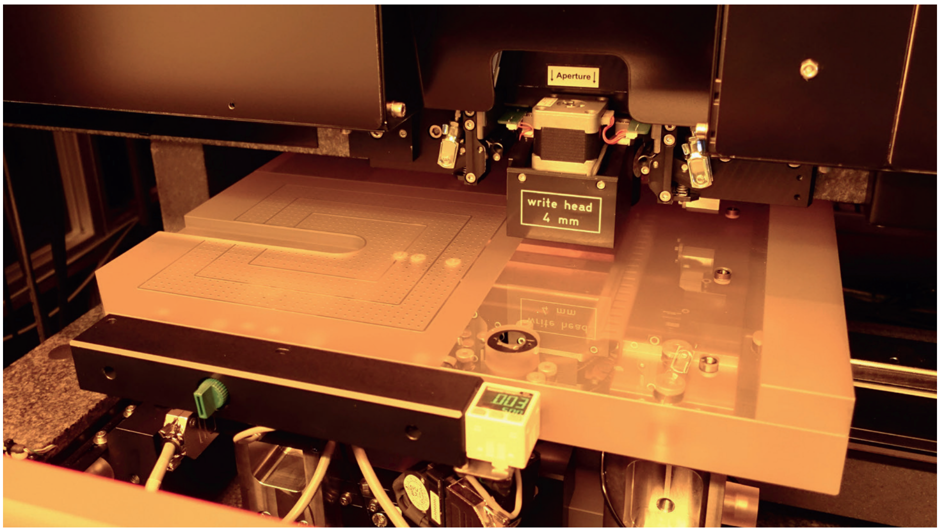


Figure 20.1-3 *The ULTRA stage featuring the Zerodur™ chuck*

distribution of the vacuum. The ULTRA stage with the Zerodur™ chuck can be seen in Figure 20.1-3. The system used a 355 nm laser and the high-specification lens (40x / NA 0.9) that had previously been developed for the VPG⁺ HR, a lens optimized for the 355 nm laser. The address grid was half that of the VPG HR, it featured improved optical components, and a new three-point support for the substrate which meant increased positioning accuracy.

Figure 20.1-4 *The ULTRA at the time of its launch in 2018*

The resulting system was named ULTRA (sometimes also ULTRA 200, reflecting the standard maximum write area of 200 x 200 mm^2). Figure 20.1-4 shows its appearance at the time of its launch. In August 2018, the first ULTRA was installed at a beta-site, a merchant photomask shop. The ULTRA offered a similar throughput as the new release of the Volume Pattern Generators, VPG⁺, but with even higher specifications for precision, stability and resolution. It specified a write time of 45 min for a 6″ x 6″ wafer at a resolution of 0.7 µm, and 75 min for a minimum feature size of 0.5 µm. The system was targeted at the production of mature photomasks in the semiconductor industry. While the smaller technology nodes can only be addressed with e-beam lithography, a large fraction around (50%) of the masks used in the semiconductor industry are still produced using laser lithography.

The ULTRA did successfully achieve the planned specifications and the reliability required of a production system. However, the market for mature photomasks was strongly contested and the competition was very active, and therefore, the number of sold and installed ULTRA systems fell short of what had been expected. Nevertheless, ULTRA systems were and still are being sold to Asia, in particular to merchant photomask shops.

Due to repeated customer enquiries, a direct imager (DI) for microstructures based on the VPG/ULTRA was later (2023) released as a dedicated system, optimized for direct writing. It was based on the VPG technology, but incorporated options specifically for the use of writing high-resolution microstructures in i-line resists.