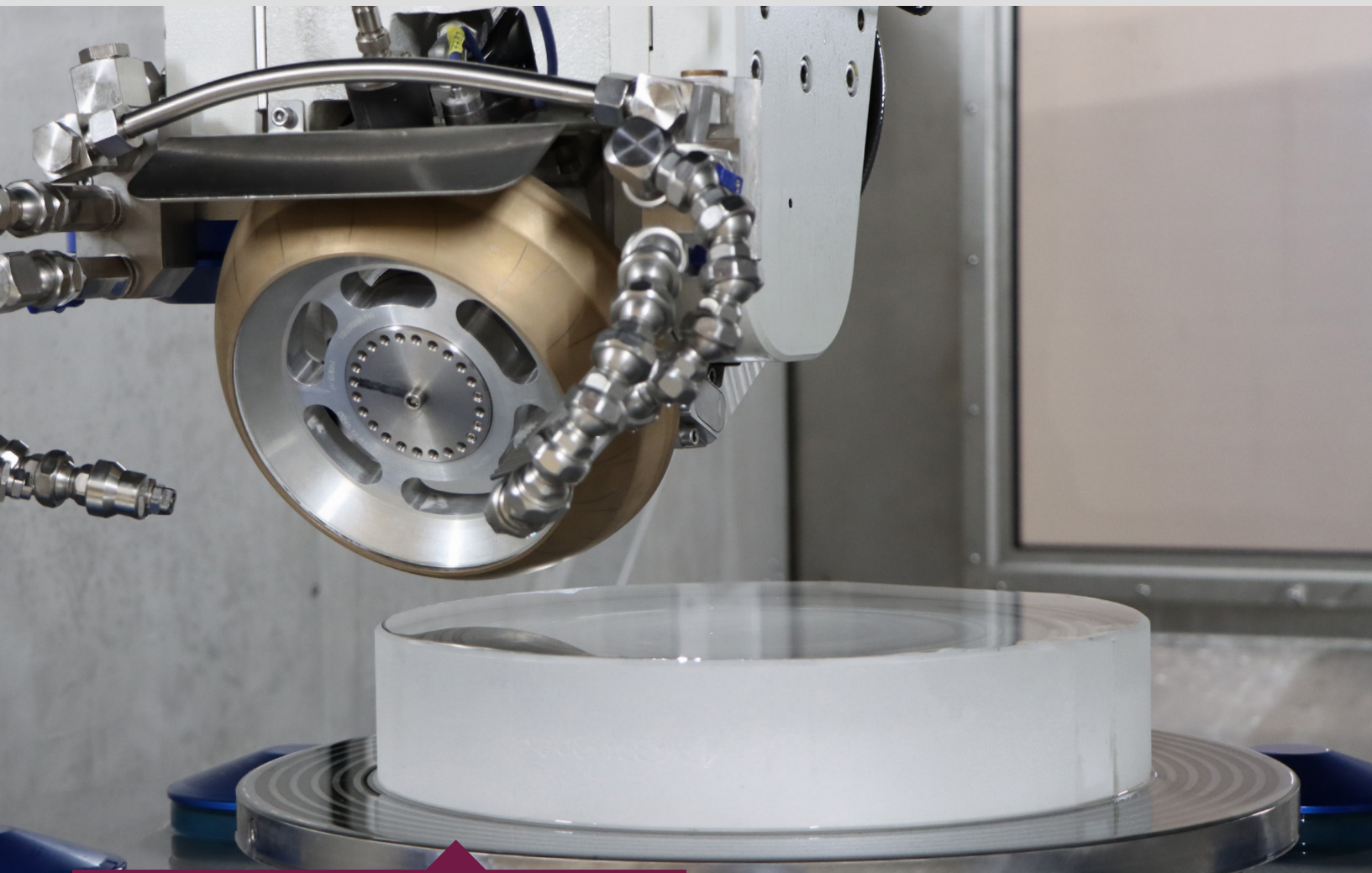




OptoTech

UPG Technology

Ultra-Precision Grinding of Advanced Optical Components With the OptoTech UPG-Series

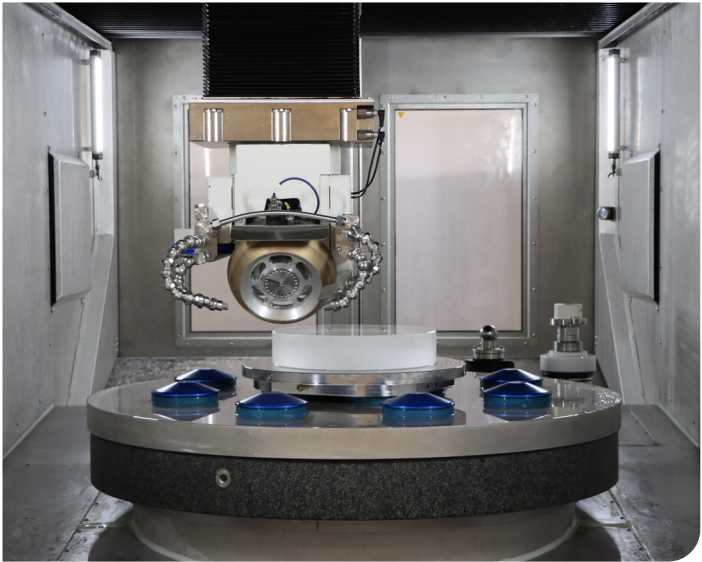


Rely on a technology that sets new standards: With ultra-precision grinding technology, optical components are manufactured with the highest accuracy. The near-complete elimination of subsurface damage reduces subsequent polishing effort to an absolute minimum – significantly accelerating your processes. For you, this means shorter lead times, lower manufacturing costs, and a fast return on investment. Precision that pays off.



ULTRA-PRECISION GRINDING
AS A KEY TECHNOLOGY

Ultra-precision grinding is a high-precision manufacturing process used to achieve **surface qualities and dimensional accuracy in the nanometer range**. It is particularly useful where conventional grinding processes reach their limits- for example, in the production of very high-quality optical components such as lenses, mirrors, or freeform optics. Ultra-precision machining is of key importance for companies that manufacture optical components, as competitiveness is increasingly determined by technological precision. Those who offer **tighter tolerances and better optical performance** prevail in the market. Ultra-precision machining is therefore a key process for the quality and innovation of optical products.



With its **UPG series**, OptoTech has created a completely new machine platform that offers its customers unprecedented grinding precision for component sizes up to 80, 500, 1000, 1500 and 2000mm. Back in the year 2000, OptoTech launched the ASM 300 CNC generator, our first machine with hydrostatic components that offered highest precision grinding for the first time. Based on this knowledge, we designed the **ultra-precision generator UPG 500 CNC in 2009 - the first of it's kind in the optical industry** and the start of a new era in high-end optical processing. In 2013, OptoTech successfully delivered the **UPG 2000 CNC - the largest and, with a weight of over 80t, also the heaviest optical processing machine in the world**.



	UPG 80 CNC-2C	UPG 500 CNC	UPG 1000 CNC	UPG 1500 CNC
Working Range Diameter	10 mm - 80 mm	10 mm - 500 mm	10 mm - 1000 mm	10 mm - 1500 mm
Amount of Axes	4 (X, Y, Z, C)	4 (X, Y, Z, C)	4 (X, Y, Z, C)	4 (X, Y, Z, C)
Dimensions (w x h x d)	1800 x 2400 x 2500 mm	3325 x 2960 x 3550 mm	3650 x 3800 x 3800 mm	5000 x 3900 x 4350 mm
Weight (approx.)	approx. 5000 kg	approx. 15500 kg	approx. 32000 kg	approx. 58000 kg

BENEFITS OF ULTRA-PRECISION GRINDING AT A GLANCE



Highest
Accuracy



Ultimate
Lens Quality



Lowest Subsurface Da-
mage (SSD) <5µm



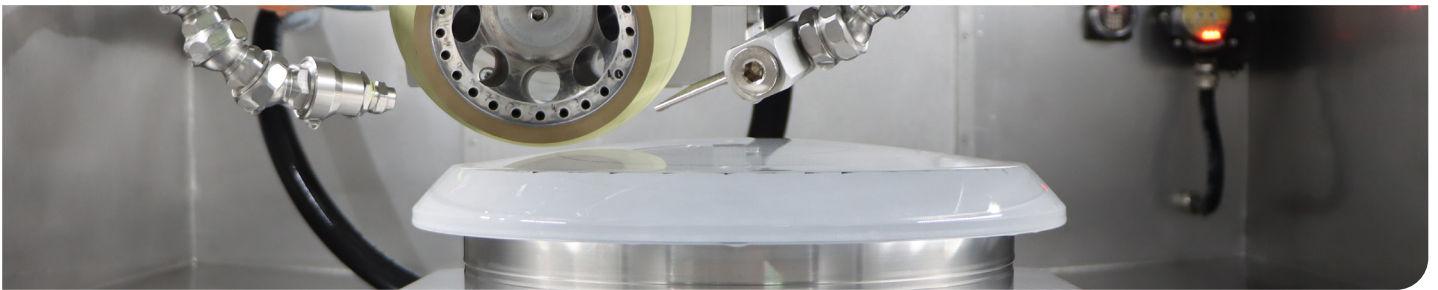
Lowest Mid Spatial
Frequency Errors (MSF)



Huge Polishing Time
Reduction (>10x shorter)



Fastest Return on
Investment



MOTIVATION FOR ULTRA-PRECISION GRINDING OF OPTICAL COMPONENTS

The continuous increase in performance requirements for optical systems, especially in EUV lithography, has driven demand for optics of the highest quality at industrially scalable volumes. At the same time, cost efficiency in production remains a decisive factor.

Within the optical manufacturing chain, polishing represents the most time- and cost-intensive step. The **main limitation arises from mid-spatial frequency (MSF) errors**, which cannot be efficiently corrected in the polishing process and thus significantly affect both process time and final surface quality.

Ultra-precision grinding provides a highly effective solution to this challenge by **reducing the MSF to the lowest level** and by **minimizing the Subsurface damage (SSD)** in the optical component. Our grinding machines are designed with:

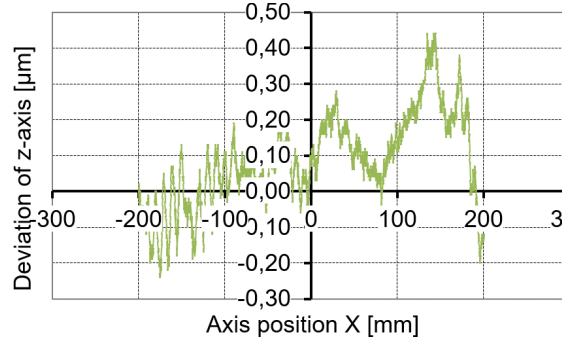
- A thermally stable and rigid granite machine base
- Hydrostatic guides in all linear axes for friction-free motion
- Hydrostatic spindles ensuring highest rotational accuracy
- Smart, precise thermal management of drives, hydraulics, and cooling ensures excellent workpiece surfaces
- Advanced process control strategies for stable and repeatable results

This system architecture enables the generation of surfaces with **subsurface damage (SSD) below 5 µm**, precise enough to be measured interferometrically.

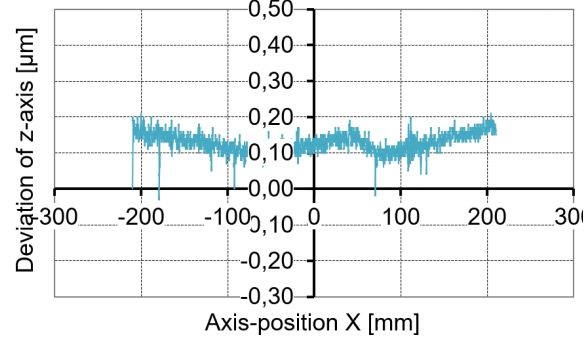
Compared to a conventionally manufactured lens, an ultra-precision ground lens can be polished **more than ten times faster**.

Comparison of Precision and Ultra-precision Grinding: AXIS DEVIATION

Precision Grinding Machine: Axis deviation of X-axis to Z-axis



UPG Machine: Axis deviation of X-axis to Z-axis



- Significant differences between the deviations of the axis systems between precision and ultra-precision grinding machines
- Less fluctuations in the UPG axis system due to hydrostatic bearings
- Absolute deviation precision $\Delta z_{\text{precision}} = 0,63 \mu\text{m}$ vs. $\Delta z_{\text{UPG}} = 0,12 \mu\text{m}$



More than 5x higher precision with the UPG series

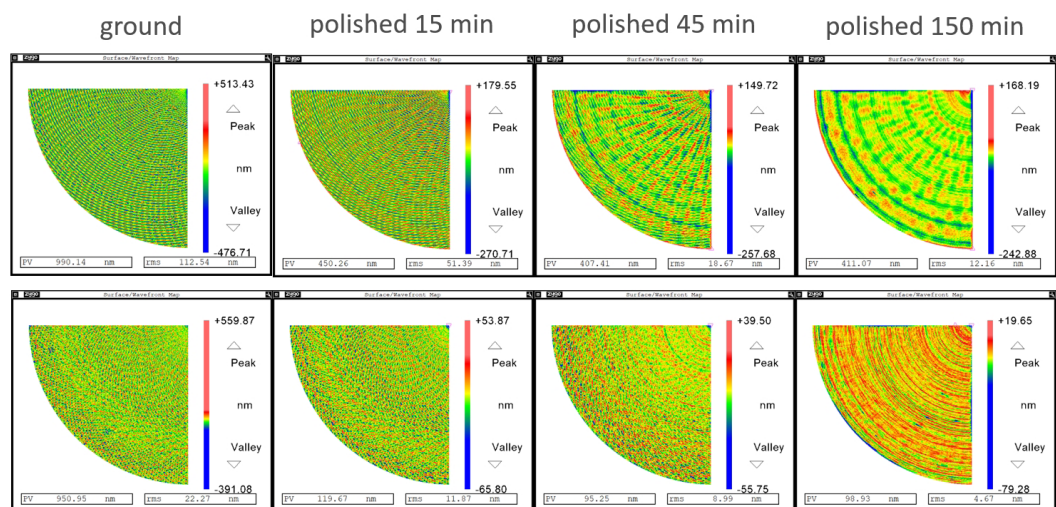
Comparison of Precision and Ultra-precision Grinding: HIGH FREQUENCY ERRORS

Precision Grinding:

Reduction of the rms value from 112nm to 12nm

UPG:

Fast reduction of the rms value with very low baseline value from 22nm to 4.6nm

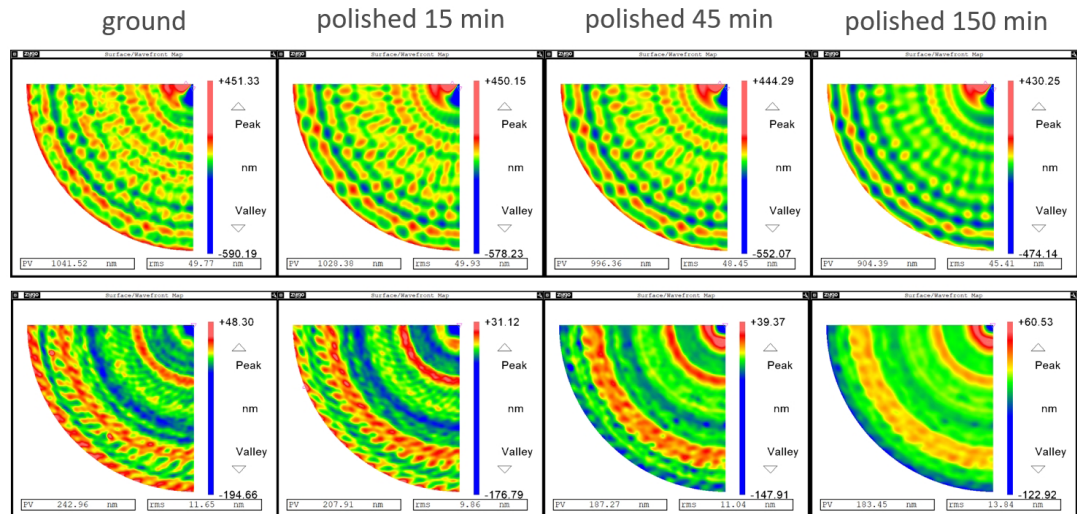


RMS of the high-frequency errors is significantly lower before and after polishing

Comparison of Precision and Ultra-precision Grinding: MID-SPATIAL FREQUENCY ERRORS (MSF)

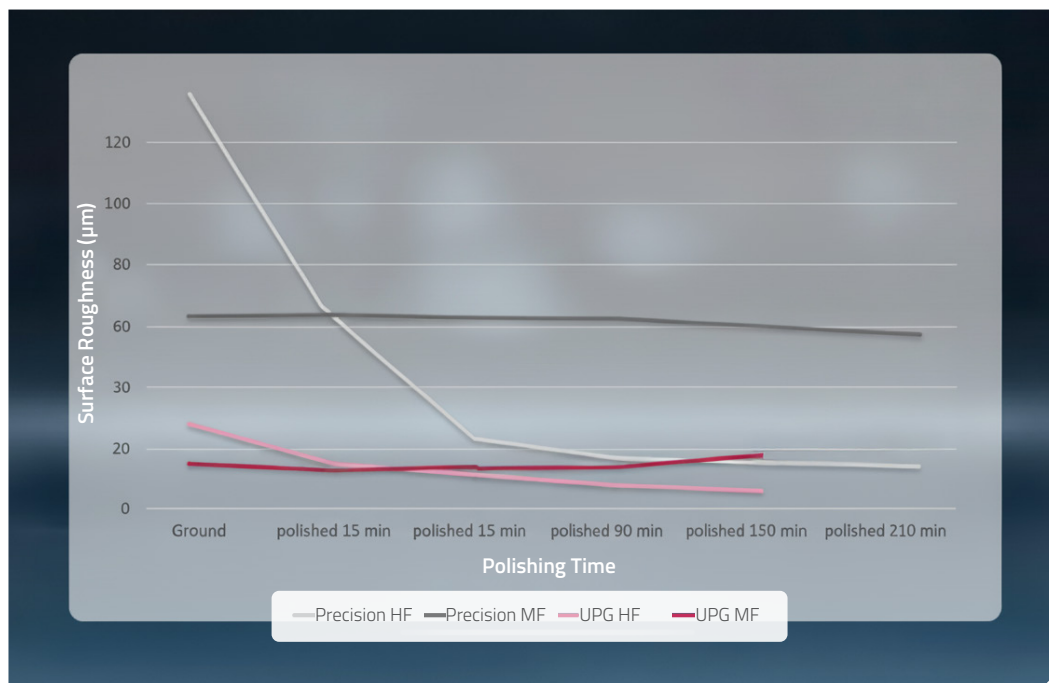
Precision Grinding:
Slightly decreasing rms
value, starting at
50nm

UPG:
Constantly low rms
value at
11.6nm



MSF can't be removed by polishing. MSF are on a lowest level due to UPG technology

Comparison: DEVELOPMENT OF SURFACE QUALITY OVER POLISHING TIME



Starting values of UPG already 5x better compared to precision grinding
Polishing time >10x shorter (15 min Ultra-Precision vs. 210min Precision)

LOWEST SUBSURFACE DAMAGE

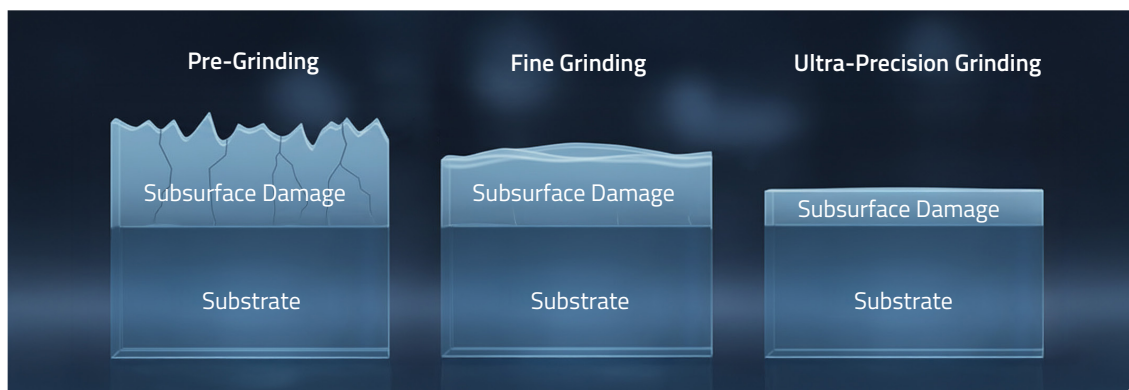
About Subsurface Damages (SSD)

During the grinding of hard brittle materials such as optical glass, ceramics, silicon wafers, and sapphire, **subsurface damage (SSD)** refers to the microstructural alterations and defects that occur beneath the machined surface. These defects result from crack initiation and propagation caused by abrasive interactions during grinding. In simple terms, SSD represents hidden flaws beneath the surface that **weaken the material's strength, reliability, and optical performance**.

SSD significantly affects the mechanical and optical quality of components. While subsequent polishing and finishing operations can remove the damaged layer, the time and effort required depend directly on the quality of the preceding grinding process. Poor grinding produces deeper SSD, increasing polishing time and cost, whereas **high-precision grinding minimizes SSD depth**, improving both efficiency and final product quality.

Each grinding and polishing step is designed to remove enough material to reach the deepest defects left by the previous step, gradually reducing SSD. Polishing can reduce SSD to less than 1 µm after fine polishing. However, even with very fine abrasives, **SSD cannot be completely eliminated, and finer polishing steps increase processing time and cost**.

Therefore, **controlling subsurface damage during grinding and polishing is essential**. Proper management of SSD ensures material strength, optical performance, and efficient production of high-quality components.



Influence of Grinding Technology on Subsurface Damage and Polishing

The quality of the grinding process plays a crucial role in determining both the type and severity of subsurface damage (SSD) and the subsequent polishing effort required for optical components. **SSD can be broadly classified into high-spatial frequency (HSF) defects and mid-spatial frequency (MSF) defects**, which behave differently during finishing:

- **High-spatial frequency (HSF) defects** are relatively larger-scale subsurface flaws. These defects **can be removed effectively through polishing**, and the time required for polishing depends directly on the initial surface quality produced during grinding. Better initial surface quality results in shorter polishing times and higher efficiency.
- **Mid-spatial frequency (MSF) defects** are finer-scale flaws that **cannot be significantly reduced by polishing**. If MSF defects are introduced during grinding, they will remain in the surface, negatively affecting optical performance. The only way to prevent poor MSF defects is through **high-quality grinding technology**.

In this context, **ultra-precision grinding** offers a significant advantage. By **minimizing both HSF and MSF defects from the start**, it ensures a **high-quality initial surface, reduces polishing time, and improves the overall mechanical and optical performance** of brittle materials. This demonstrates that the correct grinding technology is not only essential for surface quality but also for process efficiency and cost-effectiveness in optical component manufacturing.



Leading to the Solution: the Need for Ultra-Precision Grinding

Given the critical impact of subsurface damage on component quality and production efficiency, it is clear that **reducing SSD at the grinding stage is key** to improving the entire manufacturing process. Conventional grinding methods inevitably produce SSD that must be removed through time-consuming polishing steps, which increases both processing time and cost.

Ultra-precision grinding technology offers a solution by **significantly minimizing the formation of subsurface damage** during grinding. By controlling abrasive interactions with extreme precision, this technology reduces the depth and severity of SSD, which in turn dramatically decreases the amount of polishing required. As a result, ultra-precision grinding not only preserves the mechanical and optical quality of brittle materials but also **enhances overall process efficiency and cost-effectiveness**, making it a highly attractive approach for manufacturing high-quality optical components.



Ultra-Precision Grinding leads to SSD < 5µm, depending on substrate and tool

FASTEST RETURN ON INVESTMENT

Due to the **huge time savings in the polishing process**, adding an **ultra-precision generator** to your production will not only boost your productivity, but also monetary **pays off after shortest time**. The technological advantage is **greater the larger and more expensive the manufactured optics are**.

An **OptoTech UPG** usually **pays for itself after just 2 years***, because of

- **Significantly higher optical surface quality** after ultra-precision grinding
- **Huge polishing time savings**
- **Higher productivity** in optics manufacturing
- **Lower costs per lens**
- **Significantly higher profit margin**

*Assumptions:

- High-end Ø250mm lens with approx. 3.300€ profit per piece
- Pre- and fine grinding before ultra-precision grinding
- Pre-polishing and corrective polishing
- 2 shift manufacturing (8h per shift)
- Surface quality after UPG will be 50% better compared to standard CNC grinding
- Polishing time will be at least 50% shorter
- Profit margin with a UPG is 20% higher



With UPG-Technology, return on investment is possible after just 2 years*

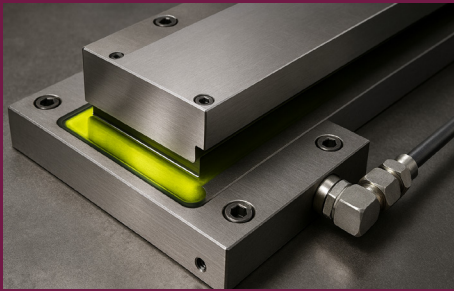


ADVANCED HYDROSTATIC COMPONENTS

Precision Through Superior Hydrostatics

Our group has pioneered hydrostatic technology and today ensures a **secure and stable supply chain** for these critical components. With decades of proven expertise, we integrate advanced hydrostatic solutions that deliver **unmatched stiffness, damping, and vibration absorption**—two essential factors for achieving **ultra-precision grinding**.

In the **UPG Series**, these hydrostatics provide a **level of stability and precision that conventional systems simply cannot match**. **Hydrostatic guidance in all linear and rotary axes** ensures **excellent smooth running, freedom from wear, and maximum positioning accuracy**. High stiffness allows tools and workpieces to maintain their exact positions under load, while optimized damping **absorbs vibrations and eliminates chatter** – ensuring **perfect surface finish and form accuracy**, even under the most demanding conditions.



Hydrostatics – Precision through Fluid Bearing Technology

In hydrostatics, moving machine parts are not supported by direct contact but by a **thin film of pressurized fluid**. This technology **virtually eliminates friction and wear**. In mechanical engineering, it offers decisive advantages: **outstanding smoothness of operation, excellent damping characteristics, extreme positioning accuracy, and significantly extended component lifetime**. The result is machines that operate **reliably, precisely, and efficiently – even under the highest loads**.

Unique Technological Advantages

Wear-free operation

Contact-free guidance ensures long-term, consistent precision with minimal maintenance. Unlike conventional systems, wear is eliminated, enabling accuracy that remains unchanged for decades, extremely low maintenance, and maximum machine uptime.

Extreme stability

Thanks to our patented hydrostatic technology, **stiffness is up to 5x higher** compared to conventional solutions, while simultaneously delivering superior damping. This unique combination suppresses chatter, minimizes tool deflection, and ensures **perfect surface finish and dimensional accuracy**.

Thermal Stability – Zero Drift

With integrated oil recooling, **thermal drift is virtually eliminated**. Machines equipped with hydrostatics operate at a **constant temperature**, ensuring accuracy from the very first workpiece and stable performance throughout extended production runs.

Perfect Motion Control – No Stick-Slip

Friction effects such as stick-slip can severely limit accuracy during directional changes or at low feed speeds. With hydrostatic guides, friction is proportional to speed and remains extremely low. This **ensures smooth reversals, stable feed at micrometer levels, and flawless contour accuracy** without reversal marks.

Exceptional Run Quality

Hydrostatic spindle bearings and guides achieve **radial and axial runout below 0.1 µm, with peaks as low as 30 nm**. This **extraordinary smoothness** translates into **ultra-precise machining results, even at maximum speeds and under heavy loads**.

For the customer, this translates into machines capable of producing **flawless surfaces, maintaining peak accuracy over time, and running with minimal downtime**. With hydrostatics, the **UPG Series delivers ultra-precision grinding performance today – and for decades to come**.

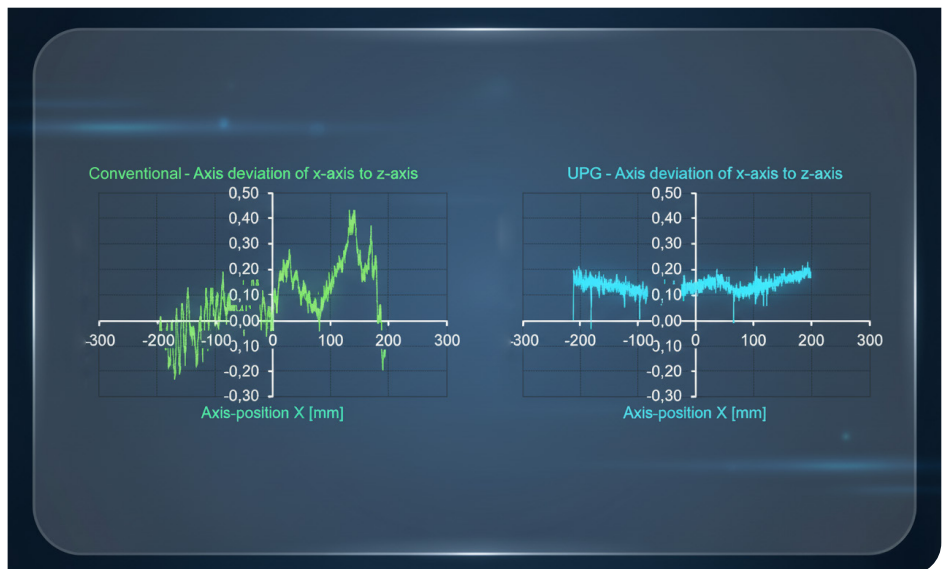
Measured Advantages – Axis Deviation (Conventional vs. Hydrostatic)

To validate the benefits of hydrostatics, we conducted a direct comparison between two machine configurations: one system with **conventional bearings** and another with **hydrostatic bearings**. The deviation of the X-axis relative to the Z-axis was measured under identical conditions. The results clearly demonstrate the **decisive performance advantage of hydrostatics**:

1. Absolute Deviation:

- conventional: $\Delta z = 0.63 \mu\text{m}$
- hydrostatic: $\Delta z = 0.12 \mu\text{m}$

**More than 5× higher precision
with hydrostatics**



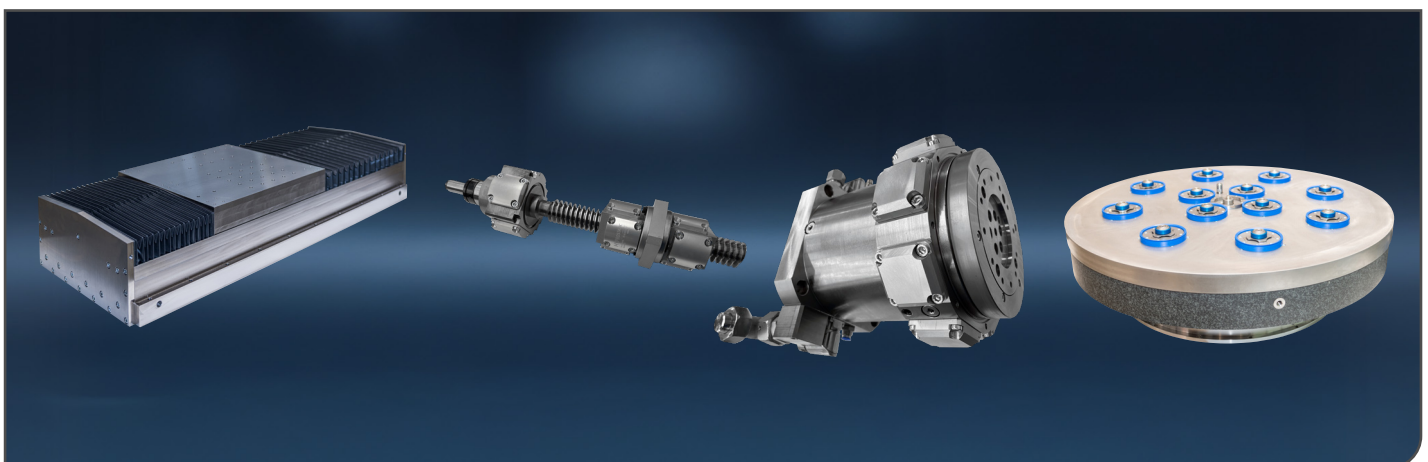
2. Motion Stability: The UPG system exhibits far fewer fluctuations thanks to hydrostatic bearings.

3. Error Elimination: Rolling effects in the cylinder running surfaces, visible in conventional systems, are **absent in hydrostatics**.

Result: Hydrostatic bearings ensure **stable axis behavior, smoother motion, and consistently superior machining accuracy**.

Proven Expertise in Optical Grinding

We have been successfully applying **hydrostatic components in optical grinding machines since the early 2000s**. Building on this expertise, we introduced our **first UPG in 2009**, marking a milestone in ultra-precision grinding technology. Since then, our **continuous refinement and deep know-how** in hydrostatic integration have established us as a **trusted leader in optical grinding solutions**.



Hydrostatic Components (left to right): Hydrostatic Guides, Hydrostatic Thread Rod, Hydrostatic Spindle, Hydrostatic Table



CORE COMPONENT: PRECISION GRANITE BASE

Naturally Stable. Technically Perfect.

The foundation of the UPG machines is made of **high-precision granite** – a natural material to **maintain precision over many years of operation**. Its **dense, stress-free structure** maintains **dimensional integrity under heavy loads** and over extended periods, making granite the ideal base for ultra-precision machinery. Compared to metallic materials like steel or cast iron, granite offers clear advantages that directly **enhance machining accuracy, reliability, and long-term performance**.



Key Advantages of the Granite Base:

- **Exceptional Thermal Stability** – Low thermal expansion and heat conductivity ensure **consistent precision** even under fluctuating temperatures. Granite expands far less than steel or cast iron, **preserving geometry and alignment**.
- **Active vibration damping** – Granite **absorbs vibrations, resulting in extremely stable measurements and perfect surface finishes**. Material **damping is more than ten times higher** than steel or cast iron, **enhancing positional accuracy, surface finish, and tool life**.
- **Long-term dimensional stability** – Granite retains its shape over time, keeping tools and workpieces **perfectly aligned**.
- **Chemical resistance** – Acid- and alkali-resistant, non-conductive, ideal for **sensitive environments such as cleanrooms**.



Precision Meets Performance

Granite easily meets **DIN 876 flatness standards for accuracy grade 00**, achieving **tolerances as tight as 1 µm**. Its **hardness and specific weight** support **higher feed rates and faster axis accelerations** without compromising precision.

Result: The granite base enables **UPG machines to deliver ultra-precise results down to the micrometer level ($\leq 1 \mu\text{m}$)**, making it the **optimal foundation for ultra-precision grinding**.

MASTER YOUR PROCESS WITH TRUSTED SIEMENS CONTROL

- **Proven Siemens Sinumerik One CNC-controller** for maximum process stability and availability
- **Decentralized computer architecture** (HMI-NC & PLC on separate computers) ensures reliable manufacturing, even for high-value workpieces
- **Precise machining** of even the most complex workpiece geometries
- **OptoTech and Siemens expertise** in drives, servo controllers, and CNC path control **for sub-µm accuracy**
- **Demonstrated path accuracy of 500 nm** on the UPG 500 CNC at the Tool-Center-Point
- **Proprietary OptoTech CAM software "F-Cube"** with closed-loop interfaces to UP measuring machines
- **Optimal generation of ultra-precise, optically effective surfaces** on UPG machine platforms



OptoTech processing cells for ultra-precision production **SAVE TIME & MONEY**



80 Series

Processing cell with closed loop metrology for workpieces up to 80mm (depending on lens geometry):



MCG 150 CNC
Pre- & Fine Grinding



UPG 80 CNC-2C
Ultra-Precision Grinding



MCP 150 CNC
Corrective Polishing



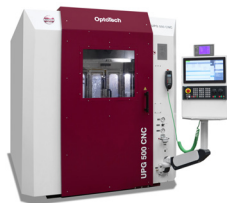
OWI 150 XT 1500
Measuring

500 Series

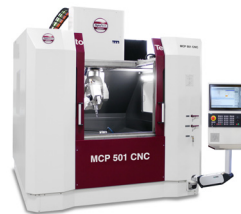
Processing cell with closed loop metrology for workpieces up to 500mm (depending on lens geometry):



MCG 500 CNC
Pre- & Fine Grinding



UPG 500 CNC
Ultra-Precision Grinding



MCP 501 CNC
Corrective Polishing



MSI 300
Measuring

1000 Series

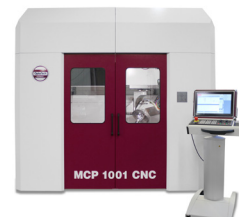
Processing cell with closed loop metrology for workpieces up to 1000mm (depending on lens geometry):



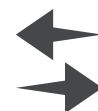
MCG 1000 CNC
Pre- & Fine Grinding



UPG 1000 CNC
Ultra-Precision Grinding



MCP 1001 CNC
Corrective Polishing



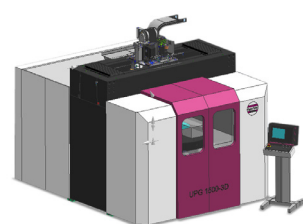
Measuring
Technology

1500 Series

Processing cell with closed loop metrology for workpieces up to 1500mm (depending on lens geometry):



MCG 1000 CNC
Pre- & Fine Grinding



UPG 1500 CNC
Ultra-Precision Grinding



MCP 1501 CNC
Corrective Polishing



Measuring
Technology



OptoTech

WHY CHOOSE OptoTech?

- Market leading company for precision optics machinery
- 40 Years experience in optical machinery manufacturing
- Complete processing cells available - All from one source
- Pioneer in ultra-precision grinding machinery - First in industry
- +25 Years in building optical machinery with hydrostatic components
- Hydrostatic components integrated in OptoTech Group supply chain
- +15 Years experience in building ultra-precision grinding machines
- Numerous UPG installations worldwide
- Fast return on investment due to huge polishing time savings
- Scalable technology from diameter 80mm to 2000mm
- Experienced staff for worldwide service



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