Precise Custom Manufacturing

Even in a highly industrialized society, there are still many areas in which success is not defined by large quantities but by individual, custom precision work. This often leads to intensive cooperation between specialized companies that mutually benefit from the other's technical skills and wealth of experience. A good example of this is the long-standing collaboration between the Schleswig-Holstein-based laser contract and optical systems manufacturer NU*TECH* and LASER COMPONENTS, a specialist for optical and optoelectronic components from Bavaria.

If pipes or hollow bodies are equipped with coatings to protect against corrosion and regular wear and tear, the interior cannot be processed using conventional tools. This presents a special challenge. In this specific field, NU*TECH* GmbH has established itself as a leading solution provider over the past few decades. NU*TECH* develops laser beam tools – so-called internal coating optics – which can guarantee uniform laser deposition welding for openings that have a diameter of 25 mm and larger. One optic seldom resembles the other because, in addition to diameter and penetration depth, the customer's deposition material and laser source must also be considered during development. Furthermore, the technology must be able to withstand demanding environmental conditions: Short operating distances, high ambient temperatures, and air pollution caused by smoke and powder subject tools to very high stress.

For this purpose, NU*TECH* has developed a modular system with which the most diverse customer requirements can be fulfilled promptly and economically. The laser beam is usually fed into the tool via a fiber and then collimated, focused, and deflected by lenses and mirrors. At the end of the up to two-meter-long internal coating optics, the beam meets the coating powder on the surface to be processed, which is simultaneously blown in through a nozzle from the side. This allows the powder layer, which is evenly applied to the interior of the object to be processed, to be fused at a power level of several kilowatts. The maximum processing power results from the possible size of the tool. The larger the opening for the tool, the higher the possible processing power and thus also the application rate or hardened surface per unit of time.

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The application of uniform interior coatings is a major challenge.

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Internal coating optics from NU*TECH* are modular

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Creating the Right Design through Expert Collaboration

The selection of the right lenses for the optical system is crucial to this assembly. In fact, the lenses must be designed to allow the beam to reach the exit position with as little loss as possible. This is particularly important regarding the free-beam distance, which at up to two meters is unusually long for industrial lasers, because it keeps the power density at the desired level. The type of input coupling laser used must also be considered. A wide variety of laser types and their associated beam parameter products require the design of adapted beam paths.

Torsten Bady, head of laser system technology at NU*TECH*, can affect four factors in the design of his optical system: radius, thickness, the curvature radius of the individual lenses, and their distances from each other. Optical properties are also affected by the dielectric coating of the lenses. Mr. Bady creates a computer model based on this information. The optical assembly changes depending on the design of the internal coating lance.

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A laser beam joins the coating powder with the interior of the pipe.

Theoretically speaking, it is possible to create all types of spherical lenses. It is crucial that the beam be well focused when it hits the surface of the workpiece at the end of the transmission path because this is where the power density required for the process must be achieved. The stability of the lenses is also an important aspect. At high laser power levels, even high-quality lenses heat up, and the material expands. Since quartz glass and the surrounding metal frames have different coefficients of expansion, the lens may not be too tightly enclosed; otherwise, it could be damaged during operation. However, the positional accuracy must be maintained.

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Lenses are tested with an interferometer.

Bady sends the specifications calculated by the computer to René Sattler at LASER COMPONENTS. As a laser optics product engineer with many years of experience, Sattler knows what is important to his customers. At the same time, he is also familiar with LASER COMPONENTS' production facilities and can therefore quickly determine whether the desired parameters can be met or whether he should suggest modifications. In most cases, after some iteration, both arrive at a result that can be easily implemented in production and simultaneously meet the beam requirements of the end customer. "In this step, it is particularly important that the supplier knows exactly what our requirements are," says Torsten Bady. "Like us, LASER COMPONENTS is a medium-sized company that specializes in customized solutions. While many manufacturers do not allow deviations from the 'catalog article,' Mr. Sattler is a competent partner with whom I can discuss detailed questions."

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Small Quantities Facilitate High Quality

Once both partners have agreed on a lens design, Christian Grunert – production manager at LASER COMPONENTS – and his team can get to work. The grinding and polishing machines at LASER COMPONENTS are designed for substrates with diameters from 12.7 mm to 55 mm. In contrast to industrial mass production, each substrate blank is individually clamped in the grinding machine; the machine is then adjusted separately for each type of lens. A so-called cup grinding tool – an open cylinder with diamond-coated cutting edges – is applied at a certain work angle. During the grinding process, the rotating tool removes the substrate material in such a way that a curved surface is created. The ground surface is then polished. A separate polishing tool must be used for each diameter and radius of curvature. Over the years, the manufacturer has accumulated a stock of several hundred tools. Thus, as experience increases, so, too, do the technical possibilities for the practical implementation of customer requirements.

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Many operational steps occur in a cleanroom environment.

One important aspect of the production of single pieces and small quantities is quality inspection. It is possible to test each lens individually for irregularities. For this purpose, it is examined in a high-performance interferometer after the first polishing step. Software shows where and how much the examined lens deviates from the ideal shape. The data is transmitted directly to a magnetorheological finishing (MRF) machine, where each "error" is individually reworked, resulting in an almost perfectly shaped lens with a maximum deviation of $\lambda/10$. Upon request, it is also possible to achieve an accuracy of up to $\lambda/20$.

The required precision is achieved by applying the magnetorheological polishing process: the workpiece is fixed above a wheel, which is coated with special, magnetically sensitive fluid. This so-called MR liquid changes its viscosity under the influence of magnetic fields and solidifies within milliseconds. The polishing material briefly touches the lens surface with a subaperture, and an ultra-thin layer of glass is removed. Removal is controlled by a computer based on the surface structure determined in the interferometer.

"These repeated checks and corrections are very important because when you custom manufacture small quantities, as we do, every piece must fit," says Christian Grunert, production manager for laser optics at LASER COMPONENTS. "We rely on a combination of the many years of experience of our employees and modern technology."

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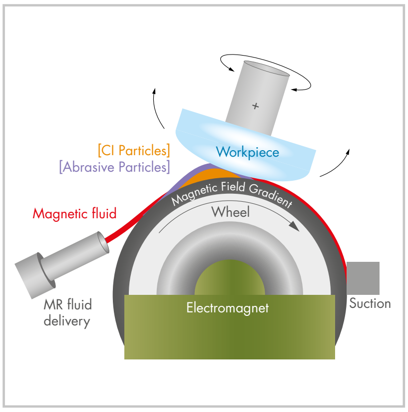
Custom Optimization through Technical Flexibility

After careful cleaning in a multi-frequency ultrasonic washing machine, the polished lenses are checked again to ensure that their surfaces are optimally prepared for subsequent coating.

Customer requirements are also the focus in the coating process. Grunert and his team can choose from different processes – each with its own advantages and disadvantages. For example, although ion beam sputtering can be used to produce particularly complex coating systems, the stress induced by this can cause the lenses and mirrors to deform. This effect hardly occurs with a conventional e-beam coating process; however, cavities that lead to water retention and thus cause a temperature-dependent spectral shift can form in coatings that are less compact. "We always choose the process that produces the best results for the customer," says Grunert. "We are also particularly proud of this flexibility because not all companies can rely on so many different options."



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The magnetorheological polishing process uses a magnetically sensitive liquid to correct the smallest irregularities.

The manufacturing process ends with an additional quality inspection, in which all surface imperfections in the substrate and coating are recorded and evaluated by experienced specialists. In fact, a high-tech device is also available for this step to objectify the results in terms of quality; however, it has been found that trained eyes with decades of experience usually achieve the same results faster.

Customization Pays Off

Torsten Bady appreciates the flexibility and quality of work provided by his partner. "I usually only need three or four lenses for my optics," he explains, "but everything has to be just right with them. Since no two lenses are alike, there are always new challenges to overcome. This can only be done with a partner who understands the field and who also sets the highest standards for his own work with each individual lens."

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