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SCHOTT Aspherical Lenses

From head-up-displays to industrial lasers: Aspherical lenses optimize performance

Introduction

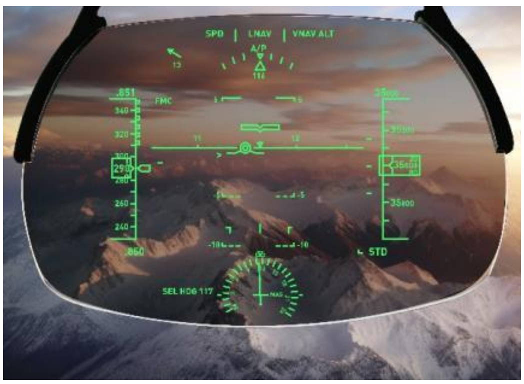
SCHOTT Academy of Optics is a free, online seminar series designed to take your industry knowledge and expertise to new levels.

Throughout the series, you will learn from leading glass and material experts as they cover various topics pertaining to the optics industry.

Visit our website for more information or to register for an upcoming seminar: schott.com/trainings/academy-of-optics

Aspherical lenses offer significant advantages in various optical applications due to their unique ability to eliminate spherical aberration, resulting in superior image quality or the ideal laser beam profile for cutting or welding. These lenses can reduce the number of elements required in an optical system, contributing to more compact and lightweight designs. Their versatility makes them ideal for use in advanced display systems such as the head-up display (HUD) systems used in aviation or in the high-power laser heads.

1. Boosting quality in HUD systems



One key application for high-end aspheric lens are HUD systems, which are used in military and civil aircraft to display crucial information in the line of sight of the pilot using the “head up eyes out principle.” Today’s HUD systems consist of a projector and a combiner screen, which use various optical components such as spherical lenses, aspheres, and mirrors to project and display information.

Aspheric lenses are used in this application because of their ability to mitigate aberrations. For example, truncated aspheres are often used in the optical projection path of the projector. Aspheres can also be combined into doublets to accomplish color correction by focusing different wavelengths onto the same image plane.

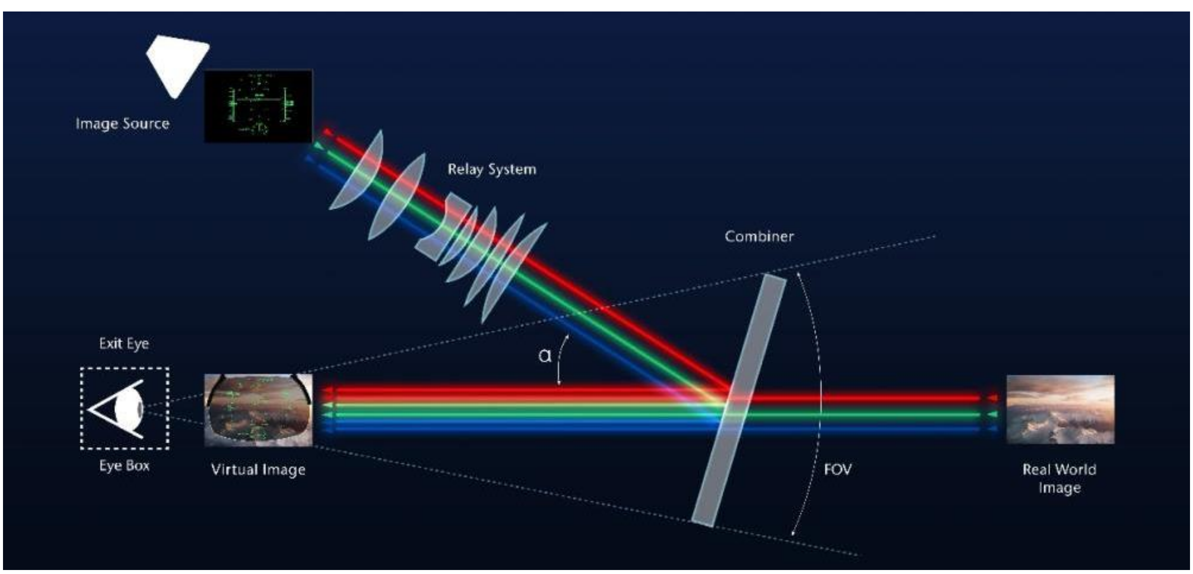


Figure 1: HUD system.

Optical components used in HUD systems must fulfill strict criteria for performance and reliability. One solution from SCHOTT are optical glasses with a unique combination of properties, including a high refractive index/low dispersion, tight optical position, high homogeneity, and high transmission. These glasses are ideal for HUD systems, available in large formats, and produced soley in Europe.

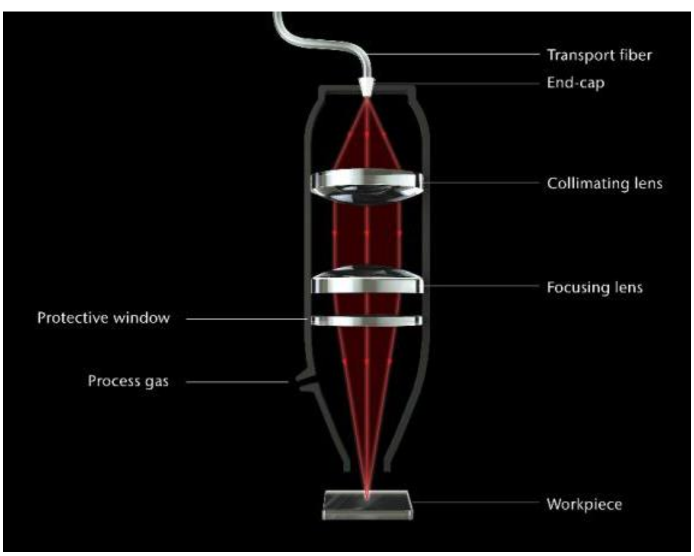
SCHOTT can also draw on our large optical glass portfolio to manufacture aspheric lenses with diameters of up to 200 mm and even up to 300 mm in some cases. For the aspheric lenses used in HUD systems, the irregularity is often in the range of IRR < 1 fringe with a max slope error < 0.15 mrad. The lens centering also has tight requirements, with an edge thickness variation (ETV) typically < 0.010 – 0.020 mm.

Depending on the HUD system's space requirements, CNC edging, and truncation — to create a lens with a squared top and bottom — might be needed. We also perform a variety of durability tests for optical coatings and cementing, according to various avionics standards.

SCHOTT is at the forefront of aspheric lens innovation, delivering exceptional performance for aerospace and defense applications. For example, we recently made an aspheric lens with a gull-wing design and a diameter of over 200 mm for a next-generation civil aviation HUD system. We also produced a ~ 120 mm aspheric mirror with a tight slope to the edge, which was used in a HUD system for a 4th generation fighter jet. For HUD projectors, we have fabricated convex/concave doublet aspheres with diameters over 120 mm and an extremely low max edge thickness variation.

Ever ready for the next challenge, SCHOTT is working to increase its offerings for aspherical optical components while also developing more complex/tighter form factors using truncation. We are also developing new freeform and off-axis components to take HUD system performance to the next level.

2. A better beam for high-power laser processing



Using a simplified view, high-power lasers consist of a laser engine and a laser processing head connected with a transport fiber. When the laser light exits the fiber and enters the processing head, an aspherical collimating lens turns the diverging light into the desired parallel beam shape. A focusing lens then ensures that the light is concentrated to achieve the best possible beam profile. In both cases, either an aspherical lens or a group of spherical lenses can be used.

Figure 2: Simplified illustration of a high-power laser processing head.

Today's laser systems often deliver powers exceeding 30 kW, imposing stringent requirements on the optical elements in the processing head. At such high powers, excessive absorption of light by these elements can be a problem because it causes the optical element to heat up and shift in focus. Thus, selecting the right substrate and coating design is crucial for maintaining low absorption and minimizing focus shift. The specific requirements of an application will determine the best substrate — fused silica, sapphire, or optical glass — to use for the lens.

For high-power laser heads, aspheric lenses can range from 10 to 300 nm in diameter with a typical height deviation of PTV ≤ 0.2 - 0.7 µm and max slope error of ≤ 0.2 - 0.7 mrad. Surface roughness ranges from ≤ 1 to 3 nm, with a surface quality up to 20/10 (S/D). Improving the surface roughness significantly enhances optical performance. Other important factors for achieving the best optical performance include the surface quality and form factor, which can be concave, convex, or gull-wing.

For this application, the coating specifications and the technology used to apply the coating are primarily driven by the specific laser application and the laser power, pulse duration, and wavelength. For high-power laser heads, a laser-induced damage threshold of even more than 100 kW/cm² (cw) is common, dependent on the pulse duration, and the reflectance should be low — often between ≤ 0.05 – 30% — so that a high transmission is maintained. The coatings should also exhibit low absorption, typically ≤ 3 – 30 ppm, to avoid heating and focal shift. Even ultra-low absorbing coatings (≤ 1 ppm) can be designed. Our anti-reflection coatings operate effectively across a broad wavelength range from 250 to 2500 nm and can be designed to be laser line-specific, multiband, or broadband anti-reflective.

3. SCHOTT's capabilities

Working with SCHOTT offers numerous advantages. We execute the entire aspherical lens manufacturing process in-house using optical glass from our Mainz, Germany facility or various grades of fused silica and sapphire. All stages of manufacturing, machining, and coating are conducted at our Yverdon, Switzerland site.

We recently upgraded our machining equipment in Yverdon to enable CNC grinding and polishing of lenses up to 300 mm in diameter. We also introduced new metrology equipment for ultra-precise measurements of aspheric and freeform lenses. Our facility employs all major coating technologies, including magnetron sputtering, ion-beam sputtering, ion-assisted e-beam evaporation, and low voltage reactive plating. We are also equipped to meet various - Defense specifications and offer a specialized anti-scratch hard anti-reflection coating that enhances abrasion resistance, crucial for defense applications and environments with harsh conditions.

With a robust global network, we ensure seamless coordination and support across diverse markets. Our capability to handle large lens sizes, coupled with exceptional form error accuracy and surface roughness, sets us apart in the industry. We also bring extensive expertise in creating value-added parts and assembling advanced aspherical lenses - like doublets. Our commitment to understanding and addressing specific customer needs allows us to provide tailored solutions and customization, ensuring that every project meets precise requirements and delivers optimal performance. "We enable customer success"

Want to learn more about precision aspheres for high-end applications?

Watch this video to get an insight into our high-precision asphere manufacturing process.
And visit our website for more information and resources: schott.com/products/aspherical-lenses

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