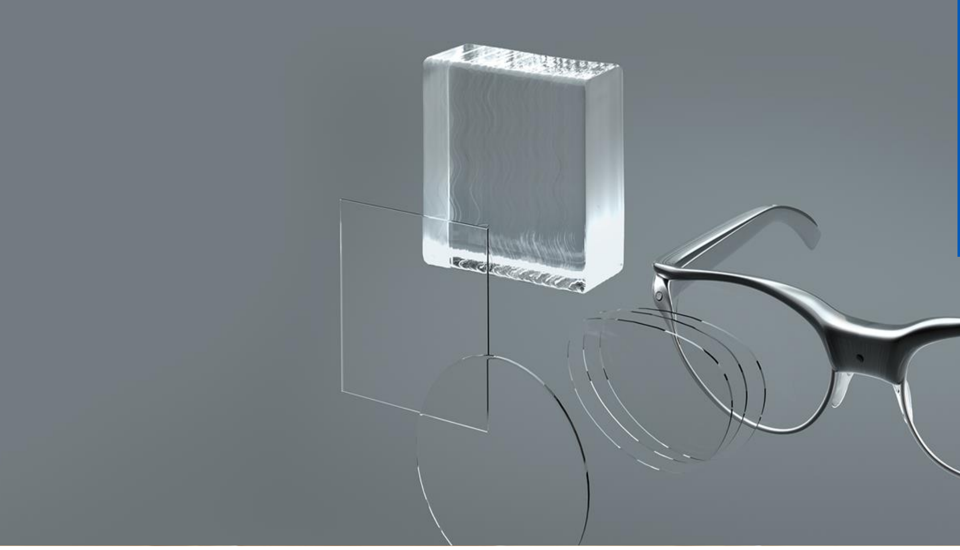


May 10, 2022

SCHOTT Optical Glass

A closer look at optical glass properties: refractive index homogeneity

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: www.schott.com/academy-of-optics

Many applications require optical components with a low spatial refractive index variation, which is known as homogeneity. However, no glass is perfect because minor chemical variations in the glass melting process cause various parts of the glass to have slightly different refractive indices. Thanks to our experience and expertise in glassmaking, SCHOTT can offer a superior range of homogeneities, depending on application needs.

1. Why do variations arise and how are they controlled?

Today, glass is made in continuous glass tanks with spatially separated but interconnected areas for melting, refining, and mixing. Carefully managing these steps together with accurate control of the chemistry used are critical for achieving high homogeneity in refractive index.

SCHOTT takes exceptional care to monitor and control both refractive index and dispersion over time during glass production by keeping all parameters, including the glass composition, as stable as possible. For large blanks, the hot forming process can contribute to variation because it converts temporal refractive index variation into spatial variation. To evaluate this, we perform simulations of the glass age during the hot forming process, which takes place in cylindrical molds. We use the information from these simulations to continuously adjust process parameters during casting to achieve excellent homogeneity even if there are slight variations of the refractive index over time.

The annealing process must also be considered. During annealing, we heat the material above the glass transition temperature and then carefully cool it to adjust the refractive index and stress birefringence. For fine annealing, we use finite element models to understand exactly how various cooling rates will affect stress distribution.

2. How do we measure and report refractive index homogeneity?

SCHOTT uses Zeiss Direct 100 interferometer systems with apertures of 300 or 500 mm to measure refractive index homogeneity. These instruments measure the wavefront of a laser collimated to the diameter of the glass with a reproducibility of about 10 nm. Because the refractive index of optical glass depends on temperature, measurements are performed in a cavity with temperature controlled to within less than 0.1° C.

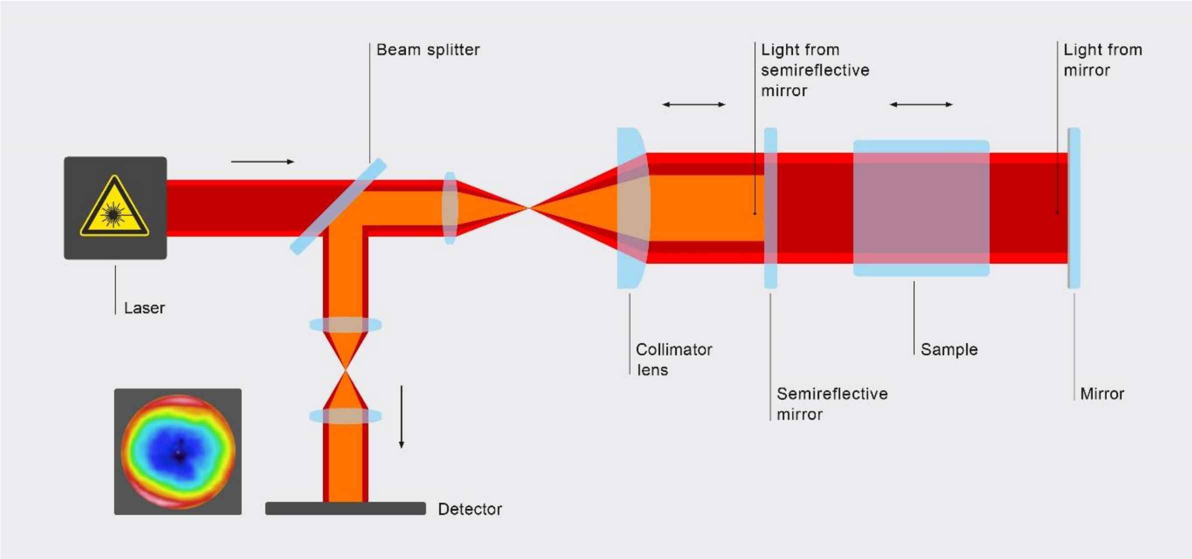


Figure 1: Working principle of Fizeau interferometer

When measuring refractive index homogeneity, contributions from the glass surfaces must be excluded so that the measurement reflects only refractive index variations. The influence of the glass surface can be removed by using either the “oil on plate” or PHom methods, which are both described in the ISO 17411 standard.

A homogeneity test certificate contains measurement results and homogeneity grades as well as a false color image of the refractive index variation to provide a visual representation of homogeneity. At SCHOTT, homogeneity as ranging from H1 to H5, with the H5 grade having the highest homogeneity.

SCHOTT homogeneity class indicator	NEW ISO 12123:2018 and ISO 10110-18:2018		OLD ISO 10110-4:1997	General applicable for
	Class indicator	tolerance limits Δn [10^{-6} or ppm]	tolerance limits Δn (+/- notation) [10^{-6} or ppm]	
	NH100	100	± 50	Common application sizes
H1	NH040	40	± 20	
H2	NH010	10	± 5	Partial volumes of the raw glass
H3	NH004	4	± 2	
H4	NH002	2	± 1	Not in all dimensions and not for all glass types
H5	NH001	1	± 0.5	

Figure 2: Homogeneity grades – ISO10110 and ISO 12123

The certificate also contains Zernike coefficients for circular apertures, which can provide additional insight into the wavefront characteristics and whether the homogeneities are relevant to a particular application. It is important to note that homogeneity should be defined by the aperture that will be used in the application because the homogeneity at the edges of a glass block may be lower than other parts due to the fine annealing process.

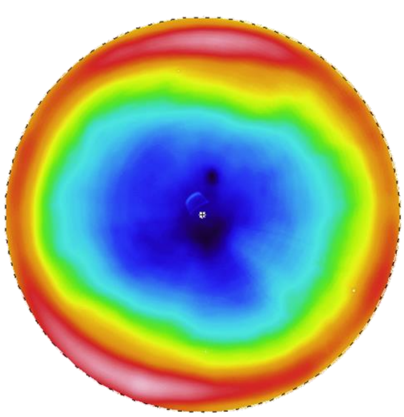


Figure 3: Measurement: Dn = 1.82 ppm

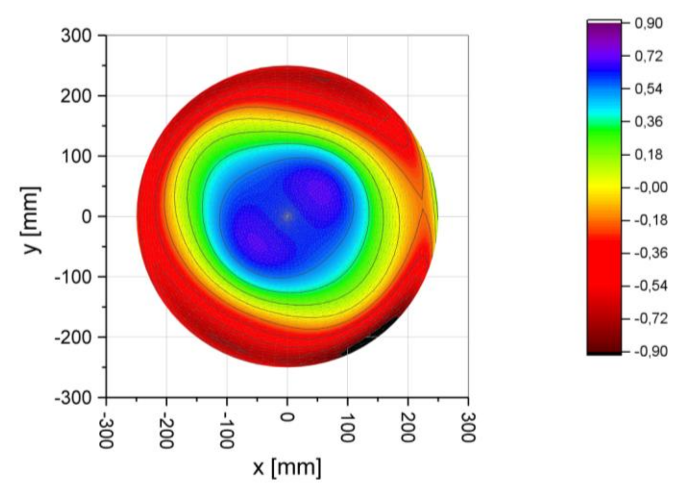


Figure 4: Reconstructed: Dn = 1.70 ppm

3. What homogeneities can we achieve?

Most of SCHOTT's glass products are available with homogeneities of H1 or higher. For pressings, we can achieve a homogeneity up to H3 for glass below 65 mm in diameter.

For block glass, we offer homogeneities up to H5, which is equivalent to 1 ppm in multiple directions for typical block glass formats of 260 x 260 x 180 mm and 200 x 200 x 180 mm. We can also provide H5 homogeneities for subapertures less than 100 x 100 mm, which are used for cubic prisms.

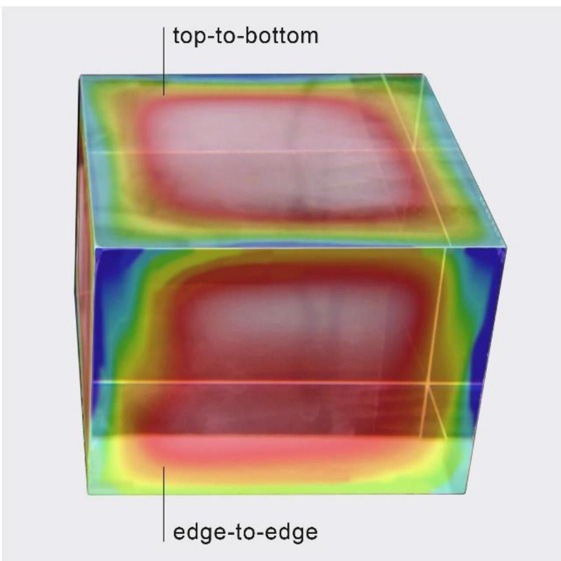
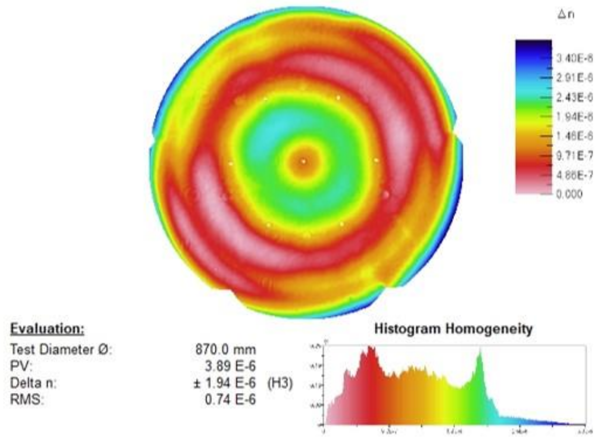


Figure 5: SCHOTT N-BK7® block glass H5 homogeneity in 3D

For large products such as cylindrical blanks that are 1100 mm in diameter and 200 mm thick, interferometers are too small to measure homogeneity directly. For these, we conduct subaperture measurements and stitch those together to form the full aperture. For a large casting with a diameter of 870 mm, we achieve H3 quality with focus removed. For subapertures of 100 mm, H4 to H5 is achievable (focus removed).



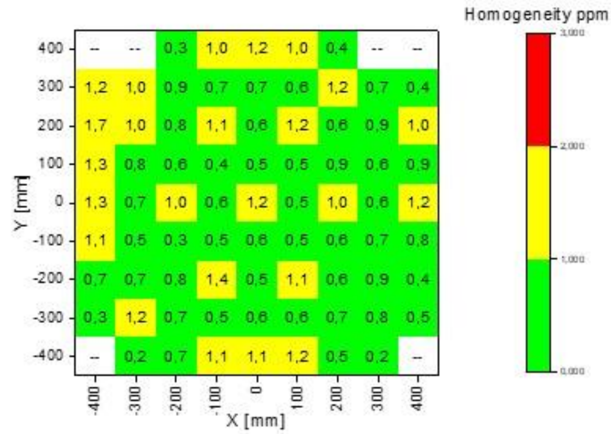


Figure 6: Homogeneity on 870 mm diameter aperture (piston, tilt and focus removed)

Figure 7: Homogeneity on 100 x 100 mm sub-apertures (piston and tilt removed)

SCHOTT has recently improved the process used to fabricate our very large strip glasses. This means we can now reach a H4 homogeneity for very large strip glasses with an aperture measurement of 800 x 400 mm and 100 mm thickness. We have qualified rectangular and round blanks in stock.

We constantly strive to improve our glass making processes to achieve even higher homogeneities across all our glass product. By continually pushing performance levels, our optical glass is helping meet the needs for even the most challenging applications.

SCHOTT Advanced Optics, with its deep technological expertise, is a valuable partner for its customers in developing products and customized solutions for applications in optics, lithography, astronomy, opto-electronics, augmented reality, life sciences, and research. With a product portfolio of more than 120 optical glasses, special materials and components, we master the value chain: from customized glass development to high-precision optical product finishing and metrology.

Want to learn more about optical glass?

For more information and resources visit our website: www.schott.com/products/optical-glass .

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