Identifying Optical Materials With Precision Accuracy

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Abstract

Material verification is a crucial aspect of the quality control process in optical component manufacture.

But when a material takes on different guises, identifying it can become a challenge. So, is there a solution?

Precision accuracy is a critical necessity with any optical component. Rigorous testing to ensure strict compliance with given requirements will always be essential; it is a vitally important demand within any industry sector. Dimensional, surface profiling and optical performance testing are significant aspects of this process, but an additional layer of assurance and quality can be achieved with the use of material verification, employing methods such as refractive index, density testing and transmission measurement. There is however a challenge surrounding the accurate identification of optical materials using these methods at a basic level, particularly where the material in question adopts a number of different guises. This challenge though is one to which the optical specialists at Knight Optical have developed a solution.

The challenge

Optical materials vary greatly, often making it difficult to identify their precise composition.

Even materials that appear similar to the naked eye can differ considerably on closer inspection, which could lead to significant quality and accuracy issues.

Optics are made from many different materials, from acrylic to germanium. Many optical materials, especially the ones that work in the visible region, look very similar on first inspection. Optical materials however are very different to each other and are specifically chosen depending on the application.

Whether optical components are being developed using raw materials or from third party sources, or are being reverse engineered for precision re-creation, it is vital to be in a position to verify the materials and products that have been used in their production. Quality assurance depends upon this knowledge. Without it, the end product could fail the test of accuracy.

The challenge of material verification however lies in the depth of precision that is possible using standard level testing methods, especially when components are made up of materials that have a tendency to adopt various characteristics.

Standard materials verification methods – simply not good enough?

Refractive index, density and transmission have traditionally been used in optical materials verification. But can they provide the depth of precision accuracy that is vital in the quest for exceptional quality?

Refractive Index

In optics, the refractive index is a characteristic of materials that defines the inverse ratio of the velocity at which light propagates through the material, versus through a vacuum. This property determines the degree of which light is bent when travelling through a material and is described by Snell's Law of Refraction.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Where θ_1 & θ_2 are the angles of incidence and refraction, and n1 and n2 are the refractive indices of the materials. For a plano material this bends the light travelling through it. For a lens, it changes the point at which it focuses.

Density

Since Archimedes yelled Eureka! we've known materials have different densities. Density is a measure of the unit mass by volume. It is determined by the chemical makeup and molecular structure of the material. If you can measure the density of a material, this can give a good indication of the material type.

Transmission

In optics, transmission is a measure of how much light propagates through a medium. Optical materials have different transmission properties depending on what they are made from and what impurities they contain. Depending on application and/or performance characteristics, optical elements can be made from many different materials. For example, many standard glasses, like borosilicate, do not transmit well in the ultra violet (UV) wavelengths of light, whereas sapphire transmits well down to 200nm (fig. 1).

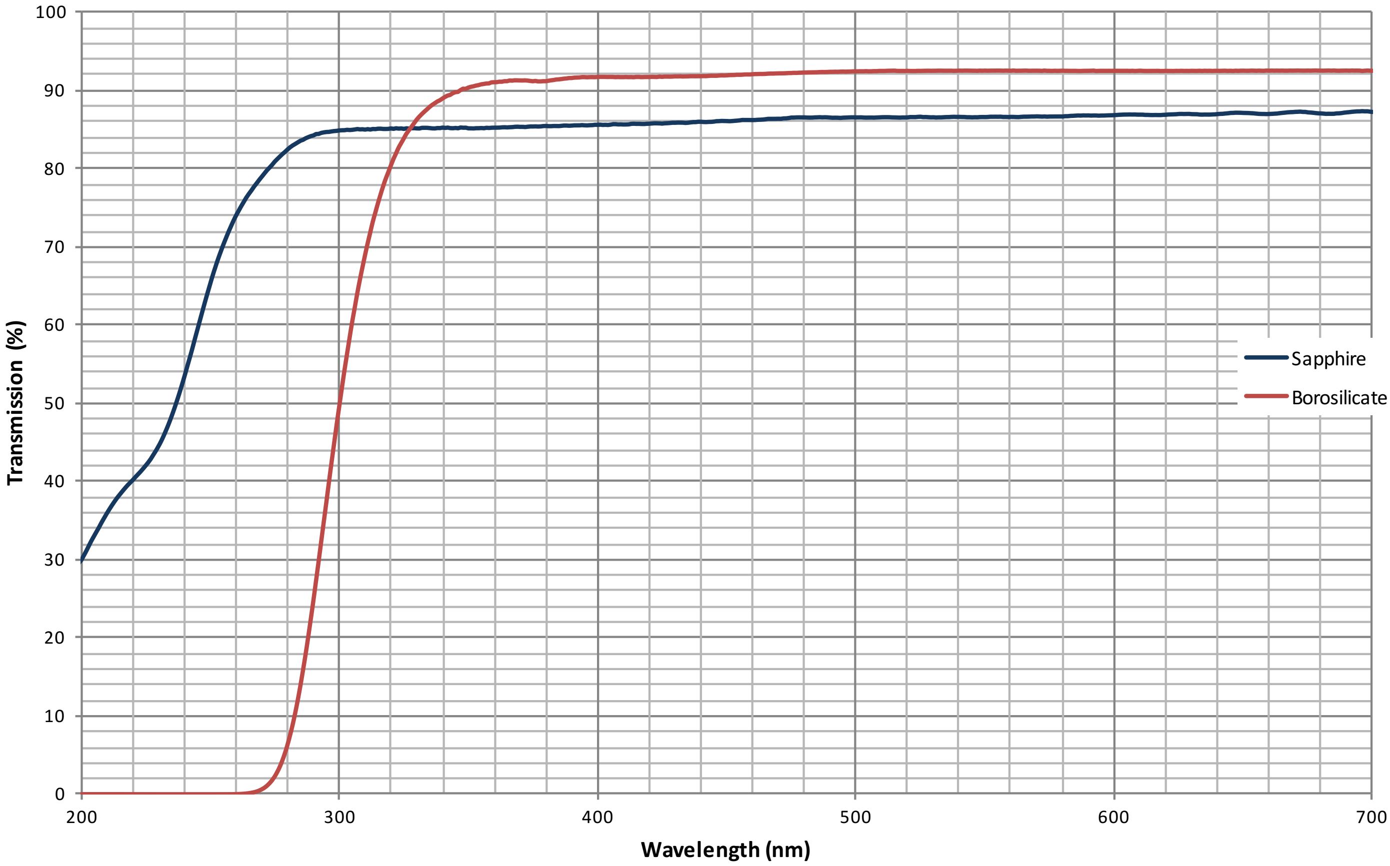

FIGURE 1. PERCENTAGE TRANSMISSION COMPARISON FROM 200-700NM OF BOROSILICATE AND OPTICAL GRADE SAPPHIRE.

Transmission - a key differentiator

Refractive index and density generally give us a good indication of what a material is. However, in some cases the same material can have different grades depending on its concentration of impurities, molecular structure and manufacturing process. A good example of this is fused silica. Fused silica can be graded for its UV and IR transmission properties.

The refractive index and densities are extremely similar, but the transmission in the UV and IR ranges are very different. Standard fused silica has very low transmission around 2700nm due to absorption from certain impurities, whereas IR fused silica has less of these impurities and has a much higher transmission in that range (fig. 2).

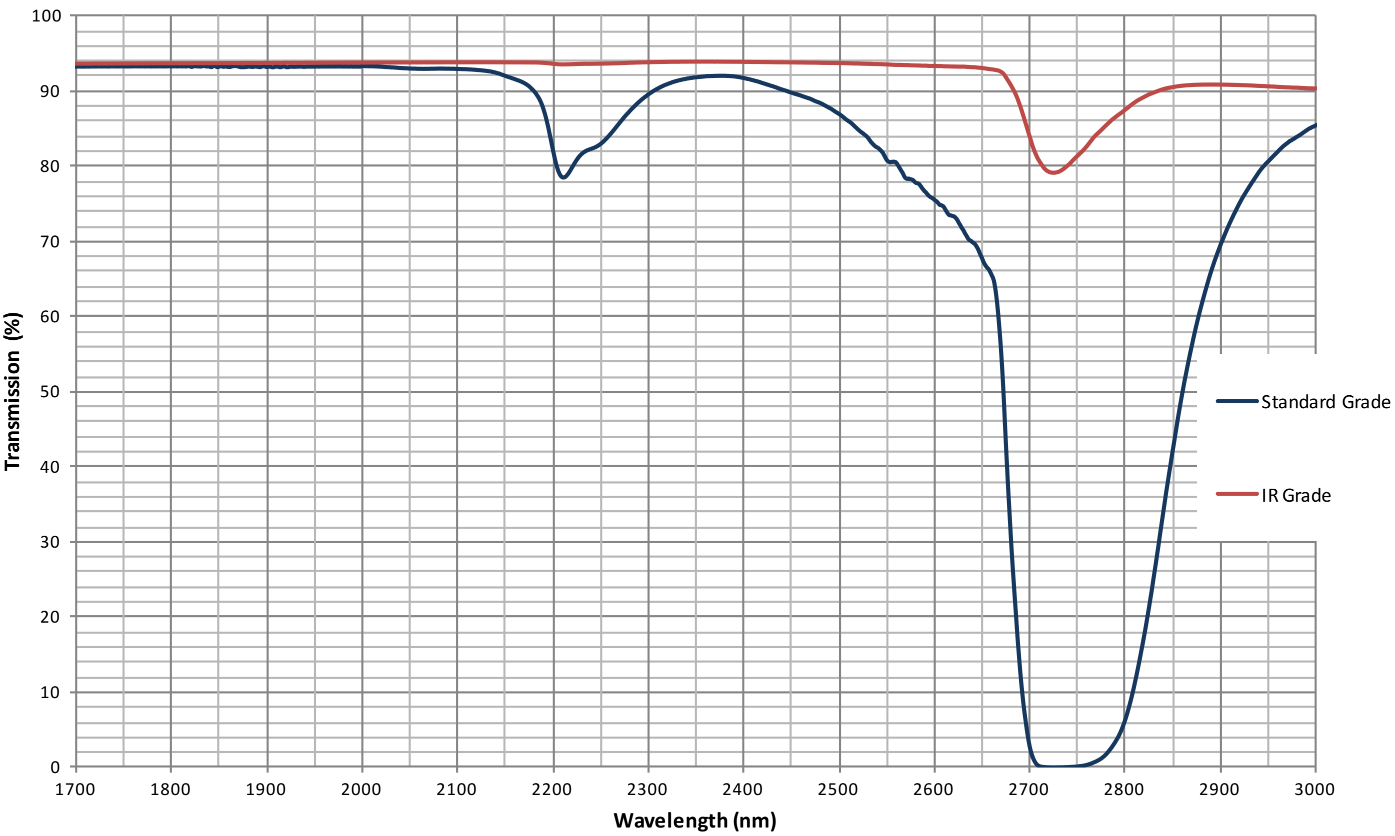

FIGURE 2. PERCENTAGE TRANSMISSION COMPARISON OF STANDARD AND IR FUSED SILICA 1700-3000NM.

Transmission is clearly a key differentiator, but is there more that can be done to resolve the challenge of materials verification for the ultimate in precision accuracy? Can the testing process be made even more in-depth?

Taking optical materials verification to the next level

Pinpoint accuracy is possible. And it can make all the difference in the quest for outstanding quality in optical components, and innovation in design.

Refractive Index Plano Lens

For a plano-optic, if you were to shine a laser onto a fixed point with a known angle of incidence from the normal, and you then introduced the plano-optic into the path of the light and perpendicular to the normal, you would see a shift in the position of the light (fig. 3).

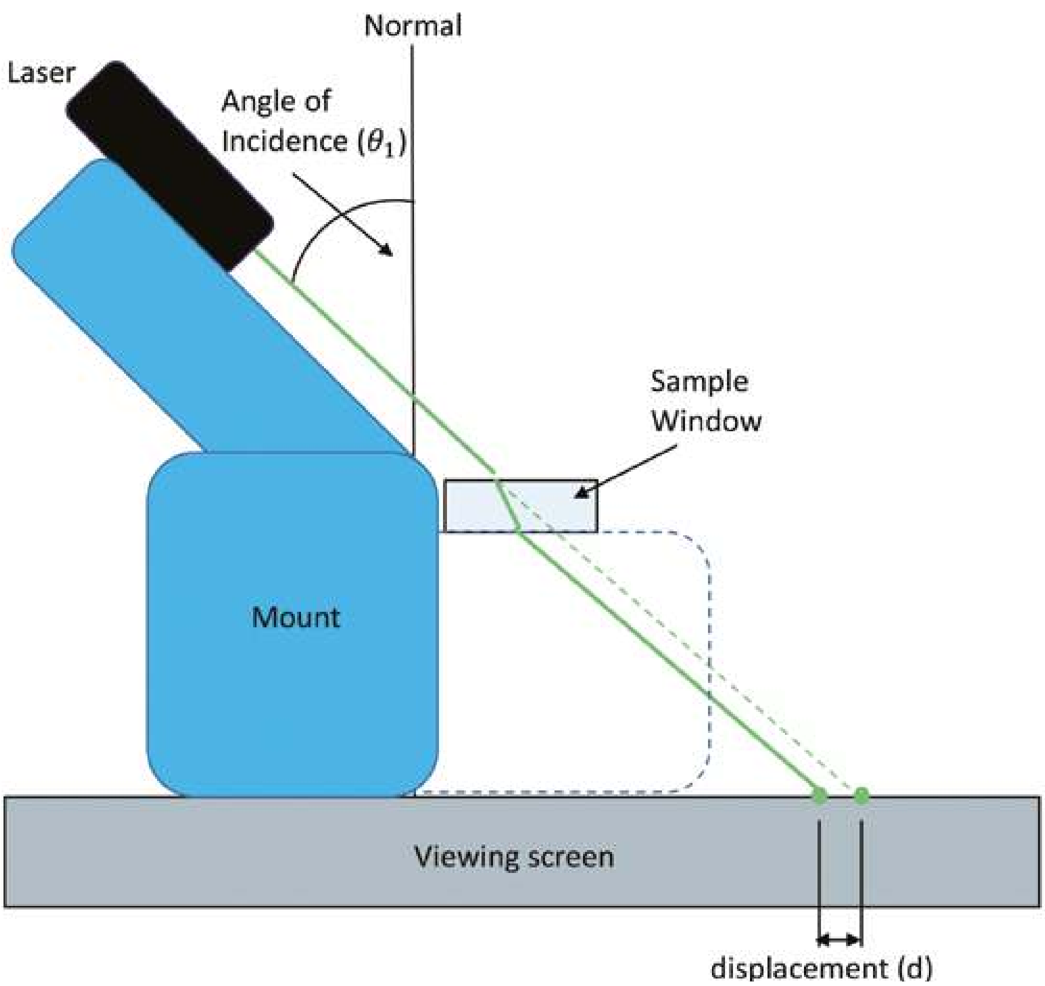

FIGURE 3. TEST SET-UP DIAGRAM SHOWING A WINDOW REFRACTING LIGHT.

Using trigonometry, this displacement allows you to calculate the material's angle of refraction. Knowing the angle of incidence and the refractive index of air allows you to calculate the refractive index (fig. 4).

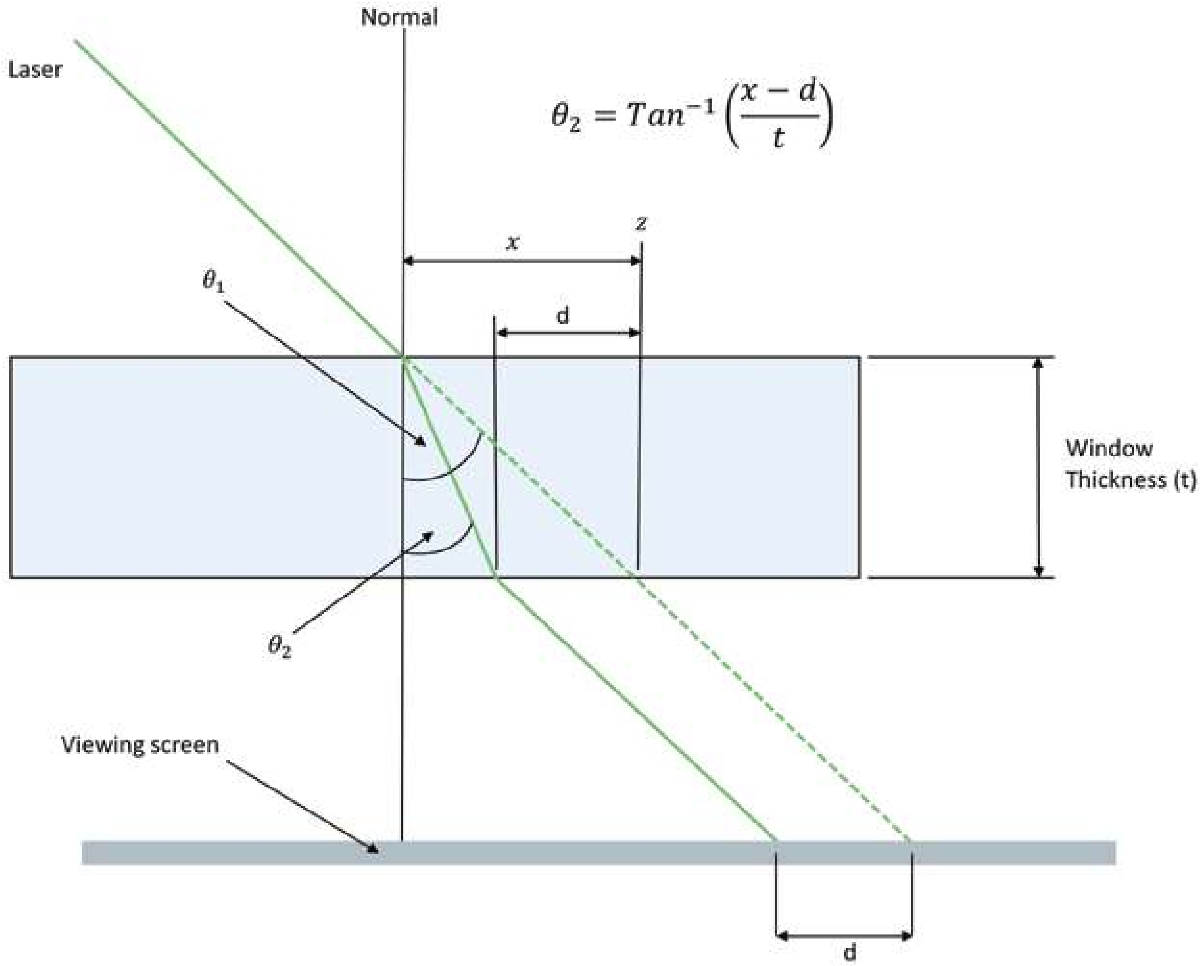

FIGURE 4. CALCULATION OF REFRACTIVE INDEX.

Using a bespoke mount with a fixed laser, and a Starrett Digital Microscope, this displacement can be measured to pinpoint accuracy. Alongside calibrated gauges, it is possible to obtain everything required to calculate the refractive index of the material.

For a spherical lens a similar method can be used to calculate the refractive index. For a lens, the displacement results in the light focusing to a certain point. There is a relation between this focal length, the dimensions of the optic and the refractive index. Using a Trioptics Optispheric, various gauges and a digital microscope, the focal length and dimensions of a lens can be measured to precision accuracy. With these measurements it is then possible to calculate the refractive index. Similar methods can be used to verify the materials in lens systems with multiple lenses/materials.

Density

Depending on the shape and material of the optics, the Optispheric, Zygo Verifire interferometer with radius slide or Starrett Digital Microscope can be used to accurately measure the dimensions of optics and calculate their volumes. Alongside calibrated scales this can quickly give a good indication of material. This does not however detect impurities in the material that may affect optical performance. So, what is the answer to this issue?

Transmission

Transmission characteristics can be measured using spectrometers which show percentage transmission (%T) vs wavelength of light. This can be very useful information when identifying an unknown material as well as identifying the quality or grade of material. Optical transmission can be accurately measured from 175-3200nm using a Cary 5000 spectrophotometer and from 1.6-25μm using a Cary 660 FTIR.

Conclusion

Knight Optical has developed and implemented methods to measure refractive index and density of optical materials. Alongside these new capabilities, we can measure optical transmission over a large range. Using the refractive index, density and transmission characteristics of a sample glass or optical component, Knight Optical can determine the most probable material it is made from or verify that it is the correct material.

In other words, with the right equipment, and the expertise and knowledge required to know exactly how to glean the information required down to the most in-depth levels, precision accuracy in optical component testing through materials verification does become a reality.

Quality precision optical component specialists

Ready to meet your challenges, equipped to fulfil your precise requirements.

A global leader in quality precision optical component design, consultancy and manufacturing, Knight Optical has always been fully committed to delivering the utmost in quality to its worldwide audience.

Our dedicated quality assurance and metrology departments ensure rigorous component testing and reverse engineering to the highest degree, guaranteeing strict compliance with customer requirements, all made possible through our ongoing investment in state of the art optical design and testing instruments, and the specialist expertise of our highly respected metrology technicians.

To learn more about our metrology laboratory services, and to discover how our in-depth quality assurance testing can deliver unrivalled competitive edge for your organisation, we invite you to get in touch.

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