CASE STUDY - AVANTES & CONVSUN

ADVANCING AR COATING PERFORMANCE WITH INTEGRATED MEASUREMENT PRECISION

INTRODUCTION

Precision has always been the backbone of progress in the optical coating industry. For manufacturers of anti-reflective (AR) coated solar glass, even the smallest variation in light transmission, often less than 0.1 percent, can define the difference between a world-class product and an average one. The transmission gain, or the improvement between coated and uncoated glass, is directly linked to the optical properties of the coating. Managing coating thickness and refractive index with high accuracy is therefore essential.

Accurate measurement of this performance is not straightforward. Solar glass typically features textured surfaces that scatter light in many directions, making conventional transmission measurements unreliable. For this reason, integrating sphere-based measurements are widely used, as they collect both specular and diffuse light. However, even these established methods can introduce subtle systematic errors that become significant when performance differences are measured in tenths of a percent.

Convsun, one of the world's leading AR coating producers, knows this challenge better than anyone. The company faced the same question as many manufacturers in the field: how to accurately measure and prove the optical performance of large glass panels under real production conditions, beyond the limits of traditional laboratory testing. In search of a practical and reliable solution, Convsun partnered with Eule27 AG, a Swiss startup, to develop an integrated measurement system that could meet industrial demands.

The system measures transmission and reflection simultaneously and calculates the optical properties that define coating performance. At its core are Avantes spectrometers, selected for their accuracy, stability, and spectral performance across the full solar wavelength range. By combining Avantes technology with Eule27's software design, Convsun has gained a measurement capability that goes beyond what conventional laboratory instruments can offer.

This development is more than an internal improvement. Convsun plans to make the system available to other manufacturers, enabling the broader industry to achieve the same level of measurement precision. The company's goal is to set a new standard for how AR coatings are evaluated and controlled, both in research and in large-scale production.

This case study describes Convsun's role in advancing AR coating measurement technology, the development of the integrated system by Eule27 AG, and the way Avantes spectrometers are integrated to deliver accurate, reproducible optical data. It shows how this approach addresses key market challenges and supports more reliable quality control and process optimization.

1. ABOUT CONVSUN AND EULE27 AG

Convsun is an international company based in Shanghai that specializes in advanced anti-reflective coatings. It was founded by Dr. XiaoLiang (Xinji) Wang, who built his expertise during more than a decade in the Netherlands, working for Unilever, DSM, and Akzo Coatings. His deep understanding of chemistry and materials, combined with a passion for innovation, laid the foundation for a company that connects scientific precision with industrial scale.

Over the years, Convsun has grown to employ more than 100 people and produce more than 9,000 tons of coating materials each year. Its AR coatings are used across several major industries, including solar energy, automotive glass, and mobile devices. The company also sees rapid growth in architectural glass and smart glass applications, where coatings must balance optical performance, energy efficiency, and durability.

Convsun's philosophy is built on measurable quality. Rather than relying solely on visual inspection or lab-scale testing, the company focuses on data-driven validation of coating performance. This approach ensures that every product delivered meets the highest standards of transmission, reflection, and durability.

By combining chemical expertise, optical science, and high-precision measurement, Convsun continues to strengthen its position as both a leading producer and a technology provider. Through new solutions, such as the integrated measurement system developed with Avantes, Convsun, and Eule27, the company is taking its role a step further, offering tools that can help others achieve the same level of process control and product confidence.

About Eule27 AG
Eule27 AG is a Swiss startup specializing in software, consulting, and custom solutions for thin film reverse engineering and automated process control in optical coating manufacturing. With over a decade of experience, their expertise includes optical modeling, spectral analysis, algorithms, and AI-driven process integration, enabling seamless hardware integration for industrial automation.

3. MARKET CHALLENGE

As demand for AR coatings increases across industries, the pressure to demonstrate performance with absolute accuracy has never been greater. The problem is that traditional measurement setups often fall short when applied to real production materials.

Most coating producers rely on laboratory instruments designed for small, flat samples, which are tested under tightly controlled conditions. These systems, including those from well-known brands such as PerkinElmer and Shimadzu, deliver excellent precision in the lab but are not designed for large-scale industrial glass or tempered surfaces. In practice, this means the data collected in research environments often fails to reflect actual production quality.

For Convsun, this was more than a technical inconvenience. The company's coatings consistently outperform competitors, yet those advantages were difficult to quantify in a way that customers could verify. When a difference of 0.1 percent in transmission can define a market advantage, measurement uncertainty becomes a real obstacle. Without reliable data, even superior coatings risk being undervalued. At the same time, Convsun saw new opportunities emerging in markets where precision measurement would soon be indispensable.

In the automotive sector, glass producers are focusing on UV and IR transmission as part of safety, comfort, and energy efficiency improvements, and the rise of head-up displays makes optical clarity a key requirement. In consumer electronics, AR coatings are back in focus, with flagship phones like the iPhone 17 relying on advanced coatings for display performance. In architecture, the move toward smart glass technologies, where coatings can adjust properties based on temperature or light, introduces new complexity that demands real-time optical validation.

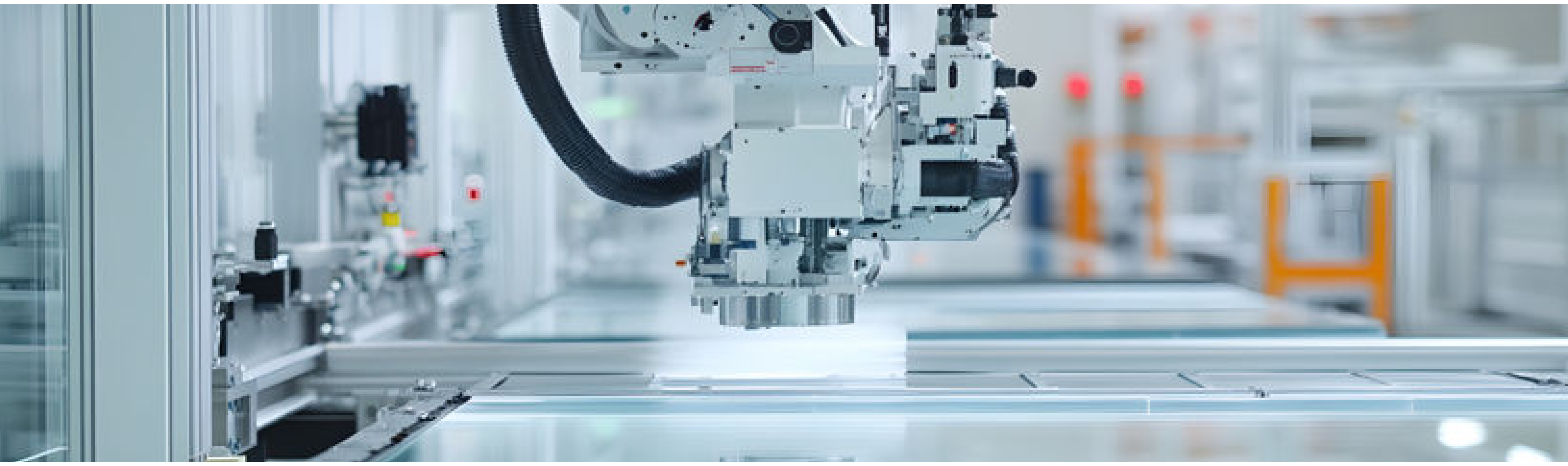
These developments created both a challenge and a business opportunity. The industry needed a new type of measurement system that could bridge the gap between laboratory precision and industrial application. Convsun recognized this early and decided to take the lead. By working with Eule27 and Avantes, the company set out to build a system that not only supports its own production but can also be offered commercially to help other manufacturers achieve the same high level of accuracy.

From Market Need to Measurement Methodology

The development of Convsun's integrated measurement system did not happen in isolation. The market challenges described earlier made one thing unmistakably clear: achieving reliable optical data for large, industrial glass panels requires a fundamentally different measurement approach. Traditional spectrophotometers, while powerful in laboratory environments, are not designed to measure large glass panes with sub-percent accuracy, especially when subtle differences in transmission determine competitive advantage. This realization shaped the collaboration between Convsun, Eule27 AG, and Avantes.

Convsun brought the industrial challenge, Eule 27 contributed modeling and system-design expertise, and Avantes delivered the spectrometers capable of capturing high-stability, high-resolution optical data across the full solar spectrum. Together, they aimed not only to create a practical measurement device but also to rethink how AR-coating performance should be measured in real production environments.

At the core of this effort lies a deeper understanding of how integrating spheres behave, why small systematic errors occur, and how these can be eliminated to uncover the true optical behavior of coated glass. The technical method behind this, combining a dual-detector integrating-sphere setup with advanced thin-film modeling, forms the foundation of the system's accuracy.



4. THE INNOVATION: ACCURATE TRANSMISSION MEASUREMENT OF AR-COATED SOLAR GLASS

Reducing measurement uncertainty and determining coating thickness and refractive index

This chapter explains the measurement principle in detail. It describes the origin of substitution error, how it affects transmission data, and how the dual-detector correction method enables precise determination of coating thickness, refractive index, and overall optical performance. This deeper insight shows how the technology supporting Convsun's new system works, and why it represents a significant step forward for AR-coating metrology.

4.1 Understanding Substitution Error

When light enters an integrating sphere, it reflects many times on the inner surface before being detected. This creates a uniform, diffuse light field inside the sphere. The total internal brightness depends not only on the light source, but also on what is placed at the measurement port.

In a typical procedure, a “100% reference” measurement is first made with an open port, effectively using air as the reference sample. However, this open port acts as a non-reflective hole, allowing light to escape. When a glass sample is then inserted, even if it is highly transparent, a small portion of light is reflected back into the sphere, increasing the internal brightness.

Because the sphere’s detectors measure the total radiance inside, this change makes the sample appear slightly more transmissive than it truly is. The result is a substitution error, a difference between the real and measured transmission caused by the changed radiance balance inside the sphere.

Although this effect is small, it becomes critical when evaluating AR coatings, where differences of less than one percent in reflection or transmission can determine product performance. For accurate coating characterization, substitution error must therefore be detected and corrected.

4.2 Correcting the Error: Dual-Detector Method

To eliminate this error, our integrating sphere setup uses two detectors (or 3 detectors in case we added a reflection detector) instead of one.

- The primary detector(s) measure the transmitted and/or reflected light as usual.
- The secondary (wall) detector measures the total internal radiance of the sphere.

When a sample is placed at the measurement port, both detectors register a signal change. The ratio between the wall detector signal for the sample and for the reference provides a correction factor that compensates for the shift in internal brightness. This correction is applied across all wavelengths, resulting in true, substitution-free transmission and reflection data.

This method effectively normalizes the measurement to the sphere’s internal light level instead of the open-port condition. As a result, small differences in coating reflectance or scattering no longer distort the measured transmission.

4.3 Measurement Setup

The measurement system is based on a 180 mm PTFE-coated integrating sphere with a 60 mm measurement port. PTFE provides very high diffuse reflectance, ensuring uniform internal light distribution.

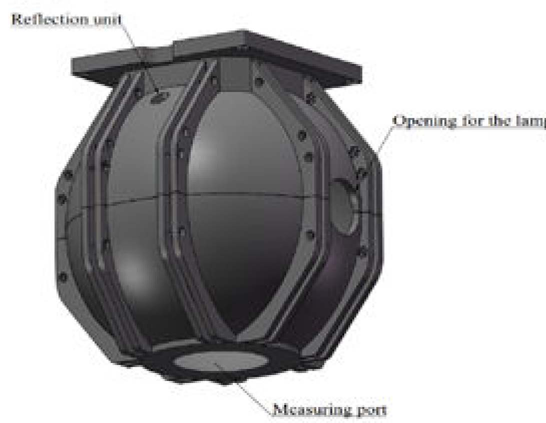
All measurement procedures, data acquisition routines, and thin-film simulation models were developed by Eule27 AG.

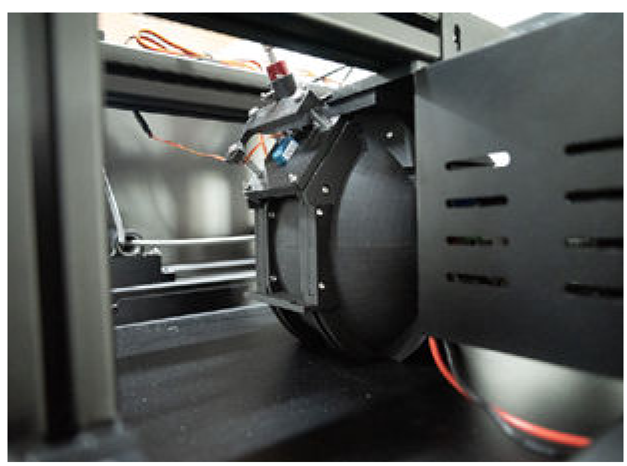
The system includes:

1. Transmission detector (8° angle): measures light transmitted through the glass.
2. Reflection detector (22° angle): collects light reflected by the glass surface.
3. Wall detector: monitors the internal radiance to calculate the correction factor.

Illumination is provided by a halogen light source combined with a UV LED module to ensure adequate signal intensity below 425 nm. Spectral acquisition is performed using an Avantes AvaSpec-ULS2048XL+ spectrometer, equipped with a 300/0.5 grating and a detection range up to 1160 nm. This configuration was chosen specifically to overcome the sensitivity drop above 1000 nm, ensuring reliable data across the entire 380–1100 nm solar wavelength range.

The sphere is positioned approximately 5 mm above the sample surface to maintain stable geometry without physical contact, and all detectors record spectra simultaneously to eliminate alignment drift or temporal variation.





4.4 Results and Interpretation

Transmission measurements N-BK7 glass (Edmund Optics) were done and compared with Edmund Optics data values. This glass is also used for calibration of the reflectance measurement. The reflection data for this calibration sample was calculated based on optical data from literature and calculated using the optical modeling software from the company Eulen. The results of the transmittance measurements are given below.

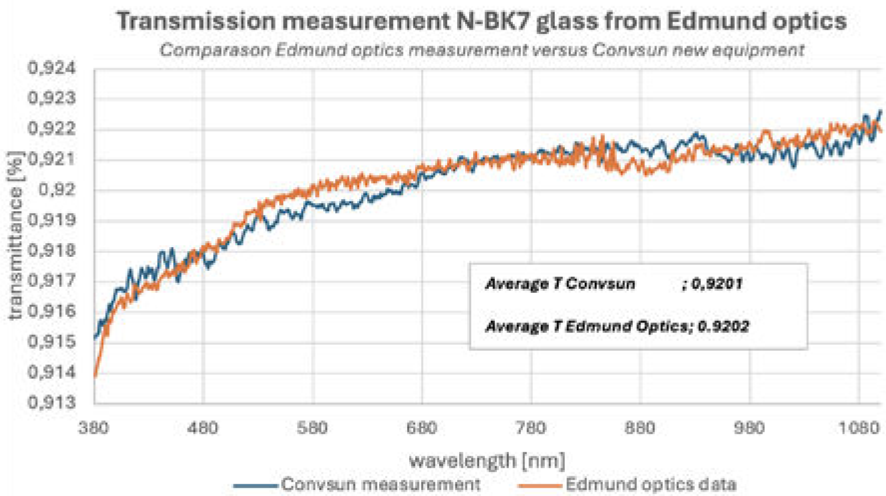


Figure 2; Comparison transmission data measured with the new Convsun spectrophotometer and data given by Edmund Optics belonging to the N-BK7 glass.

Measuring Solar glass

Using the dual-detector correction, the substitution error was reduced significantly compared to uncorrected measurements. The corrected transmittance and reflectance spectra of both uncoated and AR-coated samples closely matched theoretical thin-film calculations.

Depending on the spectrophotometer configuration, transmission and/or reflection detectors, in combination with a wall detector, were used to acquire spectral data suitable for optical modeling. Depending on the sample and measurement conditions, the optical modeling was performed using reflection data, transmission data, or a combination of both. From the measured spectra, the optical constants and layer thicknesses of the anti-reflective (AR) coatings were determined using thin-film optical modeling software.

Example 1: A single-layer AR coating deposited on solar glass was characterized using both reflection and transmission spectra. The simultaneous use of reflectance and transmittance data provided sufficient constraints for the optical model, allowing for an accurate and unambiguous determination of the refractive index, extinction coefficient, and layer thickness of the coating.

Example 2: A double-layer AR coating deposited on solar glass was characterized using reflection spectra only. The exclusive use of reflectance data was intentionally chosen to demonstrate that reliable optical modeling can be achieved using reflection measurements alone. In the photovoltaic industry, optical characterization is often performed using the so-called first-surface reflection method, which is limited to glass substrates thicker than approximately 3 mm, as thinner substrates introduce contributions from backside reflections. In contrast, the present method is based on total reflectance measurements and is therefore not affected by backside reflections, enabling accurate characterization independent of substrate thickness.

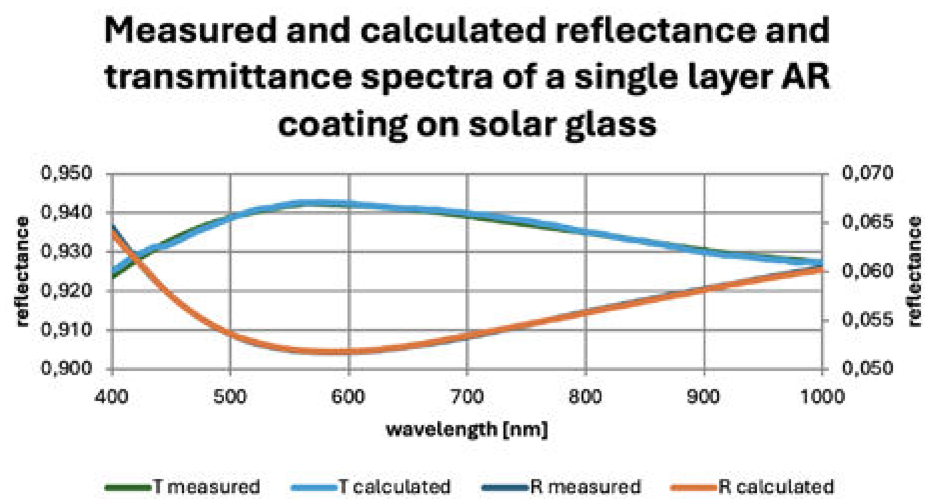


Figure 3; Measured reflectance and transmittance spectra of a single-layer anti-reflective (AR) coating on solar glass. The experimental data were fitted using thin-film optical modeling software, showing excellent agreement between the measured and modeled spectra. Coating thickness is 107 nm and refractive index of the coating is n=1.37

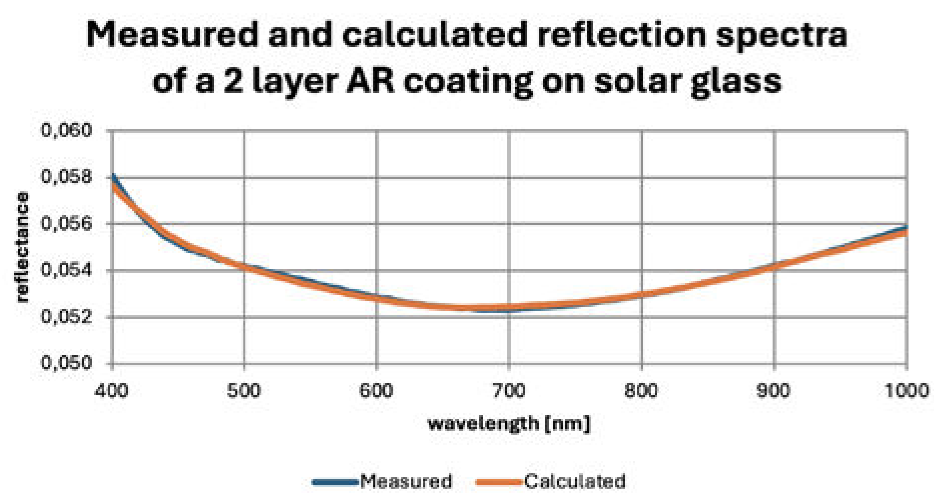


Figure 4; Measured reflectance spectra of a double-layer anti-reflective (AR) coating on solar glass. The experimental data were fitted using thin-film optical modeling software, showing excellent agreement between the measured and modeled spectra. Coating thickness bottom layer and top layer is 93 nm and 107 nm respectively. The calculated refractive indices are 1.47 for bottom layer and 1.34 for the top layer.

This precise data enables engineers and process developers to verify whether the coating process delivers the intended optical performance, and to make rapid adjustments if deviations occur.

4.5 Technical Summary

Measuring the true optical performance of AR-coated solar glass requires more than standard spectrophotometry. The dual-detector integrating sphere setup described here effectively eliminates substitution error and ensures traceable, highly accurate transmission and reflection data.

When combined with optical modeling, this approach enables precise determination of coating thickness and refractive index for both single- and double-layer coatings. The result is a deeper understanding of coating behavior, improved process control, and more consistent optical performance in solar glass manufacturing.

For manufacturers aiming to push solar-module efficiency higher, reliable optical metrology is not optional; it is a competitive advantage.

5. IMPACT FOR CONVSUN

The measurement innovation described in the previous chapter translates directly into tangible benefits for Convsun as a company. By combining advanced optical modeling, an optimized integrating sphere setup, and high-precision Avantes spectrometers, Convsun can now measure and validate AR coating performance with a level of accuracy that was previously difficult to achieve in industrial environments.

One of the most important outcomes is the ability to provide clear and measurable proof of coating performance. Small differences in transmission or reflection, often below 0.1 percent, can now be quantified reliably. This allows Convsun to demonstrate the added value of its coatings with confidence, even in highly competitive markets where performance claims are closely scrutinized.

The new measurement system also strengthens Convsun's position with international customers. For partners operating at the highest quality levels, such as manufacturers of premium solar modules or advanced display glass, accurate and reproducible optical data is essential. The ability to support coating performance with robust measurement data reinforces trust and long-term collaboration.

Internally, the system improves process control and production efficiency. Accurate feedback on coating thickness and refractive index enables faster optimization of deposition parameters and reduces the risk of deviations going unnoticed. This leads to more consistent product quality and lower scrap rates.

Beyond internal use, Convsun plans to offer the measurement system to the market. By doing so, the company extends its role from coating supplier to technology partner, contributing to the establishment of higher measurement standards within the AR coating industry. This positions Convsun as a reference point not only for coating performance, but also for optical metrology expertise.

6. LOOKING AHEAD

As optical coatings continue to evolve, the need for accurate and scalable measurement solutions will only increase. While solar glass remains a key application, the underlying measurement principles described in this case study are equally relevant to other fast-growing markets.

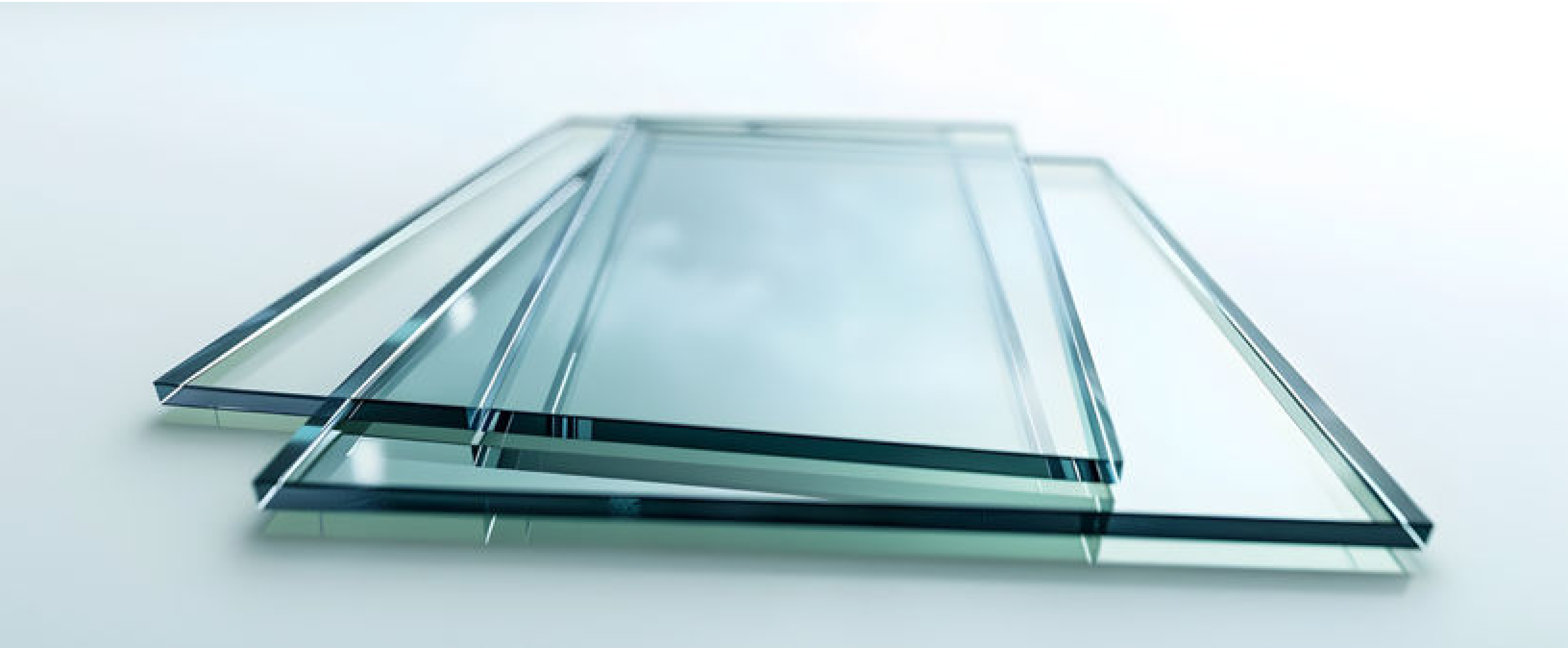
In the automotive sector, demand for precise control of UV and IR transmission is rising, driven by safety considerations, passenger comfort, and the growing use of head-up displays. Reliable optical measurement will play a central role in meeting these requirements.

In architectural and smart glass, coatings are increasingly designed to respond dynamically to light, temperature, or electrical stimuli. Monitoring these properties requires measurement systems that combine accuracy with applicability to large glass formats, an area where Convsun's approach offers clear advantages.

The consumer electronics market also continues to push optical coatings to new limits, with thinner glass, multi-layer designs, and tighter performance tolerances. As AR coatings regain importance in high-end devices, precise metrology becomes a critical enabler of innovation.

Looking forward, Convsun's ambition is to become a recognized reference for optical coating measurement standards. By combining coating expertise with advanced measurement technology and by integrating Avantes spectrometers into scalable industrial solutions, Convsun aims to support customers not only with high-performance coatings, but also with the tools needed to verify and optimize them.

More information?
Do you need more information or have questions about the technique, innovation, or the company? Feel free to contact us.



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