



The Industry-Leading Technology Behind the Ci7x00 Family of Spectrophotometers

The Ci7x00 is the flagship family of benchtop spectrophotometers in X-Rite's broad portfolio of color solutions. Offering the highest level of both accuracy and consistency in measurement, the Ci7x00 family has set a new standard for color control across formulation, production and quality assurance. This technical paper provides detailed insight into the technology powering these revolutionary products.

A Legacy of Innovation

The technology powering Ci7x00 instruments is the product of decades of innovation in color measurement. X-Rite's CE7000 benchtop spectrophotometer, launched in 1989, used a photo diode array for measuring color. When the CE7000 was introduced, the photo diode array offered the best design and performance options available for measuring light and processing color.

In the 1990s, X-Rite started to investigate the use of two-dimensional charge-coupled device (2D CCD) arrays as light detectors in instruments. These types of imagers provided low noise and excellent linearity and opened the door to the design of a multi-channel benchtop spectrophotometer—the Color i7. This pioneering product achieved a new level of performance, and provided simultaneous measurement of specular included (SCI) and specular excluded (SCE), along with the reference channel, to enable tightly coupled real-time correction of illumination uniformity.

X-Rite's legacy of innovation continued in 2015 with the introduction of the Ci7x00 family. These instruments combine the latest advances in 2D CCD array technology with sophisticated processing capabilities to deliver the industry's most accurate and repeatable color measurement yet.

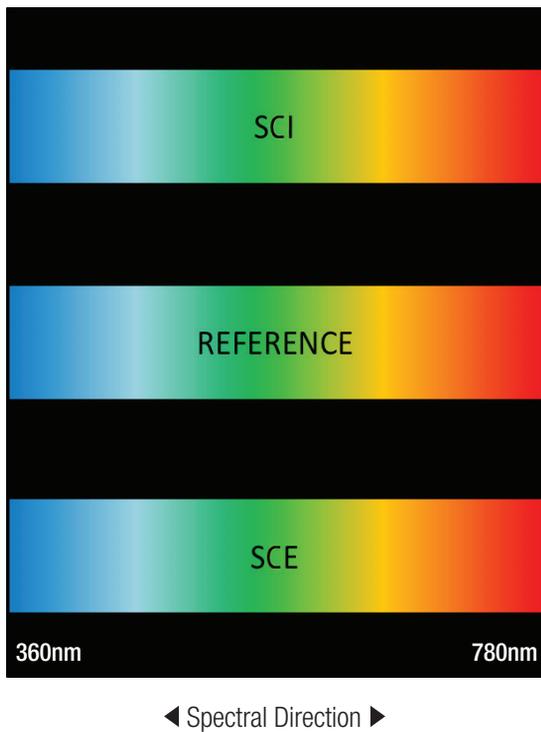
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The Powerful Array That Makes It Possible

At the heart of a Ci7x00 instrument is a high-resolution spectrometer that couples an aberration-corrected diffraction grating with a high-quality 2D CCD that is suitable for scientific instrumentation. The all-reflective design provides exceptional control over stray light, resulting in minimal spectral and spatial cross-talk in the CCD detector. This enables remarkable measurement purity, which leads to excellent dark and light repeatability and color accuracy.

The Ci7x00 family's 2D CCD array allows simultaneous, full spectral imaging of multiple measurement channels: reference channel, SCI, and SCE. Since all measurement channels are imaged simultaneously with the reference channel on the 2D CCD array, any changes to the

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instrument's light source or drift in wavelength can be detected in real-time and corrected in all measurement channels. Additionally, with the measurement channels being imaged together on the same physical 2D CCD array, the correction of errors from electrical noise and drift is greatly simplified.

In the instruments, each channel is connected by glass optical fibers to the input slit on the spectrometer. The spectrometer maps the spectral dispersion of each channel in one direction on the CCD, with the spatial dispersion mapped in a perpendicular direction to create a 2-dimensional reading. In the spectral direction, a wavelength sampling interval of just over 1nm/pixel spreads the spectrum across hundreds of CCD pixels, and produces a calibrated output range of 360 to 780nm—the most expansive wavelength range on the market.

◀ 3 MEASUREMENT CHANNELS
IMAGED ONTO A CCD ARRAY,
SEPARATED BY DARK SPACE

The Ci7x00 delivers a 20x improvement of resolution and signal-to-noise when compared to common one-dimensional technologies.

State of the Art Data Processing and Correction

In addition to its advanced 2D CCD array, the Ci7x00 instruments use multiple data processing techniques to achieve accuracy and precision. Wavelength bands are over-sampled both spatially and spectrally to provide more than 750 CCD pixel samples per wavelength per flash. Each measurement is executed through multiple flashes, which creates a “super pixel” with an effective dynamic range that exceeds that of a typical photodiode array. This results in a 20x improvement of resolution and signal-to-noise when compared to common one-dimensional technologies.

Signal-to-noise is also effectively managed through over-sampling. A dark blue repeatability test best demonstrates the Ci7x00's advances in this area. The Ci7x00 series outperforms other manufacturers as well as our own previous benchtop spectrophotometers on this test. The system also incorporates color balance filters to flatten the input light at the detector so that dynamic range is carefully managed in order to optimize signal-to-noise in the CCD. This provides low noise at all wavelengths, and clean signal detection without saturation, leakage, or cross-talk between pixels. The Ci7x00 series also implements a continuous wavelength calibration in real-time that is used to re-align the spectrum with the factory reference spectrum using no moving parts. Along with other corrections, it is this innovative whole-system design approach that allows the leading Ci7x00 device, the Ci7860, to deliver industry-leading repeatability of <math><0.01 \Delta E</math> and inter-instrument agreement as tight as $\leq 0.06 \Delta E$.

Finally, measurement accuracy can be affected by the amount of optical power being instantaneously delivered to a sample by the illumination system, especially while measuring certain fluorescent materials. Photodiode array-based spectrophotometers typically take a measurement with a single high-powered flash. Measurement differences caused by this over-powered illumination can temporarily alter some samples, resulting in color measurement errors up to 1 ΔE . X-Rite's Ci7x00 spectrophotometers use multiple lower-power flashes during a color measurement to help minimize and control this error. These are light conditions that more closely match the way the human eye sees these special samples.

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Streamline Your Workflow

Establishing and achieving the strictest color standards requires accuracy and precision at each stage of the product development process, from formulation to final production to quality control.

The Ci7x00 series solution offers the unique ability to maintain an audit trail, ensuring data traceability and integrity of standards throughout production. In the event that a product falls outside of a specified tolerance, this traceability allows for quick identification of the sources of error. Users can easily review measurement and process variables, including temperature, humidity, and even a picture of the sample being measured, during each step of the production.

The Ci7x00 family's advanced technology for accurate capture and data processing also allows operators to achieve a new level of efficiency in controlling color. Simultaneous SCI and SCE data capture eliminates the need for multiple measurements as well as the effort and potential error associated with adjusting the instrument's mechanical set-up between measurements. This is particularly valuable for the measurement of samples exhibiting gloss and texture. The ability to combine measurements of reflection and transmission also allows color experts to gather accurate data for color and translucency in a single operation.

The Ci7x00 family offers users additional measurement flexibility with optional UV wavelength cut-off filters, four transmission apertures (25 mm to 6 mm) with active laser targeting, and up to five reflectance apertures (25 mm to 3.5 mm).

The 2D CCD arrays used in the Ci7x00 family have enabled the design of industry leading instrumentation with unmatched accuracy, repeatability, and inter-instrument agreement. Customer workflow is simplified with simultaneous measurements of SCI and SCE, and operators will be able to meet their customer color requirements with less rework and wasted material. This makes the Ci7x00 an unparalleled tool for a wide range of industries.

Visit **X-Rite.com** to learn more about the ways in which the Ci7x00 series can help you meet your strictest color tolerances with maximum precision and efficiency.

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