Measuring Fluorescent Highway Sign Color: ASTM Standards, Measurement Geometry, and Instrument Selection

How ASTM D4956, ASTM E991, ASTM E2301, Agera L2, and ColorFlex L2 Fit Together

Image 1: One material. Three Measurements. Three Different Questions.

Fluorescent retroreflective highway-sign materials require specialized color measurement because their daytime appearance combines ordinary reflected light with fluorescent emission. Federal specifications establish daytime color limits for six fluorescent retroreflective traffic-control colors: Fluorescent Orange, Fluorescent Yellow, Fluorescent Yellow-Green, Fluorescent Green, Fluorescent Pink, and Fluorescent Red. This article focuses specifically on the instrumental measurement of these fluorescent retroreflective materials.

The federal daytime color specification itself establishes an important measurement framework. 23 CFR Part 655, Appendix to Subpart F, Table 3 specifies the chromaticity boundaries for fluorescent retroreflective materials using the CIE 1931 2° Standard Observer, 45°/0° or 0°/45° geometry, and CIE Standard Illuminant D65.

Within this framework, three different optical properties must be distinguished:

1. Daytime color – What color does the fluorescent sign have under defined daylight conditions?
2. Fluorescent contribution – How much of that daytime response comes from fluorescence versus ordinary reflection?
3. Nighttime retroreflectivity – How effectively does the material return headlamp light toward the driver?

These are different measurements. Understanding which question is being asked determines the appropriate ASTM method and measurement instrument.

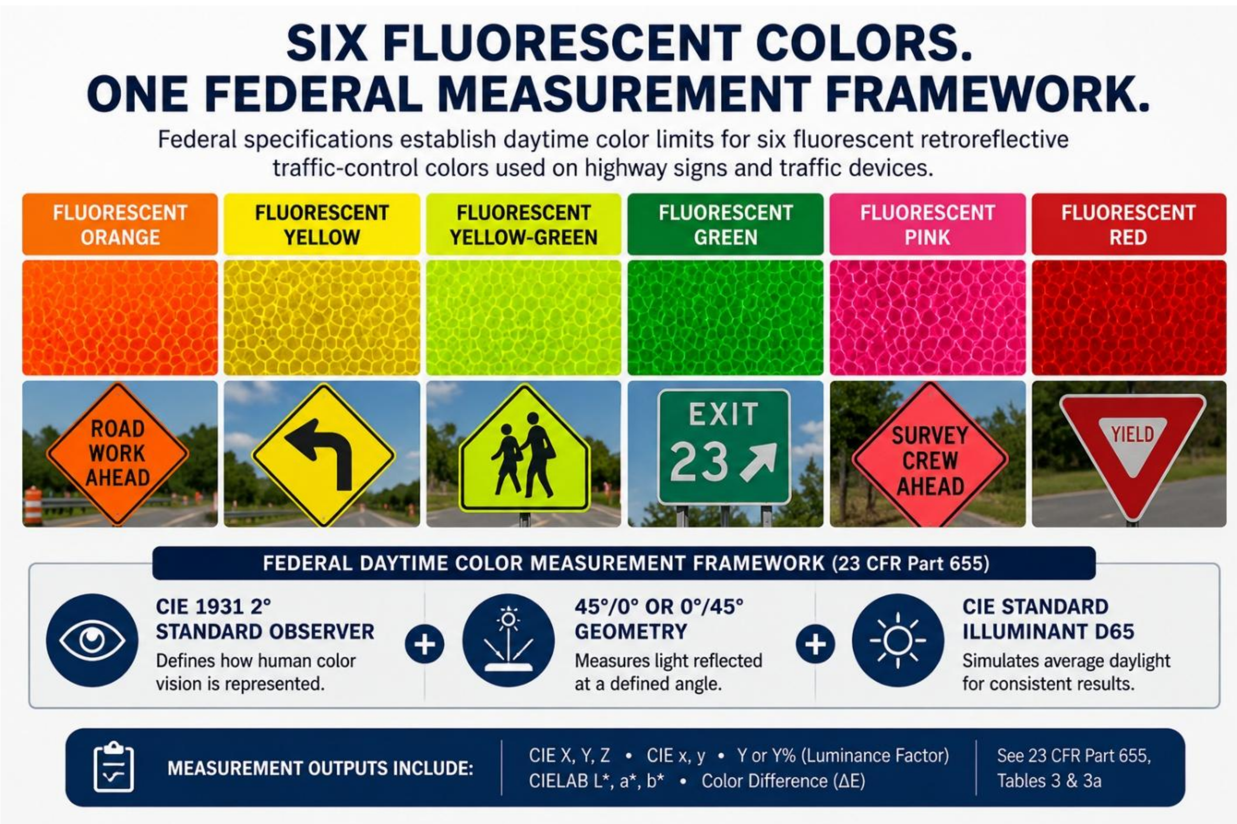

Image 2: Six Fluorescent Colors

Why Are Fluorescent Retroreflective Highway Signs Different?

Fluorescent retroreflective highway-sign sheeting combines optical technologies intended to improve visibility under different viewing conditions.

During daylight, fluorescent colorants absorb part of the incident radiation and re-emit energy at longer visible wavelengths. The resulting daytime appearance therefore contains two components:

Total Daytime Color = Reflected Component + Fluorescent Component

At night, a different optical mechanism becomes dominant. Glass-bead or microprismatic structures within the sheeting return incident headlamp light toward the driver.

This is *retroreflection,* not fluorescence.

The same material can therefore require separate measurements of daytime color, fluorescence, and nighttime retroreflective performance.

Measurement 1 – Daytime Color

What Are We Measuring?

The first measurement asks: ***What color does the fluorescent retroreflective material have under defined daylight conditions?***

The federal daytime color specification for fluorescent retroreflective materials establishes chromaticity limits for six colors:

- Fluorescent Orange
- Fluorescent Yellow
- Fluorescent Yellow-Green
- Fluorescent Green
- Fluorescent Pink
- Fluorescent Red

These limits are defined using:

- CIE 1931 2° Standard Observer
- 45°/0° or 0°/45° geometry
- CIE Standard Illuminant D65

23 CFR Part 655 also provides corresponding daytime luminance-factor requirements in Table 3a.

Typical daytime color measurements therefore include:

- CIE X, Y, Z tristimulus values
- CIE x, y chromaticity coordinates
- Y or Y% (Y% is HunterLab Y index)
- CIELAB L*, a*, b* when appropriate
- Color difference values for production quality control

For fluorescent material, the measured result represents the total color response produced under the physical illumination reaching the specimen.

It therefore includes both: *Ordinary Reflection + Fluorescent Emission*

ASTM D4956 – The Material Specification

ASTM D4956, Standard Specification for Retroreflective Sheeting for Traffic Control, establishes requirements for retroreflective sheeting used for traffic signs, delineators, barricades, and related traffic-control applications.

D4956 addresses multiple performance characteristics, including daytime color and retroreflective performance.

These requirements should not be confused because they involve fundamentally different optical measurements.

For fluorescent daytime color measurement using a one-monochromator colorimetric spectrometer, the relevant methodology is described by ASTM E991.

ASTM E991 – One-Monochromator Fluorescent Color Measurement

ASTM E991, Standard Practice for Color Measurement of Fluorescent Specimens Using the One-Monochromator Method, describes the instrumental measurement of fluorescent specimens using continuous broadband polychromatic illumination and spectral analysis of the radiation leaving the specimen.

One-monochromator instruments are commonly used for conventional color measurement, but fluorescent materials introduce an additional requirement: the physical illumination reaching the specimen influences the measured fluorescent response.

ASTM E991 therefore states that the precision with which a one-monochromator instrument can measure fluorescent specimens is directly dependent on how well its physical illumination simulates CIE D65.

This is an important distinction from ordinary nonfluorescent color measurement.

Why Physical CIE D65 Daylight Simulation Matters

For an ordinary nonfluorescent specimen, spectral reflectance can generally be measured and subsequently combined mathematically with a standard illuminant and observer to calculate colorimetric values.

A fluorescent specimen introduces another variable: The physical illumination itself influences the specimen's response.

ASTM E991 explains that differences in the spectral irradiance distribution reaching a fluorescent specimen can produce differences in measured color values between instruments.

This is why physical daylight simulation is particularly important when measuring fluorescent highway-sign materials.

Agera L2 uses:

Physical CIE D65 daylight simulation with certified Grade A CIE D65 illumination, exceeding the commonly referenced B-or-better daylight-simulation criterion discussed in ASTM E991.

ASTM E991 notes that a rating not worse than BB under the CIE Publication 51 methodology has frequently been referenced for D65 simulation, while also explaining the limitations of applying that classification method universally to fluorescent specimens.

The important measurement principle for fluorescent highway-sign materials is therefore the quality of the **physical CIE D65 daylight simulation reaching the specimen**.

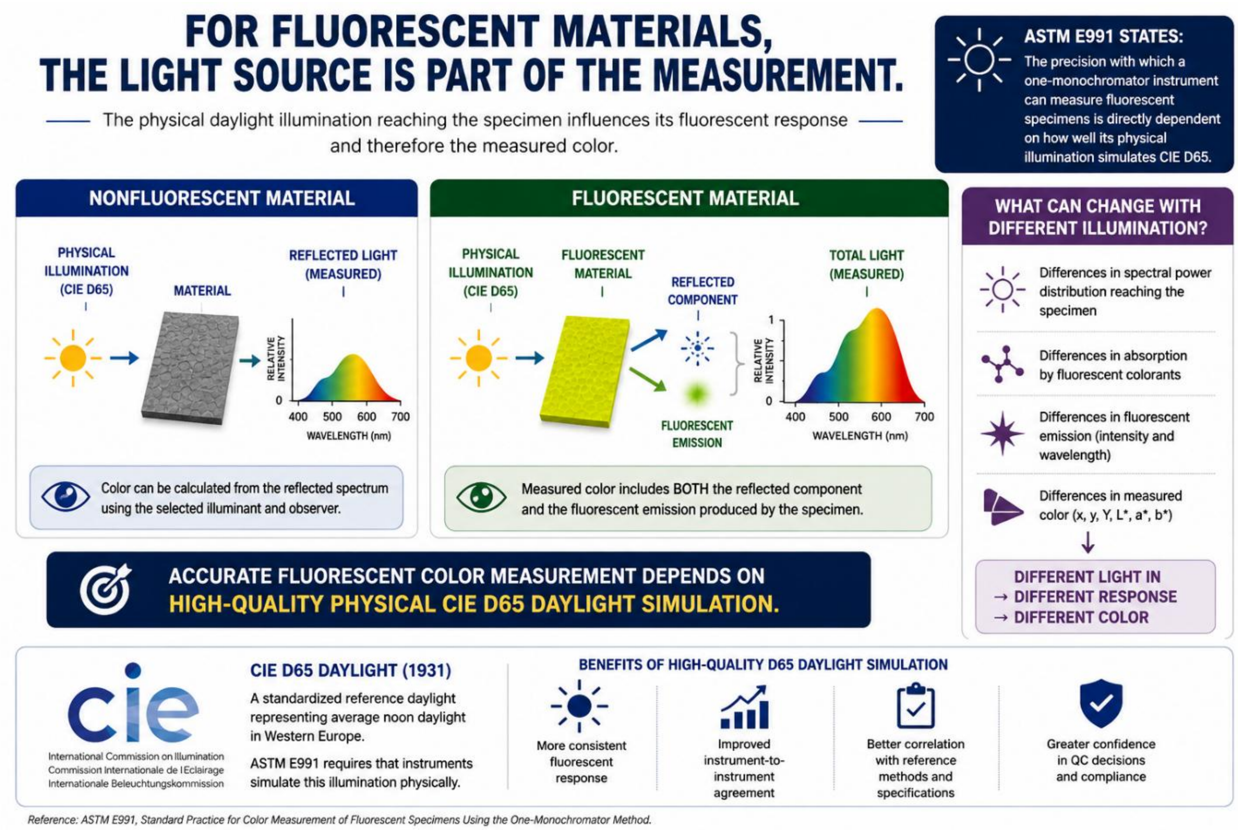

Image 3: Fluorescent Materials

Geometry Is Also Important

The federal daytime color specification for fluorescent retroreflective materials explicitly identifies **45°/0° or 0°/45° geometry** together with **CIE 2° Standard Observer + CIE Standard Illuminant D65**.

ASTM E991 similarly recommends bidirectional 45°:0° or 0°:45° geometry for fluorescent color measurement.

HunterLab offers two different implementations of this bidirectional geometry:

- ColorFlex L2 – 45°a:0° annular geometry
- Agera L2 – 0°:45°c circumferential geometry

Although 45°/0° and 0°/45° are reciprocal geometries, the way illumination and detection are distributed around an optically complex retroreflective material can influence practical measurement performance.

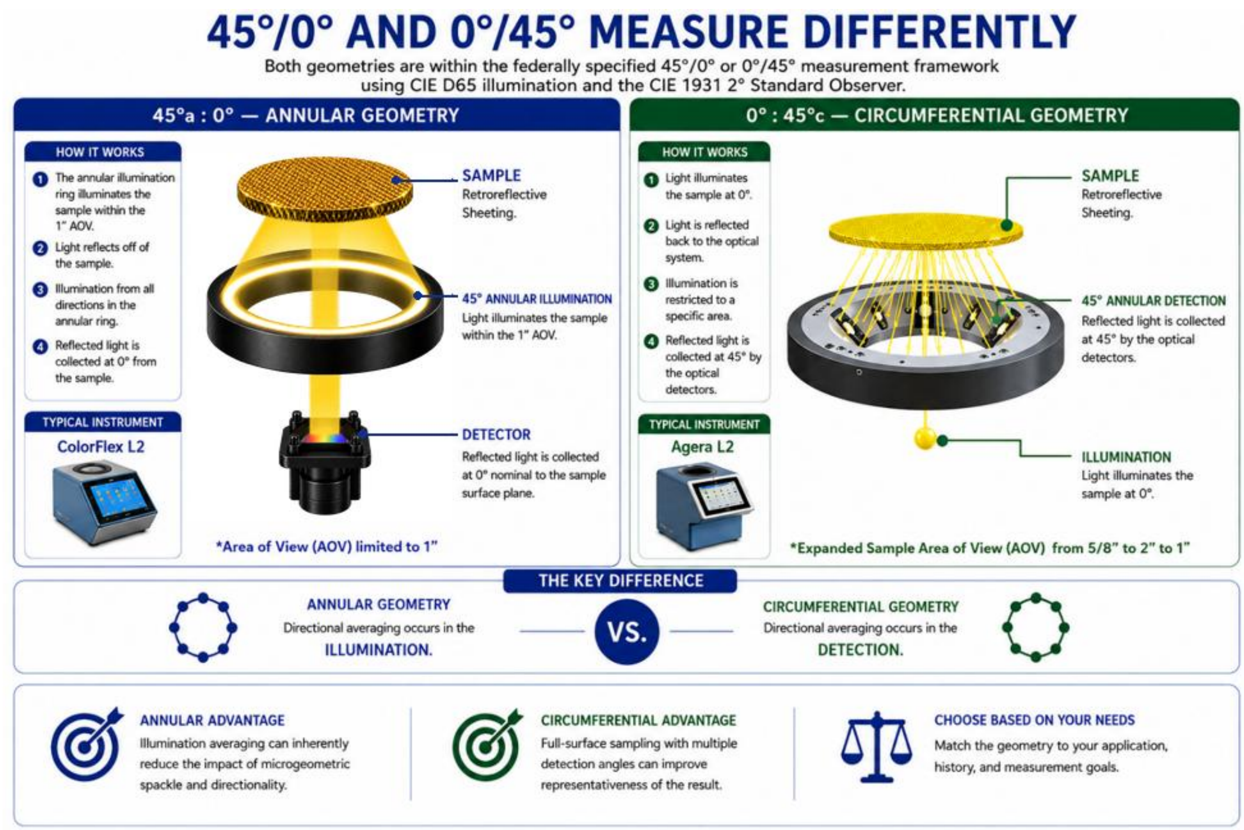

Image 4: 45°/0° and 0°/45° Measure Differently

This is especially important for microprismatic sheeting.

Annular vs. Circumferential Geometry

Annular Geometry

In this geometry, the specimen is illuminated at 45° from an annular arrangement surrounding the measurement area, while the detector views the specimen normal to its surface at 0°.

The HunterLab ColorFlex® L2 uses 45°a:0° annular illumination geometry, with a 31.8 mm (1.25-inch) illuminated area and a measured Area of View (AOV) of 25.4 mm (1 inch).

The annular architecture distributes illumination around the sample while maintaining a normal viewing direction.

Image 5: 45° annular illumination → 0° viewing

Circumferential Geometry

In this geometry, the specimen is illuminated normally at 0°, while 15 optical sensors collect the resulting radiation at 45° around the complete circumference of the measurement area.

The HunterLab **Agera® L2** is a 0°:45°c circumferential instrument, with the 15 optical sensors collecting at 45° around a full 360° sample circumference.

This distributes the detection around the sample rather than distributing the illumination.

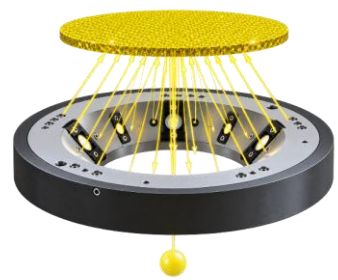

Image 6: 0° illumination → 45° circumferential viewing

The Agera® L2 includes additional port plates that expand measurement flexibility with 5/8-inch (15.9 mm), 1-inch (25.4 mm), and industry-leading 2-inch (50.8 mm) Areas of View (AOVs).

Why Can the Difference Matter for Highway Sign Sheeting?

Microprismatic retroreflective sheeting contains highly structured optical elements.

These structures can produce directional effects and localized **prismatic sparkle** when the material is measured at particular illumination and viewing angles.

Consequently, two instruments that both belong to the federally specified 45°/0° or 0°/45° geometry family should not automatically be assumed to produce numerically interchangeable measurements on every microprismatic material.

The difference is not that one geometry is correct and the other is incorrect.

The difference is how illumination and detection are distributed around the specimen.

Annular 45°/0°

ColorFlex L2 distributes the **illumination** around the specimen and observes it at 0°.

Circumferential 0°/45°

Agera L2 illuminates normally at 0° and distributes the **detection** around the specimen at 45°.

For relatively homogeneous surfaces, reciprocal 45°/0° and 0°/45° measurements are generally considered equivalent.

For strongly structured microprismatic surfaces, however, the specific optical architecture and sample orientation can influence the practical measurement result.

When Can Annular Geometry Be Advantageous?

HunterLab's experience with highway-sign materials has shown that 45°/0° annular geometry can be advantageous with some microprismatic sheeting constructions.

Annular illumination designs are typically fixed for a single Area of View, usually 1 inch (25.4 mm) in diameter, distributing the incident light around the specimen at 45° while the detector remains at the normal 0° viewing position.

This can help minimize the influence of individual prismatic reflections or sparkle entering the detector.

ColorFlex L2 can therefore be an important option when:

- Existing specifications or historical QC data were established using 45°/0° annular instruments.
- Correlation with an established 45°/0° measurement system is important.
- A particular microprismatic construction exhibits lower measurement variation with annular illumination.
- Continuity with historical ColorFlex measurements is required.

HunterLab's existing highway-sign application guidance specifically recognizes the optical complexity of these materials and includes both **ColorFlex L2 and Agera L2** as applicable instruments.

When Can Circumferential Geometry Be Advantageous?

Agera L2 uses **0°/45° circumferential geometry** and offers multiple Areas of View (AOV), including **5/8-inch diameter**, the industry-standard **1-inch-diameter,** and an extra-large **2-inch-diameter AOV** with nearly four times the measurement area. The larger AOV allows each reading to average a substantially greater area of the retroreflective sheeting, which can be particularly valuable when measuring nonuniform or highly structured microprismatic materials.

The instrument illuminates the sample normally at 0°, while **15 detectors collect at 45° around the full circumference of the measurement area**. This provides multi-directional collection in a single measurement.

However, circumferential detection should not be interpreted as inherently superior to **45°/0° annular geometry** for averaging the optical effects of microprismatic sheeting. Established industry practice recognizes an advantage for annular illumination in minimizing the influence of prismatic sparkle. This distinction is reflected in ASTM D4956 measurement practice: a 45°a:0° annular measurement can be represented by a single measurement, while use of 0°:45°c circumferential geometry requires an appropriate number of measurements and sample orientations to adequately average the directional effects of the material.

Agera L2 addresses this requirement through a different measurement strategy. Its combination of an **extra-large 2-inch AOV** and the **Essentials TotalView 360° Auto Rotator Accessory** allows a larger portion of the material to be evaluated while automatically rotating the specimen through multiple orientations. A single sample placement can therefore be used to acquire and average the equivalent of **12 rotational measurements**, substantially increasing the area and orientations represented in the final result compared with a conventional single-position measurement.

Agera L2 can be particularly appropriate when:

- **High-quality physical CIE D65 daylight simulation is critical.**
- **Certified Grade A CIE D65 illumination** is desired.
- A larger measurement area is beneficial for averaging variation across the sheeting.
- The measurement procedure requires multiple sample orientations to account for directional effects or prismatic sparkle.
- Automated rotational averaging can improve measurement consistency and reduce operator involvement.
- A new measurement method is being established rather than transferred directly from historical 45°/0° annular data.

The advantage of Agera L2 for fluorescent retroreflective sheeting is therefore not circumferential geometry alone. It is the combination of **physical CIE D65 daylight simulation, certified Grade A illumination, up to a 2-inch measurement area, 0°/45° circumferential collection, and automated 360° rotational averaging** that provides a practical approach for obtaining representative daytime color measurements from large-area, directionally sensitive microprismatic materials.

Which Geometry Should You Use?

There is no universal answer for every retroreflective sheeting construction.

The better question is: ***Which geometry best represents the material while maintaining correlation with the specification, reference method, and existing quality-control data?***

Both **45°/0° annular** and **0°/45° circumferential** belong to the bidirectional geometry family specified for federal daytime fluorescent retroreflective color measurement.

The choice should consider:

- Sheeting construction
- Directionality
- Prismatic sparkle
- Historical measurement geometry
- Existing specifications and tolerances
- Instrument-to-instrument correlation
- Repeatability and reproducibility

When establishing or transferring a highway-sign measurement method, representative production samples should be evaluated before assuming that numerical tolerances can be transferred unchanged between geometries.

Agera L2 vs. ColorFlex L2 for Fluorescent Highway Signs

Feature	Agera L2	ColorFlex L2
Geometry	0°:45°c	45°a:0°
Geometry implementation	Circumferential detection	Annular illumination
Federal 45/0 (0/45) geometry family	Yes	Yes
E991 bidirectional geometry family	Yes	Yes
Physical D65 daylight simulation	Yes (LED)	Yes (Xenon)
Daylight simulation classification	Certified Grade A	A/B
Azimuthal representation	Circumferential detection	Annular illumination
Historical 45°/0° correlation	Application dependent	Potential advantage

Feature	Agera L2	ColorFlex L2
Microprismatic sheeting	Applicable	Applicable; can offer advantages on some constructions
Routine daytime color QC	Yes	Yes, where illumination/method requirements are satisfied
ASTM E2301 bispectral measurement	No	No
Nighttime R_a measurement	No	No

Instrument selection should therefore consider not only the ASTM geometry designation but also the specific sheeting construction, physical illumination requirements, and measurement system used to establish the applicable specification or historical QC data.

Measurement 2 – Separating Fluorescence from Ordinary Reflectance

The second measurement asks: *How much of the daytime response comes from fluorescence, and how much comes from ordinary reflection?*

Conceptually: Total Daytime Response = Reflected Component + Fluorescent Component

A one-monochromator instrument measures the resulting total color response under its physical illumination.

It does not independently separate those components.

For that purpose, a different measurement architecture is required.

ASTM E2301 – Bispectral Measurement

ASTM E2301, Standard Test Method for Daytime Colorimetric Properties of Fluorescent Retroreflective Sheeting and Marking Materials for High Visibility Traffic Control and Personal Safety Applications Using 45°:Normal Geometry, uses **bispectral colorimetry**.

A bispectral system characterizes the relationship between excitation wavelength and resulting emission wavelength. This enables the fluorescent contribution to be distinguished from ordinary reflection.

ASTM E2301 serves as a referee method for determining conformance of fluorescent-retroreflective sheeting and marking materials to standard daytime colorimetric specifications.

Neither Agera L2 nor ColorFlex L2 is a bispectral instrument.

Therefore: **ASTM E991 one-monochromator daytime color measurement → Agera L2 or an appropriately qualified 45°/0° instrument**

ASTM E2301 bispectral fluorescence characterization → Bispectral instrument

These methods answer different measurement questions.

Measurement 3 – Nighttime Retroreflectivity

The third measurement asks: *How effectively does the material return incident headlamp light toward the driver at night?*

This is neither conventional color measurement nor fluorescence measurement.

It is **retroreflectivity**.

Retroreflective highway-sign sheeting uses glass-bead or microprismatic structures designed to redirect incident light back toward its source.

The primary photometric quantity is the:

Coefficient of Retroreflection, R_a

typically expressed in:

$cd \cdot lx^{-1} \cdot m^{-2}$

Retroreflection measurements use tightly controlled entrance and observation angles representing the geometric relationship between:

Vehicle Headlamp → Sign → Driver's Eye

Neither Agera L2 nor ColorFlex L2 performs this measurement.

A retroreflectometer or appropriate laboratory photometric system is required.

One Material – Three Different Optical Questions

Question	Measurement	Applicable Standard/Method	Instrument
What color does the fluorescent sign have under daylight?	Total daytime color, x, y, Y	23 CFR 655 / ASTM D4956 / ASTM E991	Agera L2 or appropriately qualified 45/0 instrument
How much is fluorescence versus ordinary reflection?	Bispectral fluorescent characterization	ASTM E2301	Bispectral instrument
How effectively does the sign return headlamp light at night?	Coefficient of retroreflection, R_a	ASTM D4956 / applicable MUTCD requirements	Retroreflectometer

The three measurements are complementary rather than interchangeable.

Recommended Measurement Approach

For routine daytime quality control of fluorescent retroreflective highway-sign sheeting, establish and document:

- **Geometry:** 45°/0° annular or 0°/45° circumferential

- **Physical Illumination:** CIE D65 daylight simulation appropriate to the method
- **Observer:** CIE 1931 2°
- **Primary Reporting:** CIE x, y and luminance factor Y
- **Measurement Methodology:** ASTM E991 as applicable to ASTM D4956 and the governing specification
- **Sample Presentation:** Standardized orientation, measurement location, number of readings, and averaging procedure

For a new measurement program, representative samples should be evaluated to determine whether **Agera L2's 0°/45° circumferential geometry or a 45°/0° annular configuration such as ColorFlex L2** provides the best combination of repeatability, reproducibility, and correlation with the applicable specification.

When replacing an existing instrument, correlation with the historical measurement geometry should be evaluated before transferring tolerances.

Summary

Federal specifications establish daytime chromaticity limits for **six fluorescent retroreflective traffic-control colors**:

Fluorescent Orange • Fluorescent Yellow • Fluorescent Yellow-Green • Fluorescent Green • Fluorescent Pink • Fluorescent Red

23 CFR Part 655, Appendix to Subpart F, Table 3 defines these limits using the **CIE 1931 2° Standard Observer, 45°/0° or 0°/45° geometry, and CIE Standard Illuminant D65**.

These fluorescent retroreflective materials present three distinct measurement requirements.

Daytime Color

23 CFR 655 / ASTM D4956 / ASTM E991

Agera L2 uses **0°/45° circumferential geometry** and physical CIE D65 daylight simulation with **certified Grade A CIE D65 illumination**.

ColorFlex L2 provides an alternative **45°/0° annular geometry**, which can be advantageous when correlating to historical annular measurements or measuring certain microprismatic constructions.

The choice between annular and circumferential geometry should consider the specific optical structure of the sheeting and correlation with the established measurement method.

Fluorescence Separation

ASTM E2301

A bispectral instrument is required when the objective is to independently characterize fluorescent and reflected components or perform the E2301 referee measurement.

Neither Agera L2 nor ColorFlex L2 is a bispectral instrument.

Nighttime Retroreflectivity

ASTM D4956 / applicable MUTCD requirements

A retroreflectometer or appropriate laboratory photometric system is required to measure the coefficient of retroreflection, R_a.

Neither Agera L2 nor ColorFlex L2 performs this measurement.

The Measurement Framework

DAYTIME COLOR

23 CFR 655 / ASTM D4956 / ASTM E991
Agera L2 – 0°/45° Circumferential
ColorFlex L2 – 45°/0° Annular, where appropriate

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FLUORESCENT / REFLECTED COMPONENT SEPARATION

ASTM E2301
Bispectral Instrument

↓

NIGHTTIME RETROREFLECTIVITY

ASTM D4956 / applicable MUTCD requirements
Retroreflectometer

The key is to match the instrument to both the optical question and the optical structure of the material. For fluorescent highway-sign sheeting, the federal specification establishes the 45°/0° or 0°/45° measurement family under D65 and the CIE 2° observer, while ASTM E991 provides the one-monochromator methodology needed to properly address the additional challenges introduced by fluorescence.