HOW-TO GUIDE

Capturing Measurement Data for Lighting Design: LEDs and Light Sources

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Measurements for Lighting Design

To develop the optimal lighting configuration for any environment, designers need accurate data about the brightness (luminous intensity) and color (chromaticity and color temperature) of light sources, fixtures, and luminaires. Lighting engineers developing LEDs, luminaires, and automotive headlamps likewise must measure and characterize the properties of these light sources to ensure correct performance of these products. Photometers, spectrometers and colorimeters are tools commonly used to measure these characteristics of light and capture information in photometric data files.

Photometric Data

Luminous intensity – Refers to the amount of light shining from a light source in a particular direction. Luminous intensity data enables lighting designers to observe the total output and angular spread of a light source in a space. For more information read about The Language of Light.

Chromaticity—Refers to the color of a light source as a combination of two characteristics: its hue (its tint or color, such as red, violet, or orange-yellow), and its saturation (also referred to as intensity or chroma). Chromaticity is mapped onto a color space (a graphical representation of all colors visible to the human eye) identified by its coordinates x,y. For more information read about The Language of Color.

Color Temperature—There are many combinations of light wavelengths that can combine to create light that is perceived as "white" (or neutral) by humans. White light that contains more blue/cyan wavelengths are perceived as "cooler" by humans; white light with a higher proportion of amber/red wavelengths is perceived as "warmer". Correlated Color Temperature (CCT) is a metric used to distinguish these different tones for light sources such as incandescent bulbs and LEDs.

Quantified in degrees Kelvin (K), cooler (bluer) lights have high CCT values of approximately 5000K or higher; warmer lights have lower CCT values approximately 2000K-4500K. CCT is an essential consideration for lighting design of interior spaces because the temperature (wavelength composition) of light sources affects not only visibility needed for human activities but can even impact human health and productivity (for more information, read about Human-Centric Lighting).

Photometric Data File Formats

Typically, light source data is captured by a metrology system (such as a spectrophotometer, photometer, or colorimeter), and these files are then used by light modeling software to create designs for luminaires and architectural lighting plans that meet any desired specifications.

IES (*.ies) and EULUMDAT (*.LDT) are the two standard file formats used for electronic transfer of photometric data. An IES file can be thought of as a map of the luminous intensity distribution of a light source, specifically, the intensity unit candela in relation to view angle. (For an explanation of lighting measurement terminology such as candela, refer to our blog post, The Language of Light).

Figure 1 shows a view angle radar plot of a light source's luminous intensity distribution (left) and a polar diagram highlighting a cross section of that intensity plot (right).

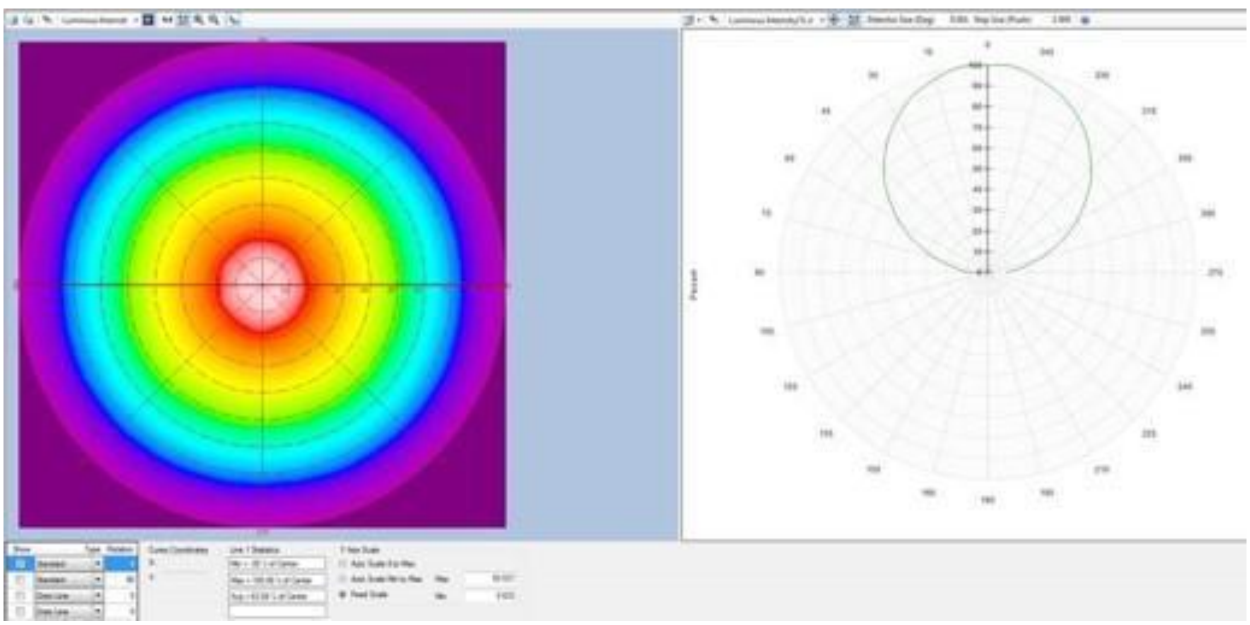

Figure 1 – View angle radar plot of luminous intensity distribution (left) and polar plot cross-section (right).

Figure 2 demonstrates using an IES file viewer to look at the same radar data from the images in Figure 1 in a 3D visualization, mapping the measured points and using the radar data to provide the full representation of the light source.

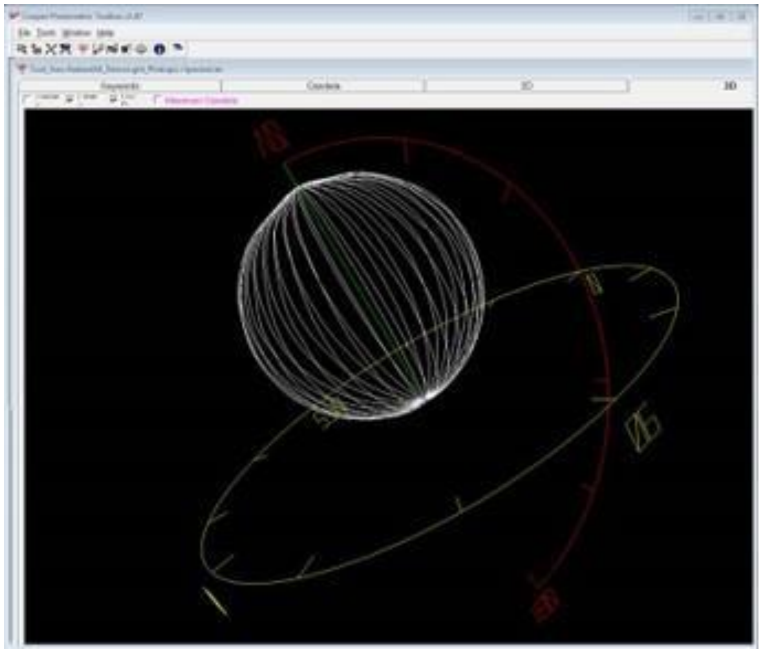

Figure 2 – IES file viewer displays radar data from Figure 1.

Tool for Measuring Light Sources: Goniometer

Radiant's fourth generation Source Imaging Goniometer® (SIG-400) is a fully automated, computer-controlled goniometric system designed specifically to meet the needs of LED researchers, developers, manufacturers, and users for LED die and device characterization. It provides precise measurement of near-field luminous intensity for LEDs and other small light sources.

The SIG-400 captures and aggregates images and flux measurements from thousands of angular viewpoints around a light source to precisely characterize the source's near-field output. The SIG-400 supports measurement of vertically oriented light sources and can be used with both microscope and extended field-of-view optics, thus providing the flexibility to measure both LEDs and other light sources.

The SIG-400 uses a ProMetric® I Imaging Colorimeter to generate highly accurate near-field models of LEDs. This data can be used directly to investigate the performance of the LED, or it can be exported using Radiant Vision Systems ProSource® Software, for use in all major optical design software packages. Capabilities include:

- Modeling of the complete spatial and angular output of a light source
- Approximately 1,500 measurements to output a complete light source characterization
- Automated motion and image capture control
- Scan set-up checklist with quick links to software features for ease of use, and completely configurable scan resolution
- Real-time, on-screen visualization of luminance measurement images, with playback option
- A record of ambient alignment images, operating conditions, and product info for sample
- Near field and far field luminous intensity distributions
- Data visualization tools: cross section, 2D isoplot, 3D isoplot, CIE color chart plot

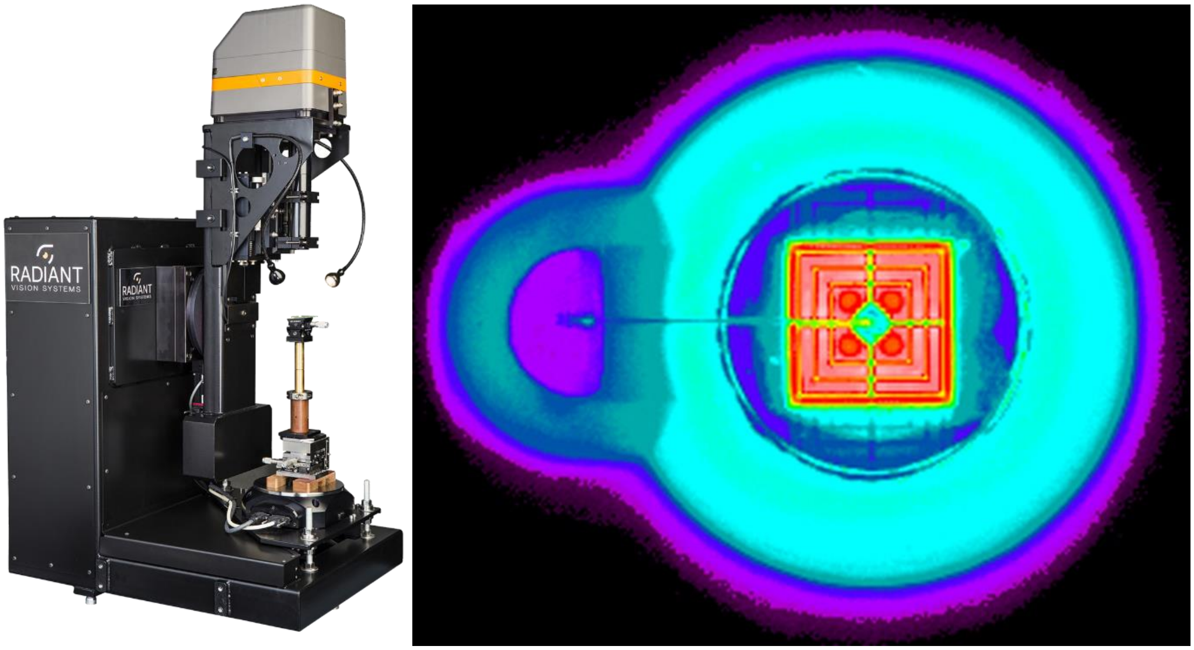

Figure 3 – At left, Radiant's Source Imaging Goniometer (SIG-400), at right, a snapshot of SIG-400 system imaging results, show in false color scale.

Tools for Creating Data Files

To create IES and LDT files, designers have their choice of systems. Traditionally, goniophotometers have been used to generate very accurate photometric data; near-field measurement systems are also an option. Radiant near-field and far-field methods are used to measure luminous intensity and illuminance distribution, as well as a light source's Unified Glare Rating (UGR), to ensure that brightness, beam patterns, and glare are accurately defined for the optimal lighting design.

Developers of automotive, transportation, architectural, and other lighting applications may need to measure large light sources. The ProMetric® Imaging Colorimeters and Photometers can be used in combination with goniometers for near-field measurement (Figure 4), or for far-field measurement of light source distributions on a wall or Lambertian surface.

Figure 4 – Measuring luminous flux at all angles of an automotive headlamp using a ProMetric imaging colorimeter and a goniometer for near-field data in a small dark room.

A light's CCT can innately enhance the color of objects when viewed under the light. Use Radiant light measurement systems to measure a light's CCT over angle to determine a source's temperature from cool to warm. Depending on the configuration, Radiant systems can also extrapolate Color Rendering Index (CRI) values (as well as CIELAB values) to determine how natural and accurate colors appear under the light source.

ProSource Data Files

ProSource® is Radiant's software for light source analysis and ray set generation. When paired with a near-field measurement system such as Radiant's SIG-400 to collect the raw measurement data, ProSource formats the data as a Radiant Source Model (RSM™) file. This file contains all light source measurement information including the image data, so you can review measurement results in detail.

RSMs are a highly accurate method for describing the near-field output of real light sources in optical and illumination design software because they contain full measurement information, including luminance images, from all viewing angles for the light source or lighting system. This wealth of data provides full flexibility in analysis, in ray set generation, and in creating 3D models of different light sources.

Generating Ray Sets

The key goal of ray-set generation is to generate an accurate set of the most important rays. The accuracy of a ray set is critical to enabling accurate modeling of the light source in an optical system. Importance-weighting (versus randomly generated ray sets) is critical to minimize the number of rays that must be traced to produce an accurate simulation in the minimum time. Importance weighting requires a full measurement of luminance and luminous intensity in all directions before any ray can be generated.

The drawbacks of random sampling include:

- Each ray can have a substantially different flux
- The same number of rays are generated in all directions, but the flux value is higher if the luminous intensity is higher
- The same number of rays are generated from all locations on the source, but the flux value is higher from location of higher luminance

Importance weighting is critical to ensure the greatest accuracy. Using importance weighting ensures:

- All rays have nearly the same flux (power)
- More rays are generated in the direction of higher luminous intensity
- More rays are generated from locations of higher luminance

Importance-weighting also minimizes the number of rays that must be traced to produce an accurate simulation, reducing measurement time.

ProSource can generate photopic, color (RGB) and spectral ray sets containing a user-defined number of rays. ProSource ray sets contain equivalent information with only 20% of the number of rays used in random Monte Carlo-generated ray sets (Figure 5). These ray sets result in faster optical design analysis times than usual with higher accuracy.

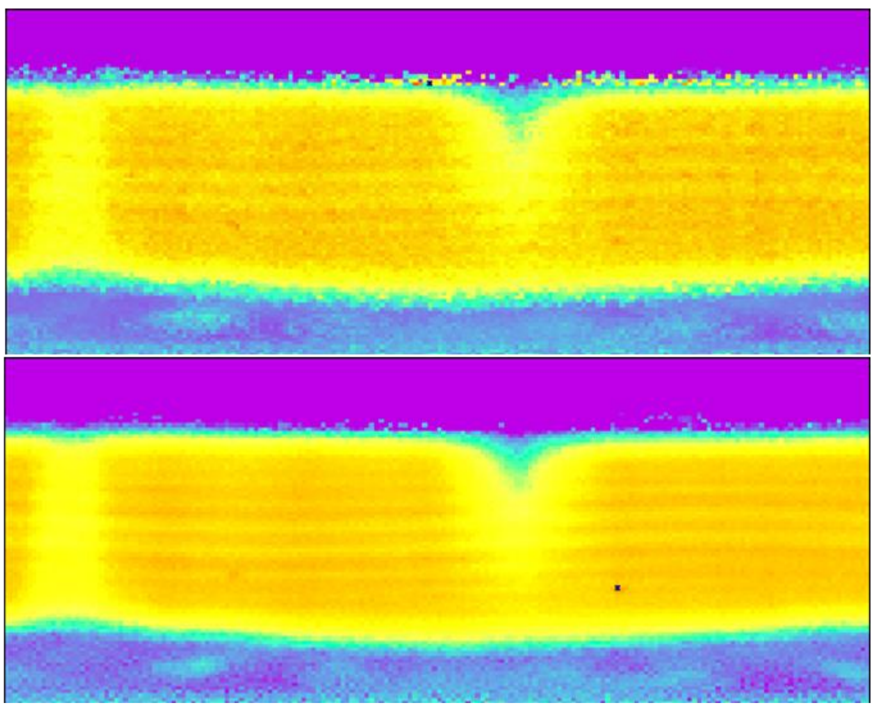

Figure 5 – Comparing ray set results using ProSource with importance weighting (bottom image) compared to typical Monte Carlo-generated ray sets. With ProSource users obtain equivalent results in far less time for more efficient measurement and testing.

Analysis and Design Tools

You can analyze and export measurement data and ray sets captured by ProMetric cameras and ProSource software. Information including photopic and spectral ray sets can be exported to many optical and illumination system design software packages, including the following, and other general file formats

- ASAP®
- FRED®
- LightTools®
- LucidShape®
- Photopia™
- IES TM-25
- Opticad®
- OSLO®
- SimuLux®
- SPEOS®
- TracePro®
- OpticStudio™ (ZEMAX)

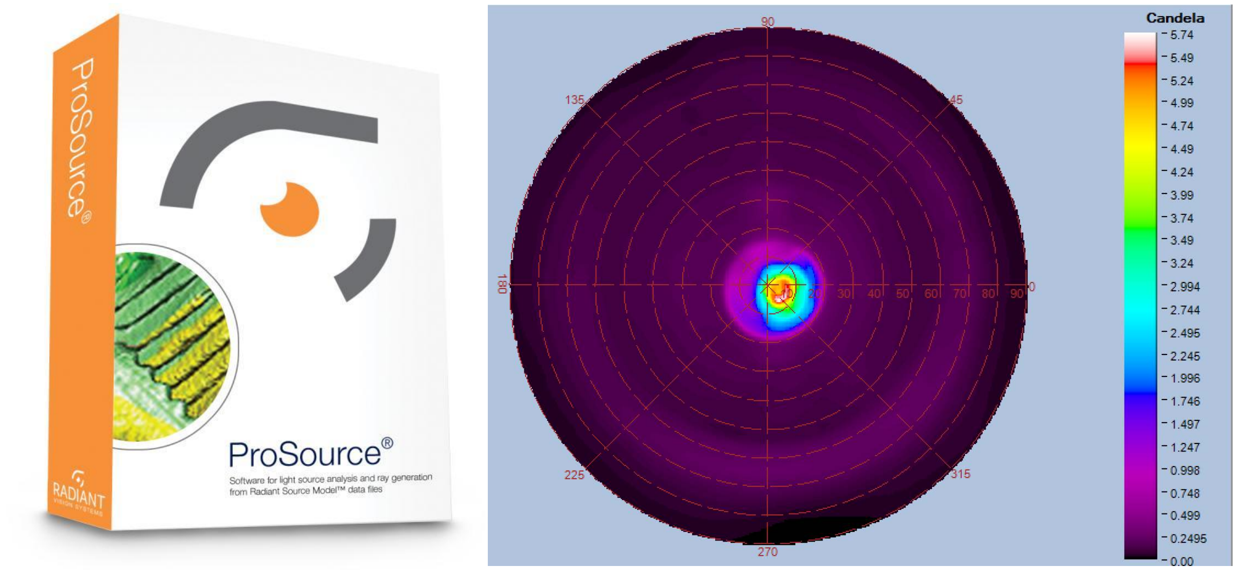

Figure 6 – Radiant's ProSource® Software (right) for light source analysis and ray set generation, image of luminous intensity measurement of a light source, shown in false color scale.

Data Visualizations

Using ProSource, users can determine CIE color coordinate (CIEx or CIE u'v'), tristimulus values, correlated color temperature (CCT) and luminance values for any point or user-defined area of the light source. Users can also view 2D and 3D data plots (Figures 6, 7 and 8) and animated images of a light source to intuitively understand its light output characteristics. Users can also view alignment images of a light source to determine the origin of the global coordinate system in relationship to specific physical features of the light source.

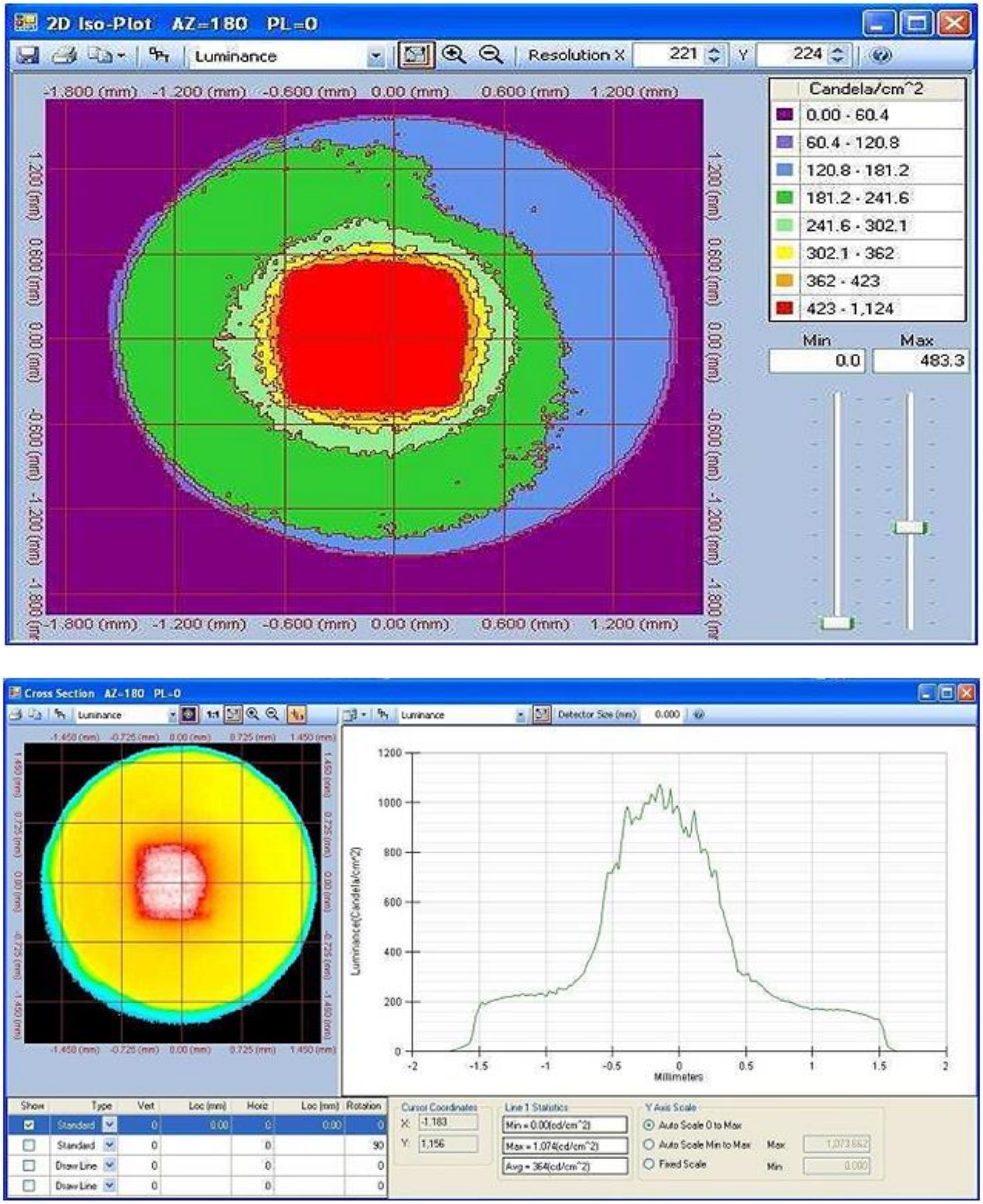

Figure 7 – Two-dimensional iso-plot (top), cross-section (bottom) from ProSource software.

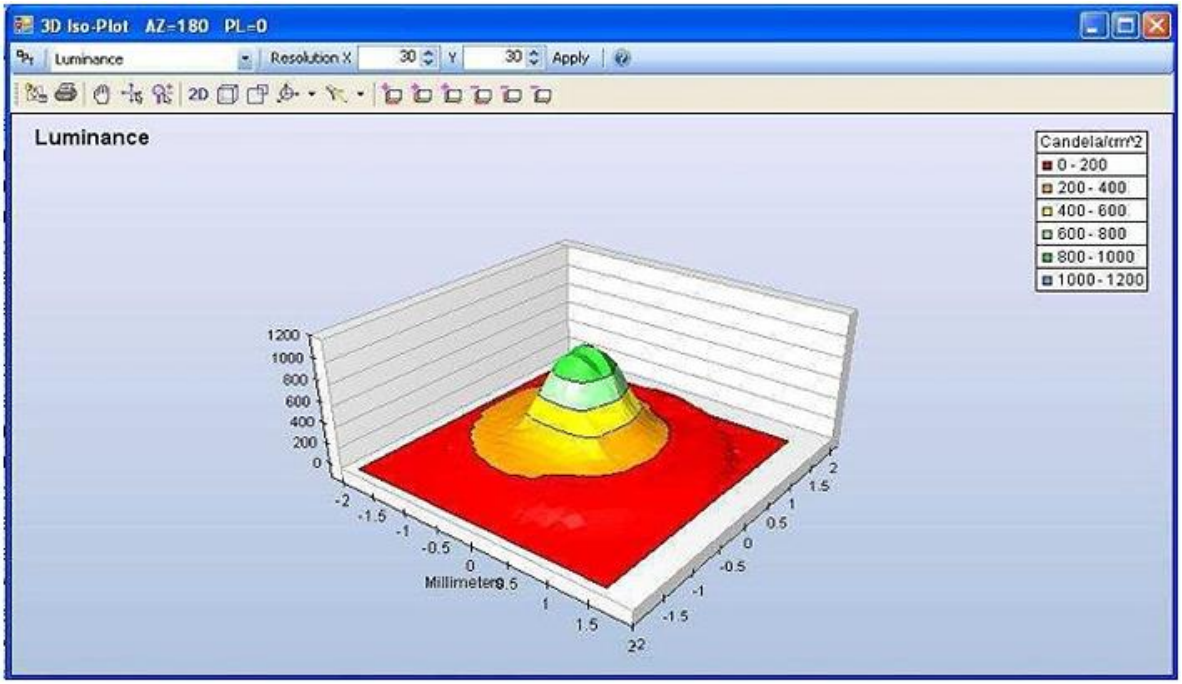

Figure 8 – 3D luminance model from ProSource software.

RADIANT
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A Konica Minolta Company

18640 NE 67TH COURT, REDMOND, WA 98052 USA
T: +1 425 884-0152 | F: +1 425 844-0153 | INFO@RADIANTVS.COM
WWW.RADIANTVISIONSYSTEMS.COM