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| IALA Guideline |

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The Measurement of Marine Lights Performance

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# Introduction

This guideline mainly concerns both photometric and colorimetric measurement of marine signal lights, which supports IALA Recommendation *R0203 Definitions of Marine Signal Lights Terms of Measurements* [1]. The main body provides further explanations, diagrams and examples to the recommendations given in R0203. They will cover the measurements as well as both processing and presentation of results. These sections are intended for measurement operators with some experience.

An appendix contains further information including introductory topics, aimed at those newer to light measurement, and more detailed topics to assist readers in obtaining accurate and precise measurements. However, it is unfeasible for a single document to transfer all knowledge and skills required. It is recommended that measurement personnel complete dedicated training courses and read additional material.

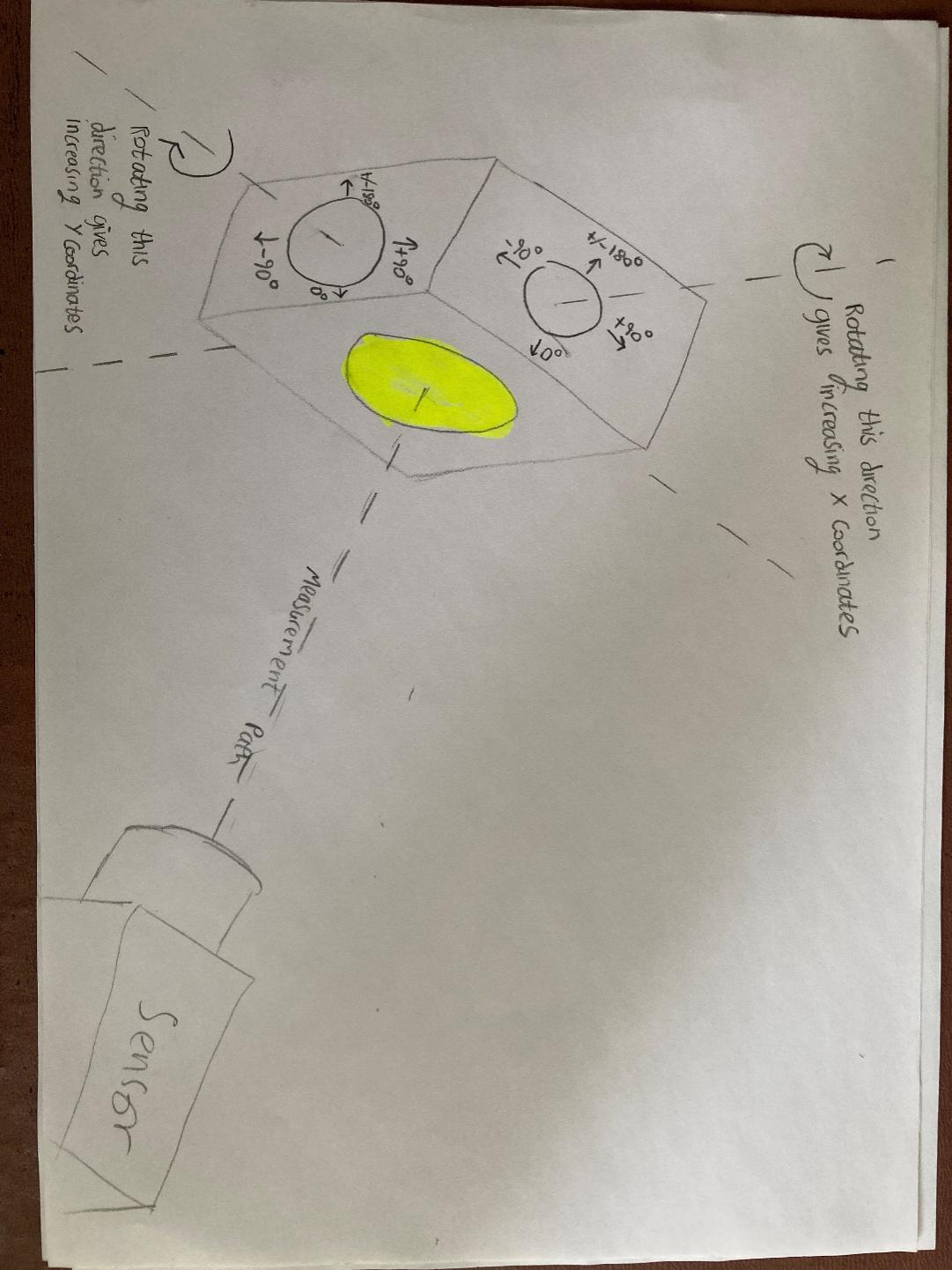
Most of the AtoN light measurement are carried out in the laboratory, where the measurement is much precise than that in the field, so this guideline mainly introduce the laboratory measurement. For the measurement in field, different states may use different methods and APPENDIX 1 6 provides three methods based on different technological approaches.

# Standard measurement conditions

## measurement geometry

R0203 recommends an X-Y coordinate system. This system is illustrated in Figure 1. The system has the following characteristics:

* The coordinates at the datum position are X = 0° and Y = 0°.
* The X coordinate is the rotation of the DUT about a vertical axis.
* Rotating the DUT clockwise increases the value of X up to a maximum of 180°.
* Rotating the DUT anticlockwise decreases the value of X down to a minimum of -180°.
* The X angle is often referred to as the “horizontal” or “azimuth” angle since the rotation occurs in the horizontal plane.
* The Y coordinate is the rotation of the DUT about a horizontal axis that is perpendicular to the measurement path. Viewing with the measurement sensor to the right of the DUT as in Figure 1:
* Rotating the DUT clockwise increases the value of Y up to a maximum of 180°.
* Rotating the DUT anticlockwise decreases the value of Y down to a minimum of -180°.
* The Y angle is often referred to as the “vertical” or “elevation” angle since the rotation occurs in the vertical plane.
* The axis of rotation and measurement path should intersect. The centre of the DUT should be positioned at this intersection.

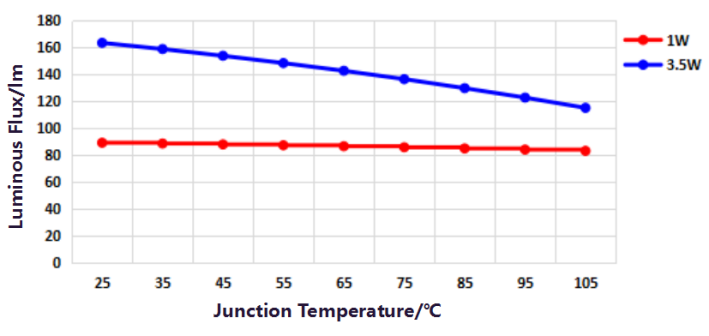
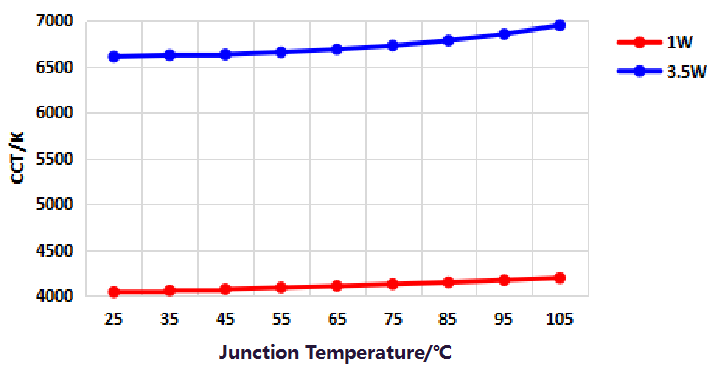


1. X-Y Coordinate System

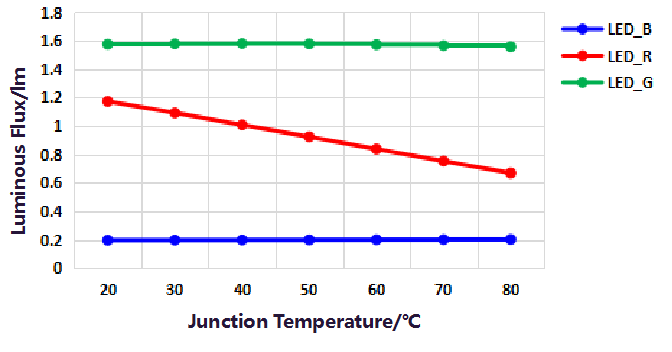
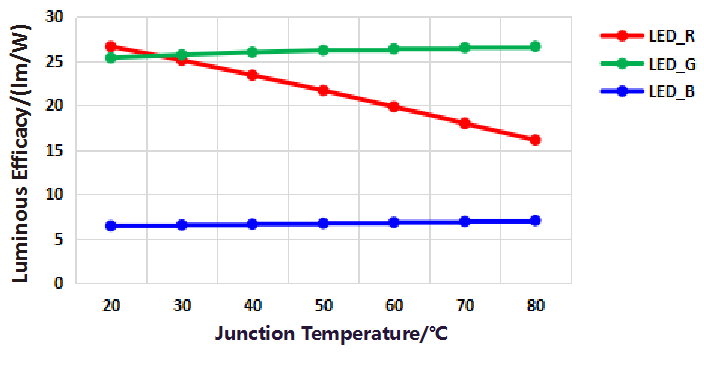
## Ambient conditions

Ambient conditions for indoor measurements maintain a relative humidity of 10 % to 65% . For LED light sources, the ambient temperature should be stabilized at 25.0 °C ±1.2°C ; for other types of light sources, it should be stabilized at 25.0 ° C ±3.0° C . There is no interference such as smoke, dust, water vapor, mechanical vibration, electromagnetic and light that affect the test accuracy. The laboratory should be in a dark room environment, and the walls in the dark room should be painted with matte black paint. The test equipment, baffles and other test accessories should be non-reflective. Measurements should be made in still air with a tolerance interval of 0 m/s to 0.25 m/s .

If the above temperature conditions cannot be met, it is recommended to use a "service conversion factor" to correct the results for measurements outside the acceptable ambient temperature range. If the client specifies a declared ambient temperature for the DUT other than 25.0°C, unless the measurement was made at that specified temperature, the measurement at 25.0°C should first be reported, and then a service conversion factor should be established to convert the measured value at 25.0°C to the value at the specified ambient temperature. The service conversion factor can be obtained by measuring the ratio of the total luminous flux (or light intensity or brightness in a fixed direction) of the DUT in a temperature-controlled box or a temperature-controlled measurement system (such as a temperature-controlled integrating sphere), and report the service conversion factor separately. If the service conversion factor cannot be experimentally determined by itself, performance curves can also be obtained from the LED manufacturer and adjusted in this way. Figure 2 and Figure 3 below are examples performance graph.

1. Example of luminous flux and CCT variations with temperature of white LED with different power

1. Example of photometric variations with temperature of monochrome LED

When applying these graphs, it must be assumed that the change in luminous flux is linear with the range of the dependent variable and that the junction temperature varies directly with the ambient temperature. But that may not be the case, especially given the flickering lights at sea. On average, however, the service conversion factor based on the data sheet may be sufficient.

In the case of outdoor measurements, the temperature and relative humidity should be noted at the time of the measurement. Any significant changes in ambient conditions during the measurement should be recorded.

## POWER SUPPLY CONDITIONS

For tests involving equipment powered by a dc power supply, the output voltage and/or current should be maintained within ± 0.2% or better, unless otherwise specified by the person requesting the measurement. When output voltage is controlled, the voltage should be monitored as close to the light source as possible. Ripple voltage should not exceed 0.4% of the DC output voltage.

For tests involving equipment powered by an external ac power supply, the output RMS voltage or current should be maintained within ± 0.4%. If the rated value is within a range, the middle value shall be taken. The AC power supply should have a specified frequency (50 Hz if there is no special instruction) sinusoidal voltage waveform. The RMS summation of the harmonic components, caused by departures from a true sinusoidal waveform, should not exceed 3% of the RMS value of the fundamental frequency. Readjustment of the output voltage may be required during measurements if adequate stabilization is not achieved.

The test voltage should be measured at the supply terminals of the DUT, not at the output terminals of power supply, to avoid errors due to voltage drop by the cables and connectors.

# Measurement preparation

## Mounting

The DUT should be installed on the goniometer and aligned with the measurement direction. The datum point should be identified on the perimeter of the DUT such that it clearly defines a direction in the horizontal plane. This may be a manufacturer’s mark or one put there by the testing laboratory. Where possible, the height of the goniometer table should be adjustable so that both the horizontal and vertical axes of the optic may be aligned with the rotational axes of the goniometer. If this is not possible, due to the design constraints of the goniometer table, the errors in measurement distance caused by tilting the table should be corrected or included in the uncertainty budget. The centre of the detector aperture should lie along the line normal to the rotational axes of the goniometer. The alignment process and its associated uncertainty should be part of the documented laboratory procedure. Since the angle of incidence is always close to zero, there is no need to carry out cosine correction.

As shown in the figure below, the DUT is installed on the rotating workbench to make sure its reference center of coincides with the rotating axis of the workbench. In addition, it should be ensured that the detector is at the same height as the reference center of the DUT. The reference center of the DUT is determined by the method in APPENDIX 1 2.1.



1. Mounting diagram

Where:

1 is the rotating workbench of goniophotometer;

2 is the photometric center of DUT;

3 is the DUT;

4 is the baffle;

5 is the detector.

When using a goniophotometer and measuring the AtoN luminaire with multiple light-emitting areas that have significant separation and which don’t comply with the specifc requirement for mesurement distance in Section 3.4, the luminaire should be measured in several steps with each light-emitting area centred accordingly.

## Settings

The light-emitting status of the DUT should be set after the whole measurement system is mounted. For different measurment item, the light status maybe different. For example, when measuring the luminous intensity versus angle, it’s maybe necessary to set the DUT exhibit a fixed light. Of course, it is not ruled out that some laboratories perform the measurment in the flashing light state in which case an appropriate character needs to be selected for the DUT.

***Note:***

*The luminous intensity of LED light sources under test may vary considerably with LED junction temperature and this can be a consequence of duty cycle of operation, for instance flash character. It is important therefore, to ensure that the peak intensity in flashing mode is measured at the character specified and clearly labelled so as not to be confused with the fixed (continuous) intensity.*

## Warm-up

All measurement equipment requiring electrical power should be switched on and allowed to warm up in accordance with the manufacturers’ operating instructions or calibration certificates before commencement of any tests or measurements. In the absence of such guidance, the measurement facility should evaluate the performance of measurement equipment to determine the required warm up period to prevent drift for each piece of equipment.

Before measurement, the measured AtoN luminaire shall be run at the power supply condition in Section 2.3 and at the specified character for a sufficient time to ensure stability. The detector is used to continuously monitor the output of the measured AtoN luminaire, which can be determined as stable when the following conditions are met:

The light output is measured every 5 minutes. After three consecutive measurements, if the relative difference of the maximum and minimum readings of light output is less than 0.5% of the last reading.

When the DUT is switched to a different light character or color for subsequent measurement, the stability should be judged again according to the above condition before measurement. Record the stabilization time for each measurement.

## Measurement distance

Before commencing a measurement, the minimum measurement distance of the DUT should be estimated. Provided the measuring distance is relatively large compared to the size of the light source (greater than fifteen times as a rule of thumb), this method is simple and accurate for unfocused light sources. However, when measuring light beam projection apparatus, such as a light source and lens or mirror system, much greater measuring distances are required to ensure an error free result when using this method.

The minimum measurement distance can be determined by measuring the luminous intensity at several different distances from the DUT, always on the same radial coordinate, and assessing the distance beyond which the resultant measured intensity is consistent [28].

For example, when the AtoN luminaire is in the steady light state, the initial distance between the photometer and the AtoN luminaire is 20 times the diameter of the lens of the measured AtoN luminaire. Then, move the photometer so that the relative distance between the photometer and the reference center of the AtoN luminaire increases by 1 m each time, and measure the luminous intensity accordingly until that the relative difference of the maximum and minimum readings is less than 0.5% of the last reading within three consecutive measurements. In practice this will be restricted to small sealed beacons, whose component parts are not measurable.

For ball shaped light sources in a parabolic mirror, which may be used for old search lights, in cases where the sizes of optical components are known, the determination of minimum measurement distance involves calculating the crossover distance. John W. T. Walsh described a method for determining crossover distance in his book on Photometry[8], as follows:

1. Crossover Distance

Where:

*d* is the crossover distance (m);

*f* is the focal length of optical system (m);

*R* is the radius of the optic aperture (m);

*r* is the radius of the light source (m).



1. Crossover Distance

An approximation of crossover distance can be obtained by the formula:

1. Crossover Distanc*e – approximation (1)*

The approximation only holds good for an optical lens system with a collection angle of approximately 63°. If the collection angle is markedly different, the full formula, as prescribed by Walsh, should be used.

Equation 2 is good for circular optical apparatus with a spherical light source but when the optical system is larger in one dimension than another; for example, a rectangular lens with a cylindrical light source, the vertical and horizontal crossover distance will be different. In this case, the formula can be expressed as follows:

1. Crossover Distanc*e – approximation (2)*

Where:

*d* is the crossover distance (m);

*f* is the focal length of the optical system (m);

*H* is the height of the optic aperture (m);

*h* is the height of the light source (m).

1. Crossover Distanc*e – approximation (3)*

Where:

*d* is the crossover distance (m);

*f* is the focal length of the optical system (m);

*H* is the width of the optic aperture (m);

*h* is the width of the light source.

Both the crossover distances of height and width should be calculated and the greater of the two used. For an omnidirectional beacon, only the vertical crossover is relevant, therefore only Equation 3 is relevant.

For a precision sector projector, the crossover distance may be expressed as follows [27]:

1. Crossover Distanc*e – Precision Sector Projector*

Where:

d is the crossover distance (m);

R is the radius of the optic aperture (m);

*α* is the requested angular resolution (radian).

**The minimum measurement distance may be taken as twice the calculated crossover distance.**

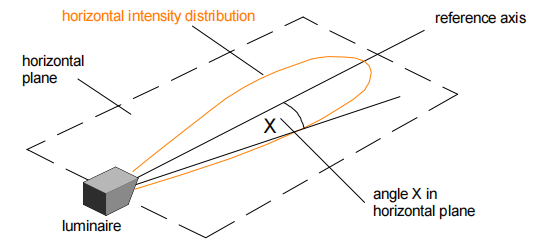
If the minimum measurement distance exceeds the length of the measurement light path, measurement should be made using of the two methods described in APPENDIX 1 1.3 and APPENDIX 1 1.4.

# Measurement of marine signal lights

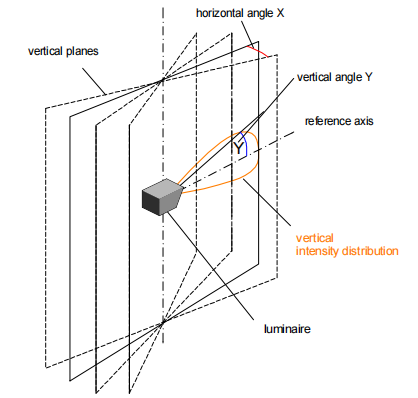
## Luminous intensity versus angle

### general

The measurement of luminous intensity versus angle is usually carried out by using a goniophotometer. According to the measurement geometry described in Section 2.1, for marine signal lights, the preferred angles on which the luminous intensity depends are named X/Y. With the use of X and Y, there is only one horizontal plane (Figure 6) and for each angle X in this horizontal plane there is a vertical plane (Figure 7). The reference axis may be chosen arbitrarily, but it is recommended to put it in the horizontal plane and for pencil beam light in or near the direction with maximum intensity and it should lie at the junction of vertical and horizontal planes. All angles should be referenced to this axis. X is in the range of -180° to +180° and for Y it is -90° to +90°.



1. Horizontal angle X



1. Vertical angle Y

With the goniophotometer, the luminous intensity distribution *I=I(X, Y)* is measured.

For omnidirectional light, the goniometer of the goniophotometer should take rotating scanning at an angle interval of no more than 0.1° on the vertical plane and no more than 1° on the horizontal plane.

For directional and rotating beacons and sector light, the goniometer should take rotating scanning at an angle interval of no more than 0.1° on the vertical plane and no more than 0.1° on the horizontal plane.

For AtoN lights array based which is composed of multiple light-emitting areas, the luminaire should be measured in several steps with each light-emitting area centred accordingly. The result of the angular dependence of the luminous intensity of each light-emitting area are added to obtain the luminous intensity distribution of the entire AtoN light.

Results of the angular dependence of the luminous intensity should be graphically presented to clearly illustrate the performance of the lantern. Graphs should be linear and annotated to identify causes of irregularities in the intensity measurements, such as shadowing due to filament supports, effects of lens seams, etc. If possible, try to give detailed data in tabular form , such as giving the table of luminous intensity versus angle.

### Vertical Divergence

IALA Recommendation *R0203* gives the following definition:

“The average of all measured Full Width Half Maximum (FWHM) values shall be reported as the vertical divergence, along with the maximum deviation of the maximum intensity from an elevation of Y = 0°.”

These parameters are calculated from a light’s luminous intensity versus elevation angle profiles. An example profile plot, annotated with the FWHM, is shown in Figure 8.

An example summary of three elevation profiles is shown in Table 1. In this example three elevation profiles are summarised, each taken at a different azimuth coordinate. The first row of results corresponds to the profile shown in Figure 2; these should be compared to aid understanding.

The FWHM is the angle between the points where the plot crosses 50 % of the peak intensity. It is possible that the intensity of the plot drops below 50 % of the peak and then rises above, giving multiple crossing points. In this situation, the innermost angle on each side of the peak is used.

Table 1 shows the angle at which the maximum intensity occurs in each vertical profile. The angle with the greatest magnitude (positive or negative) is presented as the maximum deviation of the maximum intensity from an elevation of Y = 0°.



1. Example luminous intensity versus Vertical Profile
2. Example Vertical Profile Summary

|  |  |  |
| --- | --- | --- |
| Azimuth Measurement Angle (X) | FHWM | Angle of Maximum Intensity. |
| -120° | 3.35° | -1.30° |
| 0° | 2.95° | -0.45° |
| 120° | 3.05° | 0.15° |
|  |  |  |
| Vertical Divergence | 3.12° |  |
| Maximum deviation from 0° |  | -1.30° |

**Additional guidance to add:**

**Number of vertical profiles to measure for** **different AtoN lights are as follows:**

* For omnidirectional light, measurements in a minimum of three vertical planes, preferably including and equidistant from the reference vertical plane or datum (e.g. with horizontal angle X = -120˚, X =0˚, X = +120˚), should result in graphs of the vertical profiles plotted between the points where the intensity falls below 1% of maximum.
* For sector light, at least one vertical profile per sector should be measured, one of which should be measured at the position of the 10th percentile of the intensity of the horizontal profile measured within the sector. The vertical profiles should be plotted between the points where the intensity falls below 1% of the maximum.
* For directional light, measurement should be taken in the vertical plane with X=0˚ and the vertical profile should be plotted between the points where the intensity falls below 1% of the maximum.
* For rotating light, measurement should be taken in the vetical plane at the horizotal point where the peak intensity of the individual beam lies and the vertical profile should be plotted between the points where the intensity falls below 1% of the maximum. The results of all beams should be shown.

**Normalisation：**

The profile in Figure 8 has been normalised, to the peak of the beam. This normalisation is optional and each lighthouse authority may choose whether to present absolute intensity values, normalise and what to normalise to.

### Horizontal Divergence

IALA Recommendation *R0203* gives the following definition:

“The Full Width Half Maximum (FWHM) values as measured along the horizontal plane shall be reported as the horizontal divergence. If the intensity does not fall to half maximum at any point around the light, then the horizontal divergence is 360°.”

These parameters are calculated from a light’s luminous intensity versus horizontal angle profile. An example profile plot, annotated with the FWHM, is shown in Figure 9.

The FWHM is the angle between the points where the plot crosses 50 % of the peak intensity. It is possible that the intensity of the plot drops below 50 % of the peak and then rises above, giving multiple crossing points. In this situation, the innermost angle on each side of the peak is used.



1. Example Luminous Intensity Versus Horizontal Profile

**The angle range of plotting the profiles for different AtoN lights are as follows:**

* For omnidirectional light, a graph of the horizontal profile should be plotted over ±180º from the vertical reference plane or datum.
* For sector light, graphs of the horizontal profiles should be plotted over the Sector Width.
* For directional, a graph of the horizontal profile should be plotted over the intended arc of utilization of the sector or to the points where the intensity falls below 1% of the maximum, which ever is the greater.
* For rotating light, a graph of the horizontal profile should be plotted between the points where the intensity falls below 1% of the maximum. For rotating beacons with more than one emitted light beam, the results of all beams should be shown.

### Specification Peak Intensity

IALA Recommendation *R0203* gives the following definition:

“**Omnidirectional light:** the intensity is defined as the 10th percentile of the intensity measured around the entire light at an elevation of Y=0°.”

“**Directional light without a required boundary:** the intensity at the optical centroid axis of the light”

“**Sector intensity:** the intensity is defined as the 10th percentile of the intensity measured within the Sector Width at an elevation of Y=0°.”

“**Rotating optic:** This is the peak intensity of the individual beams when the optic is not rotating.”

From the above definition, the specification peak intensity can be calculated from the horizontal luminious intensity versus angle profile.

The specification peak intensity is used to scale the effective intensity. In other words, the point where the specification peak intensity lies will be used as the datum to measure the luminous intensity versus time.

## Luminous INTENSITY versus time

### general

To determine the flash duration or effective intensity of a flashing AtoN light operating at a chosen character, the luminous intensity versus time profile should be measured. One prerequisite for the accurate measurement is to find the correct measurement direction. According to Section 4.1.4, the measurement direction is the point where the specification peak intensity lies. Another prerequisite is to select an appropriate photometer. Usually there are two kinds of photometers based on different sampling rates: conventional photometer and fast photometer. The sampling rate of the fast photometer is much higher than that of the conventional photometer, so for measurement of luminous intensity versus time, the fast photometer should be used except for some laboratories whose goniophotometer equipped with only conventional photometer, in which case a fast photometer is still needed (see the Conversion measurement method described in Section 4.2.3).

For AtoN light signals that are flashed by eclipsing or switching the light source, the instantaneous luminous intensity profile versus time (flash profile) should be plotted with the luminous intensity as the dependent variable (ordinate) and time as the independent variable (abscissa). The plot should include the entire cycle of the flash character, illustrating both the on and off periods. Secondary plots may be used to illustrate any short-duration fluctuations of the instantaneous luminous intensity.

For rotating beacons where the instantaneous luminous intensity is plotted against time by allowing the beacon to rotate under its own power, plots should show the luminous intensity profile against time for one complete revolution of the beacon. Secondary plots should also be used to illustrate individual emitted beams in greater detail.

Based on the horizontal distribution diagram of the luminous intensity of the rotating light measured in the non-rotating state (that is, the luminous intensity versus angle) and the rotating rate of the rotating beacons (that is, the angle versus time), the horizontal angular luminous intensity variation may be converted to a time-dependent luminous intensity profile at specific rotation rates for calculation of the effective intensity and flash duration.

### Flash Duration

IALA Recommendation *R0203* gives the following definition:

“The duration of the measured flash profile should be taken from the point in time when the intensity first exceeds 50% of the peak intensity value to the point in time when the intensity finally falls below 50% of the peak intensity value. The end of a flash should be considered as when the intensity falls below 5% of the peak intensity value for more than 100 ms.”

This parameter is calculated from a light’s luminous intensity versus time profile. An example profile plot, annotated with the flash duration, is shown in Figure 10.



1. Example Luminous Intensity Versus Time Profile

In cases where LED lights may have intensity spikes, pulse width modulation (PWM), a convolutional method may be used to determine the flash duration , see APPENDIX 1 3.9.

A photo detector with a sampling frequency not less than 500 Hz can be used to measure the flash duration and the rhythm of light.

### Effective Intensity

#### Direct Measurement Method

Set the AtoN light to the flashing mode with the selected rhythmic character, then after meeting the warm-up requirements of Section 3.3, use the fast photometer of the goniophotometer to measure the instantaneous intensity versus time profile of the AtoN light under the measurement distance that meets the requirements of Section 3.4 and the measurement direction described in Section 4.2.1. The measurement duration is not less than one period of the flashing light, and the sampling frequency of the fast photometer is not less than 500 Hz. If the AtoN light is modulated, the sampling frequency of the fast photometer is not less than twice of the modulated frequency. Then the effective intensity of the AtoN light can be calculated using the method described in IALA Recommendation *R0204*.

#### Conversion Measurement Method

If it is not possible to place the fast photometer but only the conventional photometer at the fixed point of the goniophotometer mentioned in the direct measurement method to measure the instantaneous intensity versus time profile of the AtoN light, the conversion measurement method can be used.

Set the AtoN light to the fixed light state, then after meeting the warm-up requirements of Section 3.3, use the conventional photometer of the goniophotometer to measure the fixed intensity of the AtoN light for three times under the measurement distance that meets the requirements of Section 3.4 and the measurement direction described in Section 4.2.1. Only the difference between the maximum and minimum values in the three measurements and the ratio of the last measurement is less than 1%, can this measurement method be used. Take the average of the three measurement as the fixed intensity .

Use a fast photometer to collect the fixed illuminance of the AtoN light at any position. Set the AtoN light to the rhythmic light state. After stabilization, use the fast photometer to measure the instantaneous illuminance versus time profile of the AtoN light at the same position. The measurement time is not less than one period of the flashing light, and the sampling frequency is not less than 500 Hz. If the AtoN light is modulated, the sampling frequency of the fast photometer is not less than twice of the modulated frequency. Use the curve of illuminance versus time to calculate the effective illuminance value as described in IALA Recommendation *R0204*. Calculate the luminous intensity versus time profile of the AtoN light by the formula:

1. Luminous Intensity Profile Versus Time

Where:

is the luminous intensity profile versus time;

is the illuminance profile versus time;

is the fixed lunimous intensity of the AtoN light (cd);

is the fixed illuminance of the AtoN light at one position (lx).

With the luminous intensity profile versus time, the effective intensity of the AtoN light can be calculated using the method described in IALA Recommendation *R0204*.

### Nominal Range

With the effective intensity of the AtoN light, the nominal range can be calculated by applying the method described in IALA Recommendation *R0202*.

## Colour and Sectors

### Signal Colour

The measurement of the colour of a light source in the laboratory is carried out by one of two methods: either by use of a tristimulus colorimeter (see APPENDIX 1 4.1), or a spectroradiometer (see APPENDIX 1 4.2). The results from either method should be reduced to x, y coordinates that enable a colour point to be plotted on a CIE 1931 chromaticity chart [24]. The light source is usually mounted on an optical bench or table to reduce the uncertainty of distance measurement.

For the light with only one color or the same color, the overall color of the light can be measured at close range or by placing the AtoN light in an integrating sphere. However, if the angular dependence of colour is being measured (for example of a sector light), a goniometer may be employed to facilitate the measurement of colour against angle on which the light source may be rotated about its light centre and several measurements carried out at different orientations. To ensure that a light source fully and evenly illuminates the measurement aperture, a diffuser or integrating sphere may be used. If the measurement angle needs to be small, then either the measurement distance should be increased or the measurement aperture should be decreased. At greater measurement distances, the lower levels of illuminance at the measurement aperture may increase measurement uncertainty considerably due to instrument noise. At least three colour measurements should be taken at different points within the arc of utilisation. The results of all measurements should be reported.

The colour of an LED is likely to change during its operation as the device current warms the junction. This means that there may be a significant colour difference between an LED exhibiting a rhythmic character with a low duty cycle and one exhibiting a high duty cycle character (e.g. occulting) or continuous light. It is recommended that an average of the colour over the duration of the flash be taken. When the tristimulus colorimeter is used, multiple measurements can be taken within the period of the flashing light to take the average; when the spectroradiometer is used, the integration time can be set as the the period of the flashing light, that is, the average color within this time can be obtained.

Further guidance on basic colorimetry can be obtained from CIE publications [14], [24], [30], [33] and [34].

The measured colour of the light should be reported in x, y coordinates according to the CIE 1931 chromaticity chart. Compliance with the appropriate IALA colour region should also be reported with reference to IALA Recommendation *R0201*.

If all points lie within the recommended boundary, results may be shown as a scatter plot on a chromaticity chart. However, if there are deviations in colour from the recommended regions, a Cartesian plot of x, y chromaticity against angle is preferable because the angles at which deviations occur can be seen.



1. Scatter Plot of Red LED AtoN Light over 360°

### Sectors

A sector light usually display different colours for different sectors, so the colour of the sector light varies with angle. For example a sector light with white, red and green sectors, the colour should be measured in at least three points within each coloured sector. The results of all measurement should be reported.

There are several key parameters for a sector light, such as sector colour boundary, sector intensity boundary, sector width, sector boundary, and sector of uncertainty whose definition are given by IALA Recommendation *R0203*. These parameters are calculated from a sector light’s luminous intensity and colour versus horizontal angle profiles. An example profile plot, annotated with the these parameters, is shown in Figure 12.

In this example, the **Red Sector Colour Width**, taken between the Red Sector Colour Boundaries, covers 1.5° from -56.9° to -55.4°. The **Red Sector Intensity Width** which is the angle interval across the full width half maximum (FWHM) intensity (i.e. taken between the Red Sector Intensity Boundaries), covers 1.4° from -56.6° to -55.2°. Therefore, according to the definition of Sector Width given by IALA Recommendation *R0203*, the **Red Sector Width** covers 1.2° from -56.6° to -55.4°.

The **Green Sector Colour Width**, taken between the Green Sector Colour Boundaries, covers 1.8° from -54.8° to -53.0°. The **Green Sector Intensity Width** which is the angle interval across the full width half maximum (FWHM) intensity (i.e. taken between the Green Sector Intensity Boundaries), covers 1.2° from -54.6° to -53.4°. Therefore, the **Green Sector Width** covers 1.2° from -54.6° to -53.4°.

Since the Red Sector Width and Green Sector Width have been determined, as the **Sector of Uncertainty** should be the angle between the adjacent Sector Width, so the Sector of Uncertainty between the red and green sectors covers 0.8° from -55.4° to -54.6°.

The **Red/Green Sector Boundary**, which should be taken as the centre of the Sector of Uncertainty, is -55.0°.

**IALA R0201 Red**

**IALA R0201 Green A**

-57.0

-56.8

-56.6

-56.4

-56.2

-56.0

-55.8

-55.6

-55.4

-55.2

-55.0

-54.8

-56.6

-54.6

-54.4

-54.2

-54.0

-53.8

-53.6

-53.4

-53.2

-53.0

Luminous Intensity

Horizontal Angle

(degress)

Colour

FWHM

FWHM

10% of Maximum

Red Sector Colour Width

Green Sector Colour Width

**Green Sector Width**

**Angle of**

**Uncertainty**

Red Sector

Intensity Width

Green Sector

Intensity Width

**Red Sector Width**

Angle of

Uncertainty

10% of Maximum

Angle of

Uncertainty

**Red/Green Sector Boundary**

**Green/Blank Sector Boundary**

**Blank/Red Sector Boundary**

1. Plot of Colour and Luminous Intensity Versus Horizontal Angle of Red and Green Sectors

When carrying out measurements of sector lights it is important to bear in mind the accuracy of alignment of the measurement datum point. If the resolution of the angular measurement is 0.1 degrees, it is necessary for the datum point to be aligned with the measurement instrument to better that half that resolution angle. The angular uncertainty of this datum alignment should be quoted along with the measurement results.

It may be necessary for the horizontal angular information given in the results, i.e. that reported from the goniometer, to be replaced with the bearing from seaward of the intended location of the light. In this case, care should be taken to align the goniometer datum with the cardinal points of the compass and, where possible, to show bearings of landmarks intended for alignment.



1. Plot of Colour and Luminous Intensity Versus Horizontal Angle of Red and Green Sectors



1. Plot of Colour and Luminous Intensity Versus Horizontal Angle of Red and Green Sectors

# Definitions

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA dictionary) at <http://www.iala-aism.org/wiki/dictionary> and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

In addition, for this document the following definitions are relevant:

# abbreviations

DUT Device Under Test

# references

1. IALA. (2022) Recommendation R0203 Definitions of Marine Signal Lights Terms of Measurement.

# Further reading

Any texts that are recommended to the reader without direct reference in the text should be listed within this section using the same syntax as the reference list. Sources should be listed using the **Further reading** style.

1. Einstein, A. (1905) Relativity: The Special and General Theory of Relativity
2. Idle, E. (1984) The Galaxy Song
3. Further Technical Guidance
   1. The Measurement Laboratory
      1. Overview
      2. Stray and ambient light control
      3. Folded Path Measurement
      4. Zero Length Measurement
   2. The Device Under Test
      1. Reference center
   3. Photometry
      1. Photometric distance law
      2. Measurement by Photometer
         1. Spectral Correction Factor
      3. Measurement by Spectroradiometer
      4. Calibration by Substitution with Calibrated Light Source
      5. Calibration using Known Distance
      6. Relative Photometry of Optical Systems
      7. Measurement of Luminous Flux
      8. Measurement of Modulated Light
      9. The convolution to determine flash duration
   4. Colourimetry
      1. Measurement by Spectroradiometer
      2. Measurement by Tristimulus Colourimeter
   5. Measurement Equipment Requirements
      1. Photometer
      2. Spectroradiometer
      3. Colouromiter
   6. Measurement in the Field
      1. Measurement of character of AtoN light based on spectral analysis
      2. Measurement of AtoN light based on image processing technology
      3. Measurement of Vertical Profile Using prisms