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Guideline on Sector Lights

# introduction

Sector lights have been used as an Aid to Navigation (AtoN) since the 19th century. Many different methods are used to provide sector lights. In addition, there are several emerging technologies that may be used to provide sector lights.

# BACKGROUND

A sector light is an aid to navigation that displays different colours and/or rhythms over designated arcs. The colour of the light provides directional information to the mariner.

A sector or a limit between two sectors may indicate a fairway, a turning point, a junction with other channels, a hazard or something else of importance for the navigator.

When a fairway is covered by a white sector, the convention to a vessel approaching the light from the seaward side must be a green sector to starboard and a red sector to port as per IALA Maritime Buoyage System colour convention for Region A; for Region B the colours are reversed. The white sector indicates safe passage, however this does not always hold true in the entire radial length of the sector. The fairway may alternatively be marked with lighted buoys or leading lights.

When designing fairways, consideration should be given to all possible types of aids to navigation to find the best solution for the particular site.

The requirements for sector lights can be a complex task. The process should be carried out with reference to a good quality chart of the area. In many cases, good local knowledge is also required and factors such as tidal flow, currents and background lighting may need to be considered (refer to Chapter 5).

A sector light may indicate one or more of the following boundaries of a navigable waterway.

• change of course position;

• shoals, banks, etc;

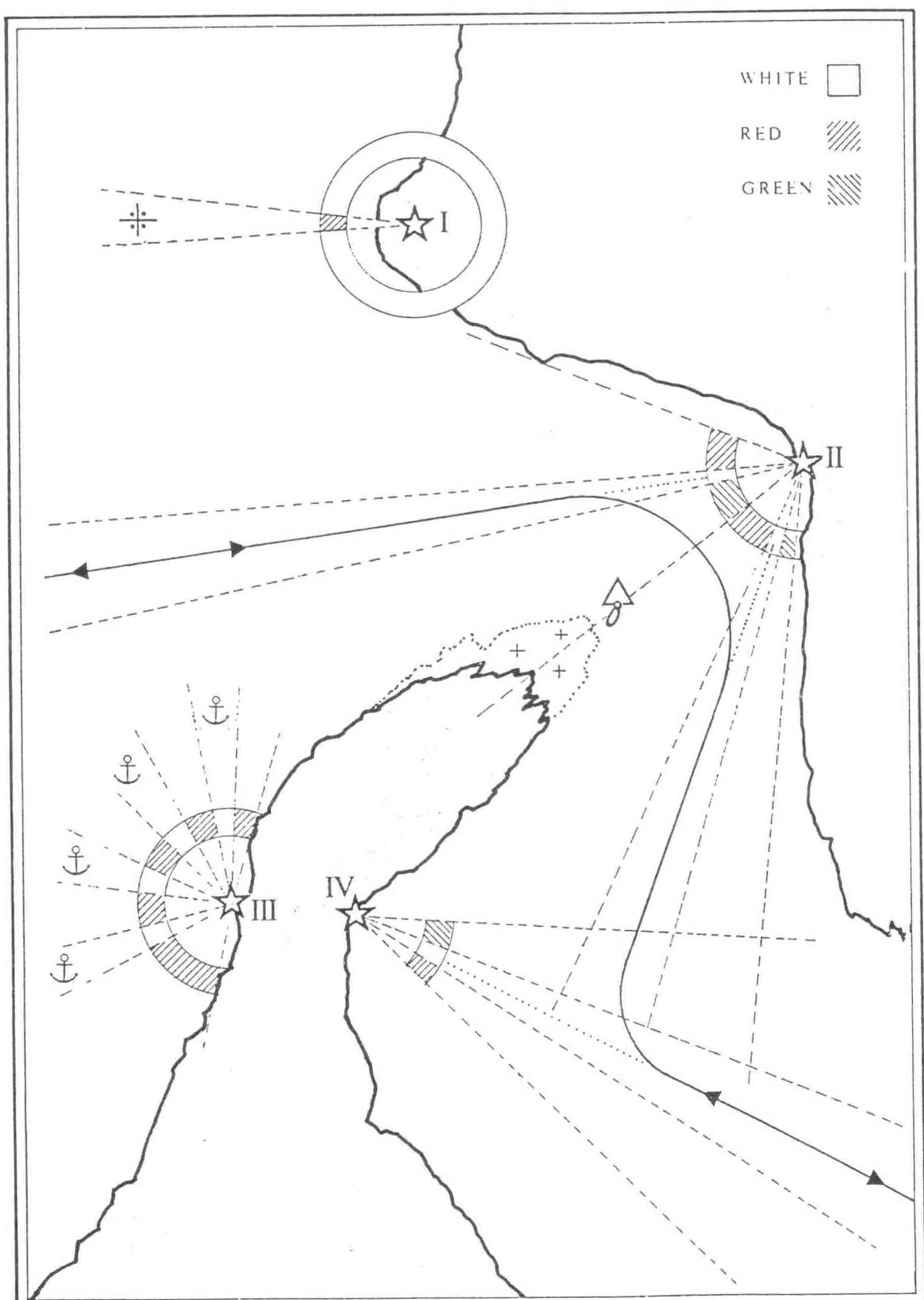
• an area or position (e.g. an anchorage);

• the deepest part of a waterway;

• position checks for floating aids;

• boundaries of a navigable waterway

Some examples of sector lights applications are illustrated in Figure 1, Figure 2 and Figure 3.



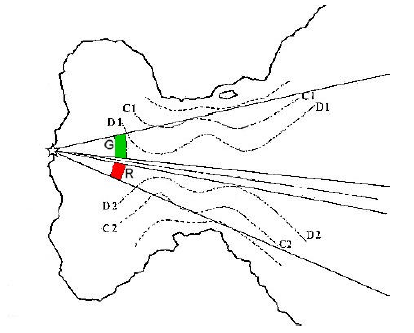
1. Several applications for sector lights.

Light I is a coastal white light with a red sector indicating a danger. In this application high boundary accuracy is not essential.

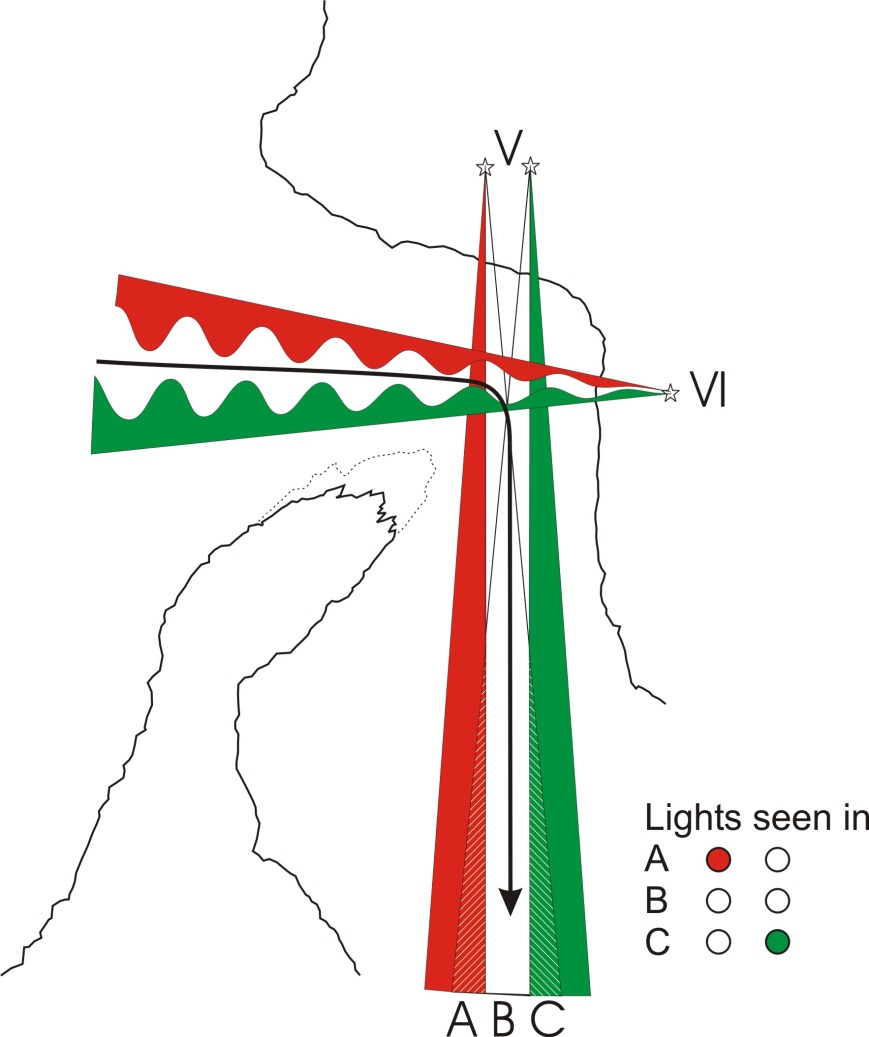
Light II is a sector light obscured over the shore, with two white sectors indicating a safe channel. The boundary between the red and the green sector also indicates the position of a buoy.

Light III is a sector light with a red light and 4 white sectors indicating four anchorage positions. It is obscured over the shore.

Light IV is a sector light with a white sector indicating a safe channel. It is obscured over the shore.



1. A single sector light marking a narrow channel



1. Multiple sectors arrangement marking a channel

Light V in Figure 3 shows two sector lights arranged to create a parallel sector light system. This arrangement has five sectors. Each sector can have its own flash character or colour.

Light VI indicates oscillating boundaries which could be made up of five or seven sectors and can be used to improve identification of the vessels lateral position

# Purpose

The purpose of this document is to provide the IALA membership with guidance on the principles of operation, practical design and installation of sector lights.

This document does not provide guidance on the nautical requirements.

# definitions

Numbers in brackets refer to IALA Dictionary entry.

## Sector Light (2-5-215)

A light presenting different characters (usually different colours) over various parts of the horizon of interest to marine navigation

## Angle of uncertainty (2-5-230)

The horizontal angle of the region of indefinite character near the boundaries of a sector of a sector light.

The limits or boundaries of a sector are not always precisely cut off due to the characteristics of the light source and merging of colours or changing rhythms between adjacent sectors. The transition zone is defined by an "angle of uncertainty".

## Sector Screen / Cut Screen (2-4-125)

An opaque screen so placed as to provide a sharp cut-off to a beam in sector light, and to reduce the angle of uncertainty.

## Vertical Divergence (2-1-200)

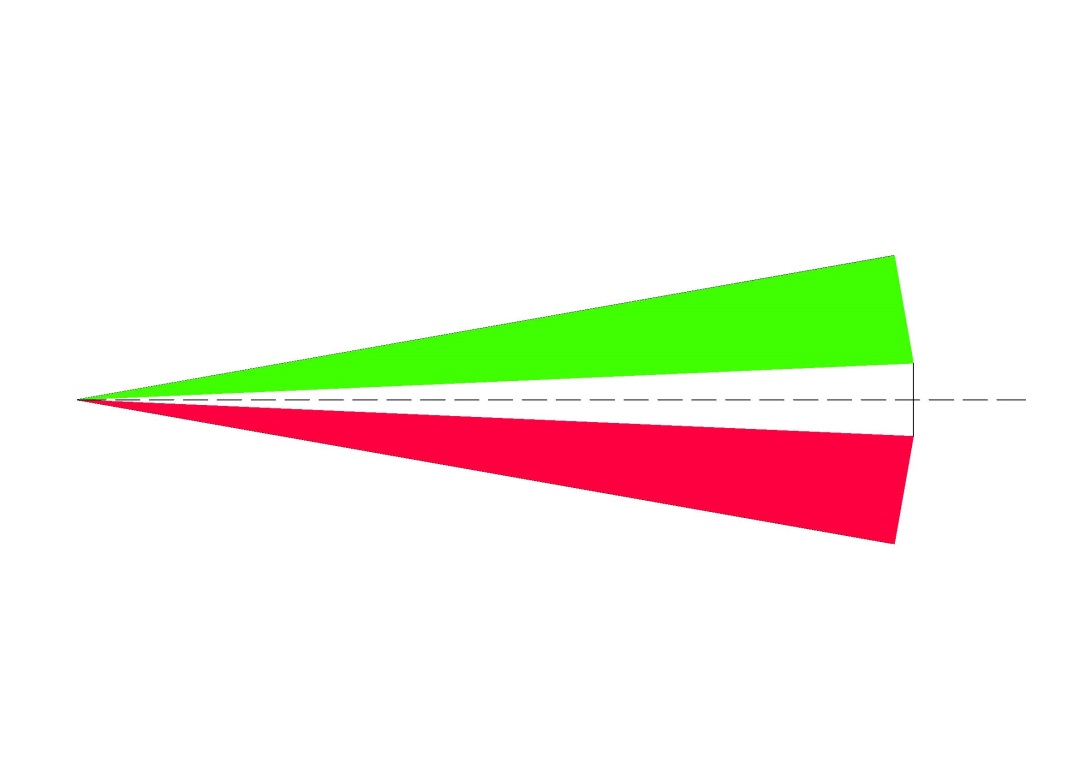
Vertical divergence is the total projected angle in the vertical plane. The associated intensity reduction factor must be given with vertical divergence (usually 10%).

## Oscillating Boundary

A method of giving more information of position near the sector boundary to the mariner by creating a light character with alternately flashing colours (figure 3).

## Total Subtense

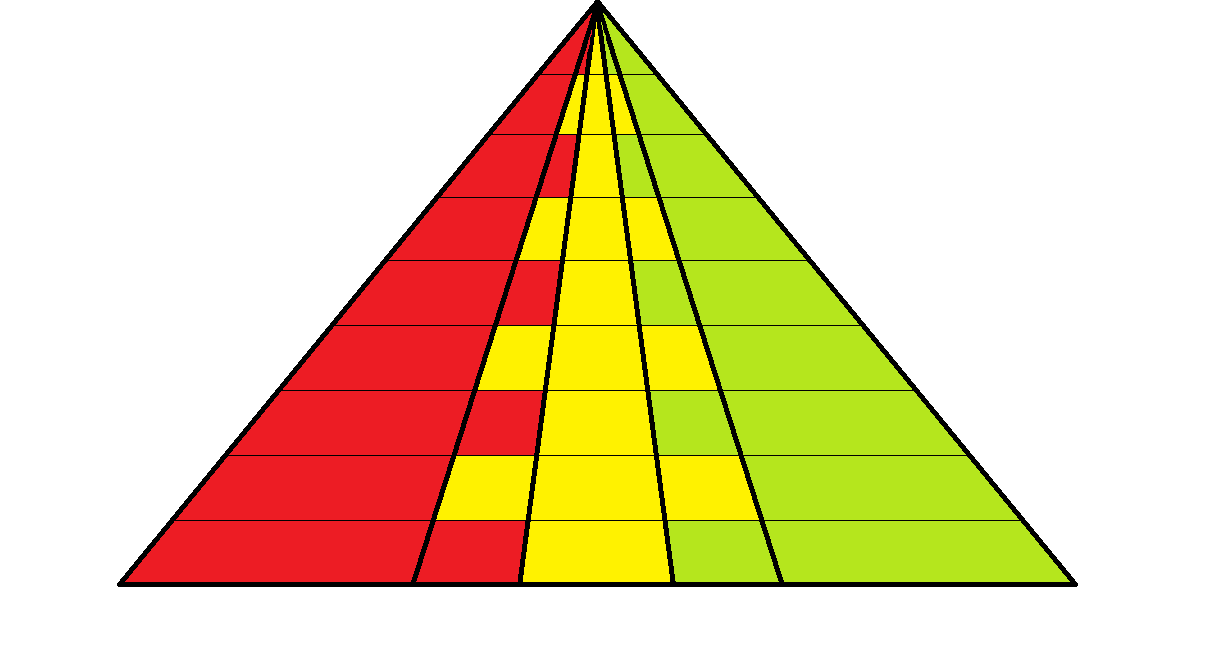
Total Subtense is the total projected angle in the horizontal plane. In projectors the basic light beam is circular in cross-section, and is masked down to a rectangle as shown in the diagram.



1. Subtense angle of projected beam

## Alternating Sector

An alternating sector is created by time-slicing of overlapping sector signal, applying a rhythmic character to the white sector and red/green sectors in apposite phase.



1. Alternating sector

## Sector Accuracy

Due to manufacturing tolerances on lenses, filter glasses and lens-mounting systems, the actual location of a sector boundary may be displaced from the intended place. Accuracy is the maximum angle between intended and actual location.

# basic principles

## Key Parameters of Sector Lights

Each sector of a sector light is described by

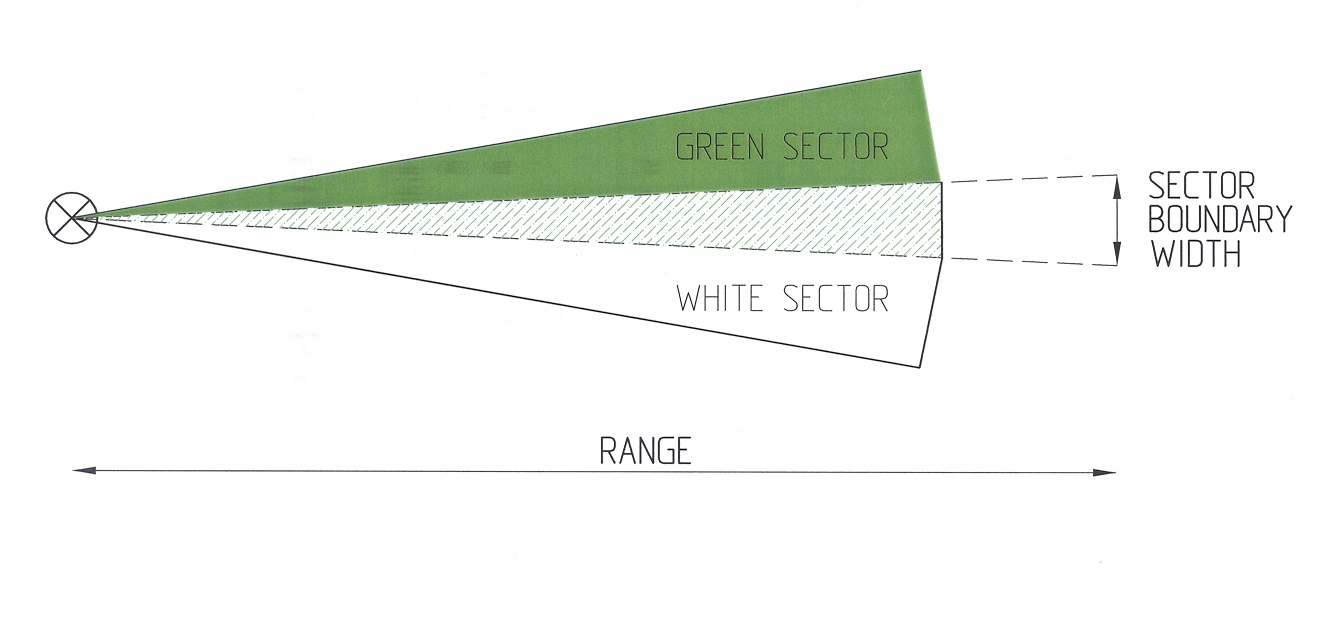
* sector width (angular subtense in horizontal plane)
* colour,
* intensity,
* flash character,
* uniformity of intensity across the sector,
* angle of uncertainty between adjacent sectors,
* vertical divergence.

Definitions of main parameters are provided in Paragraph 3. Detailed description of relevant concepts is provided below.

## Angle of uncertainty

The angle of uncertainty is the region where the colour and/or the flash rhythm change. The mariner typically sees a mixture of the two sector characters and this causes an uncertainty where the mariner is unable to distinguish between the two sectors. The understanding of this aspect is very important for the design of a sector light.

In most cases the angle of uncertainty should be as small as possible,



1. Angle of uncertainty

The basic mechanisms that determine the achievable minimum angle of uncertainty differ between types of Sector Lights (see 6 and 7).

## The Use of filters in sectorlights

In Sector Lights where optical filtering of a single light source is used, the luminous intensity, and thus the range, of each sector may vary considerably due to different transmission factors of the optical filters.

The spectral characteristic of the light source has a major impact on the light output from a coloured filter. It is necessary to match the light source with a filter material having a suitable spectral transmission, thus providing a light whose chromaticity is within the IALA recommended colour region (see E-200 part 1 Colour).

The transmission factor of the colour filter will determine the intensity and therefore range of coloured sector. Some typical values of transmission factors are given in the tables below.

1. Tungsten filament lamp (colour temperature approx. 3000 K)

|  |  |
| --- | --- |
| Colour | Transmission |
| Red | 0.08 - 0.25 |
| Green | 0.08 - 0.25 |
| Yellow | 0.50 - 0.70 |

1. Discharge lamp (colour temperature approx. 5500 K)

|  |  |
| --- | --- |
| Colour | Transmission |
| Red | approx. 0.13 |
| Green | approx. 0.22 |
| Yellow | approx. 0.55 |

1. White LED (colour temperature xKelvin)

|  |  |
| --- | --- |
| Colour | Transmission |
| Red | xx |
| Green | xx |
| Yellow | xx |

E.G. A red filter used a discharge lamp will only allow 13% of the light radiated from the white light source.

There are a number of materials, including glass and plastic, suitable for filters. It is generally easier to get large filters in plastic rather than glass. When using plastic filters, the filter material must be ultraviolet stable and be suitably fitted to ensure that the heat generated by the lamps does not distort it.

# TYPES OF SECTOR LIGHTS

There are two basic types of sector lights: omni-directional and directional. Omni-directional sector lights generally cover up to 360 degrees. Whereas directional sector lights only cover a relatively small arc.

Many technical solutions exist for generating sectors. They may be categorized in a number of ways, one of which is by the optical method applied. The two most common technologies for the provision of sectored light signals are as follows:

* Point Light Source Sector Lights (for large sector angles or omnidirectional)
  + Single light source and filters
  + Multiple Source Sector Light (MSSL)
* Projector Sector Lights (for small sectors)

Older technologies are:

* Slot sector light
* Use of colour filters in rotating optics

New developments are:

* Rotating colour switching sector light

For each of the above methods the choice of light source will have a large impact on the performance of the sector light.

A comparison between the basic types of Sector Lights is made in table 3.1. A more detailed description of each is shown in Section 4.

1. Comparison of the difference technologies of sector lights

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Type | **Practical**  **Night Time Range** | **Precision/ Angle of uncertainty** | **Max. Sector width** | **Typical Min. Sector width** |
| **Point Source** | Up to 20 M | Medium (0.25º-0.75) | 360º | 1º |
| **Projected** | Up to 30 M | Very High (1 minute of arc, 0.017º) | 25º | 0.2° |
| **Slot** | Up to 30 M | Low Boundary width is constant with range | 45º | 1º |
| **Rotating colour switching sector light** | Up to 15 M | 1° - 2° | 360° | 8° |
| **Colour filters in rotating optics** | Up to 20 M | 1º - 20° | 360º | 7º |

# Point Light Source Sector Lights

## Single light source and filters

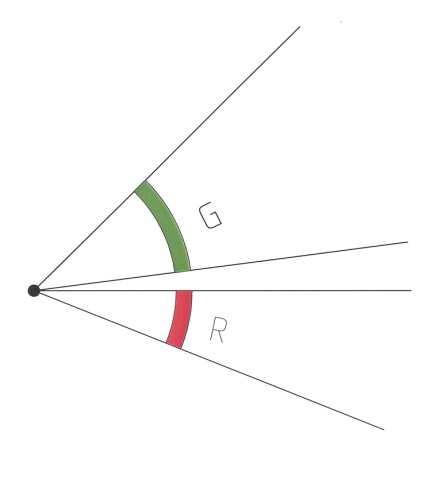
This type of sector light is sometimes referred to as a “traditional sector light” due to the fact that they have been in use for more than 100 years. They can be generally categorised as shadow method sector lights, in which a coloured sector is generated by placing a piece of coloured glass or plastic (such as polycarbonate or acrylic) against the lantern house glazing or against the light itself. This casts a coloured shadow over the water at the required sector.



1. Single light source sector light with drum lens

### Principle of operation

Point source sector lights generally take the form of a point light source, usually a lamp within a drum lens with one or more optical filters placed at some distance, screening the light and producing each sector in the desired colour.

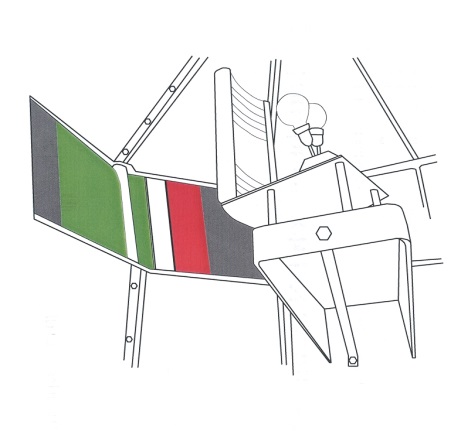


1. Basic operating principle of Point Source Sector Lights

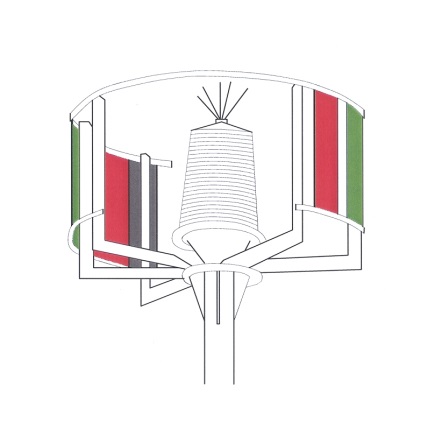
The physical position of the optical filters used with a light source should be mechanically adjustable for proper alignment of the individual sectors and sector boundaries.

In order to ensure sufficiently small angles of uncertainty between sectors, it is important to locate the optical filters at sufficient radial distance from the light source.

The optical filters may be located internally within the lighthouse glazing or external to a lantern.



1. Internal filters in lantern house



1. External filters on small lantern

On small lantern sector lights consisting only of a lantern, the manufacturer may provide fixed internal filters. In the latter case it is not possible to adjust the sector boundary and the angle of uncertainty is likely to be quite large.

### The light source

In a Point Source Sector light, the horizontal dimension of the light source is important to achieve small sectors as well as small angles of uncertainty.

It is important to correctly focus the light source within the optical apparatus as any small mis-alignment can result in altering the sector boundaries. This problem can be overcome by either using a pre-focussed light source or incorporating a means of accurately aligning the light source as each new lamp is installed.

The spectral characteristics of the light source must match the desired spectrum of each coloured sector as mentioned in the section on basic principles. I.E. the light should contain sufficient red and green radiation.

In general halogen and metal halide lamps achieve good results concerning the aspects above.

### Angle of Uncertainty

The shadow method can be used where very sharp sector boundaries are not required. The angle of uncertainty may be 1-3 and intensity may vary. As with any optical apparatus, precise positioning of the lamp is essential. The sector boundary will move if the lamp filament is moved, as it might when a lamp is replaced.

In the Point Source type of sector light the ratio between the horizontal dimension of the light source (d) and the distance between the light source and the optical filter (D), determines the angle of uncertainty (), and thus the width of the boundary region at any given distance from the sector light.



1. Factors that determine the angle of uncertainty in point source type of sector lights

The mathematical relationship between the factors is as follows:

Angle of uncertainty = (d/D) x 57 (degrees) (equation 1)

where

d = Horizontal dimension (width) of light source.

D = Distance from filter to light source.

Equation 1 is the angle subtended by the light source width d at the edge of the filter which is distance D away from the light source. The multiplier 57 is an approximate conversion from radians to degrees, 360°/2\*π. In this case, α is the angle between the light source being fully covered by the filter and being completely uncovered by the filter (see figure a) when viewed from a distance by an observer.

The angle of uncertainty can be reduced by decreasing the width of the light source or by increasing the radial distance to the coloured filter.

If space on the AtoNs structure is not a limiting factor, it is usually possible to achieve an angle of uncertainty of around 0.5° with this type of sector light.

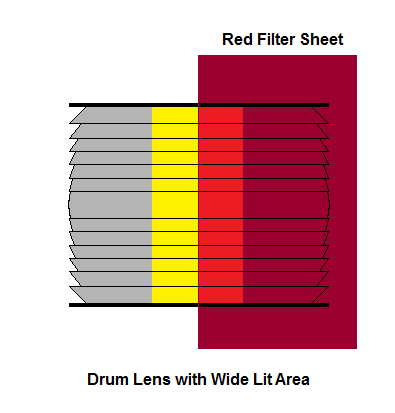
Equation 1 is known to be somewhat pessimistic. Regarding the colour visible from a far distance, it will not change immediately, when the observer enters the sector of uncertainty defined by equation 1.

An exact method for finding the angle of uncertainty based on the observed colour is presented in 6.5.

### Filter size

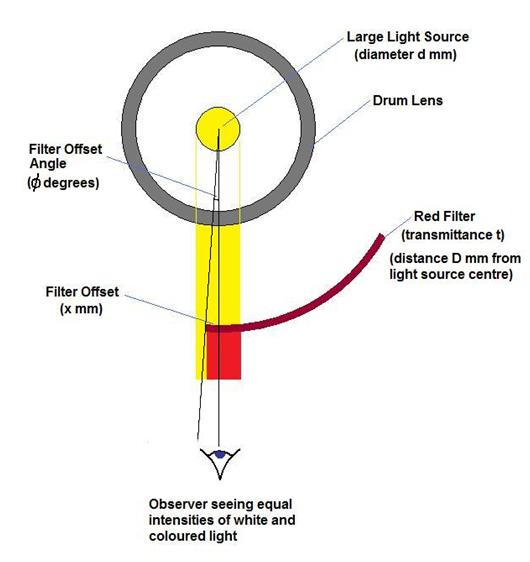
When a coloured sector is required, the size of the filter should extend beyond the given sector angle.

The white sector is more intense than the coloured sector which shows a fraction t of the intensity of the white sector. As a result the white light will dominate and the resulting colour will be still in the white region.



1. Observer’s View at the Assumed Nominal Sector Boundary

To avoid this, the coloured filter should be made larger by a filter offset so the intensity of coloured and white light is equal at the sector boundary.



1. Plan View of the Drum Lens

The filter offset distance, the distance between the edge of the filter and the nominal sector boundary, can be determined by the following:

 (equation 2)

where: x is the filter horizontal offset distance in millimetres;

t is the filter transmittance as a factor of one;

d is the horizontal width (or diameter) of the light source

in millimetres.

The angular offset of the filter, the angle between the edge of the filter and the observed sector boundary, can be determined by the following:

[radians] (equation 3)

or

 [degrees] (equation 4)

where: *ϕ* is the filter horizontal angular offset of the filter edge;

*x* is the filter horizontal offset in millimetres;

*D* is the distance from the centre of the light source to the filter edge

The filter offset occurs at both edges of the filter, so the required angular width of the filter is always greater than the sector angle covered by that filter.

Therefore, for a single sheet of filter material, the width of the sheet should always be greater than the width of the sector by twice the horizontal filter offset (sector width + 2x / sector angle +2 *ϕ*).

Remarks: In practical terms it is often useful to use two pieces of filter material that overlap in the centre of the sector. This allows for some adjustment during the checking procedure.



1. Filter offset applied on both sector boundaries

### Advantages/Disadvantages

Robust, retrofitting, relatively small cost, low maintenance.

Possible large angle of uncertainty, ranges of 15M+ are not achievable, filter degradation

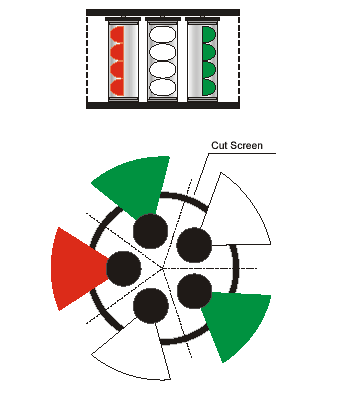
## Multiple Source Sector Light (MSSL)

Point Source Sector Lights using LED technology generally require at least one omni-directional tier per colour (red, white and green). Multiple tiers of the same colour are used to achieve the required range. Sector/cut screens are used to determine the sectors required.

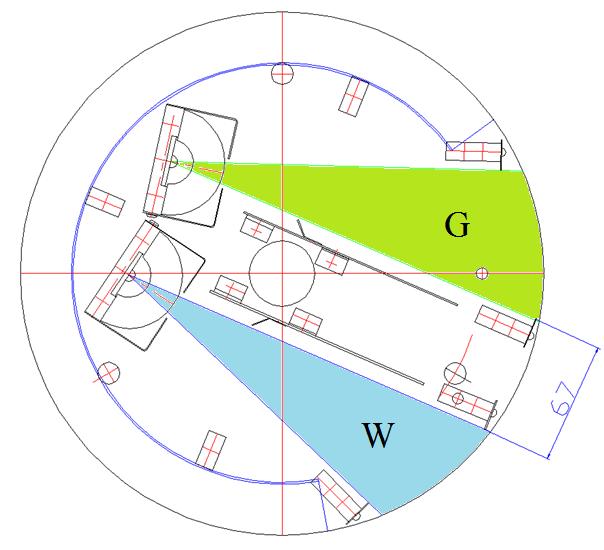
The use of LEDs has led to alternative methods for producing sector lights. Using several LED light sources a Multiple Source Sector Light (MSSL) can be realised. Some examples of MSSL and their principles of operation are as follows:-

### Principle of Operation

MSSL produce the sector signals using several LED light sources equipped with individual lenses and beam forming screens that are distributed in horizontal plane as off-centre point sources. An example of placement of LED / lens blocks on one tier of an integrated MSSL is provided in figure 15 and figure 16.



1. Example of a Multiple source LED sector light with four tiers



1. Multiple LED sector light with cutting screens

Depending on the light source and cut screen geometry implemented for separating the sector signals, usable segment of an MSSL starts at a distance L1 that is typically from tens to a couple of hundreds of meters from the AtoN position (figure 17). A blind patch of the size of the cut screen (D, typically not exceeding 100 mm) extends to infinity, increasing the sector boundary region slightly.

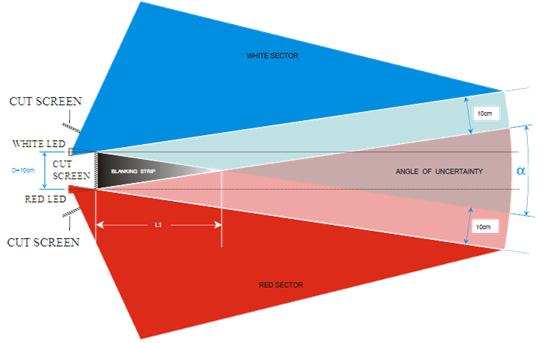


Figure x Visibility example of light signals generated by a Multiple Source Sector Light

Beginning of the usable segment of an MSSL can be estimated using the following formula:

L1 = A x D / d (equation 5)

where

A = Distance from light source to cut screen in [mm];

D = Horizontal extent of the cut screen between sector light sources in [mm];

d = Horizontal dimension of light source in [mm].

### Light source

Although in theory it is possible to build Multiple Source Sector Lights using incandescent light sources and filters, this technology is currently implemented using LED light sources.

Light signal modules employed inside a MSSL may be of varying complexity, ranging from a single unprotected LED/lens assembly to a fully weather proofed LED/lens module with several vertical LED arrays, redundant circuitry and low-level modulation input for control of flashing.

### Angle of Uncertainty

Multiple Source Sector Lights are suitable for sites where high precision of sector borders is not required. Angle of uncertainty depends on a particular implementation with typical values in the range of 0.2° to 0.6°, with longer distances from light sources to cut screens (larger enclosure diameters) providing resolution improvements.

The mathematical relationship between the factors is as follows:

α = Angle of uncertainty [minutes of arc] ≤ 3750 / A

where

A = Distance from light source to cut screen in [mm].

Angle of uncertainty should be the input parameter for MSSL design for preliminary estimation of feasibility of MSSL application.

### Advantages

* Once manufactured to site specification, installation on AtoN site requires minimum efforts
* Sectors with widely varying luminous intensities can be implemented inside a single enclosure
* Different sectors can utilise different rhythmic characters
* Sectors with overlapping borders displaying alternating colour signals with isophase rhythmic character at the boundary can be created using a multi-tiered construction
* LED modules with dual (redundant) circuitry can be employed for increased dependability
* Power consumption of optimally combined LED arrays of different sectors is typically lower than in case of single-source-per-tier screened omnidirectional solutions
* Distributed modular design allows to utilize existing lantern house at the AtoN site, bypassing shadowing effect of window frames
* In case of a modular construction, light source replacement can be accomplished efficiently onsite when necessary and does not require re-adjustment of sectors
* Modular design allows stocking of spare modules for extended life cycle support

### Disadvantages

* Once manufactured to site specification, sector configuration cannot be altered
* Not available off-the-shelf - engineering costs are involved in the design process of each sector light

# Projector Sector lights

Projected light is a specialised form of sector light that can generate sharply defined sector boundaries. This feature is particularly useful for applications that require one or more narrow sectors.

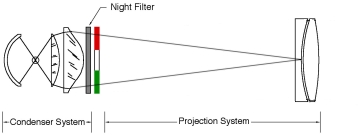
## Principle of operation

### Single Light Source

In this type of sector light, an image of the desired sectors is produced, and projected through a lens. While the image of the desired sectors may be produced in a number of ways, the most common way of producing it is by precisely machined optical filters. The principle is the same as in a slide or an overhead projector, focused at infinity. Vertical strips of coloured filter glass, optically ground and highly polished on their edges to fit closely together, are used as the "slide" or "film" to divide the beam into different sectors. The condenser system collects light radiating from the lamp and spreads it uniformly across the coloured filter.

An image of the filter is projected out to infinity. Sector boundaries may appear blurred within the first few hundred metres as they are out of focus, but will be very sharp at working distances.

Small changes in lamp filament position may cause minor changes in intensity within the beam, but will have no effect on the boundary positions, which are fixed by the projection (or objective) lens system.



Projection lens

Coloured filter

Night filter

1. Basic operating principle of Projector Sector Lights

The objective lens and the filter assembly together determine the total subtense. Different objective systems are used to obtain all the different subtenses with optimal efficiency. Generally smaller subtenses require larger objective lenses and longer barrel lengths. A smaller subtense with the same size lamp would provide a greater intensity and range.

A projector Sector Light uses colour to convey information to the mariner about his angular position relative to the light. The process of "colouring" a beam involves filtering out many colours and only allowing the desired colour to pass.

If the filter does not block off enough undesired colours (wavelengths), there can be problems with the light appearing to change colour in fog. If the selection of wavelengths that is passed is too narrow, the light will not be intense enough.

The Sector Light is bright enough to use by day if sufficient power is available to operate the necessary size of lamp.

The size of lamp that can be fitted is limited by physical size constraints of the optical arrangement. If greater ranges are required than can be achieved with the largest lamp then it is possible to operate two projector light units in a bi-form arrangement.

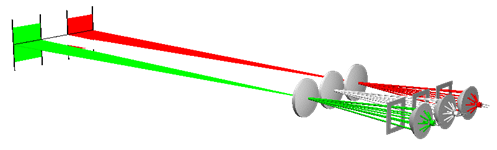
Greater range is achievable by using a smaller subtense for the projector.

### LED Projector Sector lights

LED light sources are available in a range of monochromatic colours and do not need the use of coloured filters. They can provide an energy efficient light source for a coloured sector light, as the light is generated directly in the desired colour and no light is wasted by absorption in sector filters. The filter cost is avoided, as are the cleaning problems often associated with filter installations. Because of the spectral characteristics of white LED lights, coloured filters should not be used with these sources.

Using an individual coloured LED projector for every sector, the resultant is a multi beam LED Projector Sector Light (Figure 12). Single beam LED Sector Lights can be created using various methods including the use of mirrors (Figure 13).

This technology requires that the sector limits must be adjusted very carefully relative to each other. It is almost impossible to adjust the sectors on-site.



1. Multiple beam LED projector sector light



1. Single beam LED projector sector light with mirrors

## Angle of uncertainty

Some sector projectors can overcome boundary inaccuracies by the design of the projector optics. These projector sector lights are so precise that a complete colour change at a sector boundary occurs over an angle of less than 1 minute (0.02°) in most models. This corresponds to a lateral distance of just 1 metre at a viewing distance of 3.5 km. This angle is as small as the human eye can resolve.

In addition the intensity is maintained right to the edge of the beam, and does not reduce the further the observer is away from the axis.

## Advantages/Disadvantage

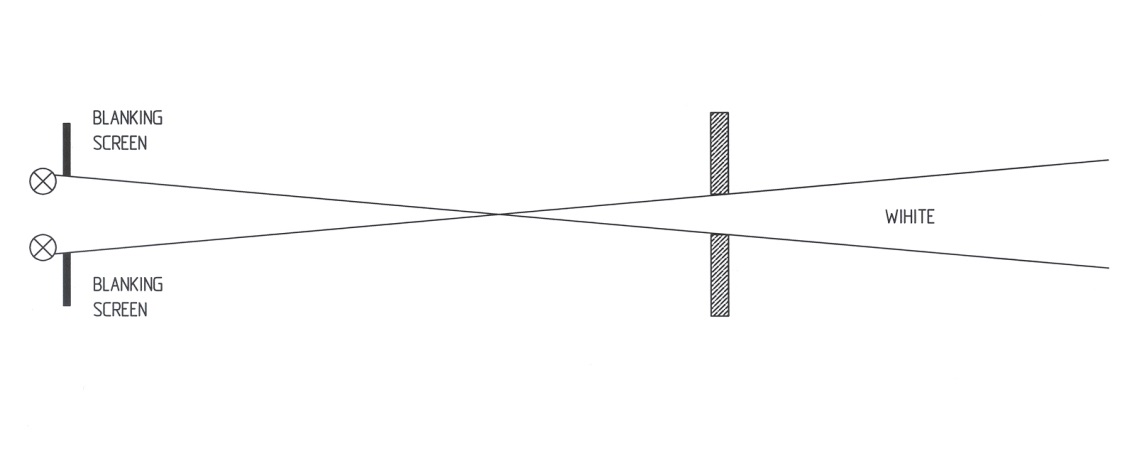
nn

## 

# Slot sector light

## Principle of operation

Slot sector lights consist of one or more light beams directed to a focal aperture (slot) at some distance. The ratio between the focal aperture width and the distance between the light source (assuming a point source) and the slot aperture defines the horizontal angle of the sector.



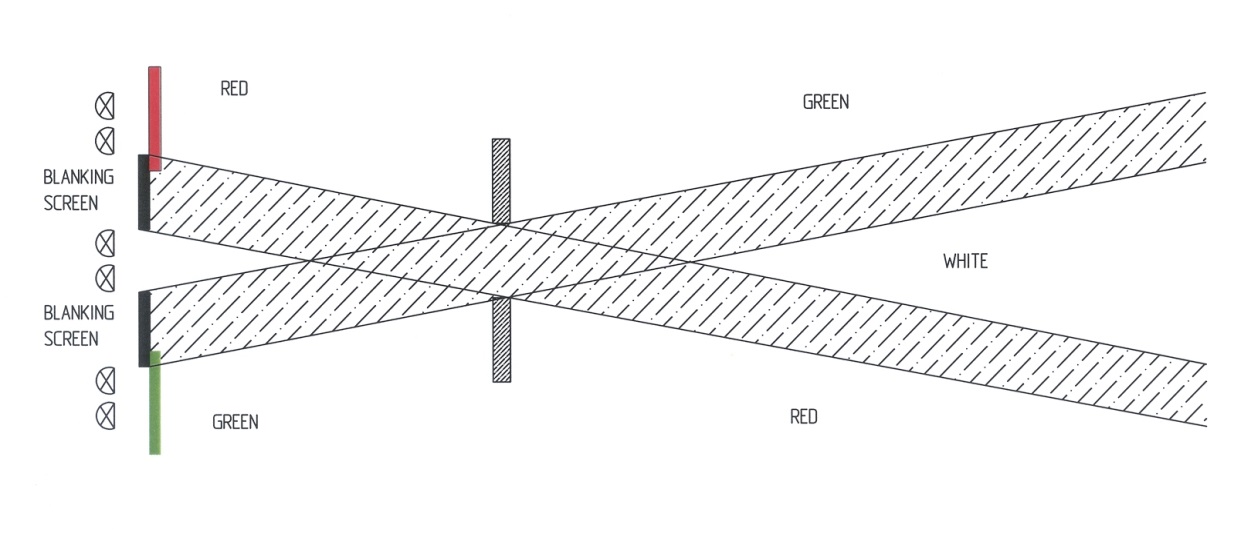
Light source

Focal aperture

Slot aperture

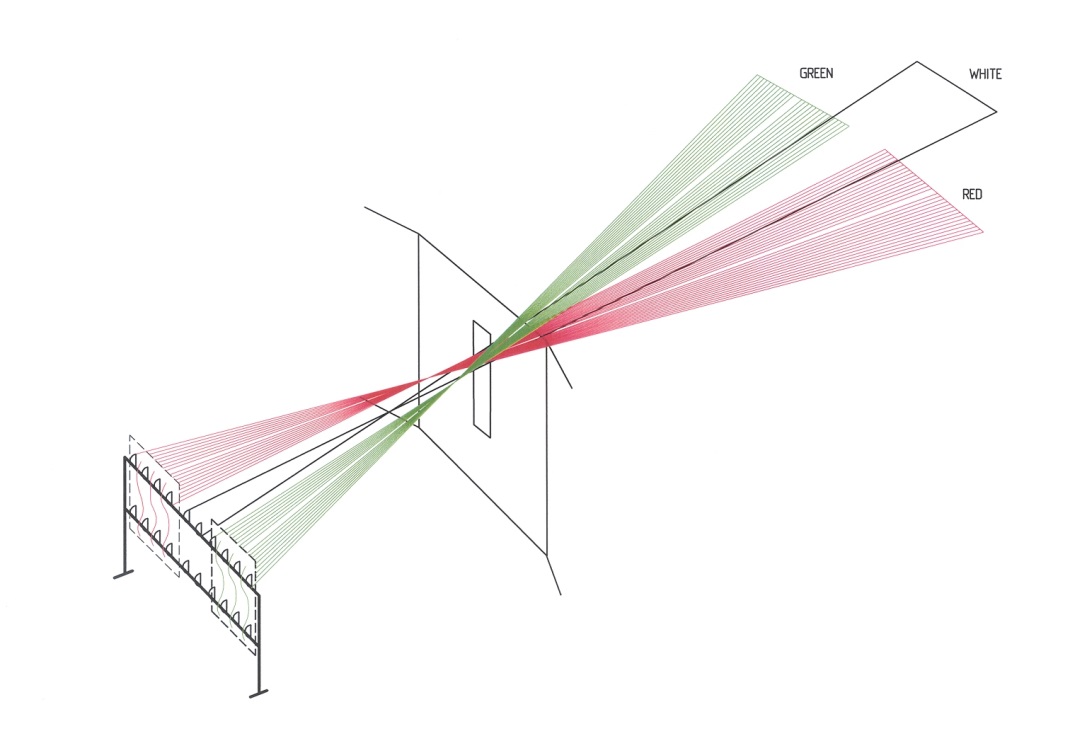
1. Basic operating principle of Slot Sector Lights

In the above example, there is only one sector. The principle may however be extended to a number of light sources of different colours yielding a number of sectors of different colours, and if need be different rhythmical characters.



Slot

1. Light Source Array

**

1. Basic operating principle of Slot Sector Lights(Three light sources and three sectors)

Coloured sectors are arranged with coloured glass mounted directly in channels in front of the lamp.

The boundaries are defined with baffle plates. The baffle plates are some millimetres wider than the focal apertures in the lantern house, to compensate for refraction of light around the baffle plate edge and provide the light exactly at the boundary crossing. The baffle plates are mounted in the same way as the filter glass.

Using an array of lamps as the light source, the luminous intensity in different sectors can be altered depending on the number of lamps used in that sector. The lamps can be connected in several separate groups, which are switched on in sequence, thus giving a stable power load and a character like a rotating light. With a Slot Sector Light it is possible to create very distinct boundaries and sectors if the lamps are placed a long distance from the slot.

## The light source

The light source depends on the application. Sealed beam lamps, PAR 56 200W 30V, mounted in simple stands are typically used as a light source. Systems with up to 2 x 96 lamps have been build, but smaller systems also exist with only a couple of boundaries and 3-6 lamps.

An advantage of such a lamp array is that a burned out lamp will not lead to a total loss of light in boundaries or sectors, but only a reduction in luminous intensity in that part of a sector as the boundary is illuminated by several overlapping lamps.

LED technology can be used in the Slot Sector Lights.

## Angle of Uncertainty

## Advantages/Disadvantages

# Use of colour filters in rotating optics

The application of accurate coloured sectors with a classical revolving pencil beam is not easy to achieve. Therefore it is not recommended to use this type of sector lights for new installations.

However, in many situations it is advantageous to use this arrangement to support the existing optic in a lighthouse.

## Principle of Operation

A Rotating Optic Sector Light consists of a central light source inside a circular arrangement of Fresnel lens panels (pencil beam projection). The Fresnel panels rotate around the light source at the rotation centre. The whole optic is surrounded by one or more filters or opaque screens.



1. Rotating Fresnel Lens

## The Light Source

A Classical revolving pencil beam light requires a compact light source to ensure a single flash for each Fresnel lens panel. The colour is produced by filtering, so the light source should have a light spectrum with enough spectral power for the filtered wavelengths to achieve the desired range and colour.

Refer to IALA Guideline 1043 on Light Sources for filter transmission parameters

Preferred light sources are:

* Halogen incandescent lamps
* Metal halide lamps
* Short arc discharge lamps (e.g. xenon lamps)

LED as a light source requires more care.

* In general it is necessary to use an arrangement with more than one LED, so the size of this arrangement should be small enough to produce a single flash for each Fresnel lens.
* Most phosphor converting white LEDs (PCLEDs) have only a small spectral output for Green and Red. As a result the filtered coloured light may be outside the IALA colour regions. Therefore, the white LED and the filter material have to be selected to ensure that the resultant intensity and colour are acceptable.

## Angle of Uncertainty

Unlike a point source sector light, the angle of uncertainty of a rotating optic sector light depends not on the width of the light source but on the width of the Fresnel lens panel and its distance from the edge of the filter. This is because the Fresnel lens panel can be regarded as an aperture through which a magnified image of the light source is seen by a distant observer. Since a typical lens panel is much wider than the light source and closer to the lantern glazing where the filter is usually installed, it follows that the angle of uncertainty for a rotating optic sector light will be much greater than that of a similar sized point source sector light.

The optic also rotates past the filter edge and the magnified image of the light source will be seen to move across the lens panel as the optic rotates. This apparent sideways movement of the light source image adds to the angle of uncertainty.

The angle of uncertainty is therefore difficult to calculate but can be estimated by first calculating the offset distance of the filter. This is the extra width of filter required to account for the difference in intensity between white light and coloured light at the sector edge.

The filter offset distance can be calculated as follows:

(equation)

where: x is the filter horizontal offset distance in millimetres;

t is the filter transmittance as a factor of one;

w is the horizontal width of the lens panel in millimetres.

The filter offset angle can then be calculated as follows:

(equation)

where: ϕ is the horizontal angular offset of the filter edge from the beam centre (or filter offset angle);

x is the filter horizontal offset distance in millimetres;

f is the focal distance of the lens panel

e is the distance from the centre of the lens panel to the filter.

The angle of uncertainty can then be estimated, accounting for the effects of lens panel rotation, as follows: (equation)

where: *α* is the estimated angle of uncertainty at the sector boundary

*ϕ* is the calculated offset angle

It should be noted that a change of colour may be observed during the flash. Colour variation within the flash may be more noticeable when the observer is close to the light.

## Advantages/Disadvantages

Rotating optics have the advantage of being able to produce high intensity flashes of light. However, the flash duration is usually relatively short and this may not be suitable for some applications where a longer flash is needed to determine colour. The angle of uncertainty of a rotating optic sector light is typically an order of magnitude or greater than that of a point source sector light. An angle of uncertainty of ten degrees is not unusual and this limits its usefulness to applications where sector edge marking does not need to be precisely defined.

Apparatus consisting of a high intensity rotating beam within a lantern can be more susceptible to false flashes. If a white false flash is seen in a coloured sector, its intensity can be nearly as great as the filtered, coloured true flash. Great care should therefore be taken to ensure that all false flashes are eliminated.

Rotating optics that consist of asymmetrical lens panels, where the bullseye is offset from the centre of the lens panel, should not be used with sectors.

In applications where a sector is required to mark a hazard but the boundaries of the sector are not critical, a coloured filter can be used with a rotating pencil beam to create the sector.

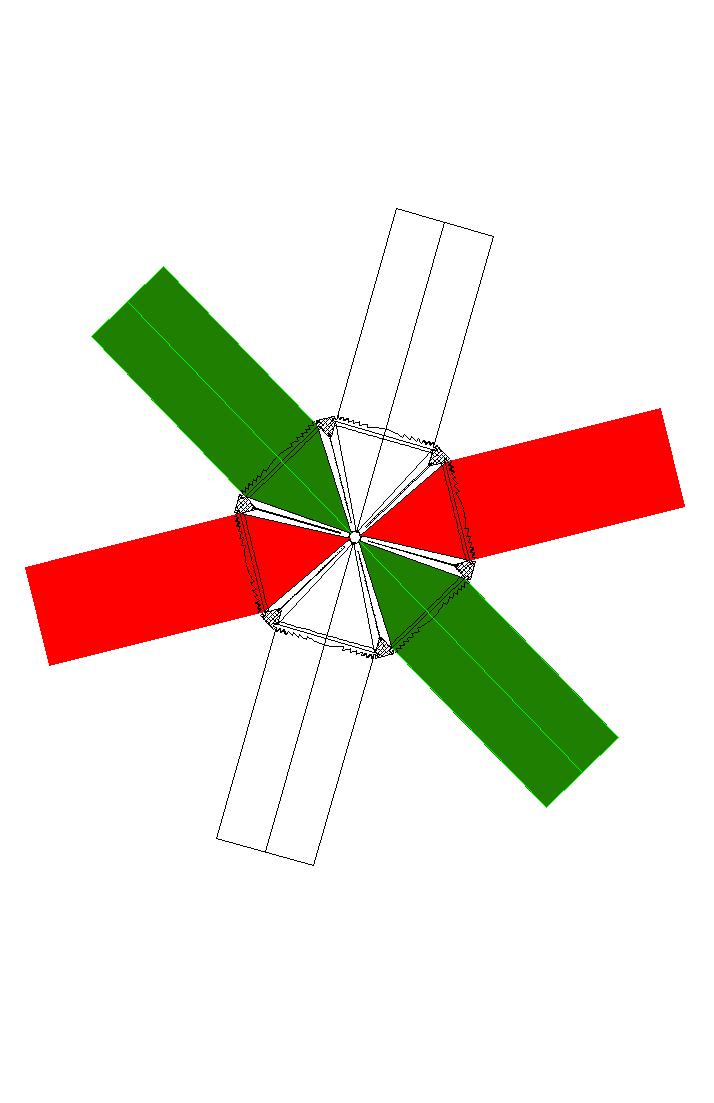
It may be noted however, that in modern revolving optics of small diameter and yet of high luminous intensity such as obtained with sealed beam lamps, arranged in a vertical stack, coloured sectors have been successfully applied.

# Rotating Colour Switching Sector Light

## Principle of operation

Rotating LED light sources can be used for producing several light beams of different colours with spatial distribution in sectors as required in particular application. Each combination of an LED and a lens produces a different beam that can be precisely controlled in time during rotation. Each sector signal is produced by the LED/lens system at a specific time when passing through the designated sector. Basic rhythmic character of such light sector system depends on selected speed of rotation.

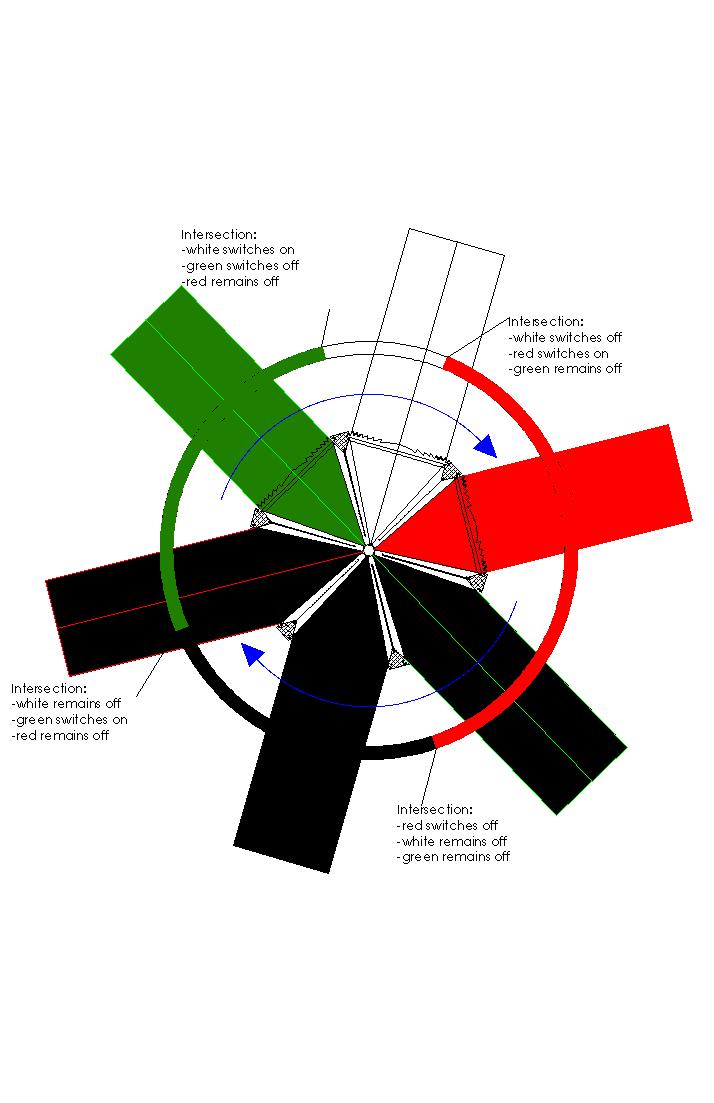
Figure x shows an example with 6 lenses (2 white, 2 green, 2 red). Thus, we obtain an equipment producing 2 white beams, 2 green beams and 2 red beams.



1. Top view Rotating Colour Switching Sector Light

When rotating, an electronic control detects the angular position of the optic and switches on each LED during the passage through the sector required.

For example, when the lens with white LED points into the direction of the white sector, it is programmed to switch on, providing white light only within the limits of the white sector. The same applies for green and red sectors (see figure x). In case of blank sectors all LEDs are switched off.



1. Example operation mode for single flashing light of 3 sectors

## Light source

This technology is only possible with fast switching LED.

## Angle of uncertainty

The angle of uncertainty depends on the horizontal divergence of the single beam with typical values of 1° to 4.7°.

## Advantages

* The sector configuration is merely a matter of programming, with the possibility of any kind of configuration, from only one sector of a single color up to complex multiple sectors of different colours.
* The modification of the width of any sectors can be done by programming without the need of physical handling or modification of the equipment.
* High luminous intensities can be achieved in comparison to sector lights which illuminate the whole sector.
* Power consumption is typically lower than in case of single-source-per-tier screened omnidirectional sector light.

## Disadvantages

* Low angular precision
* Mechanical moving parts
* Single point of failure in electronic control
* Only for short flashes

# FURTHER CONSIDERATIONS

The following steps are recommended when preparing a specification for a sector light.

1. Night Only or Day + Night

The first decision is whether a night-only signal is required, or a day and night signal. If a day and night system is required, the method of intensity reduction must be determined. This may affect the choice of optic apparatus.

1. Determine Required Intensity

Intensity is determined from the range required and the conditions under which viewing occurs (transmissivity of atmosphere, level of background lighting). IALA recommendations should be consulted.

1. Choose Total Subtense

There is a trade-off between subtense and intensity – the greater the subtense the less the intensity (for a given lamp) (this is specific for projectors).

1. Angle of Uncertainty (Boundary Resolution)

Angle of uncertainty must be considered depending on the precision of the guidance required.

1. Choose Lamp Size

The required range, optic apparatus and the available power source will influence determination lamp type and size. Sector lights powered from renewable energy sources such as PV solar or wind generally use low power lamps or LEDs in combination with high performance lens systems.

1. Oscillating Boundary Option

This option used in optic apparatus provided by some manufacturers is useful in critical applications where early warning of deviation from a sector (or approach to a sector) is required. On energy-critical sites it may be less attractive because of the long on-periods required for its effective operation.

1. Determine Individual Sector Angles

Each sector light is configured for its end use. For most applications red, white and green sectors are chosen. Sectors are specified reading from left to right when looking towards the light from seaward, with red on left (System A) or on right (System B). Determine the bearing and angle required for each sector.

1. Check Vertical Divergence

Sketch a vertical profile through the light and viewing area. Check that mariners on highest and lowest vessels at closest and furthest points can all fall within the vertical divergence of the light.

1. Specify Flash Character

Determine the character for the sector light, bearing in mind the characters of other nearby AtoN lights. In general, a longer flash length provides better performance. For renewable energy systems, the additional energy consumption arising from long flash length must be balanced against the ability of the power system to provide the required energy. Flash characters are not suitable to use with oscillating boundaries and therefore consideration must be taken of the back ground lighting for the fixed sectors.

1. Specify Night Intensity Reduction (if applicable)

When the sector light is available both day and night, some night intensity reduction is usual. Night intensity is a percentage of day intensity.

1. Reduced Intensity in White Sector: Yes or No

Intensity in the white sector of incandescent light source can be reduced by 30% using neutral density filter to match the intensities in the coloured sectors.

1. Reflections

Ensure that there are no unwanted reflections from lantern glazing, sash bars, obstructions, etc.

1. Connections to Other Devices

Determine if connection or synchronization is required with other lights, special controllers, monitoring.

1. Vertical divergence regarding short distances

As with all AtoN structures, the design and materials used in the construction of sector lights should be capable of withstanding the forces imposed at the site in storms and be resistant to corrosion, due to the salt laden marine environment. The design of structures should also facilitate maintenance access. The amount of twist and sway of the structure need to be considered in the overall design as excessive movement could undermine the application of the sector light.

Since the bearing of a sector light is critical, structures supporting sector lights must be particularly resistant to twisting to ensure that the sector lights remain accurate.

The sector produced by a sector light should fulfil a number of essential requirements. It should have the right colour, its intensity has to be high enough to provide the required range, the luminous intensity has to fulfil the requirements and it has to cover the correct angle.

* There is no reference of the vessel’s lateral position within the channel until a sector boundary is reached. This may cause a problem in channels subject to a strong cross current. For vessels with local knowledge, the zones defined by the angle of uncertainty can sometimes provide a useful guide to the vessel’s proximity to a sector boundary.
* Where Lateral information is required consider using oscillating boundaries.
* Where practicable, there should be a margin of safety between the sector boundary and adjacent hazards. If an appropriate safety margin cannot be achieved within the sector boundary, the hazards could be marked separately
* Zones defined by the angle of uncertainty should be considered an additional margin of safety over the actual sector boundary (see 5.7).
* The design process for a sector light needs to consider the speed and manoeuvrability of vessels likely to be negotiating the sector, how quickly they can respond once they cross a sector boundary and the situations that may develop when other vessels are in the vicinity (see 5.7).
* When using coloured filter in a sector light, the design should take account of the spectral distribution of the light source and the proportion of this light transmitted through the filter material. The process should also check for potential for glare problems.
* The period of the light flash should be selected to provide ample time for a mariner to recognise the transitional phases that occur at the sector boundary[[1]](#footnote-1) (preferred Occulting or Isophase rhythm). This is particularly important for high-speed craft.
* Rhythmic characters cannot be used with oscillating boundaries as false signals can be generated.
* A white light is normally the first preference for a lighthouse or beacon. If a single coloured sector is added, the preferred colour for the sector is red.
* If a white sector light is used to mark a navigation channel, coloured sectors may be used either side of the white to indicate the lateral limits. In such cases it is common practice to use red and green sectors that follow the convention of the IALA Maritime Buoyage System.
* Multiple sectors can be used to provide a better indication of a vessel’s lateral position within the channel but at the expense of complexity for both the system designer and navigators.
* Bearings, directions of leading (range) lines and limits of sectors should always be stated in terms of the bearings that would be seen by the mariner. Bearings may carry a suffix ‘TBS” or True Bearing from Seaward as confirmation.
* The white sector indicates safe passage, however this does not always hold true for the entire length of the sector.
* The boundaries between sectors are always more or less diffuse. This also holds for the boundaries between light and dark sectors.
* When using coloured filters, the range of red and green light is approximately ¾ of the range of the white light, depending on light source and filter material.
* The coloured filter material used to create sectors must match the spectral characteristics of the light source to provide the required colour and intensity in the coloured sector.
* The range of red and green sectors may be enhanced at the design stage by the inclusion of intensifying prisms that are added to the main drum lens. The ranges of the red or green sectors may then be equal to the white sector.
* Ice or grime on the glazing of a lighthouse may cause coloured sectors to appear white. It may also make the light faint or invisible.
* The lantern glazing (or lantern panes) both absorbs and reflects light. The reflection of a beam against the inside of the glazing may give rise to false flashes of the wrong colour within a sector. Such anomalies can be minimised by tilting the glazing, by using curved panes or by using sector screens.

During the design of Sector Lights, with incandescent special attention should be paid to transmission factors and chromatic characteristics of the optical path. In a sector light having red, white and green sectors, the central white sector is about five times more intense than the colour sectors. It is possible to balance the luminous intensity between sectors using neutral density filters, which reduce the output intensity but does not change the colour, or using intensifying prisms. Where there is no background lighting, it may be appropriate to use a 25% neutral density filter in the white sector to provide the same intensities in all three sectors. With moderate level of background lighting, a 50% neutral density filter can be used instead of clear glass in the white sector. Because most background lighting at night is white, this gives comparable conspicuity within all three sectors.

When a sector light is used for both day and night operation, the intensity for night viewing must be reduced to between 1% and 10% of the daylight intensity for equivalent conspicuity, however each application should be considered individually.

This is more than can be achieved by voltage reduction at the incandescent light source, without having the filament turn orange, and without interrupting the halogen cycle on tungsten-halogen lamps. A combination of automatic insertion of a neutral density filter (giving reduction down to 5%) and voltage reduction (giving reduction down to 20%) can be used to reduce intensity to 1% of daytime intensity. Alternatively a lampchanger can be used to automatically engage a low power lamp for night operation.

For LED light source intensity reduction can be achieved by means of current reduction, however the Pulse Width Modulation (PWM) may need to be applied in some cases to maintain the colour spectral properties.

Reflections in sector lights can be particularly important because of the risk of the reflected light being mistaken for the true sector light by the mariner. When installing sector lights care must be taken to avoid reflections from lantern glazing or obstructions in/ near the sector.

# INSTALLATION AND VERIFICATION

Due to the significant impact of small deviations in alignment of sector lights on navigation safety, it is of importance that engineering, manufacturing and installation are carried out with care.

Proper measurement, installation and verification procedures must be implemented at each stage of the deployment process.

For details on measurement see IALA-Rec. E-200-3.

## Angle definition

Once the sector boundary angles have been determined, these need to be converted from the goniometer scale to a compass bearing and reciprocal compass bearing. This will enable the sectors to be checked with figures published in the Admiralty List of Lights or with the navigational requirement.

|  |  |
| --- | --- |
| **Compass Bearing (lighthouse)** | **Reciprocal Bearing**  **(ship)** |
| 0 | 180 |
| 350 | 170 |
| 340 | 160 |
| 330 | 150 |
| 320 | 140 |
| 310 | 130 |
| 300 | 120 |
| 290 | 110 |
| 280 | 100 |
| 270 | 90 |
| 260 | 80 |
| 250 | 70 |
| 240 | 60 |
| 230 | 50 |
| 220 | 40 |
| 210 | 30 |
| 200 | 20 |
| 190 | 10 |
| 180 | 0 |
| 170 | 350 |
| 160 | 340 |
| 150 | 330 |
| 140 | 320 |
| 130 | 310 |
| 120 | 300 |
| 110 | 290 |
| 100 | 280 |
| 90 | 270 |
| 80 | 260 |
| 70 | 250 |
| 60 | 240 |
| 50 | 230 |
| 40 | 220 |
| 30 | 210 |
| 20 | 200 |
| 10 | 190 |
| 0 | 180 |

## General remarks

The installation and verification process depends on whether a new piece of equipment is setup or an existing equipment is updated.

Many new sector lights have manufacturer sectors already setup in a laboratory to comply with the customer’s specification. In this case the installation process is reduced to levelling and rotating the lantern for the correct sectors.

Other lights house where existing equipment is being updated with the addition of filter material a more complex process is required. In this case each sector boundary has to be adjusted individually. Some sector lights which are not setup by the manufacturer have to be setup in the same manner.

If replacing an existing light, mark the sector boundaries from the old light on a convenient existing structure. This can be used for confirmation after installation of the replacement light.

## Installation of new sector light with factory setup sectors

The installation of a new sector light requires that the equipment complies with the specified specification which includes the sectors and a datum. This datum could be a notable local feature (landmark) or North, The sectors should be verified by a test report of the manufacturer.

For high precision sector lights the datum should be replaced with an alignment telescope.

NEW FIGURE A1 required

Once the lantern is installed it should be levelled. Then the lantern is rotated to align with the reference point (landmark, north).

NEW FIGURE A2 required

Commissioning of the sector light should be carried out by a vessel. The task is to sail round all sectors and sector boundaries to ensure that the light complies with the navigational requirement. This requires the mariner to carefully observe the change in colour of the light at each sector boundary and recognition of colour change may best be achieved if a fixed light is exhibited for the duration of the commissioning procedure.

NEW FIGURE A3 required

## Register plate method

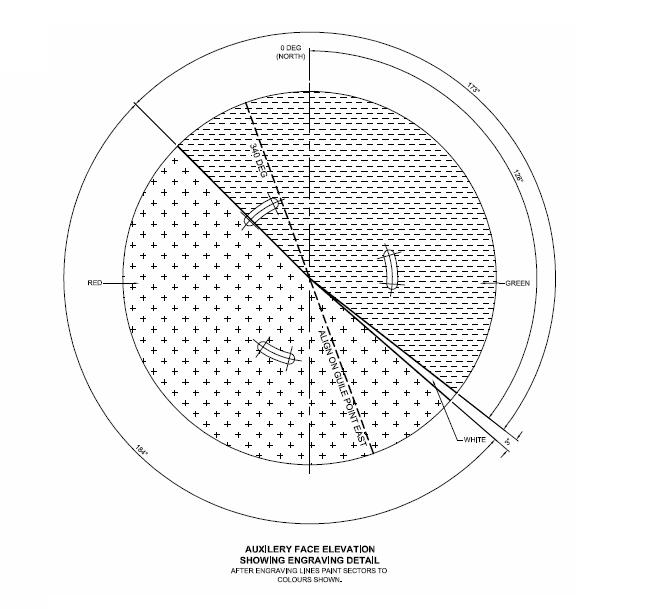
The adjustment of the sector light may be easier when using a register plate.

****

1. Sector Light mounted on a Register Plate

The design of the register plate should include slotted fixing holes to enable it to be rotated about its vertical axis so that it can be aligned with the relevant landmarks and/or references. It should also include markings pertinent to the station on which the sector light is to be fitted as follows:

* a true North mark;
* a diametric line at the relative bearing of a previously agreed landmark or landmarks;
* radial lines at the relative bearings of the sector boundaries;
* colour identification of the sectors
* note: the thickness of the line markings on the register plate should be no more than 0.5mm.



1. Drawing of Register Plate

Please note that if the slotted hole for mounting is in line with the landmark bearing line, the nut and bolt may obscure your view along the line (across the plate).

* Place the register plate on the pedestal mounting plate, roughly aligning the true North radial mark on the register plate with true North using a magnetic compass or similar.
* Using nuts and bolts, loosely secure the register plate in its approximate position on the mounting plate (bearing in mind that the plate will have to be turned to finely adjust its position).
* Look along the diametric landmark bearing line marked on the register plate in the direction of its respective landmark and rotate the plate until the diametric line is aligned with the landmark.
* If there are other landmarks, check their respective lines for correct alignment and adjust to get the best compromise between all landmarks.
* Tighten the nuts and bolts carefully and recheck the landmark alignments.
* Mount the sector light assembly above the register plate (see figure x) and loosely secure (bearing in mind that the light will have to be turned to adjust its position).
* Ensure the light is level by using the integral level or a spirit level across the top of the light assembly.
* Rotate the light assembly until the true North datum mark on the sector light base (marked during the light range measurement procedure or by the manufacturer) is aligned with the true North radial mark on the register plate.
* If appropriate, ensure all other marks on the lantern perimeter are aligned with their corresponding radial marks on the register plate.
* Tighten the nuts carefully and recheck the alignment with the register plate.

The installation procedure should now be complete but further adjustment or alignment may be necessary during commissioning.



1. Close-up Sector Light Mounting on a Register Plate



1. Graduated Scale marked on the Secondary Mounting Arrangement

## Installation of new sector in existing lights

A sector can be installed in an existing light by the addition of filter material or opaque screens. At first the nominal size of the filter material and screens should be calculated taking into account the height of the optic, the distance between light source and filter / screen and the sector width.

NEW FIGURE A4 required

And a formula

The actual size of the filter material / screen should be greater than the nominal size (see 5.1).

In practical terms two pieces of filter material that overlap in the centre of the sector should be used if two boundaries need to be adjusted. This allows for some adjustment during the checking procedure.

NEW FIGURE A5 required

The filter material / screen should be installed as far from the light source as possible (normally at the inside of the glazing). It should be moveable during the installation and have a facility to lock it in place once sectors have been commissioned.

The filters / screens should be installed roughly to the required sector. A theodolite can be used with a datum if practicable..

For the commissioning procedure a ship is required to adjust and verify the correct sectors. It has to be noted that the sector edge may not exactly match up with the filter material / screen edge (see 5.1).

## Commissioning

Measurement of sectors should be carried out by at least two experienced observers. Testing should be conducted under good weather and water conditions, preferably clear and transparent air.

Observations made from a long distance should be carried out in complete darkness.Prior to testing, the sector light system should be inspected to ensure that it is functioning correctly and glazing, lens, etc are clean. It is recommended when the light has long eclipses to alter the character to fixed light.

Sector light "angle of uncertainty" is the horizontal angle of the region of indefinite character near the boundaries of a sector of a sector light (e.g. neither white nor red but somewhere in between). Each sector light and even each sector boundary of that light may give a different angle of uncertainty.

For sector boundaries with a wide angle of uncertainty, the bearing at which the change in colour is perceived in one direction may be significantly different to that in the other direction. In this case, each direction should be treated separately and a mean of several recorded bearings for each direction taken. This will result in two mean values, the mean of which can be taken as the sector boundary bearing and the difference of which can be taken as the angle of uncertainty of the sector boundary.

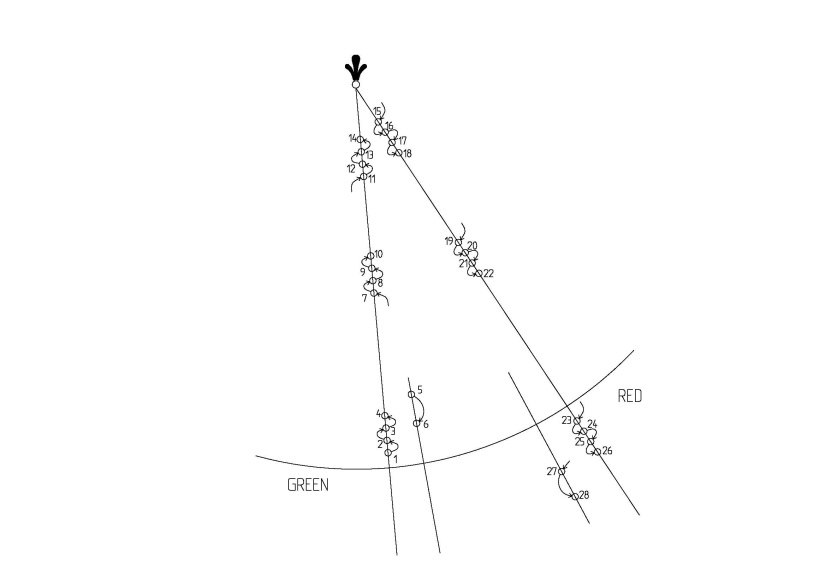
NEW FIGURE required

For example, in one direction the change of colour from red to pink may be recorded three times and the mean taken. In the other direction, the change of colour from white to pink may be recorded three times and the mean taken. The mean of these two means would be the sector boundary bearing. The difference between the two means would be the sector boundary angle of uncertainty.

Each mean sector boundary bearing should be compared with the published data for that station and reported accordingly.

It should be borne in mind that on most stand-alone sector lights there is no readily available means of adjusting a sector boundary. Therefore, if there is a significant departure from the published bearing, either the whole beacon has to be turned, which will affect all other sector boundary bearings, or the equipment will have to be returned to shore to be adjusted on a light measuring range. If necessary, the whole light assembly can be rotated to seek an all round compromise between the errors at all sector boundary bearings.

Measurement is carried out at a number of different positions as indicated in Figure 20 presenting one of many methods to ensure that the sectors are correctly marked throughout the usable part of the sectors.



1. Sector light testing using a boat

Measurement near to hazard protected by the sector boundary

Determined boundary for white light

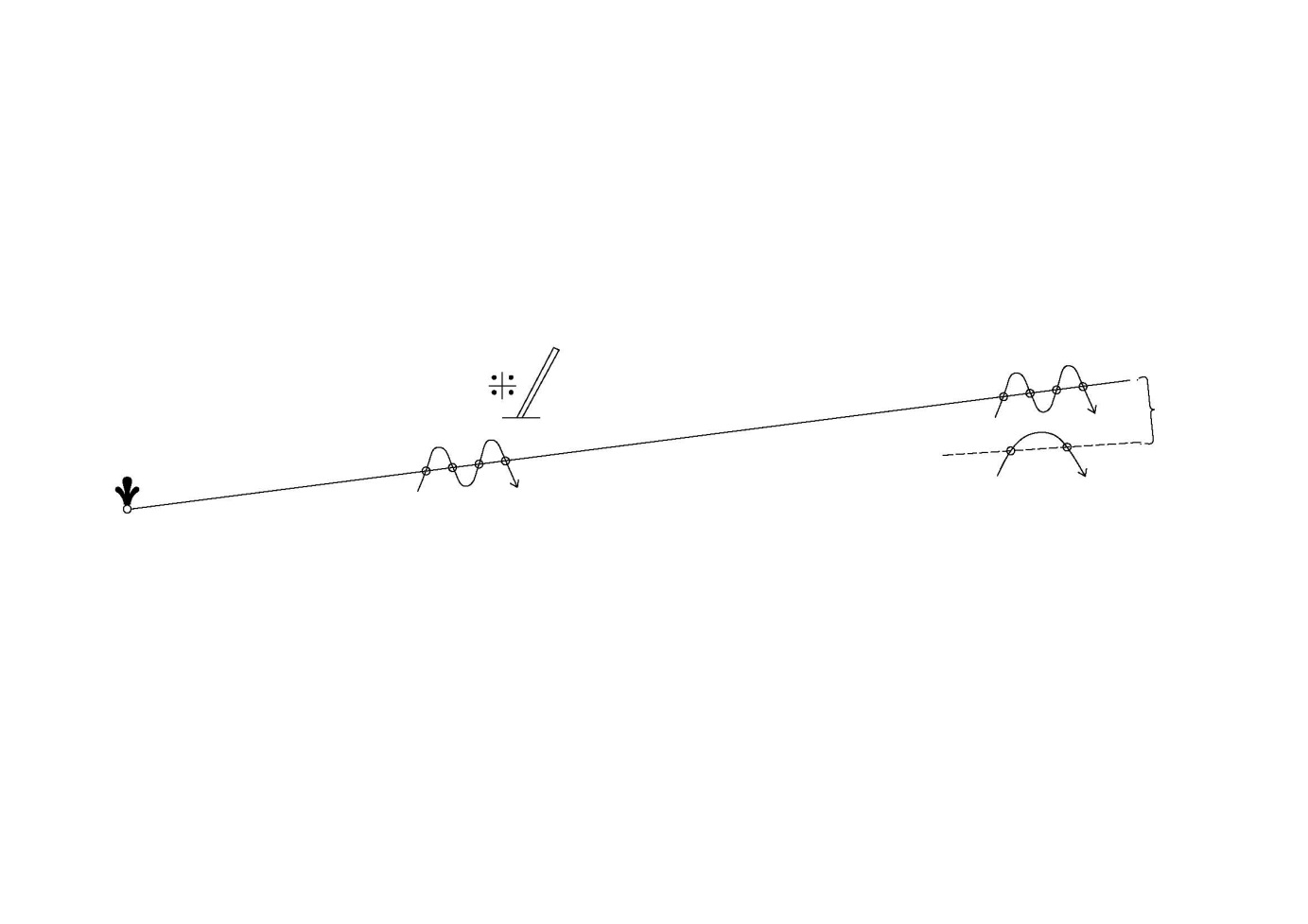
Sector of uncertainty

Boundary for clear white light

The number of observations varies depending on the length of the border.

At least 2 (normally 3-4) locations should be tested, one of which is close and one at the outer end of the sector. The spread of observations is important to determine the angle of uncertainty.

Every measurement group contains of about 4 observations

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However, each uncertainty contribution should be considered carefully for each station and each sector. When using an electronic chart and positioning by DGNSS, the greater the distance between light and vessel, the more accurate the bearing and consequently the lower the angular uncertainty. This increased accuracy is offset by the ability to observe a change of colour in a light when it is much smaller in the eye (smaller subtense angle) and much dimmer. In the case of white/green boundaries, there is potential for colour confusion at low levels of observer illuminance, particularly for flashing lights. At greater distances of observation therefore, the change from white to green, or vice versa, might not be easily distinguishable.

## Effect of weather conditions

Navigators navigating with the help of multi-coloured sector lights are warned about the certain risks prevailing during the cold season. There are always uncertain angles between the sectors, within which it is difficult to determine the colour of the light.

During the cold season the range of these uncertain angles may increase substantially due to snow and ice coating or formation of mist. The light could then be interpreted as white in sectors where it under normal conditions will be seen as coloured. Furthermore a false light in dark sectors, originating from adjacent sectors, might be observed under these same conditions.

When navigating with the help of sector lights it is therefore very important to make sure that the vessel is on the course line by taking frequent and careful positions, especially during the cold season.

## Example 1: Alignment telescope method for sector lights marking a narrow channel

A projector sector light with 3 sectors of different colours is often used to mark a narrow channel. The white central sector shows the safe narrow channel. The other sectors are red and green and show to the mariner that he is outside the safe channel.

Some manufacturers use relocatable filters or screens for the projector. The sectors can be changed in size and position. Some other projectors have fixed sectors, so there is only the need to adjust the projector on the whole.



In both cases the adjustment of the sectors or the projector during installation is a difficult task. The fixed telescope method can therefore be used to simplify the installation procedure.

This method may be used for omnidirectional sector lights as well.

### Principle

The centre of the white sector is regarded as the optical axis of the projector. In the workshop or light laboratory a telescope with crosshair or reticule is fitted to the projector. The telescope is adjusted so that the centre of the crosshair shows in the direction of the optical axis of the projector. This means that the optical axis of the projector and the telescope are parallel.



During installation, a vessel with high precision positioning equipment should align itself to the centre of the safe sector. The projector is rotated while looking through the telescope, until the vessel appears at the centre of the crosshair.



1. view through telescope



1. Sample of practical installation with fixed telescope method

Remarks:

* It is assumed that the sectors are already correctly set in a laboratory or workshop, so the adjustment with the telescope is the only task during installation. However, it is recommended to check all the sectors by moving across with a ship.
* The adjustment may be done both horizontally and vertically.

### Alternative

In some cases it is more convenient to use a landmark to adjust the projector. The landmark however may not be on the axis of the safe channel but has an angular deviation  to the axis. In this case the telescope has to be adjusted with the angular deviation to the projector axis.



1. Adjustment to a landmark

### Adjustment in workshop or laboratory

The fixed telescope method requires a preliminary adjustment of the projector and the telescope in a workshop or laboratory.

Due to the limited viewing or measurement distance the adjustment of the telescope has to take into account the lateral position of the telescope to the projector's axis.

The size and location of the sectors can be measured by a goniophotometer or projected on a screen. The projection screen should have a distance of at least 20 m to the projector.

When X is the horizontal distance between the projector axis and the telescope axis, the distance between the screen marks for the axis and the telescope should have a distance X as well. This will ensure that both axes are adjusted parallel to each other.



The same holds true for the vertical plane. In nearly all cases the telescope is placed a vertical distance Y above the optical axis of the projector. So the mark on the screen must have a distance Y.



## Example 2



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# References

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8. IALA Recommendation E-112 On Leading Lights, Edition 1.1 December 2005
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10. A Study of Filtered Sector Lights by Ian Tutt, March 2012
11. Minimum photometric distance by Frank Hermann 2006
12. Annex

Guidelines should have Annexes. Appendices are attached to Annexes.

1. ANNEX HEAD1

Body Text

To restart the Annex Heading numbering at 1:

* Office 2003, go to Format / Bullets and Numbering / Restart numbering (lower left in the box)
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1. See also IALA Recommendation E 110, The Rhythmic Character of Lights on Aids to Navigation, Paragraph 2.4. [↑](#footnote-ref-1)