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Optimal Lamp Selection Considering Vision during Driving Condition

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Abstract : *This work is a comparison of different illuminants to find the optimal solution for different road lighting condition.The spectrum of different lamps are analysed phtotmetrically under spetroradiometer and datas are analysed keeping in mind the task of driving on road at night as base and thus approaching to an optimal solution.*

Keywords : *Optimal road lighting solution, spectrum analysis, task of driving, spetroradiometer.*

I. INTRODUCTION

The human eye as shown in Fig. 1 contains mainly cones and rods cell each with its own spectral sensitivity as photopic sensitivity and scotopic sensitivity. The peripheral area surrounding the fovea consists of both rods and cones with a ratio of about 17:1. Foveal region in mainly consists of cone cells which mainly contribute in photopic vision. At night time under roadway lighting, both cells are active. For distant object detection and recognition, such as a pedestrian on a roadway, only cones are responsible. The rod response, does not contribute to the visual task of direct object recognition [1]. Visual tasks like brightness perception, peripheral guidance and detection of objects not in the line of sight are affected by rod response. Both rod and cone sensitivity functions are needed for proper object detection [1].

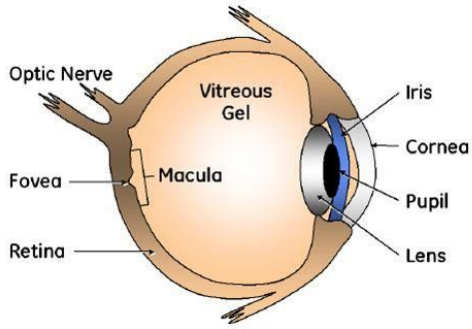

Fig. 1 human eye cross-section

Optical signals received by rod and cone are transferred to brain where color perception is done by cone between 350 nm to 750 nm whereas in night or low light condition rod senses the wavelength of 400nm to 610 nm. [2]. There is an intermediate luminance level (0.001candelas/m2 to 3 candelas/m2) referred to as Mesopic vision as shown Fig. 2, where both rod and cone cells remain activated together. So the roadway lightings are recommended under mesopic range of vision by CIE [3] and IESNA [4]. Cones have a peak response in the yellow-green region of about 555nm and rods have a peak response in the bluish-green area of about 505nm. As both having different sensitivities to colors they can be represented by two different sensitivity curves called photopic curves and scotopic curves.

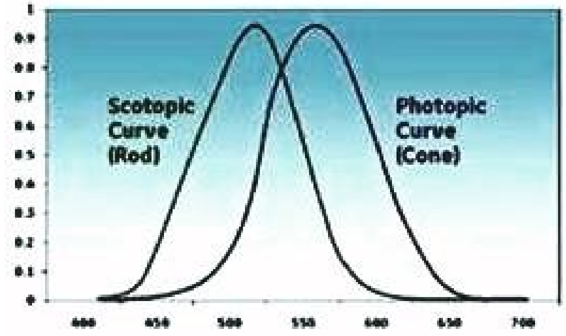

Fig. 2 photopic / scotopic curves

II. MESOPIC VISION AND ROAD LIGHTING

The gradual change from photopic to mesopic happens when the light level is reduced [5]. This is why mesopic response functions have to be established for different levels of mesopic luminance, which is very difficult [6].Adrain shows that with the reduction of the light level the equivalent lumens of yellow sources were reduced, while the equivalent lumens of white sources were increased [7].Also Lewin clearly explained the location of line of the maximum sodium emission (589 nm), as well as a powerful line in the metal halide lamp output (436 nm), are presented [8]. Thus the effect of lamp spectral distribution is considerd while evaluating whether a light source is advantageous for the visual performance of humans for road lighting or not [9].

From Fig. 3 it is clear that under low light visual sensitivity moves towards shorter wavelengths. This is known as Purkinjee shift. As per the research done by Anstis [10] it can be said that the dark-adapted retina is more sensitive to shorter wavelengths at greater eccentricities, that is a clear Purkinjee shift. As spectrum has an effect on vision so the above facts can be considered as the basis for choosing the optimal light sources in road lighting.

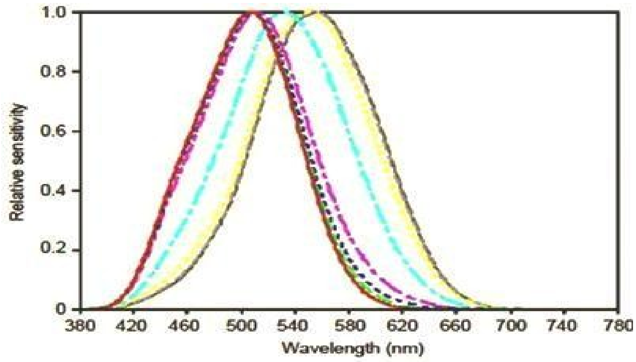

Fig. 3 the purkinjee effect as light level decreases

III. VISION AND NIGHT TIME DRIVING

While driving at night, drivers need to monitor the road ahead for motor vehicles, cyclists etc and have to recognize traffic signals. Also they have to judge the speed and distance of other vehicles. All these tasks are coming under both foveal and peripheral vision i.e. both on and off axis targets. Detection of object mainly occurs in the periphery as visual field is larger than foveal field, so while choosing a lightsource ,its effect on visual field size need to be considered. Also larger field helps the driver to detect an object earlier [11].In comparison with foveal vision, overall brightness perception involves the stimulation of both central and non-central regions of retina. In night time as both rod and cone are active so ultimately mesopic sensitivity need to be considered. The four distinct tasks, a driver has to do in night time driving are - direct viewing the object, overall brightness perception, off-axis object detection and overall movement detection[12].

3.1 Direct viewing the object (central vision)

Direct object detection comes under photopic sensitivity function for which cone receptors, which exists in fovea (central part of retina)are responsible. This task is totally independent of brightness perception of the surrounding environment [13].

3.2 **Overall brightness perception (full field vision)**

This is how light is perceived in a broadly lit spatial area and at night how secure we feel in it [14]. This perception is initiated by both rod and cone photoreceptors throughout the entire retina, so both scotopic and photopic photometric quantities are needed to accurately describe the perceptions [15].

3.3 **Off axis object detection**

Acquisition of visual information not in the line of sight by perceiving overall brightness using both rods and cones comes under this category of task. So it indicates about a mesopic conditions which will contribute to both guidance and off-axis target detection [16].

3.4 **Overall movement detection**

It is important to identify central as well as peripheral movement during night time driving. Central movement detection is primarily governed by photopic spectrum [17]. At mesopic light levels, non-central movement detection is better with more bluish light as compared to more yellowish light both set at the same photopic level [18]. It indicates that rod response is involved in non-central movement detection.

IV. SPECTRAL ANALYSIS OF DIFFERENT LAMPS

Light sources and illuminants can be characterized by their spectral power distribution (SPD).Spectral power distribution describes the per unit area per unit wavelength of any radiometric quantity(photometric quantity for only visible length of light).Here the spectral power distribution (SPD)curve and different photometric datas obtained from the readings of spectroradiometer of different lamps is analysed. Different lamps of almost common lumen package are analysed on the basis of wavelength , correlated colour temperature and colour rendering index and so on with the help of spetroradiometer in the laboratory(dark room) keeping all other lights switched off .

4.1 **Low pressure sodium vapour lamp(sox)**

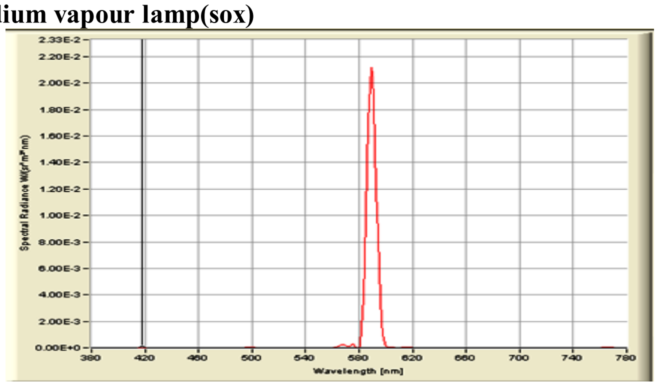

Fig. 4 spectral power distribution curve of sox

TABLE 1 Test Result of Low Pressure Sodium Vapour Lamp

NAME	SOX
Luminance[cd/m²]	3.07E+03
Correlated colour temperature[K]	1795
Dominated wavelength[nm]	589
PE[%]	99.2
CRI	5

SOX are basically a yellow coloured source and are monochromatic. Its colour rendering index is very low. It shows its single peak at 589 nm as shown in the Fig. 4 which is obtained from spectroradiometer reading is very near to human highest spectral sensitivity at photopic region i,e at 555nm and has almost no other wavelength found in other range. Its purity index is 99.2%. So the total light of this lamp is accumulated in yellow region. The other photometric readings obtained from spectroradiometer are given in the TABLE 1. The efficacy of this light source is very high. It helps on sight detection of objects that is object in front of line of sight thus helps in foveal detection where mainly cone cells are activated. But it contributes least to the perception to the overall brightness and off axis movement detection. But this kind of lamp is very popular to the area that mainly effected with fog for the detection of distance object at direct line of sight as for it purity in spectrum it dispersed less.

4.2 High pressure sodium vapour lamp (son)

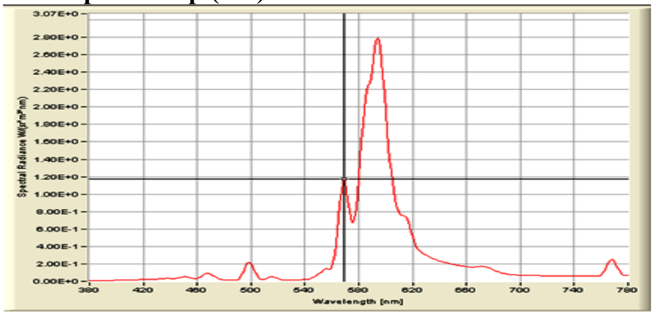

Fig. 5 spectral power distribution curve of son

TABLE 2 Test Results of High Pressure Sodium Vapour Lamp

NAME	SON
Luminance[cd/m²]	4.48E+03
Correlated colour temperature[K]	1904
Dominated wavelength[nm]	589
PE[%]	87.7
CRI	27

SON is also a yellow coloured source giving its highest peak at 589nmas shown in Fig. 5, but also has other wavelengths in very small amount other than this yellow wavelength. Its purity index is 87.7%.The other photometric quantity obtained from spetroradiometer reading is given in TABLE 2. It is mainly helps in foveal detection of object i.e object at direct line of sight; again it contributes a little for peripheral detection and overall brightness perception. Its colour rendering index is not worst as in case of SOX. Its CRI is 27. Distant targets straight ahead at line of sight are very well detected under SON. As it also have other wavelengths, so it also helps in dirtection of objects by colour differentiation. So till date it is the most popular lamp that is used for road lighting purpose.

4.3 Metal halide lamp (cdmt)

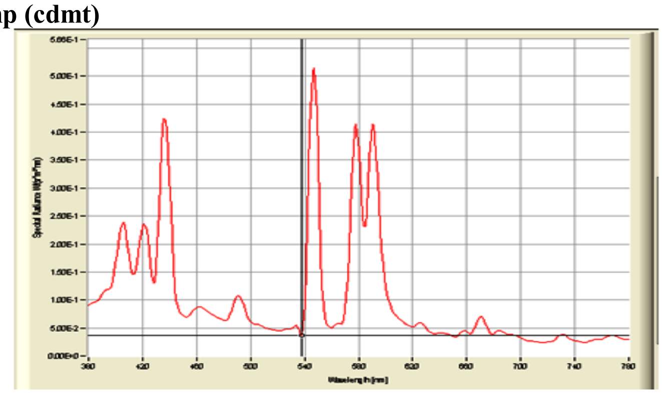

Fig. 6 spectral power distribution curve of metal halide(cdmt)

TABLE 3 Test Results of Metal Halide Lamp (cdmt)

NAME	MH(cdmt)
Luminance[cd/m²]	6.57E+03
Correlated colour temperature[K]	5026
Dominated wavelength[nm]	494
PE[%]	2.6
CRI	85

Metal halide (CDMT) i.e ceramic discharge type is the light source whose CCT is near cool white region. It shows its highest wavelength near blue region at 494nm as shown in Fig.6. So in low lighting condition also its equivalent lumen remain effectively high as in low lighting vision like scotopic vision,highest spectral sensitivity is near 505nm which is near bue region. It has got moderately high efficacy and have a very good

CRI i.e. relative CRI= 85.1. Other photometric readings of metal halide obtained from spetroradiometer is given in TABLE 3.It shows its wavelength both near yellow and blue region but prominent near blue region. Thus it helps mainly in peripheral vision but also contribute in foveal vision. Thus it is a very good choice of lamp for mesopic vision. It helps mainly in viewing off axis moving target and also contributes in viewing target at direct line of sight. But it suffers badly for shorter life span.

4.4 Compact flourescent lamp (cfl)

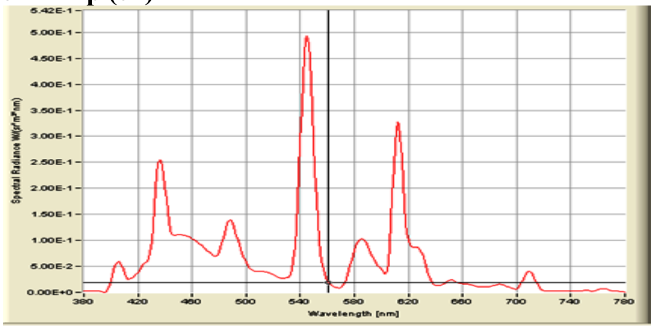

Fig. 7 spectral power distribution curve of cfl

TABLE 4 Test Results of cfl

NAME	Cfl
Luminance[cd/m²]	5.98E+03
Correlated colour temperature[K]	6185
Dominated wavelength[nm]	491
PE[%]	5.1
CRI	83.8

CFL (PL) is mainly a white coloured source having its dominant wavelength near blue region at 491nm as shown in Fig.7. Its efficacy is good and have very good colour rendering index. The reading of CFL obtained from spetroradiometer is given in the TABLE 4. It also got wavelength near yellow region as well as near blue region. Because it has its dominant wavelength near blue region it helps to perceive the spatial brightness more, thus contributing more in creating sense of security and also its equivalent lumen remain high in case of low lighting condition also.But it has limitation in the range of wattages. Thus it is more helps in slow speed residential roads.

4.5 Led lamps

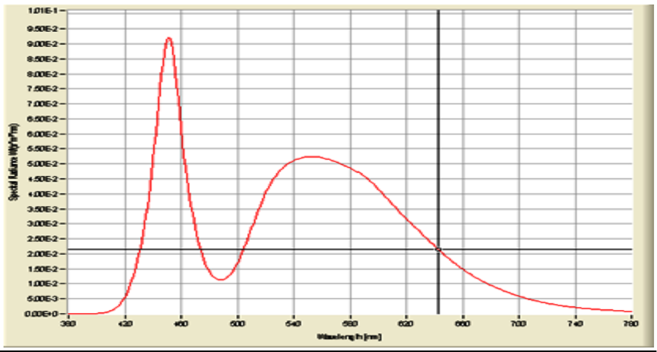

Fig. 8 spectral power distribution curve of led

TABLE 5 Test Results of led

NAME	Led
Luminance[cd/m²]	5.99E+03
Correlated colour temperature[K]	6041
Dominated wavelength[nm]	491
PE[%]	4.2
CRI	75.85

Led light (white LED) is mainly a white coloured source having its dominant wavelength near blue region as shown in the Fig. 8. Its efficacy is almost good and have very good colour rendering index i.e. relative CRI= 75.85. Other photometric readings obtained from spetroradiometer are given in TABLE 5. It has got wavelengths near yellow and also near blue showing a very smooth curve. Because it has its dominant wavelength near blue region it helps to perceive the overall brightness in low lighting condition thus contribute in creating sense of security. It also got wavelength in yellow region so it also somewhat helps in on axis view i.e. foveal vision. Thus it helps in motorized and as well as residential roads. As it is an upcoming technology. Thus with proper optics design and proper design of heat sink can prove it as better solution.

V. CONCLUSION

Above work is a study of spectral power distribution and different photometric quantity of lamps used in road lighting with their effect on human vision in different way. IESNA and CIE considered road lighting design in low mesopic level between 0.01 to 1.5 cd/m^2. It has often been argued that as colour vision is diminished at low lighting levels, it is not worth considering colour contrast in road lighting. This colour contrast i,e overall brightness perception becomes more important as traffic density on roads increases and the concept of viewing objects in silhouette [19] breaks down as other vehicles block the view of the road ahead which can became the brighter background. Thus in high traffic density condition when the visibility is limited to a shorter distance white light source like Metal halide or LED can work as a better option. These light sources also do not create any unnatural night environment in the road. CFL lamp has a limitation of wattage, so this type of lamp can be used in residential roads. SON can be used as a very good option for the kind of roads which are least populated like highways and have high speed vehicles. In this kind of roads objects which can be considered as obstacles can be detected from wide distance very quickly. They mainly come in direct line of sight. So SON can be considered as better option as it not only helps in viewing objects in direct line of sight better but also its contributes in perception of overall brightness as it also got some wavelengths in other range than the yellow wavelength range. SOX has got its single peak at 589 nm which is very near to human highest spectral sensitivity and has almost no other wavelength found in other range so this kind of lamps is very good for object detection in direct line of sight but contributes almost nothing to overall brightness, so this kind of lamp can be used for signaling purposes in hazardous condition like foggy environment. Studying all these lamp it can be concluded that optimal solution of different kind of roads are different but yet LED and metal halide lamps can be play a better option for future.

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