STUDIES ON IMPROVEMENT OF RAILWAY FOG LIGHTING SYSTEM TO INCREASE VISIBILITY IN FOGGY CONDITION AND AVOID ACCIDENTS

A THESIS SUBMITTED TOWARDS PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

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IN

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BY

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RECOMMENDATION CERTIFICATE

This is to certify that the thesis entitled ***" STUDIES ON IMPROVEMENT OF RAILWAY FOG LIGHTING SYSTEM TO INCREASE VISIBILITY IN FOGGY CONDITION AND AVOID ACCIDENTS"*** submitted by **PUSPASISH MAL** (Exam. Roll No. **M4ILN22022**, Registration No.154045 of 2020-2022) of this university in partial fulfilment of requirements for the award of degree of Master of Engineering in Illumination Engineering, Department of Electrical Engineering, is a bonafide record of the work carried out by him under my guidance and supervision.

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CERTIFICATE OF APPROVAL

This foregoing thesis is hereby approved as a creditable study in the area of Illumination Engineering, carried out and presented by **PUSPASISH MAL**, in a manner of satisfactory warrant its acceptance as a pre-requisite to the degree for which it has been submitted. It is notified to be understood that by this approval, the undersigned do not necessarily endorse or approved the thesis only for the purpose for which it has been submitted.

FINAL EXAMINATION FOR EVALUATION OF THESIS.

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DECLARATION OF ORIGINALITY AND COMPLIANCE OF ACADEMIC ETHICS

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as part of my **Master of Engineering in Illumination Engineering** studies.

All information in this document have been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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TO WHOM IT MAY CONCERN

This is to certify that Sri Puspasish Mal, studying (M.E.E.) in illumination Engineering at Jadavpur University has done project work "Studies On Improvement of Railway Fog lighting system to increase visibility in Foggy condition and avoid accidents". The TRD wing of Eastern Railway, Sealdah Division has extended full support for field study at Lakshmikantpur- Namkhana section. The work has been executed successfully. The result of experiment was satisfactory. This will go a long run in improving illumination profile in foggy condition. Indian Railway will be immensely benefited in regard to punctuality if the project becomes viable in all respect.

Wish all good future to Sri Mal.

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OVERVIEW OF THE THESIS

CHAPTER I Provides reason behind developing a fog safety system and proposed model.

CHAPTER 2 describes about fog, fog formation and different types of fog.

CHAPTER 3 describes about light and fog relationship and how visibility in foggy condition can be increased.

CHAPTER 4 describes about LED and proposed system to increase visibility in fog, using monochromatic LED luminaire.

CHAPTER 5 provides the simulated results of the fog lighting system by using DIALUX.

CHAPTER 6 provides the experimental results, results analysis and comparative study of both setups.

CHAPTER 7 deals with the conclusion and future scope of the thesis.

REFERENCES

ANNEXURE-I contains the information about LED driver

ANNEXURE-II contains the specification of the goniophotometer which was used in experiment.

ANNEXURE-III contains the specification of the WAP-5 loco.

CONTENTS

CHAPTER 1

INTRODUCTION

In the past two years, numerous accidents have occurred throughout India during the coldest months of December and January, claiming many lives and injuring countless others. On October 23, 2017, four people died and one person was injured after being run over by a train in Munger, Bihar, as a result of poor visibility brought on by fog.

A detailed examination of the data showed that hundreds of flights are delayed for hours and hundreds of railway accidents occur each year as a result of fog, with the majority of incidents occurring in the winter due to low visibility. The residents of the highly populated Indo-Gangetic plain experience discomfort due to the disruption of both road and train traffic (most fog effected area of India). Fog has always had an impact on human life, but in recent decades, as social and economic activity have greatly increased, that impact has multiplied. Drought and meteorological disaster account for more than 70% of natural disaster damage. The most frequent weather conditions are flood, thunderstorms, and fog. In the same situation, the total economic damage caused by fog is comparable to that caused by tornadoes and hurricanes [1].

A significant number of tiny liquid water droplets or ice crystals suspended in a specific air volume close to the ground make up fog. Fogs and clouds share the same physical characteristics. Fog can be defined as a cloud that touches the ground. According to the meteorological definition of fog, it is a condition of the atmospheric air with visibility less than 1 km, as measured close to the surface. Fogs reduce visibility in the immediate vicinity.

In general, local orographic conditions, the current synoptic situation, and atmospheric circulations have a significant impact on fog development and existence. It can develop everywhere there are land or water surfaces. It has significant meteorological significance despite not being a climate-forming component because of its localised development, capacity to lower temperature amplitudes, and close relationship to humidity parameters. The thermal and radiative budget of the atmosphere, air quality, waterways, flora and fauna, air-surface interactions, and many other aspects of the ecosystem are significantly impacted by natural fog, a form of condensed water that exists in the atmosphere. Fogs can seriously disrupt and affect societal life and functionality (such as air, surface, and sea transportation) in addition to reducing visibility, which results in a staggering number of injuries and fatalities.

FOG specifics were covered in CHAPTER 2.

1.1 PURPOSE OF FOG SAFETY SYSTEM REQUIREMENT:

Fog has a variety of effects on human life, including on air quality and visibility. Fog slows down our way of life in terms of things like mail delivery, travel, and other forms of transportation. Below are specifics regarding how fog affects human life.

1.1.1 CONSEQUENCES FOR AIR QUALITY:

Smog, which is a combination of smoke and fog, and hazy fog are two frequent names for urban air pollution. Smog comes in two flavours: photochemical (Los Angeles type) and classical (London kind). Classical smog typically occurs in the fall and winter, close to the ground, in windless circumstances, and at temperatures around 0 °C. It is caused by the interaction of particulate matter with sulphur dioxide. Since it results from the interaction of NOx, CO, O3, and volatile organic compound (VOC) with sun radiation, photochemical smog is common during the summer season and typically occurs around noon [2].

Due to the presence of potentially irritating substances as well as polluting primary or secondary particle matter, smog or haze-fog can have a negative influence on both air quality and human health. The degree of smog or haze-fog formation is mostly determined by the amount of atmospheric aerosol loading and meteorological factors, particularly air humidity. Significant factors defining or influencing the loadings of the atmospheric air with polluting aerosols or chemical compounds and, in turn, the occurrence and evolution of smog or haze fog include natural air circulations, solar irradiation, as well as some anthropogenic ones brought on by traffic or industrial fuel combustion, heating, fires, or other human activities in the industrial and construction sectors.

1.1.2 IMPACTS OF FOG ON HUMAN HEALTH:

Acid fog is made up of air pollutants such nitrogen oxides (NO_x), sulphur dioxides (SO_2), ozone (O_3), sulfuric acid (H_2SO_4), and nitric acid (HNO_3). The latter two are primarily responsible for the acidity of the fog. Exposure to tiny aerial aerosol particles (especially acidic ones), microorganisms, sulphur oxide, and sulphur dioxide is linked to an increase in respiratory mortality and morbidity, as well as cardiovascular and lung cancer mortality [2]. Details about air pollutants are provided in Table 1.1.

System and Diseases	Pollutants
Respiratory system	NO_x, SO_2, O_3, VOCs, microbes, heavy metals (As, Cd, Cr, Cu, Ni, Va, and Zn), $PM_{2.5}$ and PM_{10}
Cardiovascular system	NO_2, SO_2, O_3, CO, dioxins, heavy metals (As, Cd, Hg, and Ni), $PM_{2.5}$ and PM_{10}
Hematological system	VOCs (benzene), heavy metals (Cd, Cu, Pb, and Zn)
Urinary system	Heavy metals (As, Cd, Pb, Ni, and Zn)
Nervous system	CO, VOCs, dioxins, heavy metals (As, Cu, Pb, and Hg)
Digestive system	Dioxins, heavy metals (Zn)
Muscular system	CO
Reproductive system	Heavy metals (Cd, Pb, Ni, and Zn)
Spontaneous abortion, fetal growth, fetus central nervous system development, children mental development and infant mortality	Heavy metals (Pb), dioxins, NO_2
Bone diseases	Heavy metals (Cd and Ni)
Skin diseases	Heavy metals (As, Cr, and Ni)
Alzheimer and Parkinson diseases	Heavy metals (Zn)
Genetic damages to the chromosomes, cyto-toxic, mutagenic	VOCs (benzene), heavy metals (Rh, Pt, Pd)
Cancer	NO_x, SO_2, O_3, CO, VOCs, dioxins, heavy metals (As, Cd, Cr, Pb, Hg, Ni, Rh, Pt, Pd, Va, and Zn)

Notes: VOCs—volatile organic compounds; $PM_{2.5}$ and PM_{10}—particulate matter with diameters $< 2.5\,\mu m$ and $< 10\,\mu m$, respectively.

Table.1.1. Effects of air/fog pollutants on human health.

Following is a summary of how air and fog contaminants affect human health and how they work:

- NO_x primarily affects the respiratory system, producing respiratory infections, bronchoconstriction, nose and throat irritation, and dyspnea (particularly in asthmatics). NO_2 causes lesions that resemble those of emphysema and is linked to higher rates of neonatal mortality and cardiovascular illnesses.
- SO_2 influences the respiratory system in a way similar to nitrogen oxides.
- O_3 results in inflammation of the lungs and a decline in lung capacity. In middle-aged adults without a history of heart disease, it is also known to start cardiovascular illnesses and trigger acute coronary events.
- The cardiovascular system is impacted by CO, which binds haemoglobin to change its shape and lessen its ability to carry oxygen, which in turn impacts the brain and heart. Concentration problems, confusion, delayed reflexes, hypoxia in the neurological system, and issues with the muscular system are all brought on by CO.

- The central nervous system is affected by volatile organic components like benzene, which also cause anaemia, lymphopenia, thrombocytopenia, and pancytopenia. One kind of leukaemia is also brought on by benzene. VOCs can also cause headaches, nausea, dizziness, and irritated eyes, noses, and throats. The risk of cancer is present in all gaseous pollutants.
- Dioxins have an impact on the digestive system, causing cell damage, gastrointestinal and liver cancer, and the growth and development of the fetus's central nervous system. They also have an impact on the cardiovascular system, increasing death from ischemic heart disease.
- Arsenic, nickel, and vanadium are examples of heavy metals that have an impact on the respiratory system and are known to cause asthma, emphysema, and lung cancer; mercury, nickel, and arsenic are examples of heavy metals that have an impact on the cardiovascular system and are known to cause tachycardia, increased blood pressure, and anaemia; lead, arsenic, and mercury are examples of heavy metals that have an impact on the nervous system and are Pregnancy-related lead exposure raises the dangers of spontaneous abortion, stunted foetal growth, congenital defects, and lesions of the developing neurological system.

Particulate matter (particularly ultrafine and fine particle size modes) affects the cardiovascular system, causing myocardial infarction and blood vessel occlusion, as well as the respiratory system by causing lung inflammation.

1.1.3 IMPACTS OF FOG ON TRANSPORTATION:

Fog's ability to occur has an impact on a wide range of human activities. Fog can occasionally result in inconveniences, significant costs, and even fatalities. Fog makes it harder to see, which affects our ability to drive, sail, fly, and other activities. CHAPTER 3 discusses in more detail the relationship between fog and light. Fog can cause a total economic loss that is equal to tornadoes, or, in certain situations, winter storms and hurricanes, when it comes to the effects it has on all forms of transportation (air, sea, and land). Fog has been blamed for accidents up to 10% of the time in areas prone to it, especially when many vehicles are involved. Fog-covered airports frequently postpone take-offs and refuse to admit aircraft for safety reasons.

The effect of fog on transportation can be classified into two ways:

1.1.3.1 DIRECT EFFECT:

The worst and most common direct effect of fog is accidents. Accidents happen when it's foggy outside because visibility is reduced.

Four persons were murdered and four others were injured when a car slammed into a truck in the early hours of Sunday in the Kandhamal area of Odisha, according to an NDTV report from Sunday, February 13, 2022 [3].

A 37-year-old man was murdered and 16 other people were injured when their bus slammed with another car that was travelling in front of it on the Agra-Lucknow Expressway in Firozabad on Saturday owing to excessive fog, authorities said in this NDTV report from Saturday, February 13, 2021.

According to an NDTV report from Saturday, January 30, 2021, a private bus collided with a truck on the Moradabad-Agra Highway in Uttar Pradesh this morning due to poor visibility caused by dense fog, according to an official. At least 10 people were killed and about a dozen were injured, according to the report.

Icy winds swept north India on Wednesday, with Amritsar in Punjab reporting the lowest minimum temperature in the plains. Meanwhile, dense fog enveloped several parts of Uttar Pradesh, where eight people died when a bus collided with a gas tanker amid reduced visibility, according to an NDTV report from Wednesday, December 16, 2020.

According to NDTV report dated Wednesday December 16, 2020, eight people died while 21 sustained injuries here on Wednesday morning when an Uttar Pradesh Roadways bus collided with a gas tanker amid reduced visibility due to fog, police said.

According to NDTV report dated Monday December 7, 2020, one person was killed and over a dozen people injured in separate multi-vehicle pile ups due to fog on two expressways in Greater Noida on Monday, officials said.

According to the Times of India report dated January 8,2018, New Delhi, road accidents and fatalities due to fog and mist have increased significantly over the past three years. While 16 people were killed daily in such accidents in 2014, it increased to 21 in 2015 while in 2016. more than 25 people died in similar crashes every day, according to the latest report of road transport ministry.

Only Uttar Pradesh, West Bengal and Haryana put together had more than half of the total fog and mist-related road fatalities in 2016. Such fatalities increased five times in Haryana. Government officials said since all these accidents and deaths happen in two-three months. there is a need to put special focus on managing the crisis.

According to a different story from the logical India dated February 12, 2016, a major pileup this morning on National Highway I near Kamal, Haryana, resulted in the deaths of four family members and the serious injuries of over 25 additional travellers. According to reports, a truck that was stopped on the road in thick fog is what caused the collision. Such circumstances cause serious wrecks all over north India each year. Four individuals were instantly killed a few weeks ago when a car in Lucknow crashed into a canal as a result of heavy fog. A 50-car pileup on the Yamuna Expressway near Delhi, which was reported as happening on January 24, 2016, resulted in the death of one person and other injuries.

On how fog contributes to accidents, there are numerous reports available.

1.1.3.2 INDIRECT EFFECT:

Any civilization's most potent parameter is time. Timing is crucial for every type of job, and a species can live in the world if they can adjust over time.

However, fog really wastes some time because it slows down traffic, making it necessary to take longer to perform the same work than in clear weather. This traffic snarl can have several negative effects on people's lives, including

I. Effects on agricultural products:

Agricultural items, especially fruits and vegetables, cannot be stored for an extended period of time since they degrade quickly. As a result, agricultural products rely heavily on the transportation infrastructure.

Example:

Assume local farmers produced M pounds of vegetables. N is the production cost, while (N/M) is the cost per vegetable.

These products are consumed by residents in region B. However, the fog causes transportation delays, which causes many vegetables to deteriorate. Vegetable quantity arriving at location B is M-O

Therefore, cost per vegetables = (N/(M-O))

so, cost per vegetables increases.

II. Effects on manufacturing products

The economy of today is a market economy. The market is governed by supply and demand. In the supply and demand game of business, timing is crucial. Any form of transportation delay can hinder demand if the most profit is to be made, which means that products must be supplied at a specific time when demand is at its peak. (Others may meet the demand.)

III. The fog is also slowing down administrative work.

1.2 PROPOSED SYSTEM:

According to extensive research conducted worldwide, improved sight between vehicles lowers the probability of an accident by more than 30%. In light of this, the International Road Federation (IRF), a global organisation dedicated to promoting road safety, requested the Indian government to mandate front and rear fog lights for all automobiles last year.

Any vehicle can be equipped with fog lights, which provide a clearer view of the road ahead by shining their illumination beneath the region.

It has been tried to build certain solutions that can be useful in foggy weather in order to overcome those problematic transportation system scenarios.

a) Monochromatic light source:

This method aims to improve visibility under foggy conditions. Fog may be penetrated by monochromatic light; hence data must be gathered by boosting the monochromatic light's intensity (data about how clearly and from what distance a person can detect an object in foggy weather). Chapter 4 of the book contains information on the system.

CHAPTER 2

FOG

2.1 INTRODUCTION:

Large numbers of tiny liquid water droplets or ice crystals suspended in a certain volume of air close to the ground make up fogs. Fogs and clouds share the same physical characteristics. Fog can be defined as a cloud that touches the ground. Fog is a condition of the atmospheric air with visibility less than 1 km, as measured close to the surface, which reduces visibility in the immediate vicinity.

In addition to the hydrosphere, fogs are another example of liquid water in the Earth's atmosphere. In general, local orographic conditions, the current synoptic situation, and atmospheric circulations have a significant impact on fog development and existence. It can develop on both land and aquatic surfaces. It has significant meteorological significance despite not being a climate-forming component because of its localised development, capacity to lower temperature amplitudes, and close relationship to humidity parameters.

The thermal and radiative budget of the atmosphere, air quality, waterways, flora and fauna, air-surface interactions, and many other aspects of the ecosystem are significantly impacted by natural fog, a form of condensed water that exists in the atmosphere. Fogs can significantly disrupt and impair societal life and functionality (such as air, surface, and sea transportation), as well as diminish visibility, which results in a staggering number of injuries and fatalities. Fogs can also have negative impacts on human health, either directly or indirectly, depending on the physical, chemical, and composition of the droplets (respiratory and radiation diseases, skin and eye damages, secondary health effects, etc).

2.2 DEFINITION:

The term "Fog" is typically distinguished from the more generic term "cloud" in that fog is low-lying, and the moisture in the fog is often generated locally (such as from a nearby body of water, like a lake or the ocean, or from nearby moist ground or marshes).

Officially. fog is defined for visibility less than 1000 meters. This limit is suitable for aviation purposes but for people on road this limit is 200 meters. Severe disruption to road, rail and air traffic occurs when the visibility falls below 50 meters.

2.3 FOG- PHYSICAL BASIS, GENERAL CHARECTERIZATION:

2.3.1 PHYSICAL BASICS OF FOG:

Water covers more than 70% of the Earth's surface. Two hydrogen atoms and one oxygen atom bound together by covalent bonds make up its molecule. Water is the foundation of terrestrial biological life; its existence and balance are crucial for all living organisms on

Earth due to its special physical and chemical qualities, abundance, and structural/phase variety. Water can be found in the solid (ice), liquid (liquid water), and gaseous phases of matter (water vapor). Transitions between the three phases of water take place depending on the interaction of the ambient temperature T and pressure P. The water phase diagram is another name for the pressure-temperature (P-T) diagram [4] that conditions the phases' coexistence, coexistence, and transitions. The Clausius-Clapeyron relation mathematically defines the discontinuous phase transitions between two water phases:

$$dP / dT = L / T\Delta v \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.1)$$

where L is the specific latent heat and Δv is the specific volume change accompanying the phase transition. The Clausius-Clapeyron ratio states that for every 1 degree C increase in temperature, the equilibrium vapour pressure of the atmosphere—also referred to as its "water-holding capacity"—increases by around 7%. The August-Roche-Magnus formula can be used to roughly express the water-holding capacity:

$$e_s(T) = 6.11 \exp \{17.63T / (T+243.04)\} \quad \ldots\ldots\ldots (2.2)$$

where $e_s(T)$ is the equilibrium, or saturation, vapor pressure in hPa and the temperature T is in degrees Celsius. This equation states that for a constant relative humidity, an increase in atmospheric temperature (caused, for example, by the greenhouse effect) causes an exponential increase in atmospheric absolute humidity. It should be emphasised that this deduction's relevance to atmospheric phenomena is controversial and might not hold true in the case of convective processes, which result in relative humidity variations that cause air drying, cloud formation, etc.

2.3.2 WATER DROPLET NUCLEATION:

Nucleation---The creation of droplet nuclei is crucial for the development of ultrafine-mode particles, clouds, and fog. According to the presence or absence of foreign nuclei or substances, homogeneous and heterogeneous nucleation can be separated. Homogeneous nucleation happens at random and on its own. However, it necessitates exceeding the water-vapor critical supersaturation, also known as the critical supercooling. It is in charge of creating new particles, which later on can act as Cloud Condensation Nuclei (CCN, see below). There have been instances where freshly generated particles have caused the CCN number to rise by a factor of more than two in a single day. Near clouds and the tropopause, several incredibly small particles (with sizes of 3–15 nm) have been discovered. The continental boundary layer has shown the creation of ultrafine particles (diameter approximately few nm) and their subsequent expansion to about 100 nm in the following two days. A sizable portion of the particles in the atmosphere are formed by a process called nucleation from a gas phase. The four most significant nucleation mechanisms, each of which occurs in a distinct region of the atmosphere, are as follows:

1. Homogeneous binary water-sulfuric acid nucleation is the primary nucleation mechanism in industrial plumes and the free troposphere;

2. The most frequent one is homogeneous ternary water sulfuric acid-ammonia nucleation in the continental boundary layer;
3. Ion-induced nucleation of binary or ternary inorganic vapours or of organic vapours occurs in the upper troposphere and lower stratosphere;
4. The primary mechanism in coastal areas is barrier-less homogenous iodide species nucleation.

Supersaturations as high as several hundred percent would be required for drop formation in homogeneous water vapour (condensation of water vapour molecules without the presence of external condensation nuclei). The atmosphere does not experience supersaturation at such high levels. This is the reason why supersaturated water vapour does not uniformly nucleate to form cloud, fog, or ice particles. The common supersaturations seen in the atmosphere are typically less than 10%, and frequently even less than 1%. The presence of hydrophilic compounds or particles in the atmosphere is a crucial component promoting water vapour condensation into droplets (heterogeneous nucleation). Droplets can expand to tens of micrometres or more in diameter. Fog, cloud droplets, and ice particles are formed by the condensation of supersaturated water vapour on soluble aerosol particles and on insoluble but wettable particles. Water droplet formation is depicted in Fig. 2.1. Cloud condensation nuclei are aerosol particles that have the ability to create liquid cloud or fog droplets, whereas ice nuclei are aerosol particles that cause the development of ice crystals. Size is one aspect that affects a particle's capacity to function as CCN at a specific supersaturation level. the amount of solute, the presence of surface-active compounds, the shape and wettability of insoluble particles, and the presence of soluble gases. All processes that result in the creation of atmospheric aerosols are sources of CCN. The various types of aerosol particles are briefly described below. The size, origin (natural or manmade), physical characteristics (liquid, solid, organic), sources (primary or secondary), and geographic origin of the many forms of aerosols can all be characterised (desert, polar, continental, marine, rural, urban). According to their sizes, the atmospheric aerosol particles can be classified into various modes [5-9].

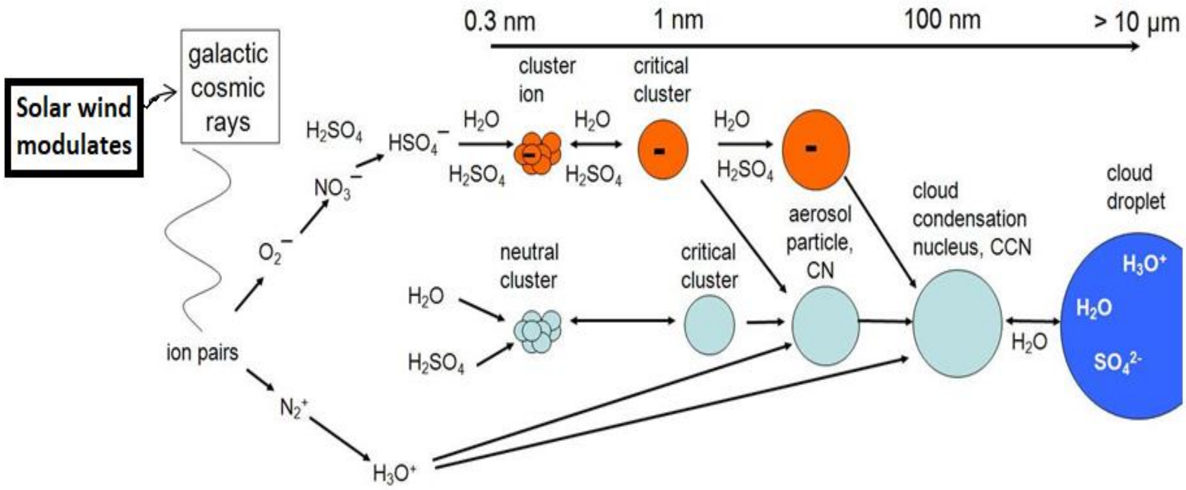


Fig.2.1. Formation of water droplet

• **Fine particles:**

- Nucleation mode: 0.001-0.01 μm,
- Aitken mode: 0.01-0.1 μm,

•**Coarse mode:** > (1 to 2.5) μm,

•**Giant particles:** >10 μm.

Sulfates and elemental carbon make up the Aitken mode particles, or Aitken nuclei. With a very low saturation vapour pressure at room temperature, metal and organic compounds the coagulation of smaller Aitken nuclei, sulphate ($SO4^{+}$), nitrate ($NO3^{-}$), ammonium ($NH4^{+}$), and hydrogen (H^{+}) ions, as well as elemental carbon, a wide range of organic compounds, and metal compounds of Pb, Cd, Ni, V, Cu, Zn, Mn, Fe, etc. are all examples of accumulation mode particles.

The coarse mode is made up of street dust or suspended soil, ash and soot from uncontrolled burning of coal, oil, and wood, nitrates and chlorides as HNO and HCI, oxides of crustal elements (Si, Al, Ti, Fe), $CaCO_3$, NaCl, and sea salts, pollen, mould, and fungal spores, as well as fragments of plants and animals.

The secondary aerosol particle family includes the Aitken mode and accumulation particles. Both by-products of combustion (mostly from anthropogenic sources) and particles produced by the gas-to-particle conversion process, which is regarded as a natural source if the precursor gases are not, make up Aitken nuclei (terpenes emitted by plants, for example). The coarse mode particles belong to the category of primary aerosol particles and have direct origins (mostly natural).

The most effective CCN is regarded to be sulphate aerosols, but recently, organic aerosols have drawn attention and are now believed to have activation capabilities on par with sulphate aerosols. Organic CCN can be both anthropogenically and naturally produced and can result from both primary and secondary organic aerosols. The main sources of primary organic CCN include combustion byproducts from burning biomass and vehicle exhaust, as well as biogenic emissions. Secondary biogenic aerosols, secondary anthropogenic organic aerosols, and soot oxidation products are identified as the main sources of secondary CCN. Primary biogenic organic aerosols are those produced in the water and include complete organisms, reproductive material, fragments, decomposing organic debris, and products of bubble-bursting processes. Secondary biogenic organic aerosols are created by the oxidation of volatile organic compounds (VOCs) released by biological organisms. These are a few of the organic aerosols that can function as CCN [10]:

1. **Monocarboxylic acids (MCA)** and **dicarboxylic acids (DCA)-** The formic and acetic acids are species that are primarily found in the gas phase, aerosols, precipitation, clouds, and fog water (belonging to MCA). in aerosol molecule form.

While only making up a minor portion of the overall particulate water-soluble organic components in the atmosphere, DCA (oxalic acid, malonic, and succinic acid) predominate.

2. **Humic-like substances (HULIS)-** aliphatic and polysaccharide-containing tiny particles with high water solubility. HULIS, which may also have a biogenic origin, make up a significant portion of continental organic aerosols. They are thought to have an impact on both the generation of CCN and the hygroscopicity of aerosols. In fog droplets, HULIS have also been discovered, and their scavenging ratio is comparable to that of inorganic ions.

3. **Bacteria (0.25-8 um in diameter)-** a collection of prokaryotic, unicellular bacteria with a wide range of metabolic processes. Temperate vegetation zones, raw crop areas (high primary output), and desert regions are proven to be sources of bacteria (relatively low production). Boundary layer, upper troposphere, stratosphere, clouds, fog, raindrops, and hailstones are all areas of the atmosphere where living and dead bacteria have been found (up to 41 km above sea level). Plant pathogenic bacteria Erwinia carotovora, as well as Gram-positive and Gram-negative bacteria Micrococcus agilis, Mycoplana bullata, and Brevundimonas diminuta, are capable of acting as CCN at low saturation ratios (from 0.07 % to 1 %).

4. **Total and dissolved organic carbon (TOC and DOC)-** large volumes of organic. Fog and clouds have been found to contain carbon (C). In distant marine habitats, its concentration ranges from 1 mg C/L to 100 mg C/L. (in polluted radiation fogs). In the clouds affected by biomass burning, extremely high quantities of between 100 and 200 mg C/L have been observed. The majority of the organic material in fog droplets is regarded as DOC.

Giant CCN is frequently used to designate CCN with dry particle dimensions >5 μm (GCCN). They make up a tiny portion of all particles and can activate at extremely low supersaturations (0.02 percent). These particles can expand to sizes more than 10 um and function as collector drops before droplet activation. Due to their vast surface area, GCCN hinder the activation of smaller particles, reducing the peak supersaturation in clouds and preventing them from contributing to cloud shaping.

2.4 FORMATION OF FOG:

When there is less than a 2.5 °C (4 °F) difference between the air temperature and the dew point, fog will form [11]. When water vapour condenses into minute liquid droplets suspended in the air, fog starts to form. Virga or precipitation falling from above, daytime heating evaporating water off the surface of seas, water bodies, or wet land, transpiration from plants, chilly or dry air moving over warmer water, and lifting air over mountains are six instances of how water vapour is added to the air. In order to generate clouds, water vapour often starts to condense on condensation nuclei like dust, ice, and salt. Fog is a stable cloud deck that typically forms when a cool, stable air mass is trapped beneath a warm air mass. It is similar to its elevated cousin status.

Normal fog conditions are close to 100% relative humidity. Either increased air moisture or a decrease in ambient air temperature causes this. Fog, however, can sometimes fail to form at 100% relative humidity and can form at lower humidity levels. If more moisture is added to air that already has a relative humidity of 100 %, the air will become supersaturated.

Drizzle or very light snow are the most frequent forms of precipitation that fog causes. When the fog's humidity reaches 100% and the tiny cloud droplets start to become larger, it starts to drizzle. This can happen when the fog layer is sufficiently raised and cooled, or when descending air forces compresses it from above. When the temperature at the surface falls below the freezing point, drizzle turns into freezing drizzle.

The height of the inversion border, which in coastal or oceanic locations also serves as the top of the marine layer, where the air mass is warmer and drier, is a major determinant of the thickness of a fog layer. The weight of the air above it, which is expressed in terms of atmospheric pressure, affects the inversion boundary's altitude the most. When the pressure is high, the marine layer and any possible fogbank will be "squashed," and when the pressure is low, it may spread upward.

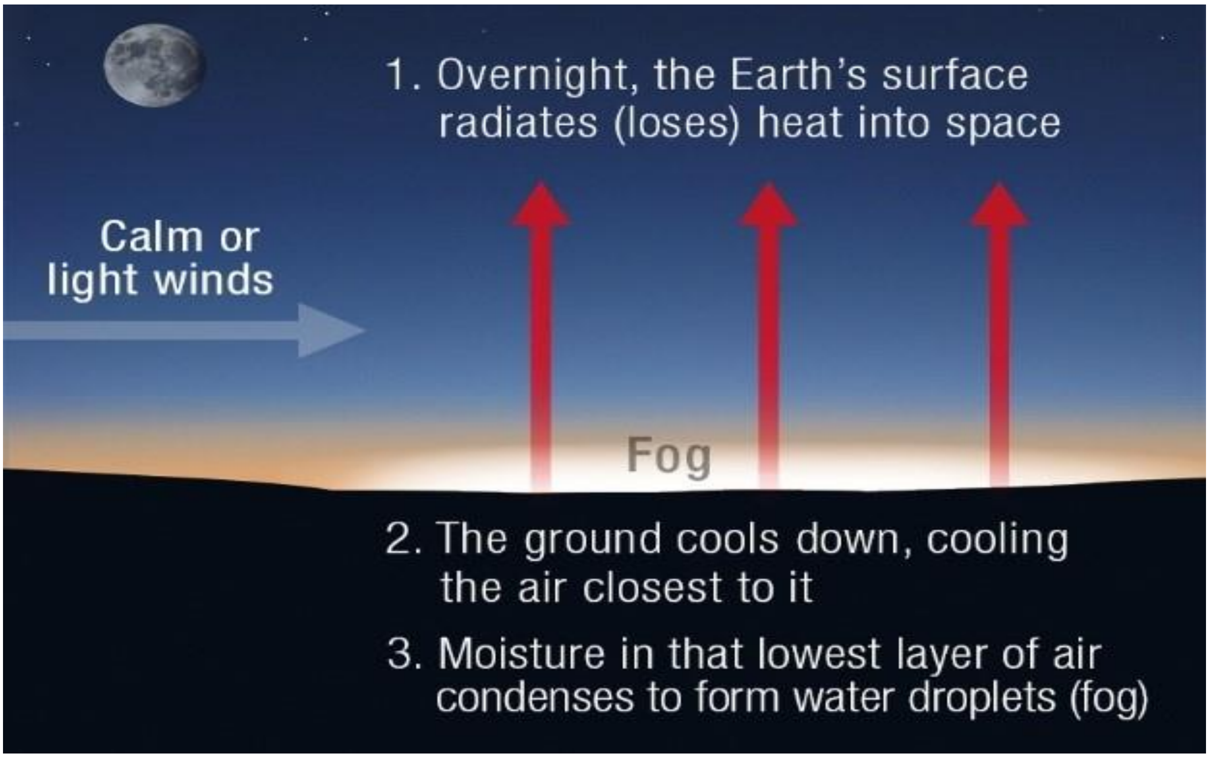


Fig.2.2. Formation of fog.

2.5 TYPES OF FOG:

Stratus clouds hanging close to the ground are frequently used to describe fog. If the difference between the air's temperature and dew point is less than 5°F, fog will result from either chilling the air (creating upslope fog, radiation fog, or advection fog), or adding moisture to raise the dew point (producing steam or frontal fog). It is referred to as ice fog when made up of ice crystals. Depending on how the cooling that generated the condensation occurred, fog can form in a variety of ways, which is why various varieties of fog are detailed below:

1) RADIATION FOG:

When there are calm conditions and a clear sky, this is created when infrared thermal radiation cools the land after sunset. The air is then conductedly cooled by the cooling ground, which lowers the temperature until it reaches the dew point and forms fog. The fog layer can be less than a metre thick in an ideal, quiet environment, although turbulence might encourage a thicker layer. Radiation fogs normally form at night and disappear before daybreak, but during the winter they can last all day, especially in locations bordered by high ground. Fall and the beginning of winter are when radiation fog is most prevalent. Tule fog is one instance of this occurrence [12]. Radiation fog formation shown in Fig 2.3.

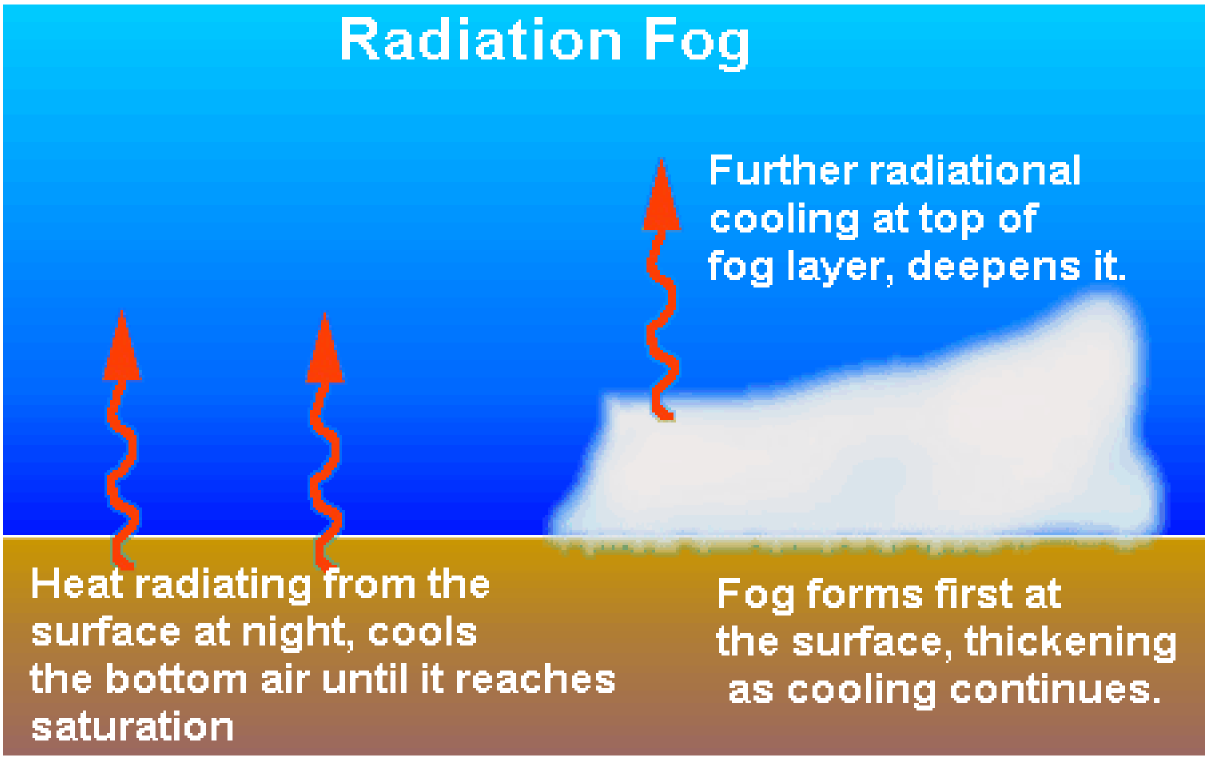


Fig.2.3. Radiation fog formation.

Fig.2.4. Radiation fog in street

Fig.2.5. NASA Image of radiation fog.

In the bottoms of valleys, radiation fog frequently occurs. Shortly after daybreak, when the ground starts to warm and the inversion disappears, it usually dissolves or burns off.

2) GROUND FOG:

This fog does not reach the base of any overhead clouds and only covers less than 60% of the sky [13]. However, the phrase is typically used as a synonym for radiation fog, which can occasionally reach depths of only a few tens of centimetres over specific types of terrain when there is no wind.

3) ADVECTION FOG:

This fog develops when moist air is cooled by advection (wind) as it moves over a cool surface [14]. It frequently occurs when a warm front crosses a region with a thick layer of snow. It occurs most frequently at sea when humid air comes into contact with cooler waters, particularly places where cold water upwells, like along the California coast (San Francisco fog). Advection fog can also be produced by a significant enough temperature difference over water or bare ground.

Strong winds can disperse, fragment, or prevent many types of fog, but significantly warmer and more humid air blowing over a snowpack can continue to produce advection fog at speeds of up to 50 mph/80 km/h or more. This fog will be in a turbulent, quickly moving, and relatively shallow layer, observed as inches/a few cm in depth over flat farm fields, flat urban terrain, and the like, and/or form more complex forms where the terrain is different. One of a number of factors causes the advection of fog along the California shoreline to move inland. It is most common in the spring or late fall for a cold front to push the marine layer coastward. The dense marine layer is drawn in throughout the summer when a low-pressure trough caused by intense inland heating forms a strong pressure gradient. Additionally, throughout the summer, a south to south-easterly flow known as a "Southerly Surge," commonly occurring after a coastal heat wave, is produced by strong high pressure aloft over the desert southwest, usually in connection with the summer monsoon. The maritime layer and any fog it may contain, however, might be broken up if the monsoonal flow is sufficiently turbulent. A fog bank will often change with moderate turbulence, lifting and breaking up into shallow convective clouds known as stratocumulus. Fig.2.6 depicts the creation of advection fog.

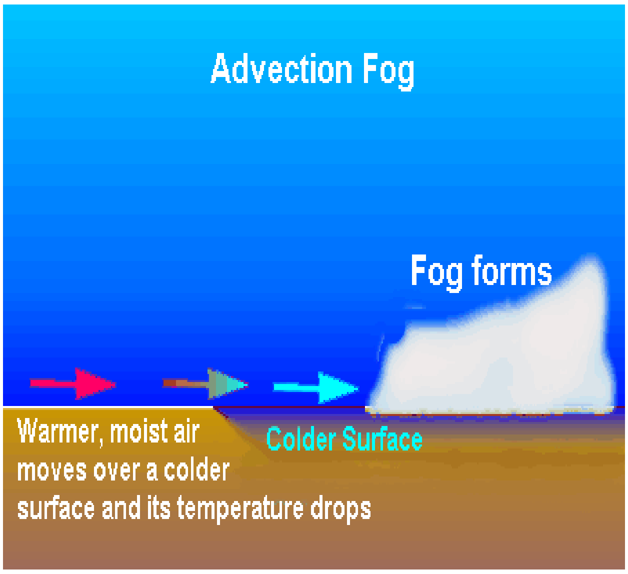


Fig.2.6. Advection fog formation.

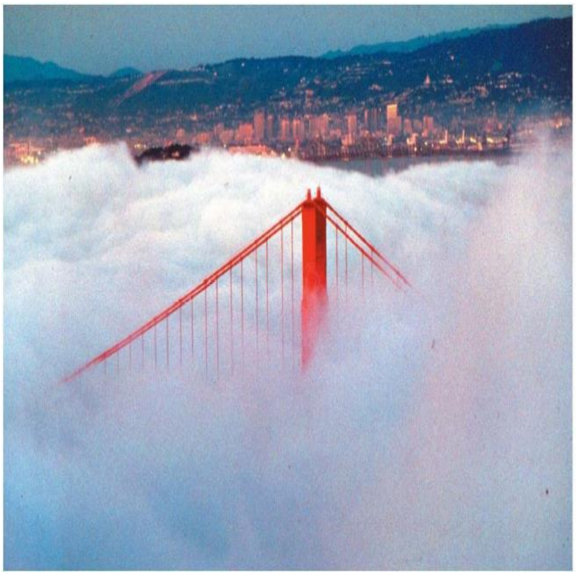


Fig.2.7. Advection fog image in reality.

4) <u>STEAM OR EVAPORATION FOG:</u>

This fog develops over bodies of water where considerably colder air is present; this circumstance can also cause steam devils to arise. This kind of fog is caused by lakes, often in conjunction with radiation fog and other factors. It often differs from most advective fog created over land in that it is a convective occurrence, similar to a lake effect show, producing fog that can be significantly denser, deeper, and appear fluffy from above. Most other fog is stratiform, and in this kind of fog, steam devils, which resemble their counterparts in the dust, are frequently observed. Figure 2.8 depicts the creation of a steam or evaporation fog.

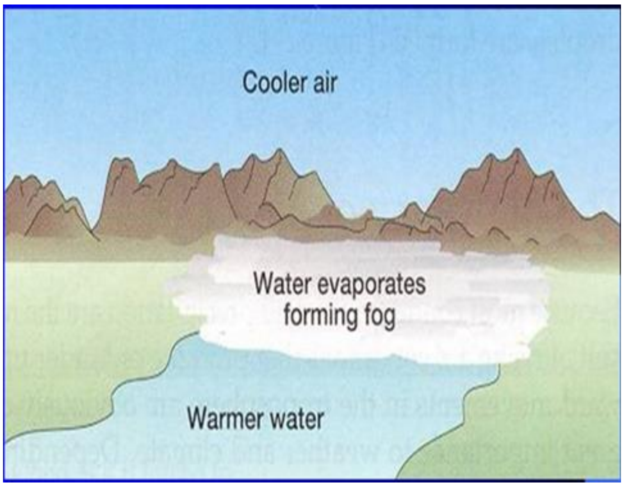


Fig.2.8. Evaporation fog formation. Fig.2.9. Evaporation fog image in reality.

5) ICE FOG:

The additional mechanisms outlined here, as well as the exhalation of moist, warm air by herds of animals, can both contribute to this fog forming in extremely low temperatures. It is comparable to the diamond dust type of precipitation, which consists of very tiny ice crystals that gently descend to the ground. This frequently happens when there is a clear sky, which can result in a variety of halo kinds as well as other effects from the sunlight being refracted by the airborne crystals.

6) FREEZING FOG:

Rime, or freezing fog deposits, are made comprised of super-cold-water droplets that instantly freeze on nearby objects.

7) FRONTAL OR PRECIPITATION FOG:

Raindrops falling from relatively warm air above a frontal surface evaporating into colder air near the Earth's surface and causing it to become saturated is how this fog develops close to a front. Frontal fog refers to the common scenario that occurs with warm fronts. As precipitation falls into the dry air beneath the cloud, the liquid droplet evaporating into water vapour, precipitation fog occurs. Precipitation fog gets its name from the condensation of cooling water vapour at the dewpoint, which causes fog to form. Formation of precipitation fog is depicted in Fig 2.10.

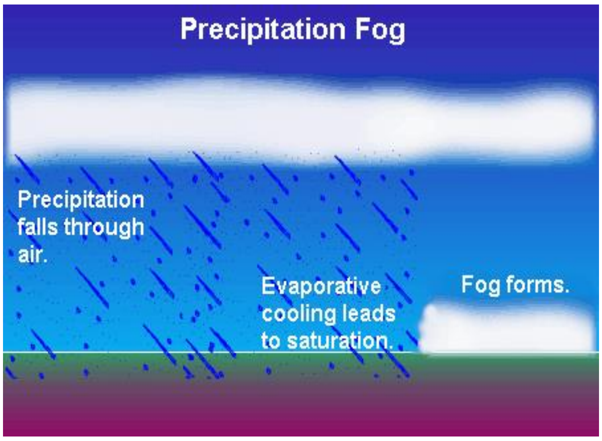


Fig.2.10. Precipitation fog formation.

Fig.2.11. Precipitation fog image in reality.

8) HAIL FOG:

Fog can occasionally form close to large hail accumulations as a result of lower temperature and increased moisture saturating a very shallow layer close to the surface. It usually happens when the hail is covered in a warm, humid layer and when the wind isn't too strong. This ground fog is often confined, but it can also be abrupt and highly dense. When the hail has had time to cool the air and as it absorbs heat while melting and evaporating, it may form immediately after the hail falls [15].

9) UP-SLOPE FOG:

This fog develops as moist air climbs a mountain or hill and condenses into fog due to adiabatic cooling and, to a lesser extent, pressure loss with altitude. Up-Slope fog formation shown in Fig. 2.12.

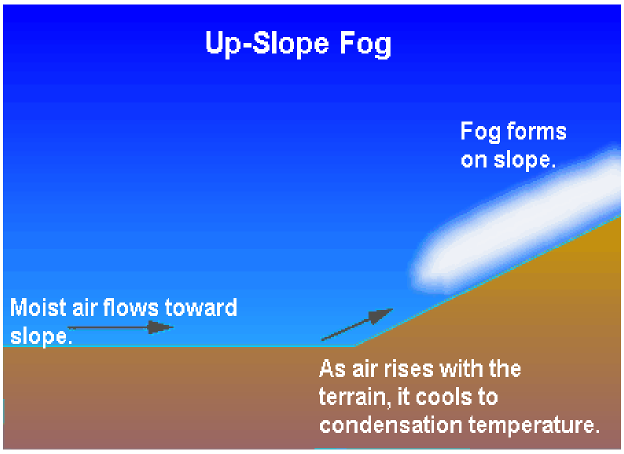


Fig.2.12. Up-Slope fog formation.

Fig.2.13. Up-Slope fog image in reality.

2.6 FOG SCENARIO IN INDIA:

Every year, thick fog blankets the Indian subcontinent, forming especially in the wintertime throughout the Ingo-Gangetic plain. The Indus and Ganga River basin's low-elevation, typically gradually sloping Indo-Gangetic plain is particularly vulnerable to wintertime continuous dense spreading fog. The most frequent contributing factors to the fog creation in this area are the regular meteorological, topography, and rising pollution conditions. The fog in question is typically referred to as radiation fog. Figure 2.14 depicts the regions of India that are prone to fog.

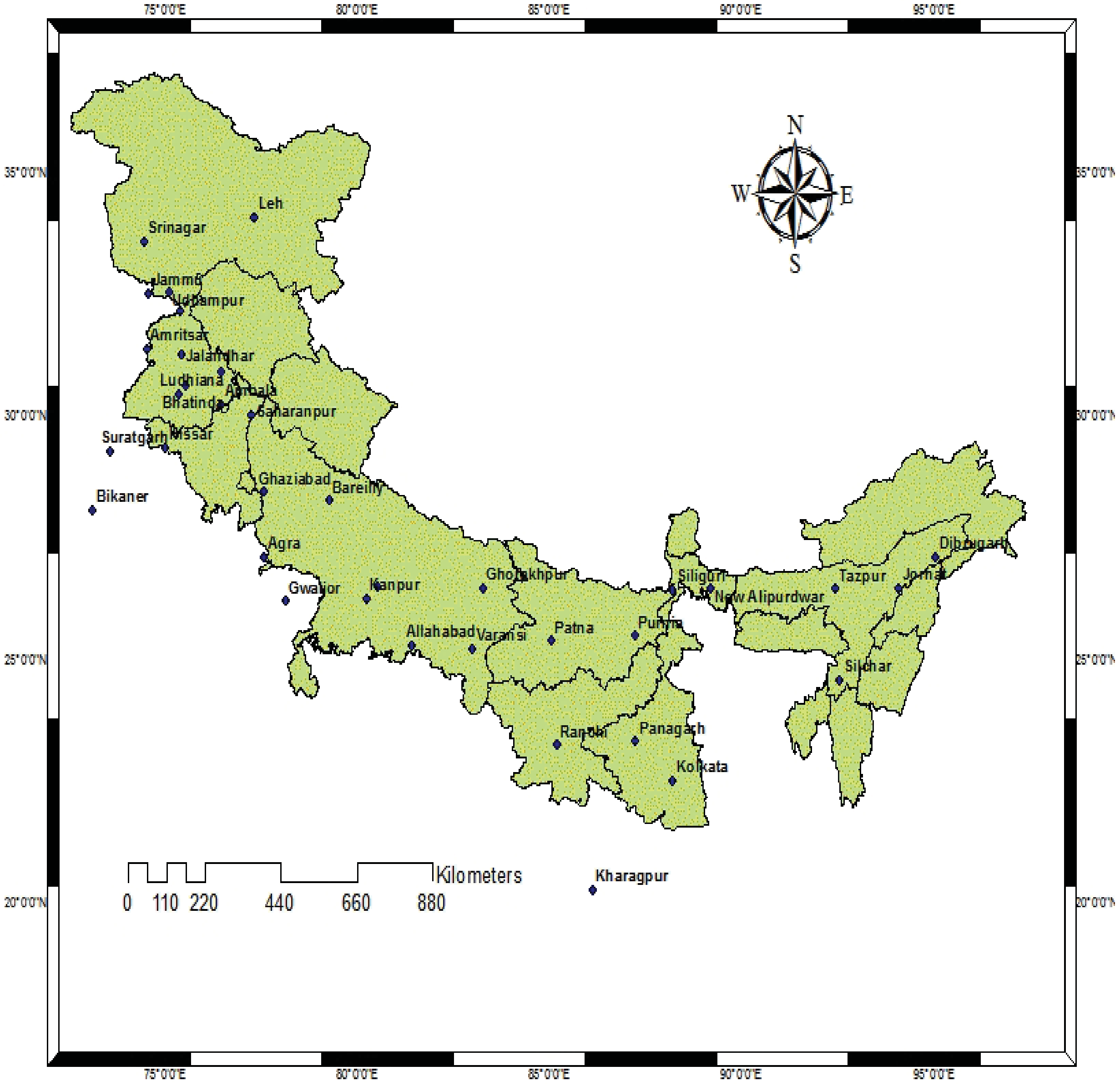


Fig. 2.14. Indo-Gangetic plain fog prone area of India

CHAPTER 3

FOG LIGHT

3.1 INTRODUCTION:

A significant number of tiny liquid water droplets or ice crystals suspended in a specific air volume close to the ground make up fog. Fogs and clouds share the same physical characteristics. Because visibility is reduced in a foggy environment, accidents frequently occur.

According to extensive research conducted worldwide, improved sight between vehicles lowers the probability of an accident by more than 30%. In light of this, the International Road Federation (IRF), a global organisation dedicated to promoting road safety, requested the Indian government to mandate front and rear fog lights for all automobiles last year.

Any vehicle can be equipped with fog lights, which provide a clearer view of the road ahead by shining their illumination beneath the region.

Fog lights have undergone different developments over the years because they are so important for safety.

3.2 HISTORY OF FOG LAMP:

Before electric lighting was available, early road vehicles used fuel-powered lamps. The headlamps and taillamps of the Ford Model T were made of carbide and oil, respectively. It took several years following its debut before all-electric lighting became a regular component. Around 1908, the first dynamo for a vehicle headlight was installed, and by the 1920s, they were standard equipment.

The first "auto signalling arm," a forerunner of the modern turn signal, and the first mechanical brake signal were both created by silent movie star Florence Lawrence. She did not, however, patent any of these discoveries, and as a result, neither of them was acknowledged nor were they profitable for her. Around 1915, tail lamps and brake lamps were first made available, and "dip" headlamps followed in 1919. In the US, the sealed beam headlamp became the only type recognised in 1940 after being introduced in 1936. In 1940, self-cancelling turn signals were invented. By 1945, signal and headlamps had been incorporated into the body's design. In 1960, halogen headlamp light sources were created in Europe. In 1991, HID headlamps first came onto the market. The first mass-produced cars with LED tail lighting appeared in 1993. In the first ten years of the twenty-first century, LED headlamps were released [16].

3.3 EFFECT OF FOG ON VISIBLE LIGHT:

Clear cloud droplets or ice crystals hanging in the air at or near the earth's surface make up fog. Therefore, when light travels through fog, it actually travels via suspended water droplets, which can lead to two major outcomes. Fig. 3.1 displays the incident light's properties.

1. Absorption: the photons (the light) disappear;
2. Scattering: the photons change their direction;
3. Refraction and dispersion;

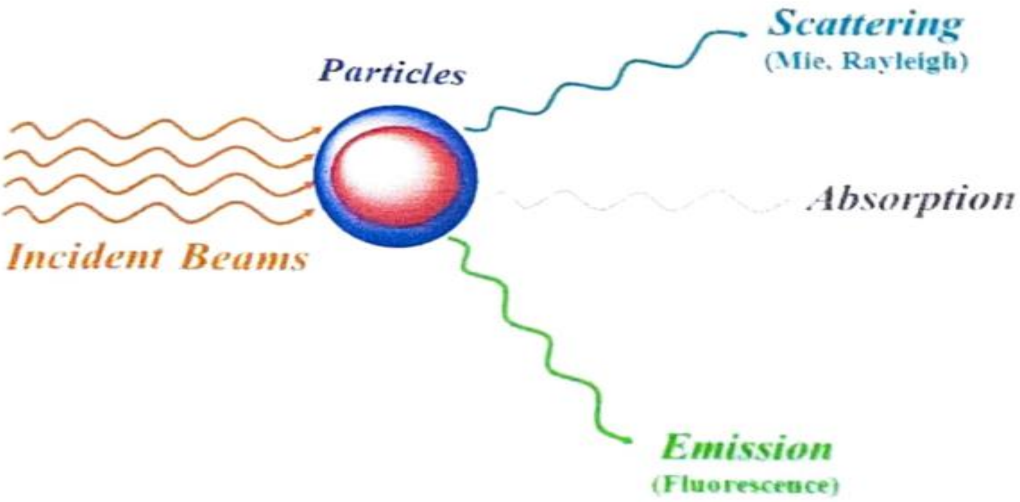


Fig3.1. Properties of incident light.

3.3.1 ABSORPTION OF LIGHT:

Absorption is the process through which light dissipates after colliding with a particle. In essence, light absorption can be defined as the process through which light is absorbed and transformed into energy [17]. In plants, this process is referred to as photosynthesis. However, any living things or inorganic materials can absorb light. It is not just a property of plants. The electromagnetic frequency of the light and the atom makeup of the item affect absorption. Light absorption is thus exactly proportional to frequency. If their energies are compatible, light is absorbed. The light will either reflect or pass through the item if they are not complimentary. Because light is typically transmitted at different frequencies, these activities typically take place at the same time (For instance, sunlight also comprises lights of various frequencies: from around 400 to 800 nm). As a result, the majority of objects either selectively transmit, reflect, or absorb light. Heat is produced when light is absorbed. Therefore, a particular material selectively absorbs light because the light wave's frequency coincides with the vibrational frequency of the electrons in its atoms.

The electron state of an object determines the amount of absorption. The "natural" frequency of electrons is the frequency at which they all vibrate. An atom's electrons become stimulated and begin vibrating when light of the same frequency interacts with it. When an atom vibrates, its electrons interact with nearby atoms to transform the vibrational energy into thermal energy. As a result, absorption differs from reflection and transmission since the light energy cannot be seen again. Additionally, because different atoms and molecules have various inherent vibrational frequencies, they preferentially absorb various frequencies of visible light.

Absorption, which is defined as a drop in radiant intensity I, can be caused by a variety of distinct events. A portion of the energy that is radiated is converted into heat as electromagnetic waves interact with the medium's molecules.

The absorption is described by the empirical expression called **Beer-Lambert law**, also known as **Beer's law** or the **Beer-Lambert-Bouguer law.**

According to the Beer-Lambert rule for solids, the loss in radiant intensity - Δl is proportional to the product of the pathlength through the material Δx and the initial radiant intensity for a parallel beam of monochromatic radiation passing through a homogeneous material-(Fig.3.2).

$$-\Delta I = I\tau\Delta x \qquad \text{...3.1}$$

where denotes the relative loss of radiant energy per unit pathlength in the material and is known as the absorption coefficient. The unit is [m^{-1}].

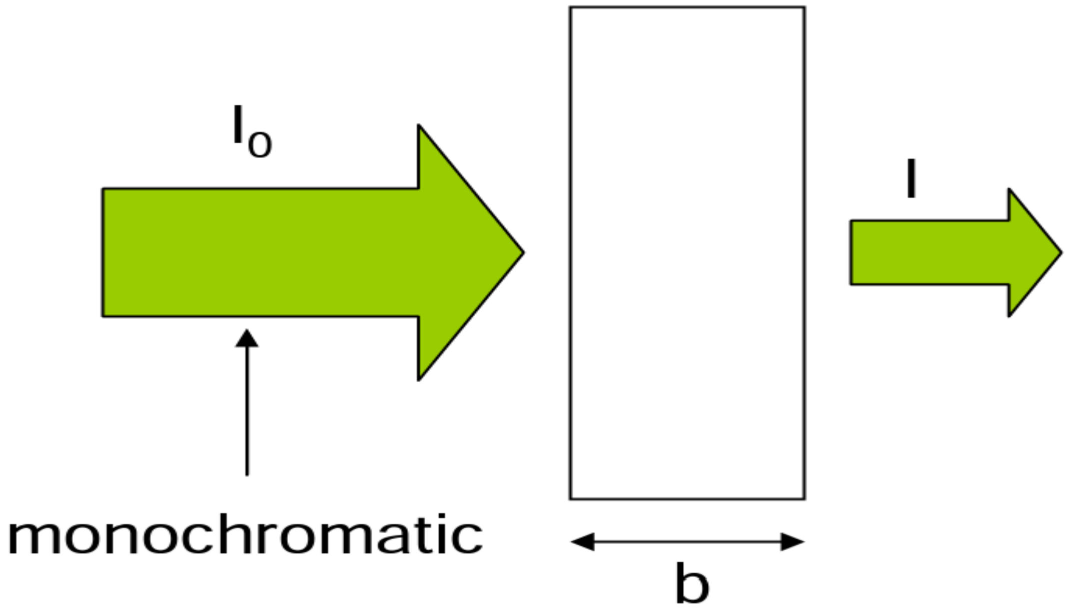


Fig.3.2 Absorption of Light

P_0 = is the incident radiant power or intensity; P = is the radiant intensity that remains; b = is the path length.

Light attenuation by the substance A material's absorption coefficient depends on the light's wavelength, which causes a variety of fascinating and frequent events (such as coloring). In the case of liquid solutions, the solvent and concentration both affect the coefficient value.

The most widely used version of the same assertion, known as the exponential law of absorption, is given by expression (3.1).

$$I = I_o\mathbf{e}^{-\tau x} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

It describes the radiant intensity I that has left the material after travelling down the pathlength x. The light's intensity as it enters the sample is expressed by lo. The so-called Beer Lambert law for transparent solid materials is expressed in equation (3.2). Figure 3.3 displays the absorption and reflection of light.

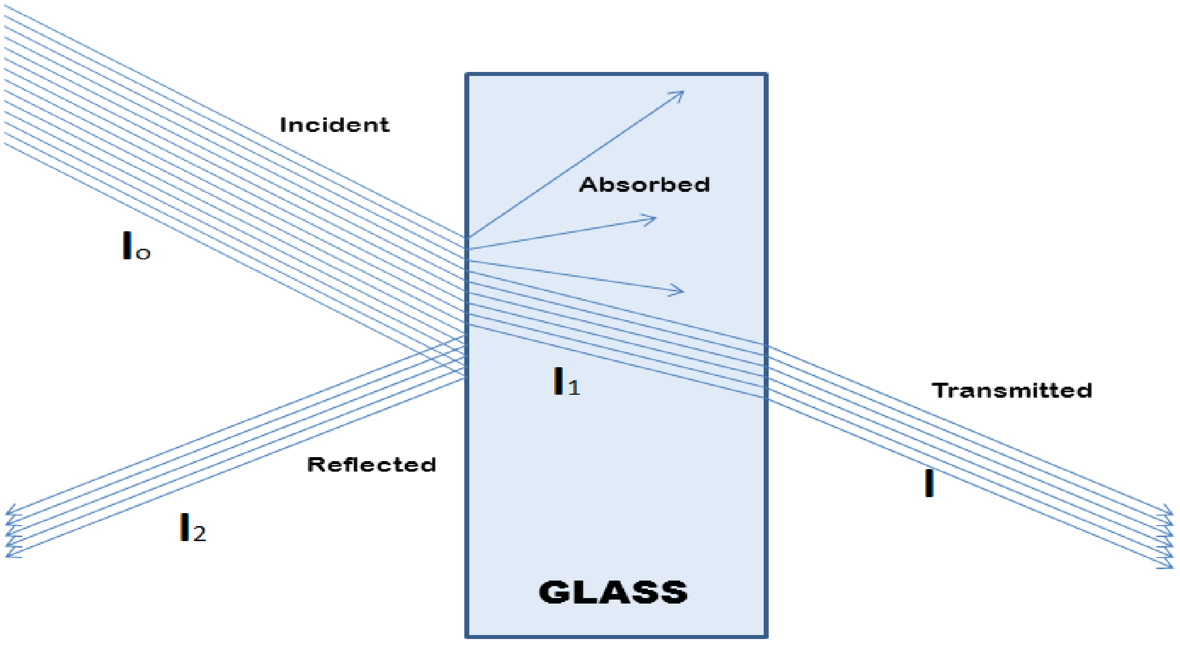


Fig.3.3. Light absorption and reflection

3.3.2 SCATERRING OF LIGHT:

Light scattering is the process by which light "hits" a small object (a particle or molecule) and changes direction as a result.

Reflection, refraction, and diffraction can all result from light being scattered by ordered particles.

The deflection of a ray from a straight path, caused, for instance, by imperfections in the propagation medium, particles, or the interface between two media, is what is meant by light scattering. The term "diffuse reflection" refers to a type of scattered reflection that is usually used to describe deviations from the law of reflection caused by imperfections that are thought to be random and dense enough (seen for fog) that their individual effects average out. Light dispersion from the surfaces of most objects makes them visible to the human eye. In fact, this is how people primarily observe their surroundings. The wavelength or frequency of the light being dispersed determines how it scatters. Even with the aid of a microscope, objects much smaller than this cannot be seen since visible light has a wavelength on the order of a micrometre. One micrometer-sized colloidal particles have been seen directly in aqueous solution.

Light hitting moisture droplets and scattering is the same physical mechanism that causes rain to scatter. However, as droplet size falls, scattering changes in both kind and quantity. More scatter, and particularly more backscatter, is produced by smaller droplets. Since very small droplets are suspended in the air to create fog, there is an increased degree of scattering, loss of contrast, and backscatter from headlights. This is the rationale for the advice against using high beams in fog.

3.3.2.1 TYPES OF SCATTERING:

- **Elastic scattering** – the wavelength (frequency) of the scattered light is the same as the incident light (Rayleigh and Mie scattering).
- **Inelastic scattering** – the emitted radiation has a wavelength different from that of the incident radiation (Raman scattering, fluorescence)**.**
- **Quasi-elastic scattering** – the wavelength (frequency) of the scattered light shifts (e.g., in moving matter due to Doppler effects).

There are more types of scattering can be defined as below:

- **Single scattering**: photons scattered only once
    - Prevails in optically thin media ($\tau << 1$), since photons have a high probability of exiting the medium (e.g., a thin cloud) before being scattered again.
    - Also favoured in strongly absorbing media ($\omega << 1$).
- **Multiple scattering:** prevails in optically thick, strongly scattering and non-absorbing media.
    - Photons may be scattered hundreds of times before emerging.

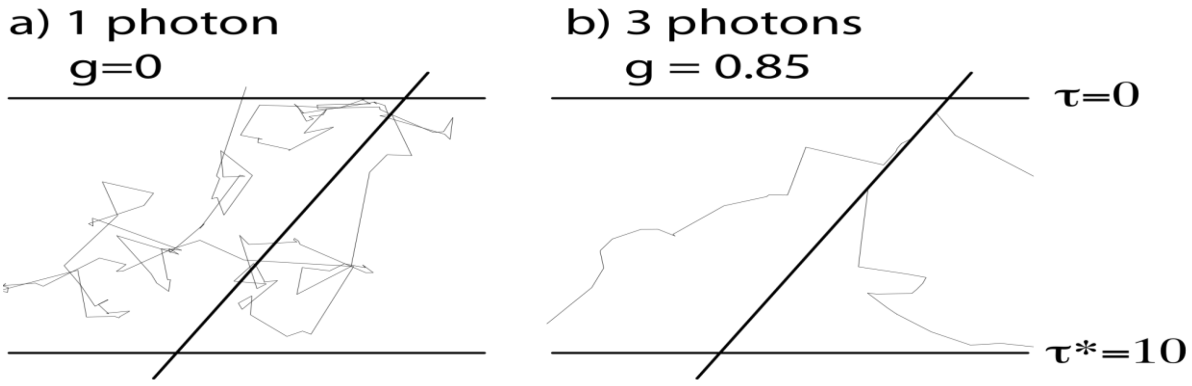


Fig.3.4. Scattering of photons

Models of light scattering can be divided into three domains based on equation (3.3). Parameters governing scattering are

1. The wavelength (λ) of the incident radiation.
2. The size of the scattering particle, usually expressed as the non- dimensional size parameter, α:

$$\alpha = 2\pi r/\lambda \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.3)$$

where r is the radius of a spherical particle and λ is the wavelength of incident radiation. Based on the value of α, scattering can be classified as

$\alpha \ll 1$: Rayleigh scattering (small particle compared to wavelength of light);

$\alpha = 1$: Mie scattering (particle about the same size as wavelength of light, valid only for spheres);

$\alpha \gg 1$: geometric scattering (particle much larger than wavelength of light).

As our main object is scattering in fog. So, we will discuss about Rayleigh scattering and Mie scattering [18].

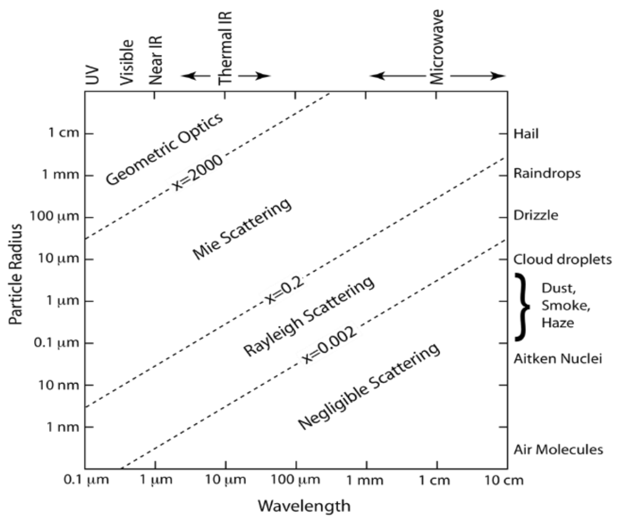


Fig.3.5. This plot considers only single scattering by spheres. (Multiple scattering and scattering by non-spherical objects can get really complex.)

3.3.2.1.1 RAYLEIGH SCATTERING:

Electric and magnetic field vectors define light as an electromagnetic wave. For the sake of simplicity, it is assumed that a plane wave with linear polarisation is impacted on a tiny spherical particle. The visible light spectrum has a wavelength of around 0.5 um. For particles far smaller than the wavelength, the wave's local electric field is always roughly homogeneous. The particle develops a dipole as a result of the applied electric field. According to classical theory, the induced dipole radiates in all directions as the electric field oscillates. Rayleigh scattering is the name for this kind of scattering.

The dipole moment" P "induced in the particle is proportional to the instantaneous electric field vector as equation (3.4).

$$P = \alpha E \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.4)$$

This formula, which has the dimension of volume and serves as a scaler for all isotropic spherical particles, determines polarisation. It is possible to drive a statement for the intensity of scattered radiation as equation from the energy of electric field generated by the oscillating dipole (3.5).

$$I = \frac{(1+cos^2\theta)k^4\alpha^2}{2R^2} I_0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

R=distance to the particle; Θ=scattering angle;

α=scaler (value depends on refractive index);

K= wave number = $\frac{2\pi}{\lambda}$;

I_0= initial intensity of the light.

With equal maxima and minima in the forward and backward directions, and a minimum at a right angle, the scattering is symmetrical with regard to the direction of the incident beam.

Blue light (short wavelength) scatters preferentially to red light, with intensity of the scattered light varying inversely with the fourth power of wavelength [19].

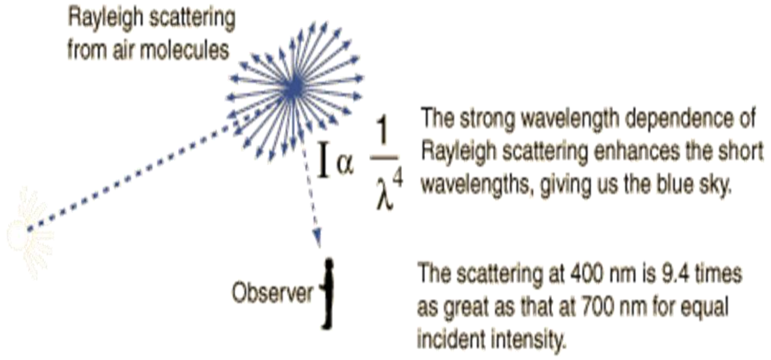


Fig.3.6. Rayleigh scattering

<u>3.3.2.1.2 MIE SCATTERING</u>:

Geometric optics offers a good approximation when the scatters are large in comparison to the light's wavelength. However, most atmospheric situations don't have large enough or small enough aerosols to be addressed easily.

The size parameter, $\alpha = \frac{2\pi r}{\lambda}$, is between 1 and 20.

By calculating the wave vector in spherical coordinates for electro-magnetic waves, as stated by "Maxwell's equations," Gustav Mie (1908) was the first to address this issue. Mic provided answers for the absorption, scattering, and extinction cross sections as functions of the scattering angle because particles typically absorb as well as scatter.

For big particles, the Mie scattering intensity is inversely proportional to the square of the particle diameter. Following particle scattering, the light beam was directed in the direction of the incident light beam. Fig. Usually, dust particles show this kind of scattering. However, during a fog, the atmosphere contains a large number of tiny water droplets, which results in less of this sort of scattering than Rayleigh scattering. In Fig. 3.7, Rayleigh and Mie scattering are depicted.

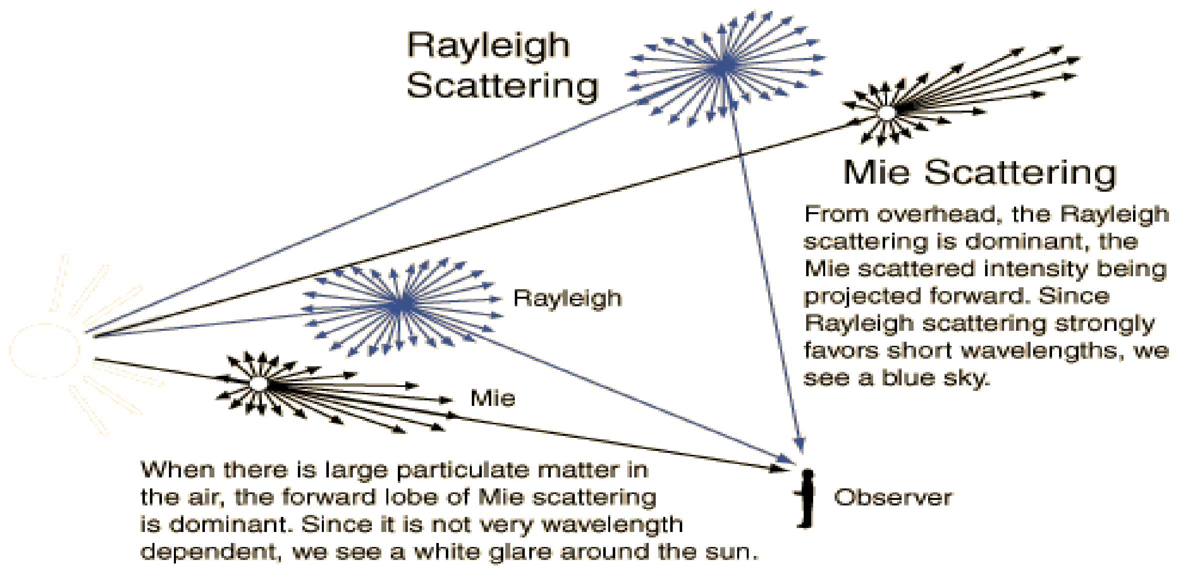


Fig.3.7. Rayleigh and Mie scattering

The object's distance and the medium's coefficient of light scattering determine how much contrast is lost. Size and density of the moisture droplets hanging in the atmosphere have an impact on this. These numbers depend on where the fog is, as droplets in cities are typically smaller because of the presence of airborne dust particles.

Since not every wavelength is impacted equally, the problem becomes more challenging as air particles get smaller. For instance, air molecules scatter short wavelengths of blue light more [19].

3.3.3 REFRACTION AND DISPERSION:

The scattering behaviour of particles depend not only on their size and shape but also on the refractive index. n. of the material as equation (3.6):

$$n = n_r + in_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.6).}$$

The real part of the index, n_r, represents the phase speed of the wave, while the imaginary part, n_i, represents the absorption of light propagating through the medium. More precisely:

$$n_r = \frac{c}{v} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.7)}$$

where c is the velocity of light in a vacuum and v is the velocity in a medium. The change in the speed of light across a medium, effectively causes the light to bend. That is, the angle of the light ray to the normal of the interface between two media, θ, changes as light passes from material of one refraction index, n_r1 to another, n_r2 as:

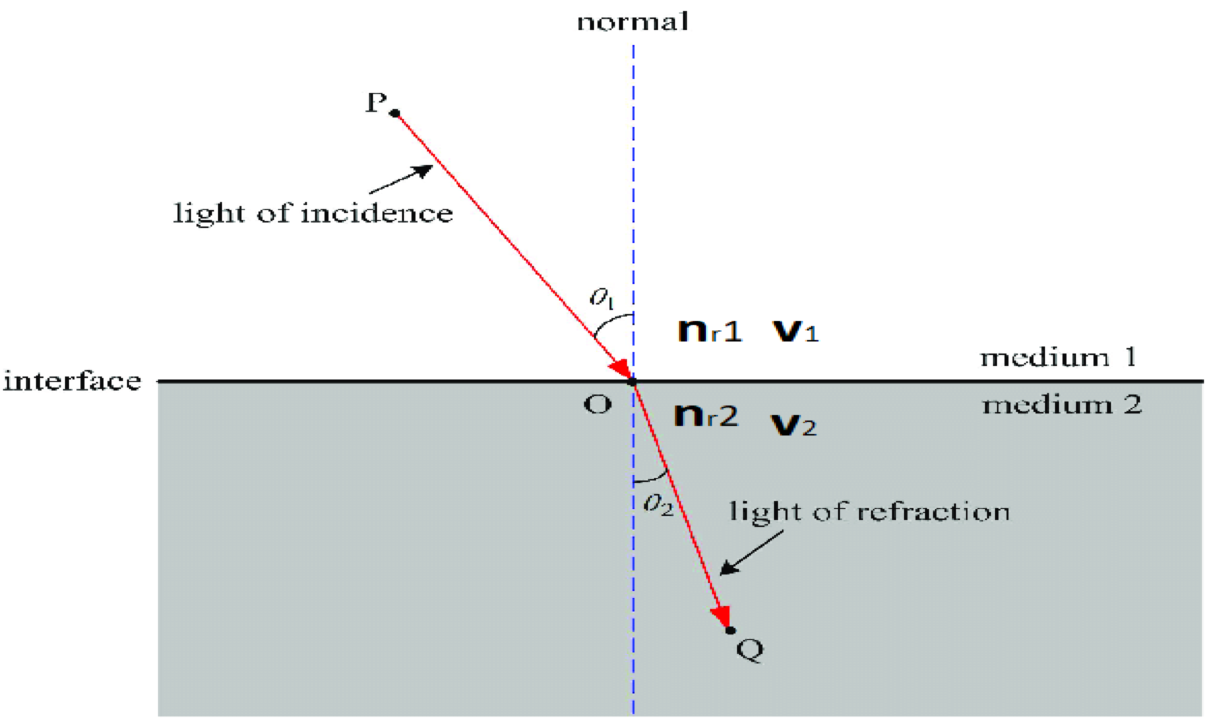


Fig.3.8. Refraction of light

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{n_r 2}{n_r 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(3.8)}$$

where the angles are shown in Fig.3.8. This called Snell's law (Equation 3.8)

So, when composite lights (mixture of different wavelength light) pass through water droplet the light changes it's medium, from air medium to cater medium.

Different wavelength light has different velocity in water medium and bends at different angle [20] shown in Fig.3.9.

So composite light disperses into individual wavelength in different direction and intensity of the light at a particular direction gets reduce.

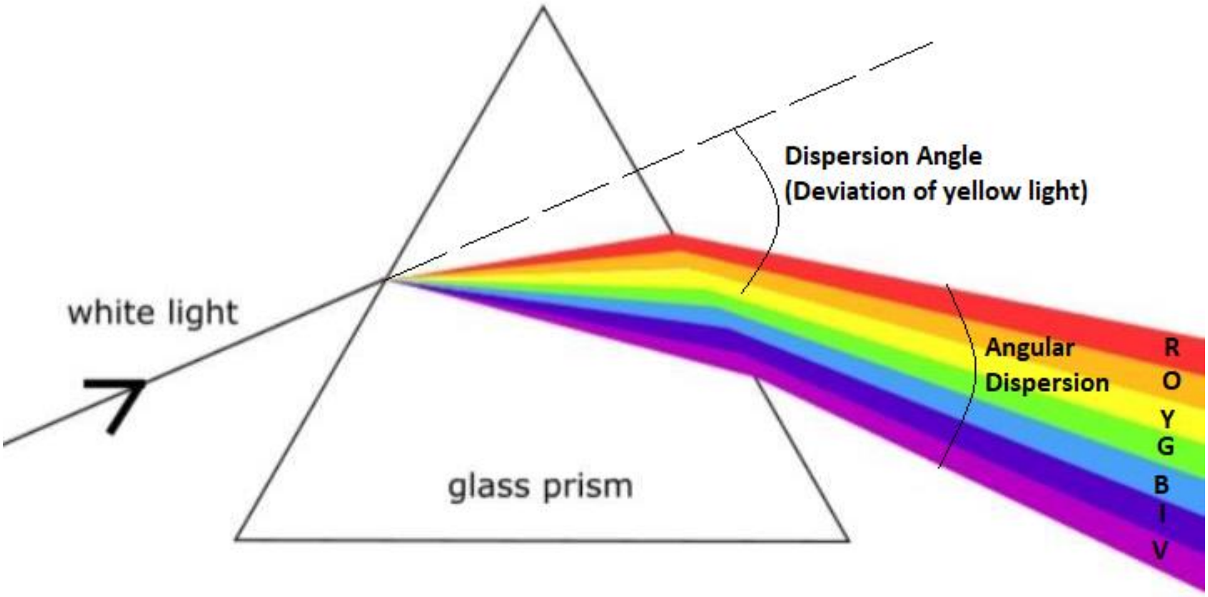


Fig.3.9 Dispersion of white light

So, from the above discussion, it can be concluded that for designing light to increase visibility in fog mainly two things have to be kept in mind:

1. **Wavelength of the light:** wavelength should be large as scattering is inversely proportional to fourth power of wavelength.
2. **Single wavelength of light:** Light should not emit composite wavelength.

CHAPTER 4

PROPOSED SYSTEM USING MONOCHROMATIC LED LIGHT

4.1 INTRODUCTION:

Tiny water droplets or ice crystals hanging in the air at or near the Earth's surface make up fog, a visible aerosol. As a result, vision is restricted due to the foggy weather, which will result in several accidents (described before in chapter 1) and much slower traffic.

The major goal of this technique is to improve visibility in foggy conditions, which will benefit both drivers and pedestrians. Accidents will decrease and the average traffic speed will rise as visibility improves. The use of monochromatic LED to improve visibility is covered in this chapter.

4.2 LED:

A light-emitting diode (LED) is a semiconductor light source that emits light when current flows through it. In the semiconductor, the recombining of electrons and electron holes causes the release of energy in the form of photons (Energy packets). The colour of the light, which relates to the energy of the photons, depends on the energy required for electrons to cross the semiconductor's band gap. White light is produced by combining many semiconductors or by covering a semiconductor with a light-emitting phosphor.

Low-intensity infrared (IR) light was produced by the first LEDs, which made their electrical component debut in 1962. Infrared LEDs are utilised in remote-control circuits, such those used in a variety of consumer electronics. Early visible light-emitting LEDs were feeble and limited to red light. Early LEDs were commonly used to replace tiny incandescent bulbs in seven-segment displays and indicator lamps. Later developments produced LEDs with high, low, or intermediate light output that were accessible in visible, ultraviolet (UV), and infrared wavelengths. White LEDs, for example, are perfect for both indoor and outdoor lighting. LEDs have enabled innovative display and sensor designs, and they are also valuable in cutting-edge communications technologies. LEDs are utilised in a wide range of items, such as lighted wallcoverings, traffic lights, automobile headlights, aircraft illumination, fairy lights, horticulture grow lights, advertising, general lighting, and medical equipment.

LEDs have a number of advantages over incandescent light bulbs, including lower power consumption, a longer lifespan, increased physical robustness, a smaller size, and quicker switching. Despite these largely advantageous qualities, LEDs do have some disadvantages, such as low voltage and typically DC (not AC) power restrictions, the inability to produce steady illumination from a pulsing DC or an AC electrical supply source, and lower maximum operating temperature and storage temperature. In contrast to LEDs, incandescent lights may be designed to operate naturally at virtually any source voltage. Additionally, they may be operated by either AC or DC current and can provide continuous lighting even at rates as low as 50 Hz. LEDs often require electronic support components in order to function, whereas an incandescent light bulb can and frequently does work straight from an unregulated DC or AC power supply.

LEDs, which are based on semiconductor diodes, generate photons when electrons and holes undergo recombination under forward bias. Anode (+) and cathode (-) are the two terminals of LEDs, and you can tell which one is which by its size (shown inFig.4.1).

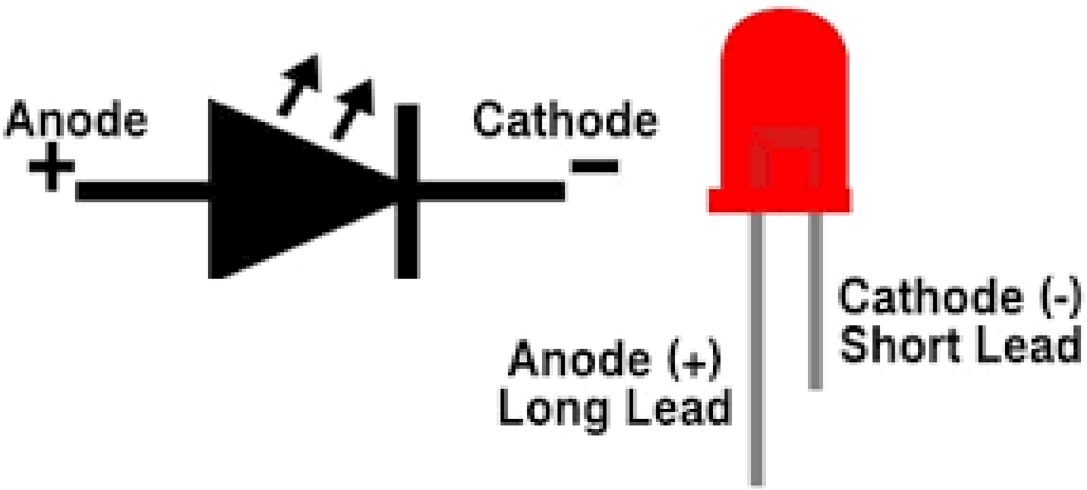


Fig.4.1. LED symbol and LED

4.2.1 HISTORY OF LED:

Electroluminescence In 1907, Marconi Labs conducted experiments utilising silicon carbide crystals and acts. The first LED was created, according to Soviet inventor Losev, in 1927. His discovery was published in Soviet and British scientific journals, but for several years there was no practical application. These light-emitting diodes were first discussed by Kurt Carl Accardo and Edward Jamgochian in 1951 using a crystal-based device with a battery or generator as the current source and a pure crystal as a comparison in 1953.

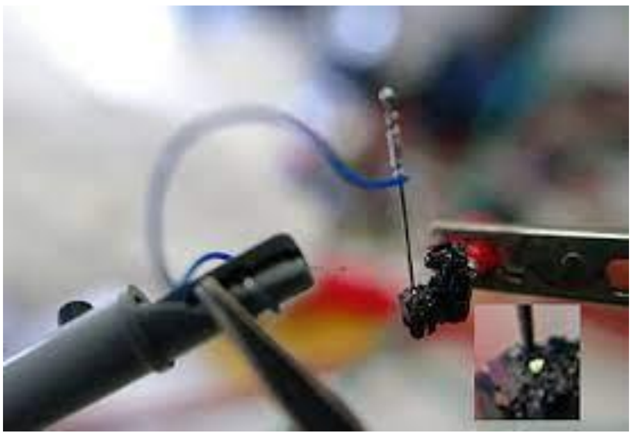


Fig.4.2.(a) contact on crystal SiCrecreates H. Round's original experiment (Source-Wikipedia.org)

Gallium arsenide (GaAs) and other semiconductor alloys were discovered to emit infrared light in America in 1955. By utilising gallium antimonide, Braunstein detected the infrared radiation produced by a simple diode (GaSb). GaAs, InP, and SiGe alloys are all available at room temperature and at various kelvins.

That primitive technology allowed for short-distance communication in 1957. As previously mentioned, Kroemer Braunstein"" had set up a straightforward optical communications link. Record player music was utilised to drive the current of a GaAs diode using the appropriate circuits. A diode located a considerable distance away picked up the emitted light. A loudspeaker played out this signal after it had been fed into an audio amplifier. The music was halted by the intercepting beam. It was a lot of fun to experiment with this arrangement. This configuration foreshadowed the use of LEDs in optical communication systems.

In the fall of 1961, James and Gary Pittman discovered that gallium arsenide (GaAs) emits infrared light when electric current is applied while working at Texas Instruments Inc. in Dallas, Texas. Biard and Pittman published their findings in a patent application titled "Semiconductor Radiant Diode" on August 8, 1962, which described a zinc diffused p-n junction LED with separated cathode contacts for effective infrared light emission under forward bias.

The U.S. patent office granted the two inventors the first patent for the infrared (IR) light emitting diode (U.S. Patent US3293513), the first modern LED, after determining the priority of their work based on engineering notebooks that predated submissions from G.E. Labs, RCA Research Labs, IBM Research Labs, Bell Labs, and Lincoln at MIT. Texas Instruments started a project to produce infrared diodes immediately after They released the SNX-100, the first commercial LED product, in October 1962. It used a pure GaAs crystal to generate light at a wavelength of 900 nm.

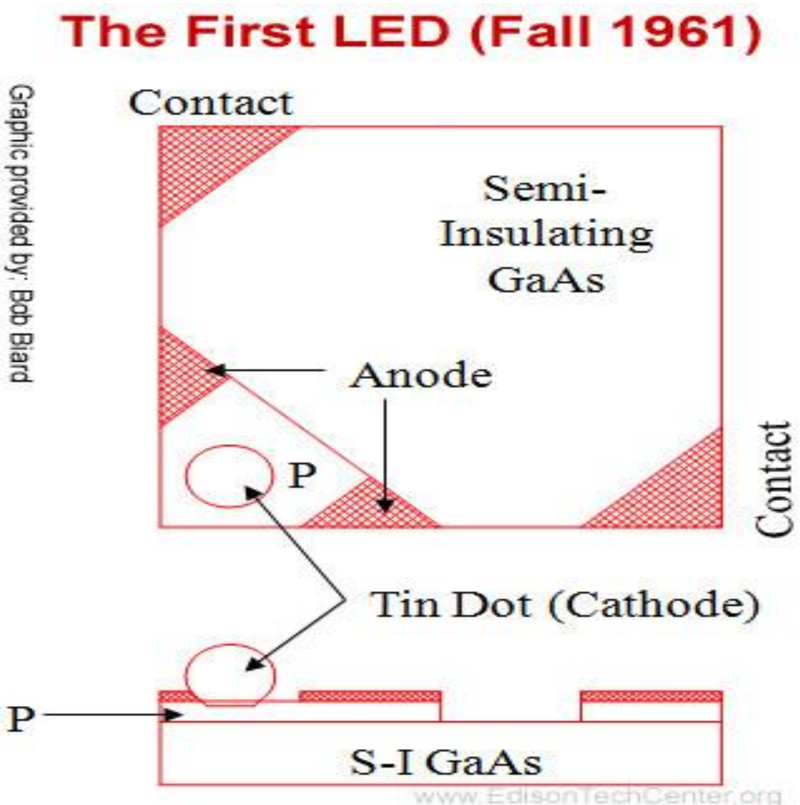


Fig 4.2.(b) Diagram of a light-emitting diode made on a gallium arsenide semi-insulating substrate with a zinc diffused region. (Source-Timeline of LED Inventors and Developments)

While employed with General Electric Company 15, Nick Holonyak, Jr. created the first visible-spectrum (red) LED in 1962. On December 1, 1962, he published a paper on his LED in the journal Applied Physics Letters. M. In 1972, George Craford, a former graduate pupil of Holonyak, created the first yellow LED and multiplied by ten the brightness of red and red-orange LEDs. T. P. Pearsall invented novel semiconductor materials that were specifically tailored to optical fibre transmission wavelengths in 1976, resulting in the development of the first high-brightness, high-efficiency LEDs for optical fibre telecommunications.

4.2.2 LED MATERIALS:

Electrical conductivities of a type of materials known as semiconductors are intermediate between those of insulators and metals. It is noteworthy that these materials' conductivity can vary by several orders of magnitude when their characteristics are altered. Additionally, temperature, optical excitation, and impurity content. Due to their electrical characteristics, this variety of semiconductor materials is a good option for studies on electronic devices. The periodic table's columns' column IV and neighbouring regions contain materials for semiconductors (Table 4.1). Because silicon and germanium are elemental semiconductors made of a single atom species, they are found in column IV. Compounds having atoms in columns III and V, as well as particular combinations of these, are where the compound semiconductors are generated from, in addition to the fundamental components, II, VI, and IV.

Table 4.1 illustrates the diversity of semiconductor materials. As we shall see, the device developer has a great deal of design freedom when creating electrical and optoelectronic parts and systems due to the wide range of electrical and optical characteristics of these semiconductors. Ge was a widely used component for diodes and transistors throughout the early phases of semiconductor research. Most integrated circuits, transistors, and rectifiers in use today (ICs). However, the materials are widely used in quick systems and devices that require illumination absorption or emissionIn light-emitting diodes, compounds with two elements (binary) in III-V, such GaN, as well as GaP and GaAs, are often employed (LEDs).

The III-V of the periodic table constitute a significant class of commercial LEDs that span the visible spectrum. The periodic table's semiconductors are displayed in table 4.1 below. GaP or GaAs are two examples of III-V components.

II	III	IV	V	VI
	B	C		
	Al	Si	P	S
Zn	Ga	Ge	As	Se
Cd	In	Sn	Sb	Te

Table.4.1 Periodic table

Elemental	IV compounds	Binary III–V compounds	Binary II–VI compounds
Si	SiC	AlP	ZnS
Ge	SiGe	AlAs	ZnSe
		AlSb	ZnTe
		GaN	CdS
		GaP	CdSe
		GaAs	CdTe
		GaSb	
		InP	
		InAs	
		InSb	

Table.4.2. Elemental & compound semiconductors

Ternary alloys, represented by the notation GaAs1yPy, are created by alloying GaAs and GaP. One quarternary (four element) III-V alloy with a direct band gap is InGaAlP [22].

Homojunction refers to the LEDs produced utilising two identical semiconductors that have been doped differently. They are referred to as heterostructure devices when they are realised utilising various bandgap materials. Brighter than a homo junction LED is a heterostructure LED.

4.2.3 WORKING PRINCIPLE OF LED:

In essence, a Light emitting diode (LED) is a pn junction diode. Incoherent light is produced when carriers are injected through a junction that is forward-biased. The majority of commercial LEDs are made with a heavily doped n and p Junction (Fig (4.3)).

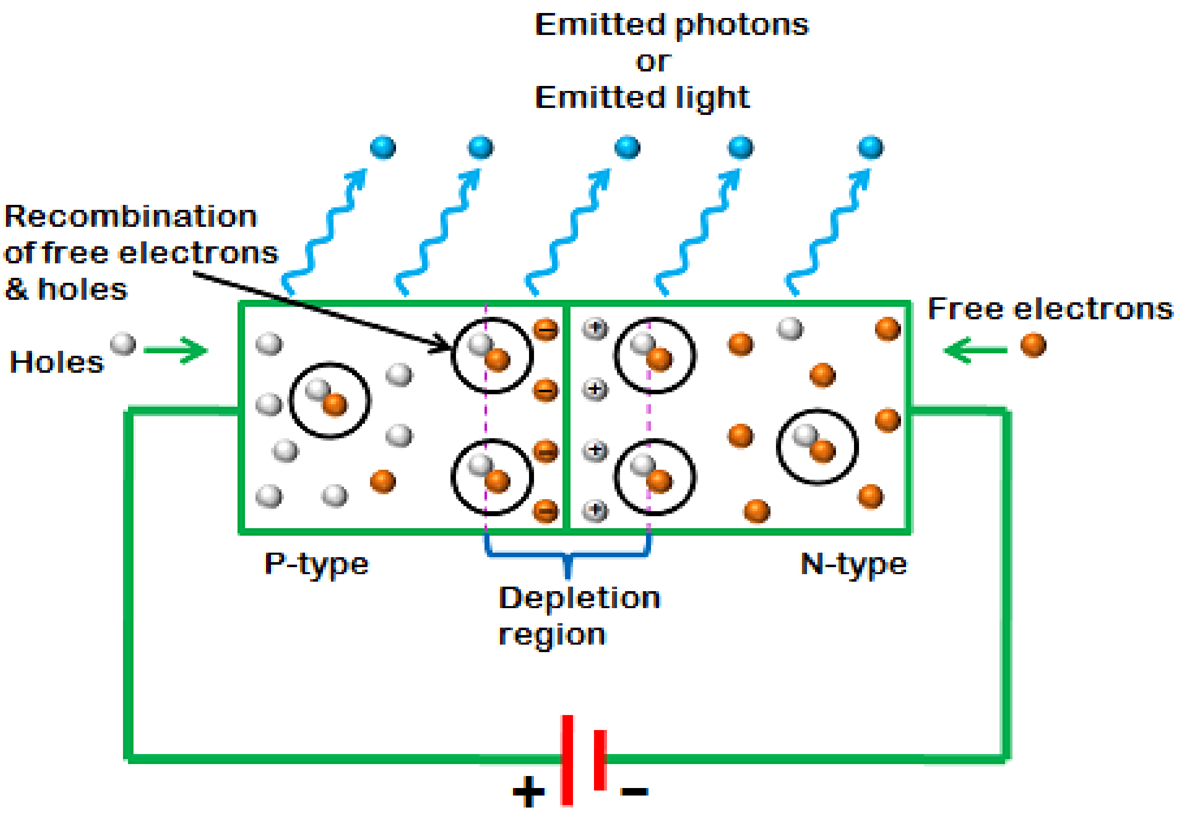


Fig.4.3. Basic LED

To understand the principle, let's consider an unbiased pn junction (Figure (4.4) shows the pn^+ energy band diagram). The depletion region extends mainly into the p-side. There is a potential barrier from E, on the n-side to the E, on the p-side, called the built-in voltage, Va. This potential barrier prevents the excess free electrons on the n^+ side from diffusing into the p side.

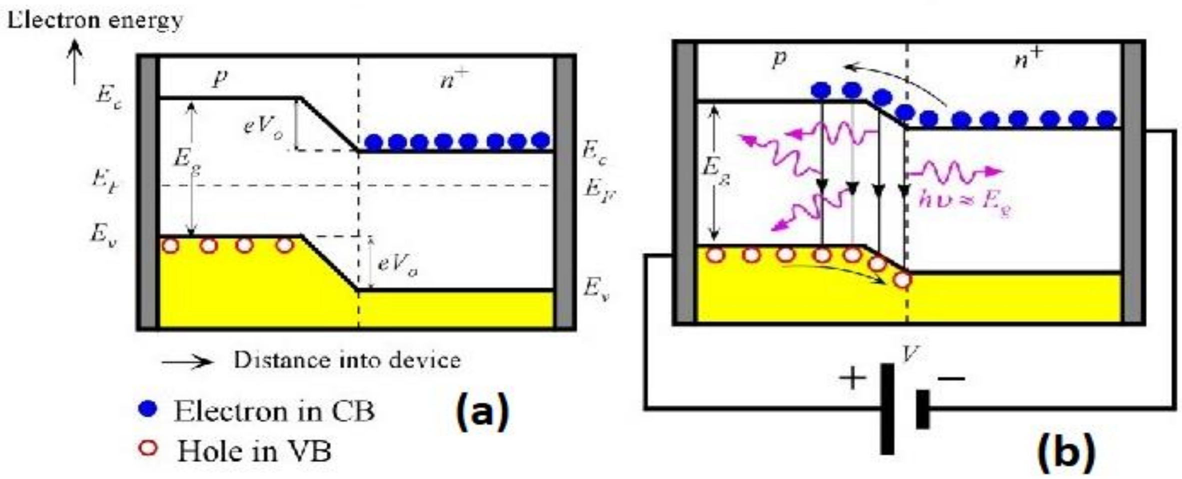


Fig 4.4. Energy band diagram of p-n^+ junction.

Fig.4.4.(a) Without bias, build in potential V_o prevents electron from diffusing top side from n^+.

Fig 4.4.(b) With forward bias, reduces V_o, allows electron to diffuse. Recombination around the junction and within the diffusion length of electrons in the p-side leads to photon emission.

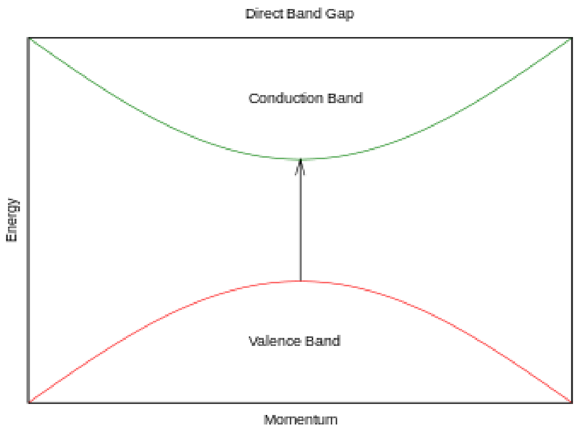
The built-in potential is decreased from V_a to V when a voltage V is placed across the junction (V_o-V). This enables the injection of electrons into the p-side from the n^+ side. This procedure is known as minority carrier injection because electrons are the minority carriers in the p-side. The current, however, is predominantly caused by the flow of electrons into the p-side because there is very little hole injection from the p side to the n^+ side (shown in Fig 4.4).

The holes combine again with the electrons that were introduced into the p-side. Photons are released spontaneously as a result of this recombination (light). Injection electroluminescence is the name of this phenomenon [23]. These photons ought to be permitted to leave the apparatus without being reabsorbed.

The recombination can be classified into the following two kinds

- Direct recombination
- Indirect recombination

1. **<u>Direct Recombination:</u>** In materials with a direct band gap, the valence band's maximum energy is directly above the conduction band's minimum energy in terms of momentum space energy (Figure 4.5. shows the E-k plot of a direct band gap material). Since the momentum of the two particles is the equal, free holes at the top of the valence band and free electrons at the bottom of the conduction band can immediately join in this material. Photon emission occurs during this change from the conduction band to the valence band (takes care of the principle of energy conservation). We call this direct recombination. Direct band-gap materials, such as GaAs, are an example of those where direct recombination happens naturally.



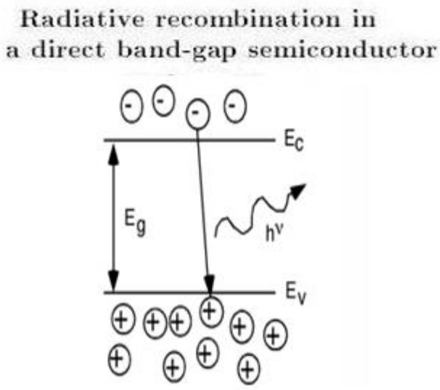


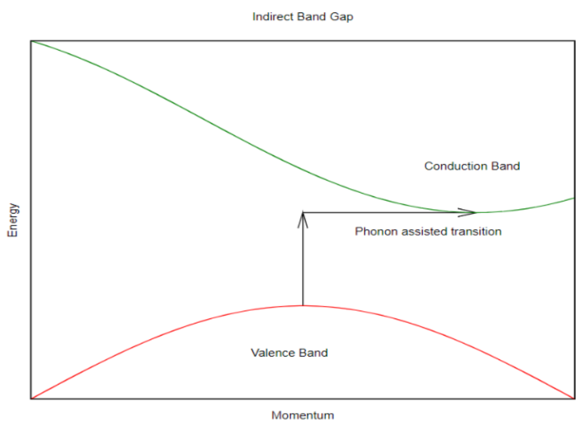
Fig.4.5. Direct Bandgap and Direct Recombination

2. **<u>Indirect Recombination:</u>** The minimum energy in the conduction band in indirect band gap materials is moved away from the valence band by a k-vector. A difference in momentum is represented by the k-vector difference. This disparity in momentum makes direct electron hole recombination less likely.

   Additional dopants (impurities) are added to these materials, creating very shallow donor states. Locally capturing the free electrons in these donor states causes the requisite momentum shift for recombination. The recombination centres are these donor states. Indirect (non-radiative) Recombination is the term used for this.

   Figure 4.6 displays an indirect band gap material's E-k plot as well as a sample of how nitrogen functions as a recombination centre in GaASP. When SiC is doped with Al, it forms a donor state; hence, its recombination occurs through an acceptor level.

   Both momentum and energy conservation should be satisfied via indirect recombination. Thus, phonon emission or absorption is required in addition to photon emission. An illustration of an indirect band-gap material is GaP.



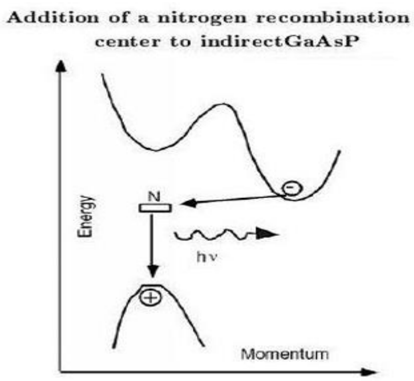


Fig 4.6. Indirect Bandgap and Non- Radiative recombination

The band gap energy of the materials composing the p-n junction determines the wavelength of the light emitted and, consequently, the colour.

The energy of the photons that are released is about equivalent to the semiconductor's band gap energy. The wavelength and the energy band gap are related by equations 4.1 and 4.2.

$$h\nu = E_g \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.1)}$$

$$\frac{hc}{\lambda} = E_g$$

$$\lambda = \frac{hc}{E_g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.2)}$$

where E is the energy band gap, c is the light speed, and his Plank's constant A semiconductor with a 2eV band gap emits light with a wavelength of roughly 620 nm, which is in the red. At 414 nm, in the violet, a material with a 3eV band gap would emit. Bandgap energy and the related colours are listed in Table 4.3.

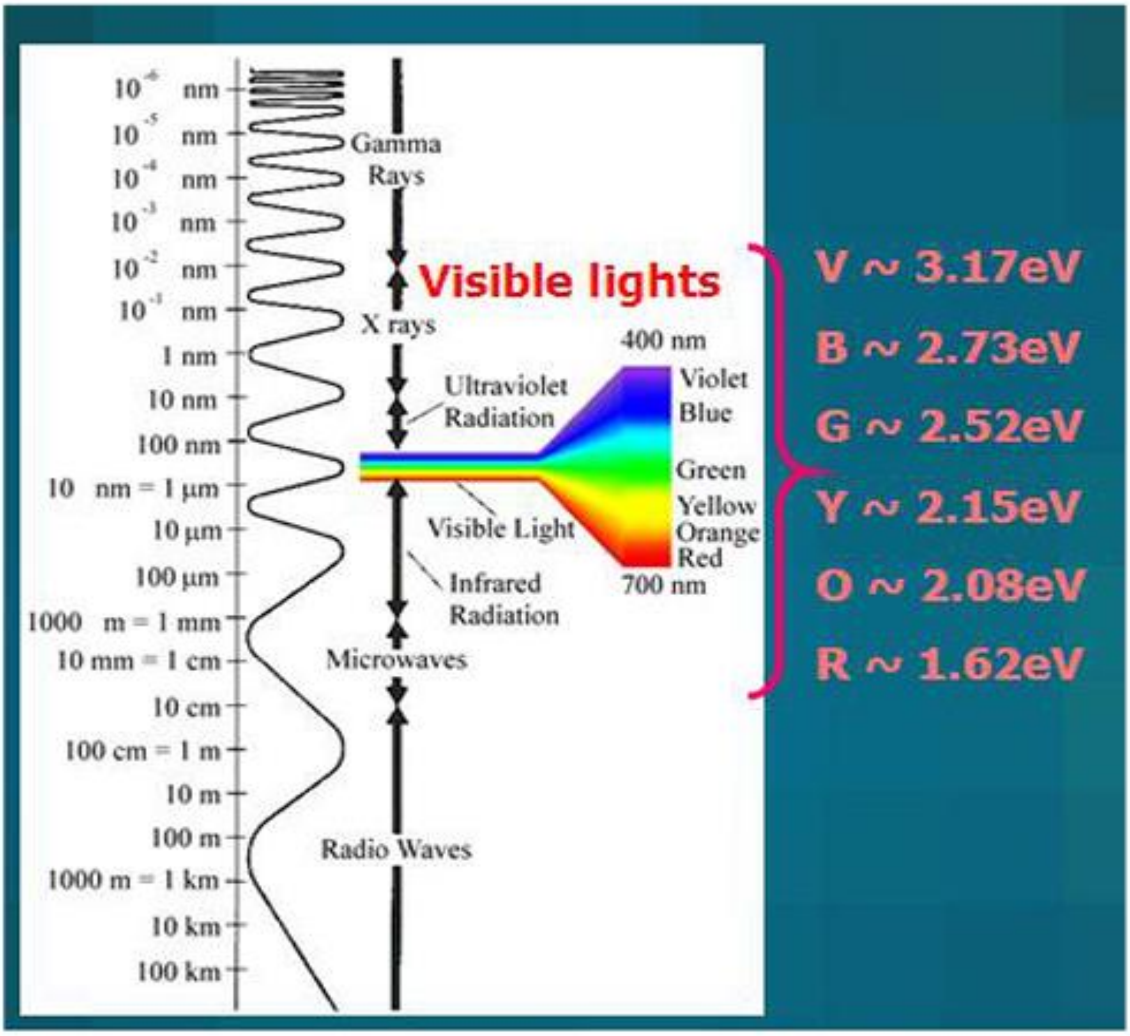


Fig.4.7. Various waves with their wavelength

Color	Wavelength [nm]	Voltage drop [ΔV]	Semiconductor material
Red	$610 < \lambda < 760$	$1.63 < \Delta V < 2.03$	Aluminum gallium arsenide (AlGaAs) Gallium arsenide phosphide (GaAsP) Aluminum gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Orange	$590 < \lambda < 610$	$2.03 < \Delta V < 2.10$	Gallium arsenide phosphide (GaAsP) Aluminum gallium indium phosphide (AlGaInP) Gallium(III) phosphide (GaP)
Green	$500 < \lambda < 570$	$1.9 < \Delta V < 4.0$	**Traditional green:** Gallium(III) phosphide (GaP) Aluminum gallium indium phosphide (AlGaInP) Aluminum gallium phosphide (AlGaP) **Pure green:** Indium gallium nitride (InGaN) / Gallium(III) nitride (GaN)
Blue	$450 < \lambda < 500$	$2.48 < \Delta V < 3.7$	Zinc selenide (ZnSe) Indium gallium nitride (InGaN) Silicon carbide (SiC) as substrate Silicon (Si) as substrate—under development
Pink	Multiple types	$\Delta V \sim 3.3$	Blue with one or two phosphor layers: yellow with red, orange or pink phosphor added afterwards, or white phosphors with pink pigment or dye over top.[56]
White	Broad spectrum	$\Delta V = 3.5$	Blue/UV diode with yellow phosphor

Table.4.3. Relation between colour, wavelength, voltage drop and semiconductor materials

4.2.4 LED STRUCTURE:

In order for the LED surface to emit light, the LED structure is essential. The following two methods are used in the design of the LEDs to guarantee that the majority of recombination occurs on the surface.

- By increasing the substrate's doping level, more free minority charge carrier electrons will rise to the surface, recombine, and produce light there.
- $L = \sqrt{D\tau}$, where D is the diffusion coefficient and τ is the carrier life time, is lengthened by doing so. However, if the length is raised over a certain point, there is a chance that the photons will once again be absorbed by the apparatus.

The structure of the LED must allow the photons it produces to be emitted without being reabsorbed. Making the top p layer thin enough to form a depletion layer is one solution. The layered structure is depicted in the picture below. The dome can be built in a variety of ways for effective emission.

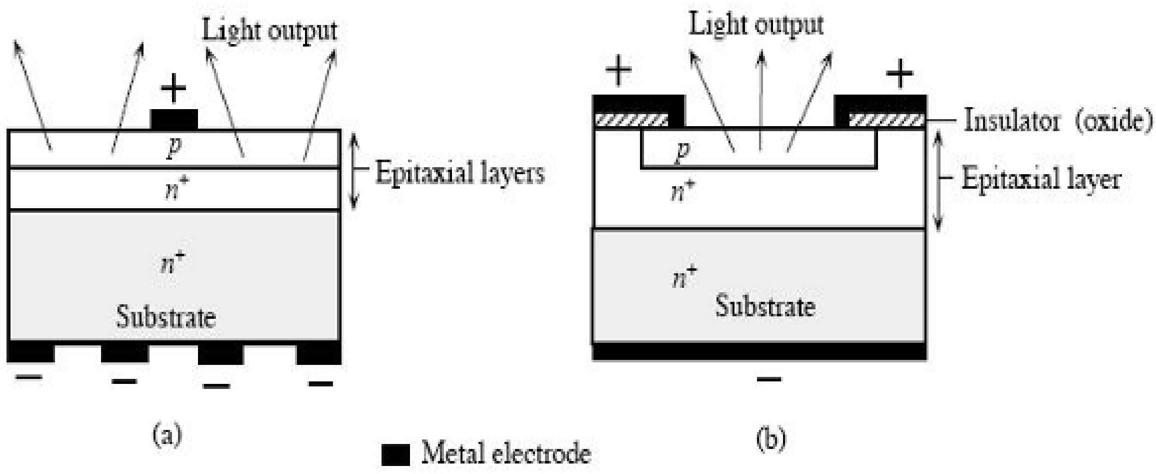


Fig.4.8. LED Structure

A schematic illustration of typical planar surface emitting LED devices.
Fig.4.9. (a) p-layer grown epitaxially on an n^+ substrate.
Fig.4.9. (b) First n+ is epitaxially grown and then p region is formed by dopant diffusion into the epitaxial layer.

An electrode is often attached to the p-type layer put on top of an n-type substrate, which is used to construct LEDs. P-type substrates are also present, albeit less frequently. Sapphire substrate is also used by many commercial LEDs, especially GaN/InGaN LEDs.

4.2.5 DIFFERENT PARTS OF LED:

Two holes and an epoxy housing, which doubles as the lens, are the foundation of an LED. The chip is mounted on the cathode lead using the reflector cup, and the anode lead and bond wire are linked after that. The reflector gathers the light, which the epoxy housing/lens subsequently emits in the chosen direction. The LED's different components are displayed in fig. 4.9 below.

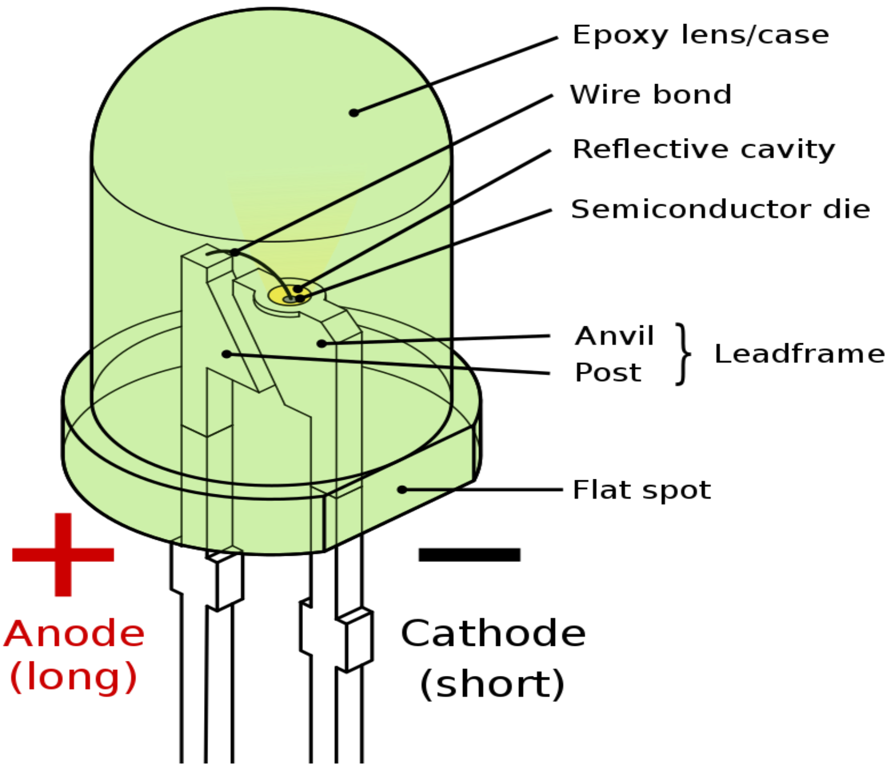


Fig.4.9. Different parts of an LED

4.2.6 DIFFERENT TYPES OF LED:

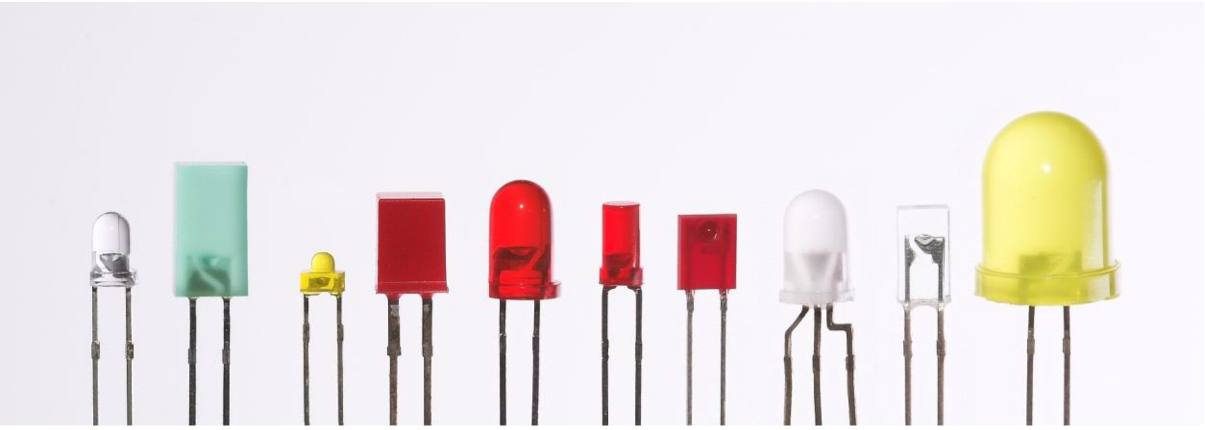


Fig.4.10 Different types of led

Different sizes and forms of LEDs are created. Though not always, the colour of the plastic lens frequently matches the hue of the light that is really emitted. For instance, infrared LEDs are frequently made of purple plastic, yet the majority of blue devices have colourless housings. The majority of contemporary high-power LEDs, including those used for illumination and backlighting, are packaged using surface-mount technology (SMT).

4.2.7 LED EFFICIENCY:

The exterior quantum efficiency (η_{ext}) of an LED is a crucial measurement. It measures the effectiveness of converting electrical energy into optical energy that is emitted. It is calculated by dividing the light output by the electrical input power. The result of internal radiative efficiency and extraction efficiency is another definition for it.

$$\eta_{ext} = P_{out}(\text{optical}) / IV \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

Where,
I = Input current,
V = Input voltage.
For indirect bandgap semiconductors η_{ext} is generally less than 1%, whereas for a direct band gap material it could be substantial.

$$\eta_{int} = \text{rate of radiation recombination/ Total recombination} \ldots\ldots (4.4)$$

The internal efficiency depends on the material's quality as well as the layer's composition and structure.

4.2.8 APPLICATION OF LED:

The uses for LED are numerous. Here are a few instances:

- Devices, medical applications, clothing, toys
- Remote Controls (TVs, VCRs)
- Lighting
- Indicators and signs
- Swimming pool lighting
- Optoisolators and optocouplers

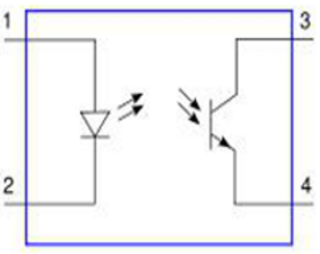


Fig.4.11. Optocoupler

4.2.9 ADVANTAGES OF USING LED:

- Incandescent bulbs don't provide as much light per watt as LEDs do, which is advantageous for battery- or energy-powered products.
- LEDs don't need colour filters like conventional lighting solutions do in order to output light that is the desired colour. This can result in cheaper initial expenses and is more effective.
- The LED's sturdy packaging can be made to focus its light. To gather light and direct it in a useful direction from incandescent and fluorescent sources, an external reflector is frequently needed.

- In contrast to incandescent lamps, which turn yellow when used in applications where dimming is necessary, LEDs maintain their colour hue when the current flowing through them is reduced.
- In contrast to fluorescent lamps, which burn out more quickly when often cycled, or High Intensity Discharge (HID) lamps, which take a while to restart, LEDs are suited for use in applications that are susceptible to frequent on-off cycling.
- Being solid state devices, LEDs are resistant to damage from outside forces. Dropped bulbs, both fluorescent and incandescent, are readily shattered.
- LEDs have a potential for a lengthy useful life. A Philips LUXEON k2 LED has a lifespan of roughly 50,000 hours, compared to the 1,000–2,000 hours for incandescent light bulbs and the normal 30,000 hours for fluorescent tubes.
- Unlike incandescent bulbs, which burn out suddenly, LEDs typically fail by gradually dimming over time.
- LEDs start to glow instantly. A standard red indicator LED will reach full brightness in microseconds; the technical documentation for the Luxeon Star from Philips Lumileds claims that it will take "less than 100ns." Even quicker response times are possible with LEDs employed in communications equipment.
- Printed circuit boards may be easily populated with even the smallest LEDs.
- LEDs, unlike compact fluorescent lamps, do not contain mercury.

4.2.10 DISADVANTAGES:

- On a capital cost basis, LEDs are now more expensive per lumen than more traditional lighting solutions. The comparatively low lumen output, necessary drive electronics, and power sources all contribute to the added cost. However, when the whole cost of ownership (including energy and maintenance costs) is taken into account, LEDs vastly outperform incandescent or halogen sources and start to pose a threat to compact fluorescent lights' continued existence.
- The operational environment's ambient temperature has a significant impact on LED performance. High ambient temperatures may cause the LED package to overheat if the LED is driven too hard, which could eventually cause the gadget to malfunction. In order to maintain extended life, adequate heat-sinking is necessary.
- LEDs need to receive the right current. Series resistors or current-regulated power sources may be used in this.
- LEDs cannot be used in applications that require a highly collimated beam of light since they do not resemble a "point source" of light. Divergence below a few degrees cannot be produced using LEDs. Commercial ruby lasers with divergences of 0.2 degrees or less are in contrast to this. However, lenses and other optical devices can be used to remedy this.
- The so-called blue-light hazard, as stated in eye safety regulations like ANSI/IESNA RP-27.1-05: Recommended Practice for Photobiological Safety for Lamp and Lamp Systems, is now capable of exceeding safe limits, which is causing an increase in worry.

4.3 LED DIVER:

The majority of people are now aware of the long-life spans and energy savings linked to LEDs, or light-emitting diodes, as a result of increased energy laws. But few are aware that these cutting-edge light sources need specialised equipment called LED drivers to function. Similar to ballasts for fluorescent lights or transformers for low voltage bulbs, LED drivers (sometimes referred to as LED power supplies) give LEDs the electricity they need to run and operate at their peak.

Drivers are necessary for LEDs for two reasons:

1. LEDs are made to operate on low voltage, direct current electricity (12–24V). However, higher voltage (120-277V), alternating current energy is typically available. High voltage alternating current is converted to low voltage direct current by an LED driver.
2. LED drivers also shield LEDs from variations in voltage or current. The current being delivered to the LEDs may change in response to a change in voltage. LEDs are rated to function within a specific current range, and their light output is proportional to their current supply (measured in amps). As a result of greater temperatures inside the LED, too much or too little current might cause light brightness to vary or degrade more quickly.

In conclusion, LED drivers change high voltage alternating current into low voltage direct current. Additionally, they maintain an LED circuit's voltage and current at the recommended levels.

4.3.1 INTERNAL VS. EXTERNAL DRIVERS

All LED light sources need drivers for the aforementioned causes. However, some LEDs—particularly those made for home use—instead of having separate, external drivers, have inbuilt drivers. Because replacing outdated incandescent or CFL bulbs is made simpler, household bulbs typically come with an integrated driver. These include LED bulbs that have a line-voltage (120 volts) input specified in their datasheet or those with standard screw-in or plug-in bases (E26/E27 or GU24/GU10 - see images below). Cove lights, downlights, tape lights, as well as specific fixtures, panels, and outdoor-rated lights, are examples of LEDs that frequently need an external driver. These bulbs are frequently employed in street, outdoor, and commercial lighting applications. Because it's easier and less expensive to replace the driver than the LEDs, they often need a separate driver. LEDs can occasionally be purchased with a separate driver. Other times, the datasheets from the manufacturer will state whether or not an LED needs a separate driver and, if so, what kind of driver it needs.

Fig.5.12. Internal and external LED Driver

4.3.2 SAVE LEDS: REPLACE EXTERNAL LED DRIVERS

It is typically possible to save an LED if the driver is changed when it stops working before the end of its rated lifetime. High internal working temperatures frequently cause drivers to fail before they should. Electrolytic capacitors, which resemble batteries, are frequently the fatal factor. An internal gel in electrolytic capacitors slowly evaporates over the course of the driver's life. High temperatures hasten the evaporation of the gel and reduce the lifespan of the capacitor, which results in the driver and consequently your LED unexpectedly failing.

The internal temperature of the driver and the external temperature of the driver case are correlated. The hottest point on most LED drivers is indicated by a small circle on the label that is known as the "TC point." To identify the driver's maximum working temperature, this point is typically indicated with a temperature. A driver will last less time if it is used at a temperature that is too close to its limiting temperature than it would if it were used at a lower temperature. Drivers with greater TC points have longer lifespan because of this. To ensure that the driver lifespan exceeds the lifetime of the LED, drivers must be utilised at working temperatures below the TC point (or they must at least have long-life electrolytic capacitors). Drivers can malfunction and need to be replaced when an LED is not exposed to either of these circumstances. The lifespan of a standard LED driver and its hotspot temperature are correlated in the graph below.

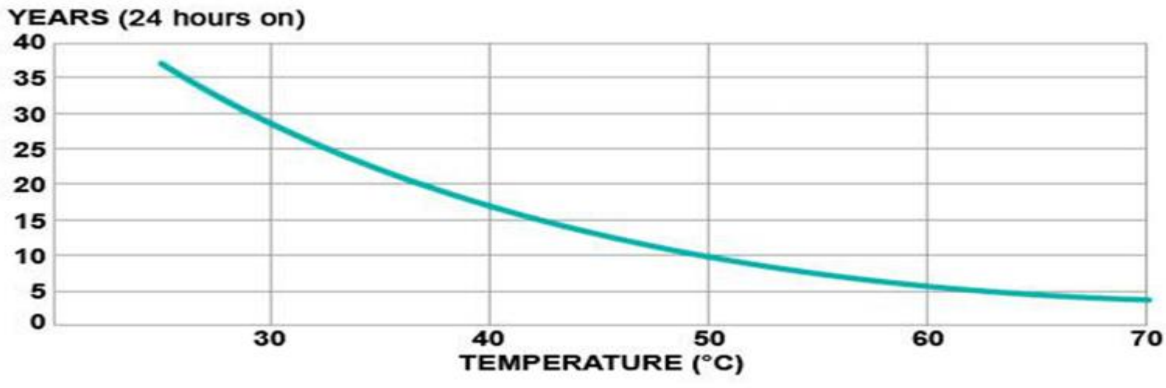


Fig.4.13. Driver Lifetime

4.3.3 HOW TO CHOOSE AN LED DRIVER:

Constant-current and constant-voltage external LED drivers are the two primary categories, and an additional category known as an AC LED driver will also be covered. The electrical requirements for operating LEDs vary depending on the type of driver used. The input/output needs of the old driver should be as nearly replicated as feasible while replacing it. The main variations are described below.

1. **CONSTANT-CURRENT DRIVERS:**

   LEDs that need a fixed output current and a variety of output voltages are powered by constant-current drivers. Only one output current, designated in amps or milliamps, will be provided, coupled with a variety of voltages that will change based on the load (wattage) of the LED. The output voltage range in the sample to the left is 4-13V DC, and the output current is 700mA. (Volts of direct current).

2. **CONSTANT-VOLTAGE DRIVERS:**

   LEDs that need a fixed output voltage are powered by constant-voltage drivers with a maximum output current. These LEDs already include an integrated constant-current driver or simple resistors to control the current within the LED module. One constant voltage, often 12V DC or 24V DC, is needed for these LEDs. The output voltage in the example to the right is 24V DC, and the output current is limited to a maximum of 1.04A[24].

Fig.4.14. Constant current LED driver

MOSO EHC Series-105W LED Driver used in this project. Details of this driver are given in the **ANNEXURE-I**

4.3.4 OTHER FACTORS TO CONSIDER

1. **MAXIMUM WATTAGE:**

   The National Electrical Code (NEC) states that LED drivers should be paired with LEDs that consume 20% less power than their maximum rated wattage (with the exception of AC LED drivers). To prevent overstressing the driver's components, drivers shouldn't be connected with LEDs that are at or higher in power than the driver can handle. For instance, if your driver has a 96 watts maximum operating capacity, it should only be used with LEDs that consume 77 watts or less (96 x 0.8 = 76.8).

2. **DIMMING:**

   The ability to dim can be built into both constant-current and constant-voltage LEDs and drivers, but only if both the LEDs and the drivers specifically state that they are capable of dimming on the product datasheet. It is safe to presume that a product cannot be dimmed if dimming is not mentioned at all in the specifications. TRIAC, Trailing Edge, or 1-10v dimmers, as well as other dimming control devices listed in the product datasheet, are frequently needed for dimmable external drivers to function. If brand-specific dimmer compatibility charts are not available, it is best to test particular LED/dimmable driver combinations for acceptable dimming performance before making significant purchases given how quickly technology is developing.

3. **POWER FACTOR:**

   How effectively an LED driver utilises electricity is indicated by its power factor. It is computed by multiplying the driver's power consumption (in watts) by the product of the input voltage multiplied by the current flowing in (volts x amps). The power factor has a decimal range of 0 to 1. The driver is more effective the closer the power factor is near 1. The power factor should be at least 0.9.

4.4 MONOCHROMATIC LED LIGHT:

Monochromatic light refers to light with a single colour, more specifically light with a single wavelength. Mono denotes single and "chroma," the Greek word for colour. Essentially, electromagnetic waves of the same wavelength are emitted by monochromatic light.

There are numerous light sources that release beams with a variety of wavelengths. Sunlight consists of seven separate colours, which means that seven individual light waves of various wavelengths are combined to produce the experience of a single colour.

Sunlight is a combination of photons with wavelengths between 380 nm and 750 nm (in visible spectrum) Pure violet will be the sole colour visible if a single light wave of, say, 450 nm wavelength is used. Similar to this, yellow hue will be visible if a light beam of wavelength 580 nm has taken.

Monochromatic light is produced by a source of light that emits only one colour at the same wavelength.

According to the description in Table 4.2 above, different semiconductor materials have different band gaps, and these varying band gaps result in different light wavelengths. For instance, if yellow colour monochromatic light needs to be produced, the band gap should be close to 2.15 eV.

4.5 REASON BEHIND USING MONOCHROMATIC LIGHT

Nowadays, white LED, Metal Halide (MH), or High-Pressure Sodium Vapour Lamp (SON) are among the lights used for road illumination. These lights' SPDs are listed below.

White LED SPD is presented in Fig. 4.15, Metal Halide SPD is provided in Fig. 4.16, and HPSV SPD is provided in Fig. 4.17.

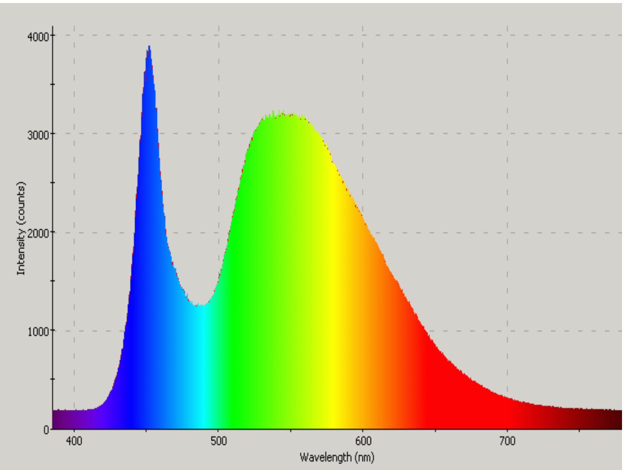


Fig.4.15. SPD of white LED

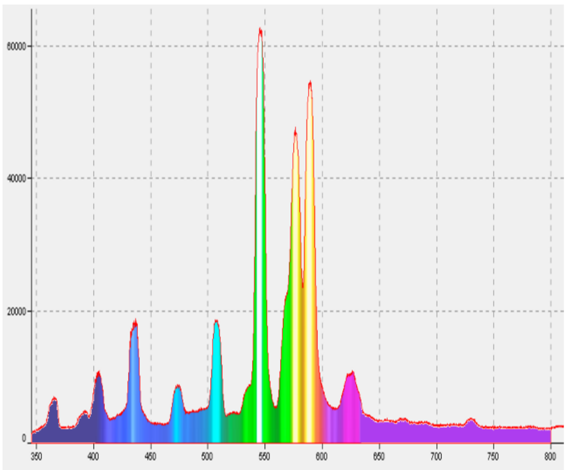


Fig.4.16. SPD of metal halide

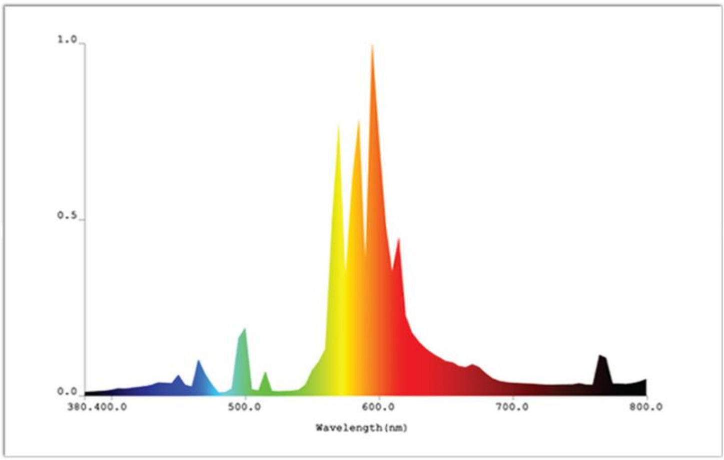


Fig.4.17. SPD of High-pressure sodium vapour lamp

Therefore, it is evident from these SPDs that all lights are a blend of several wavelengths. The term "Composite Wavelength Lights" may be used. These lights truly travel through water droplets when they go through fog. Dispersion and scattering take place when the medium changes from air to water to air. Here, a prism is made of water droplets. Light dispersion causes the intensity of the light in a specific direction to decrease.

Therefore, monochromatic light, or light of a single wavelength, will not split into other wavelength components (Shown in Fig 4.18). Thus, unlike white light, the intensity in a given direction won't diminish as much.

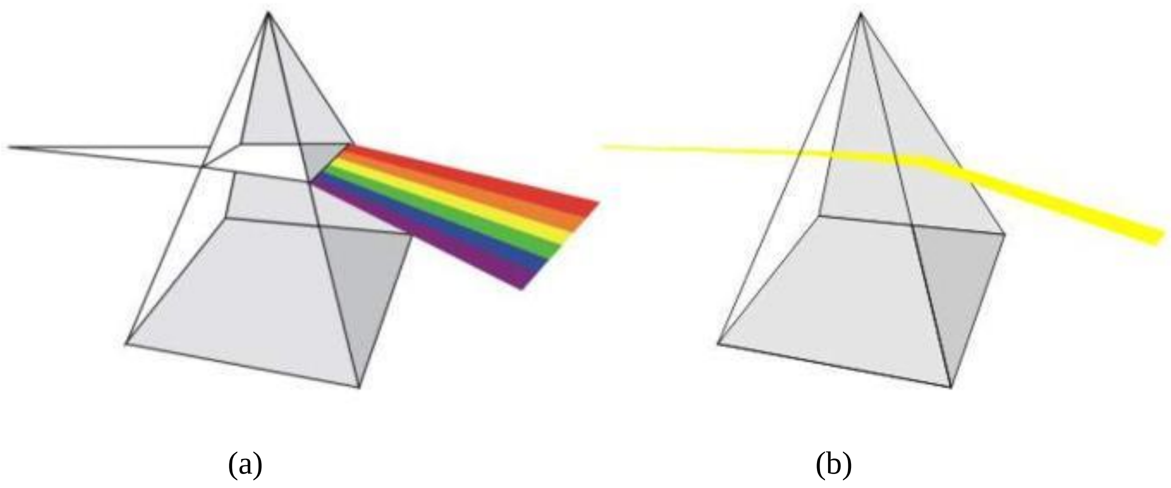


Fig 4.18. Comparison of (a) white light passing through prism and (b) monochromatic light passing through prism

4.6 COLOR OF LIGHT

The question of what shade of monochromatic light to utilise in fog now arises.

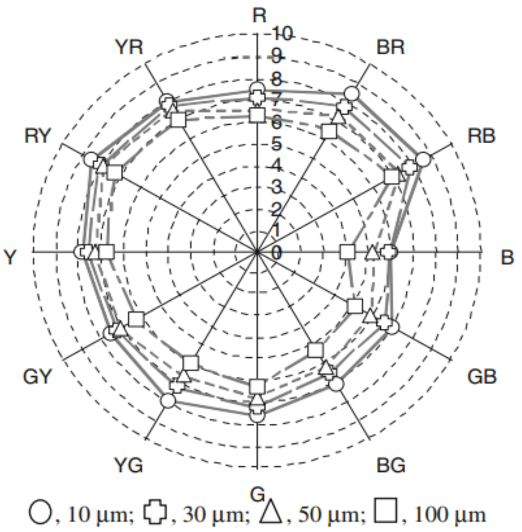
The three basic reasons behind not able to see trough fog are

1) Scattering

2) Dispersion

3) Absorption

As was said in the last chapter, all three aspects of light have one thing in common: they are all inversely proportional to wavelength. Therefore, using long wavelength light would result in less scattering, dispersion, and absorption, increasing visibility. Red has the longest wavelength in the visible spectrum, yet it is harder to distinguish objects in red light than in amber. As a result, Amber should be used. As per the experimental results discussed in below fig, we can conclude same.



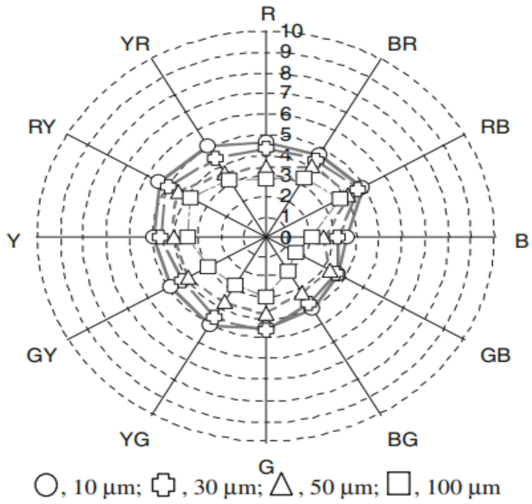


Fig.4.19.

Fig.4.20.

Fig.4.19. The characteristics of fog droplet size and the point values of perceived brightness in polar co-ordinate singular (fog density, 30 lx).

Fig.4.20. The characteristics of fog droplet size and the point values of perceived brightness in polar co-ordinate singular (fog density, 100 lx).

The results of LED evaluation sites with the same density but different droplet sizes are shown in figures 4.19 and 4.20. The evaluation points in radical directions, and the hue has been taken in circumferential directions. These numbers demonstrate how differing droplet sizes can influence how well an LED's brightness is perceived even at the same density. It starts off with a high assessment point in the Yellow component, but as it moves into the Blue component, the evaluation point starts to decline and falls in the Blue hue to its lowest point. However, even though Blue has the lowest score, when Blue and Red (RB and BR) are combined, Blue has an assessment point that is on par with Yellow [25].

CHAPTER 5

COMPUTER AIDED LIGHTING DESIGN AND SIMULATED RESULTS

5.1 INTRODUCTION:

Computer programmes like DIALux 4.13, DIALux Evo, AGi 32, Lighting Reality pro, Relux, CGLux, Calculux, Photolux, Sunlux, Lumen Micro, Lumen Designer, etc. can be used to design the lighting for a specific building or landscape. These applications use various techniques to replicate lighting designs, but their overall goals are the same. Additionally, AutoCAD is utilised to visualise the placement of luminaires in a space. Depending on their convenience, different businesses utilise various lighting software. Here I primarily use DIALux Evo.

5.2 DIALUX:

DIALux is one of the best programmes for lighting design. It is a time-saving software as compared to manual computation and is used to compute and visualise indoor and outdoor lights. [26].

DIALux aids you in adhering to the pertinent national and international requirements by calculating the amount of energy your light solution requires while you are creating it. DIALux supports the luminaires of the best manufacturers in the world, giving them the greatest amount of creative freedom during the design process.

5.2.1. ADVANTAGES OF DIALUX:

- DIALux is a completely free software.
- Virtual worlds can be created simply and intuitively with DIALux.
- Daylight and artificial light scenarios can also be simulated.
- Support any photometric data file in required format(.ies).
- Results can be compared with international standard result.
- CAD file (site planning file) can be imported or exported.
- Dynamic light scenes with LED or other colour changing luminaires.
- Planning 3D model and simulate photometric data to any buildings, landscape, façade or roadway model.
- Daylight and artificial light scenarios can also be simulated.

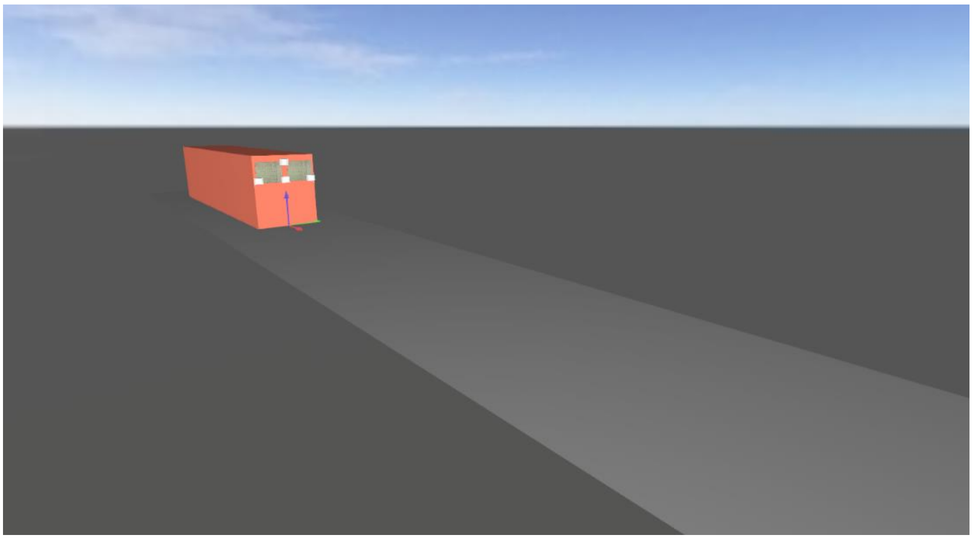


Fig.5.1. Road Lighting Design in DIALux

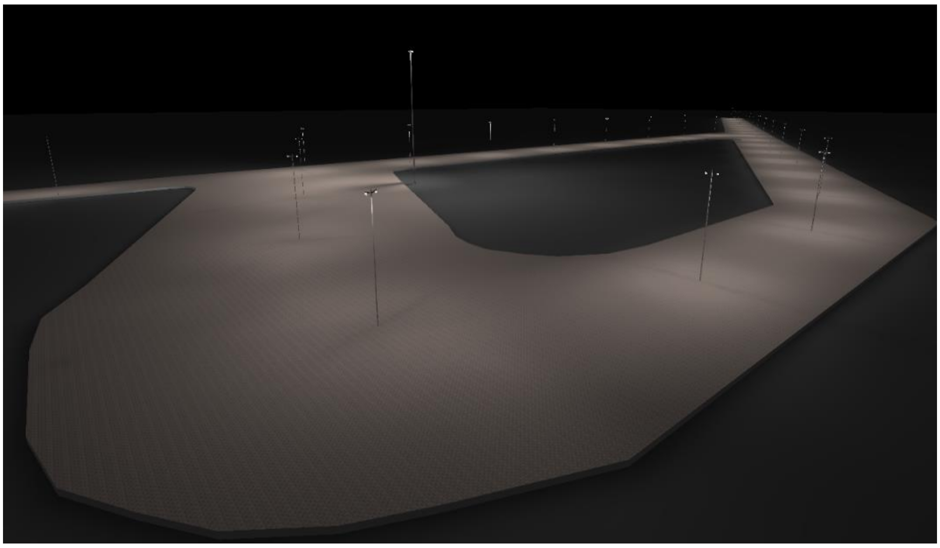


Fig.5.2. Lighting Design in DIALux Evo 10.0

5.2.2 PROCESSES INVOVLED IN DIALUX LIGHTING DESIGN:

With computer-aided lighting design, a virtual environment is created to show how the area to be illuminated would seem once the lighting equipment is in place. Therefore, there are specific actions that must be taken in order to produce a flawless visual environment. In lighting design, each step has its own significance.

1. **Steps involved to simulate the lighting design:**
   The particular steps to be followed to simulate the lighting design in DIALux are as following –

   - It is necessary to choose the lighting category for the space as well as the activities that will take place there.
   - The necessary illuminance level [27] and uniformity ratio are chosen in accordance with the requirements of the client, after consulting IS 3646 (for inside) and IS SP 72 (for outdoors). Although a uniformity ratio of at least 0.7 is preferred for indoor lighting design, in actuality, a uniformity ratio of at least 0.4 is sufficient.
   - To replicate the lighting design, the area's measurements must be supplied, and then rooms must be drawn in DIALux.
   - It is necessary to provide the Maintenance Factors and Reflectance Factors of various room components. In general, the M.F. is kept at 0.8 for indoor spaces with air conditioning.
   - The mounting heights of the luminaires must be set based on the area's height and the surface type.
   - Calculation surfaces should be brought to the location of the task. Although the designer is free to use alternative calculation surfaces based on the requirements, a calculation surface is given. For the design I used, I thought about a rectangular vertical computation surface.
   - The luminaires should be installed in accordance with the specifications for uniformity and illuminance level after the aforementioned stages have been completed. The following is a general mathematical formula for calculating the number of luminaires: –

$$N = \frac{A * E_{avg}}{n * \varphi * MF * UF}$$

Where,
N = Number of luminaires,
A = Area of the zone to be illuminated in m^2,
E_{avg} = Average maintained horizontal illumination level in lux,
n = Number of lamps per luminaire,
φ = Lumen output of Lamp in Lumens,
MF = Maintenance Factor,
UF = Utilization Factor.

Maintenance Factor (MF): Maintenance Factor, also known as Light Loss Factor (LLF), is the ratio of present illuminance for a given area to the value that would have occurred if the lamps had operated at their (initial) rated lumens and if no system variation or depreciation had occurred.

Utilization Factor (UF) or Coefficient of Utilization (COU): Utilization Factor of a luminaire is the percentage of the light emitted by the light source, which contributes to illuminance on a surface. This factor takes into account the direct as well as indirect component of light, so it is dependent on the shape and size of the room, mounting height and also the reflection properties of the surroundings.

2. **Analysis of Results:**
   The computer simulation is performed once the initial necessary input factors are taken into account, and the results, including the average illuminance value and maximum illuminance value, are compared with the requirements. A final site inspection is required following the installation of the lighting fixtures, the completion of the design and the fulfilment of all design requirements. Using testing instruments like luxmeters, brightness metres, etc., on-site data that are useful are produced. The acquired values are contrasted with the outcomes of the software simulation to ascertain whether or not the design is successful.

5.3 RAILWAY FOG LIGHTING DESIGN IN DIALUX, USING MONOCHROMATIC LED LUMINAIRE:

In this topic, I explored the simulation of my set up of four monochromatic amber luminaires. The average and maximum illuminance values at certain particular distances are my main goals.

I simulated in several combinations by grouping the luminaires by light scene because my setup consists of four different types of luminaires.

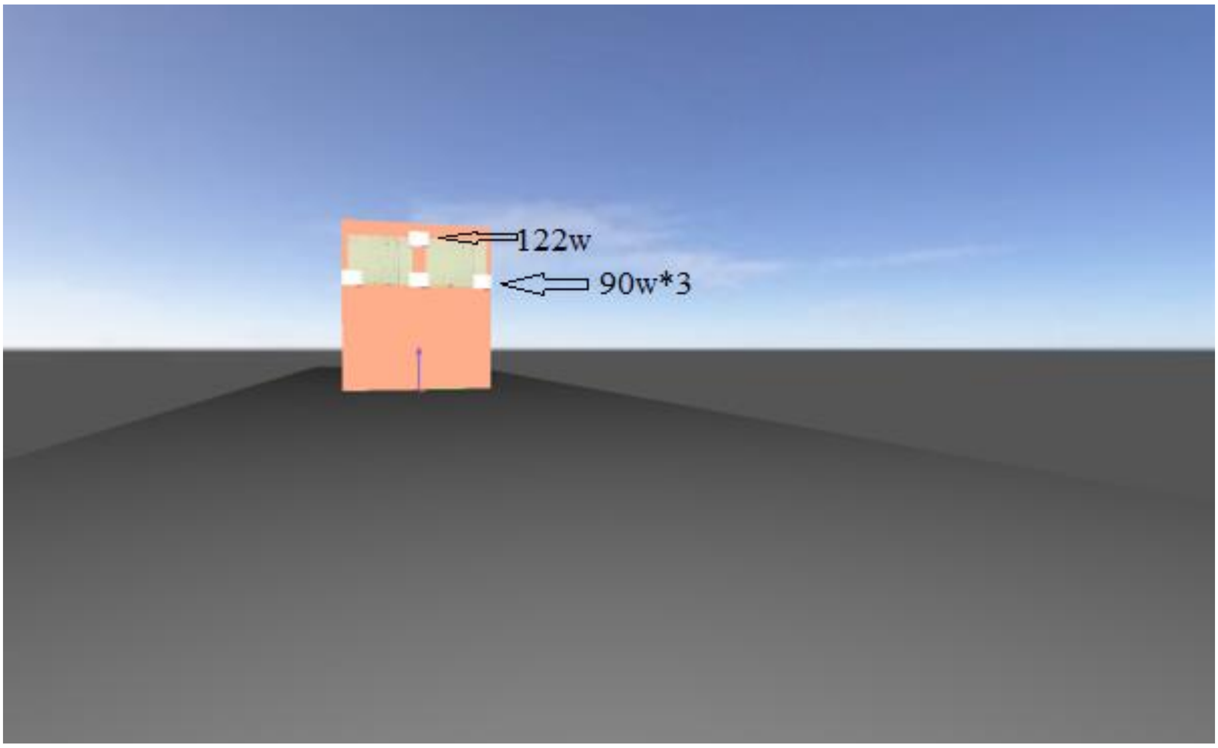


Fig5.3. 3D front view of railway Train with luminaire setup

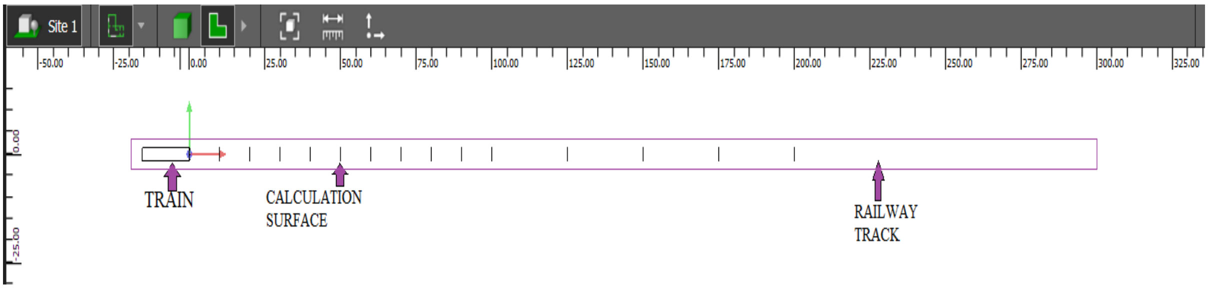


Fig.5.4. 2D floorplan view (top view) of train with track and calculation surface.

5.3.1 DESIGN INPUT PARAMETERS:

- SITE ALIGNMENT shown in below table.5.1

Site alignment	
Location	Calcutta
Longitude	88.40 °
Latitude	22.50 °
North alignment	0.00 °
Time zone	(UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi

Table.5.1. Site alignment

- **Maintenance factor** considered 0.8 for normal environmental condition.
- **Train:** Length: 15.5m
  Height: 3.5m
  Width: 3m
  Train driver's cabin window: Width: 1.25m
  Height: 1.00m
- **Luminaire:**
  1. Upper centre luminaire: Mounting height: 3.154m
  2. Line arrangement with three number of luminaires: Mounting height: 2.311m
- **Calculation Surface:** Height: 3m
  Width: 3m

  Same size vertical calculation surfaces are placed in certain distance of **10m, 20m, 30m, 40m, 50m, 60m, 70m, 80m, 90m, 100m, 125m, 150m, 175m, 200m**. All calculation surfaces are shown in fig.5.5 below.

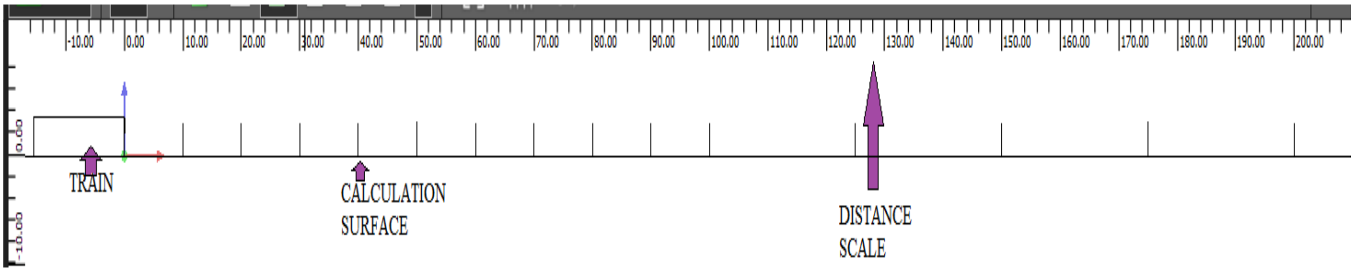


Fig.5.5. 2D Side view of train with track and calculation surface with proper distance

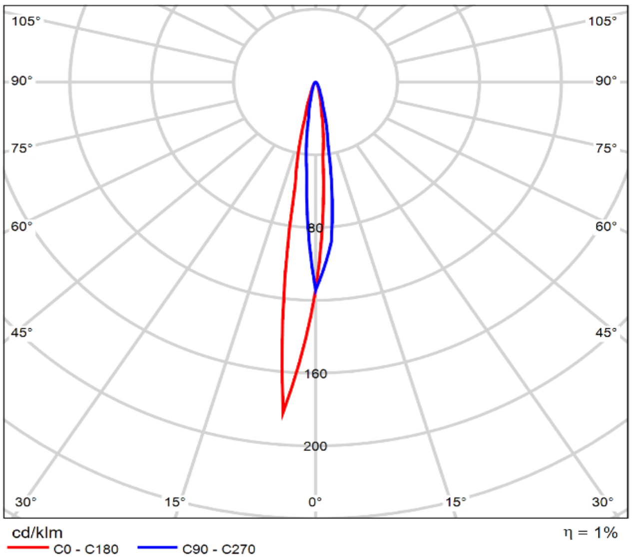
5.3.2 DESIGNED SETUP BY USING MONOCHROMATIC LED:

I have designed a setup of railway fog lighting that consist 4 numbers of luminaire and 2 different types of luminaires in certain arrangement in the manner shown below.

5.3.2.1 LUMINAIRE USED:

In this designed set up, I have used 2 types of luminaires:

1. **Amber monochromatic led light of 122w:**
   - Power: 121.59 W
   - Measurement Flux: 2090.4 lumen
   - Luminaire Efficacy Rating (LER): 17.24
2. **Amber monochromatic led light of 90w:**
   - Power: 89.80 W
   - Measurement Flux: 2363.5 lumen
   - Luminaire Efficacy Rating (LER): 26.37



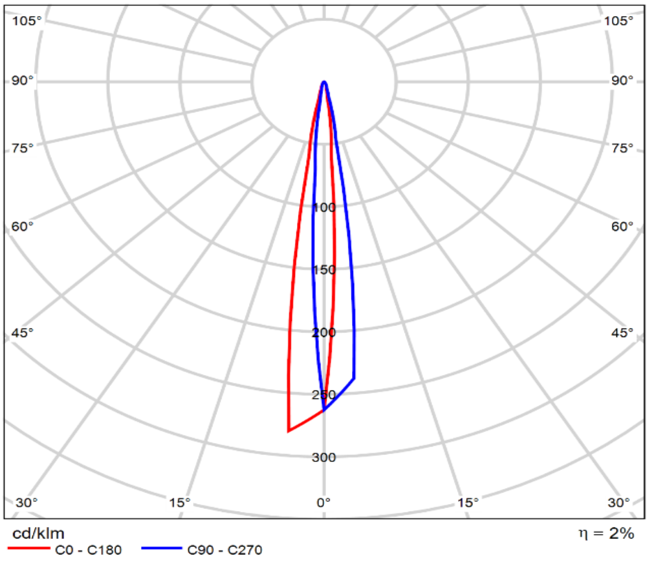


Fig.5.6. Polar Luminous Intensity Distribution curve of Amber monochromatic led light of 122w.

Fig.5.7. Polar Luminous Intensity Distribution curve of Amber monochromatic led light of 90w.

5.3.2.2 LIGHT SCENE:

As I have four numbers of monochromatic LED fog lights in my set up that's why I simulate my set up in 7 different combinations of luminaire. I made different combinations by grouping luminaires in several light scene, as discussed below:

1. **LIGHT SCENE 1:**

   In this light scene 1 I have 4 numbers of luminaires (all luminaires) in active state (powered on). Simulated results are shown in table.5.2.

   Luminaires: 122W*1 upper one; 90W*3 lower line arrangement.

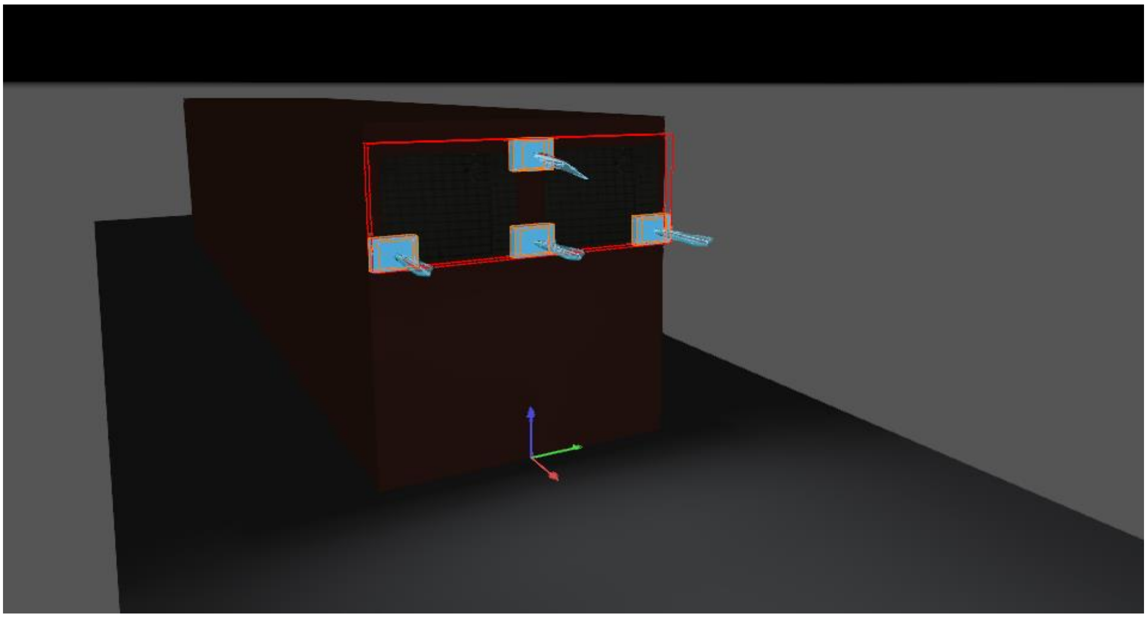


Fig.5.8. Light scene 1

2. **LIGHT SCENE 2:**

In this light scene 2 I have 3 numbers of luminaires in active state (powered on). Simulated results are shown in table.5.3.

Luminaires: 122W*1 upper one; 90W*2 right one and lift one of lower line arrangement.

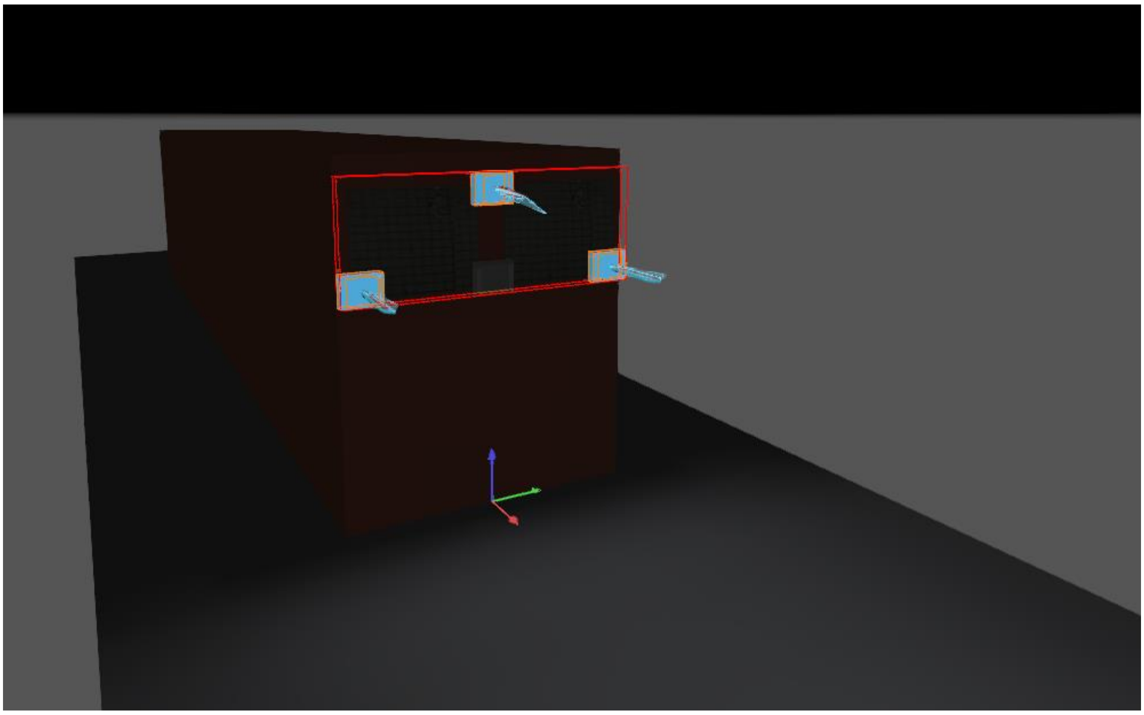


Fig.5.9. Light scene 2

3. **LIGHT SCENE 3:**

In this light scene 3 I have 3 numbers of luminaires in active state (powered on). Simulated results are shown in table.5.4.

Luminaires: 90W*3 lower line arrangement(all 3).

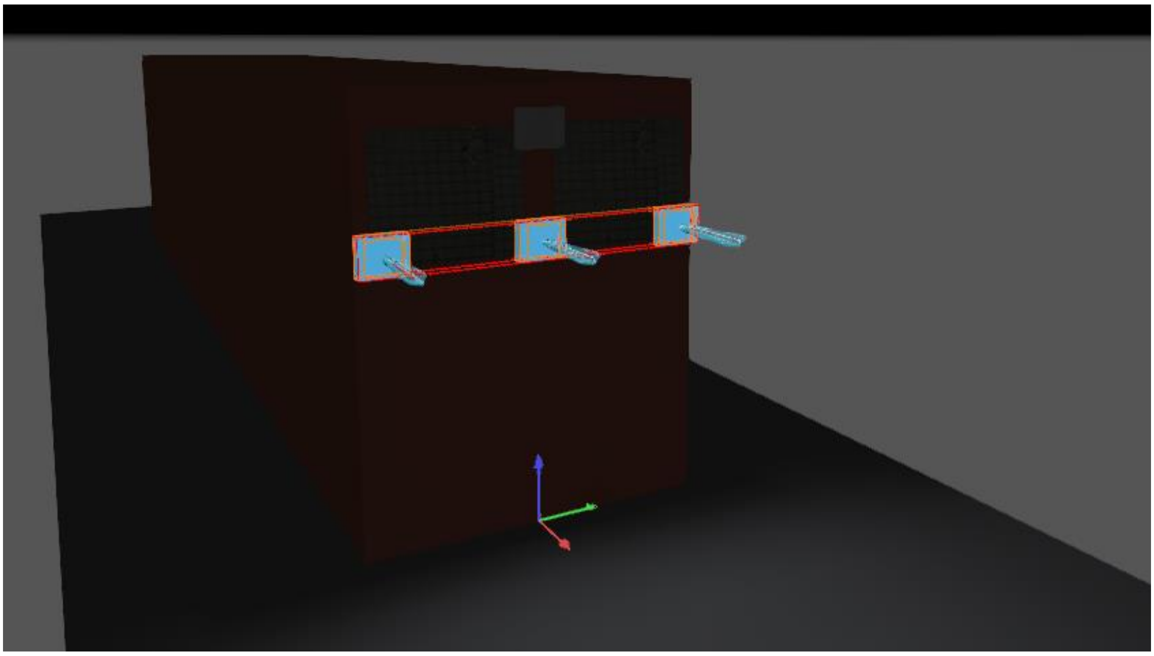


Fig.5.10. Light scene 3

4. **<u>LIGHT SCENE 4:</u>**

In this light scene 4 I have 2 numbers of luminaires in active state (powered on). Simulated results are shown in table.5.5.

Luminaires: 122W*1 upper one; 90W*1 middile one of lower line arrangement.

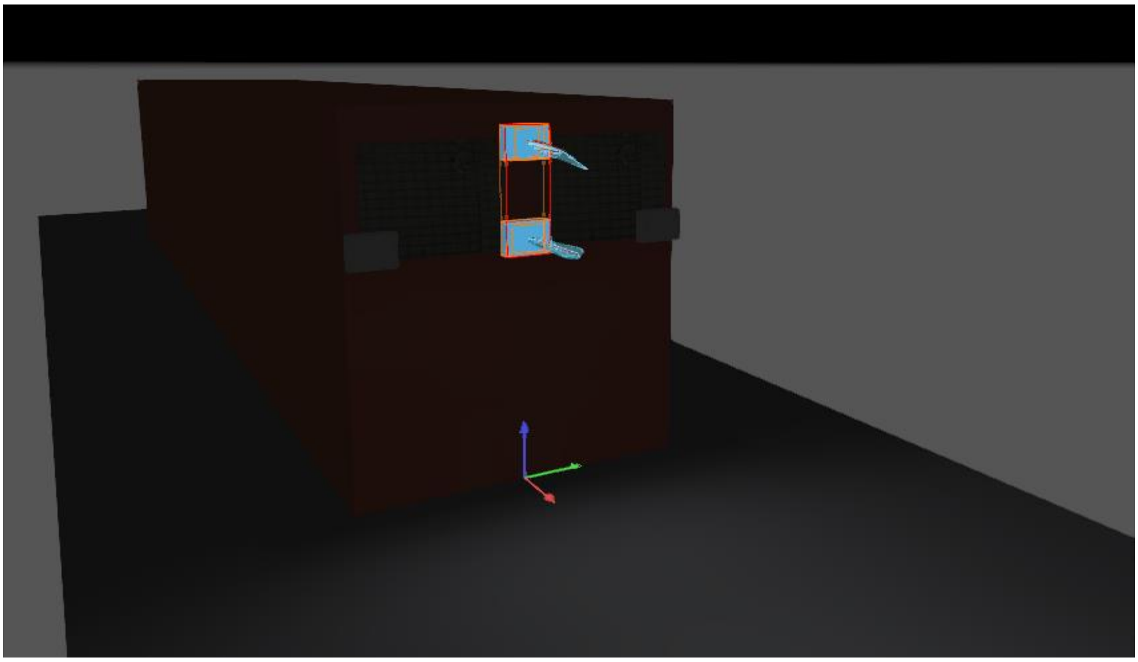


Fig.5.11. Light scene 4

5. **<u>LIGHT SCENE 5:</u>**

In this light scene 5 I have 2 numbers of luminaires in active state (powered on). Simulated results are shown in table.5.6.

Luminaires: 90W*2 right one and left one of lower line arrangement.

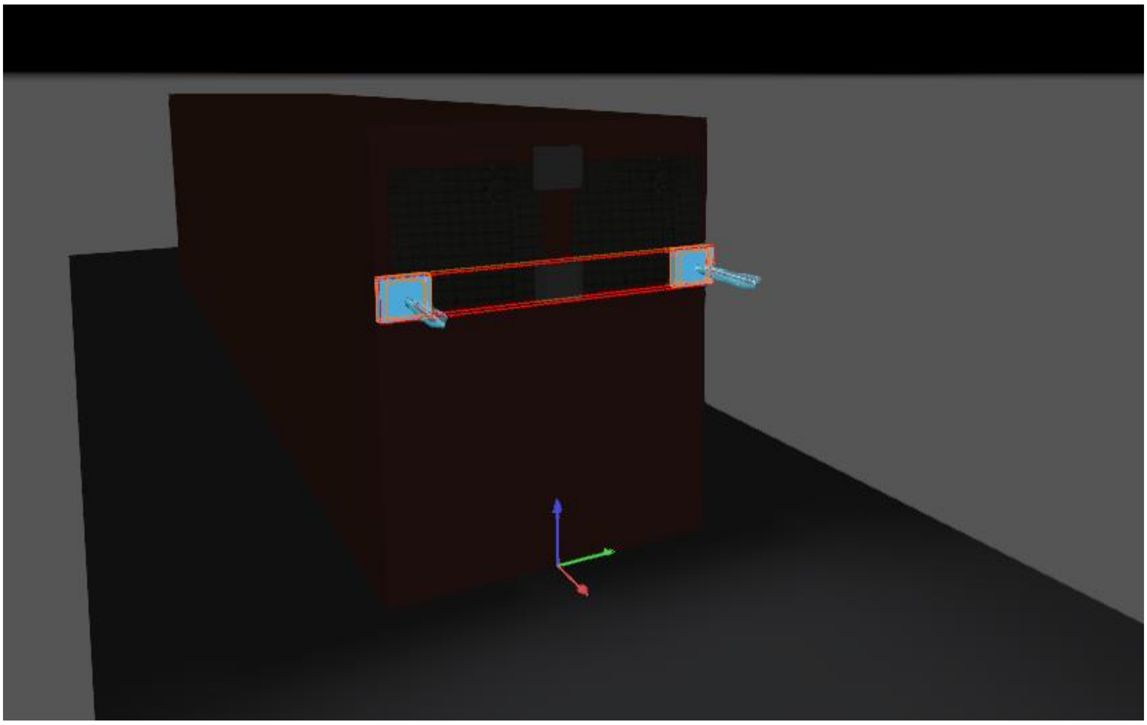


Fig.5.12. Light scene 5

6. **<u>LIGHT SCENE 6:</u>**

In this light scene 6 I have single luminaire in active state (powered on). Simulated results are shown in table.5.7.

Luminaire: 90W*1 middle one of lower line arrangement.

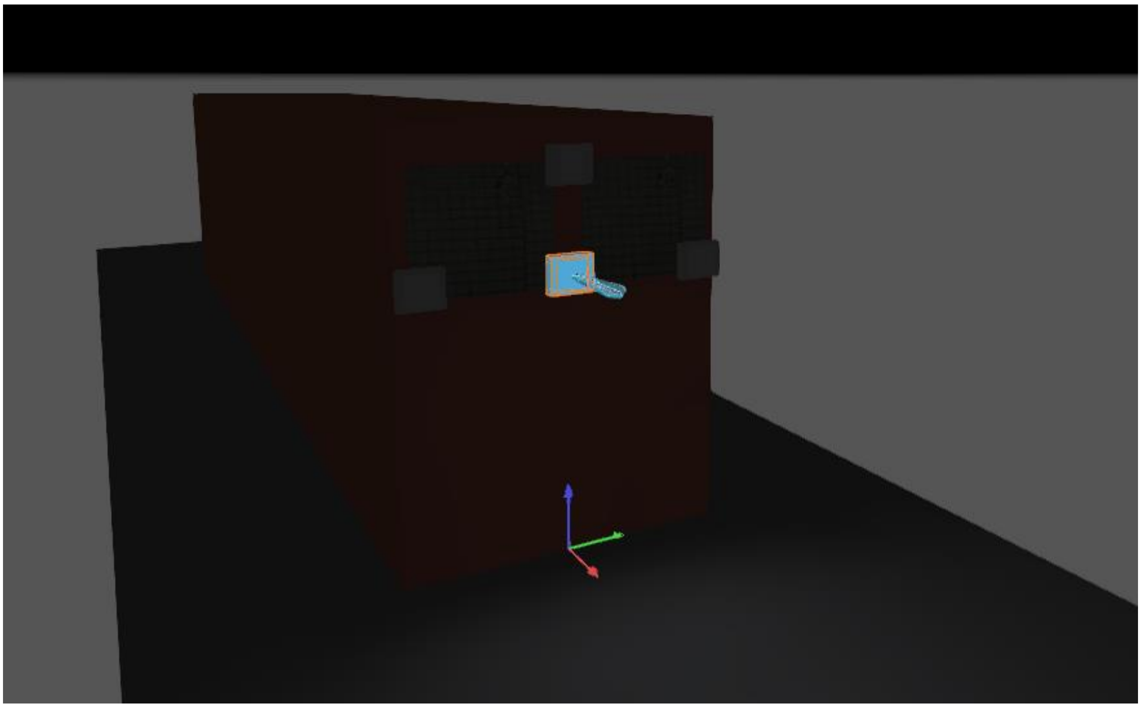


Fig.5.13. Light scene 6

7. **<u>LIGHT SCENE 7:</u>**

In this light scene 7 I have singe luminaire in active state (powered on). Simulated results are shown in table.5.8.

Luminaire: 122W*1 upper one .

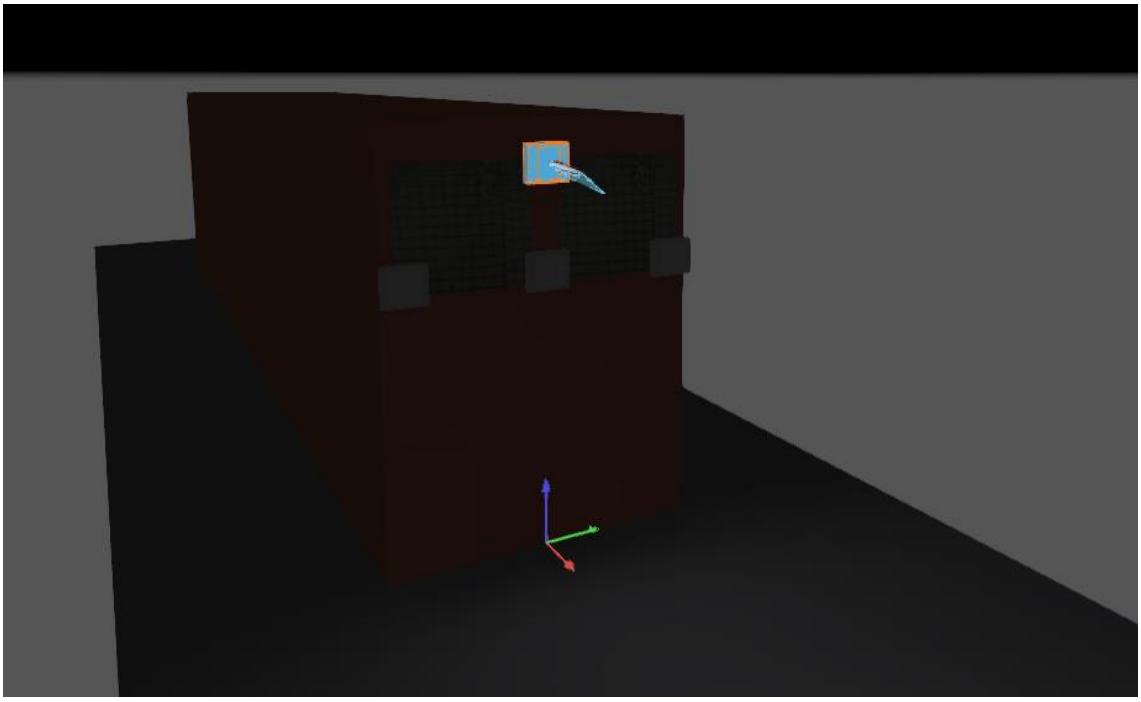


Fig.5.13. Light scene 7

➢ **<u>SIMULATED RESULTS:</u>**

Simulated outcomes are presented in tabular style, one by one according to light scenes.

Calculation surfaces

Properties	E	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	300 lx	46.3 lx	621 lx	0.15	0.075	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	144 lx	68.2 lx	202 lx	0.47	0.34	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	78.1 lx	50.3 lx	97.9 lx	0.64	0.51	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	48.0 lx	35.7 lx	56.5 lx	0.74	0.63	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	32.3 lx	26.3 lx	36.3 lx	0.81	0.72	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	23.1 lx	19.8 lx	25.3 lx	0.86	0.78	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	17.3 lx	15.4 lx	18.6 lx	0.89	0.83	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	13.4 lx	12.2 lx	14.3 lx	0.91	0.85	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	10.7 lx	9.88 lx	11.3 lx	0.92	0.87	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	8.70 lx	8.10 lx	9.15 lx	0.93	0.89	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	5.62 lx	5.29 lx	5.86 lx	0.94	0.90	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	3.92 lx	3.73 lx	4.07 lx	0.95	0.92	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	2.89 lx	2.77 lx	2.99 lx	0.96	0.93	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	2.22 lx	2.14 lx	2.29 lx	0.96	0.93	CG14

Table.5.2. Simulated results of **light scene 1** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	205 lx	33.8 lx	412 lx	0.16	0.082	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	102 lx	52.8 lx	132 lx	0.52	0.40	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	54.9 lx	38.5 lx	67.4 lx	0.70	0.57	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	33.7 lx	26.0 lx	38.9 lx	0.77	0.67	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	22.6 lx	18.9 lx	25.1 lx	0.84	0.75	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	16.1 lx	14.2 lx	17.5 lx	0.88	0.81	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	12.1 lx	10.9 lx	12.9 lx	0.90	0.84	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	9.36 lx	8.67 lx	9.90 lx	0.93	0.88	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	7.46 lx	6.95 lx	7.82 lx	0.93	0.89	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	6.08 lx	5.68 lx	6.35 lx	0.93	0.89	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	3.93 lx	3.71 lx	4.07 lx	0.94	0.91	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	2.74 lx	2.61 lx	2.82 lx	0.95	0.93	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	2.02 lx	1.94 lx	2.07 lx	0.96	0.94	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	1.55 lx	1.49 lx	1.59 lx	0.96	0.94	CG14

Table.5.3. Simulated results of **light scene 2** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	223 lx	24.9 lx	467 lx	0.11	0.053	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	112 lx	33.1 lx	177 lx	0.30	0.19	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	64.6 lx	33.6 lx	89.1 lx	0.52	0.38	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	40.9 lx	27.2 lx	51.3 lx	0.67	0.53	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	27.8 lx	21.1 lx	33.0 lx	0.76	0.64	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	20.1 lx	16.4 lx	23.0 lx	0.82	0.71	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	15.1 lx	12.9 lx	16.9 lx	0.85	0.76	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	11.8 lx	10.4 lx	13.0 lx	0.88	0.80	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	9.44 lx	8.49 lx	10.3 lx	0.90	0.82	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	7.72 lx	7.07 lx	8.31 lx	0.92	0.85	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	5.01 lx	4.72 lx	5.32 lx	0.94	0.89	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	3.51 lx	3.33 lx	3.69 lx	0.95	0.90	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	2.59 lx	2.47 lx	2.71 lx	0.95	0.91	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	2.00 lx	1.91 lx	2.08 lx	0.96	0.92	CG14

Table.5.4. Simulated results of **light scene 3** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	173 lx	29.3 lx	430 lx	0.17	0.068	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	74.2 lx	46.5 lx	101 lx	0.63	0.46	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	36.6 lx	28.5 lx	43.8 lx	0.78	0.65	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	21.5 lx	17.8 lx	24.2 lx	0.83	0.74	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	14.1 lx	11.9 lx	15.4 lx	0.84	0.77	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	9.90 lx	8.56 lx	10.6 lx	0.86	0.81	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	7.32 lx	6.44 lx	7.75 lx	0.88	0.83	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	5.62 lx	5.01 lx	5.91 lx	0.89	0.85	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	4.45 lx	4.00 lx	4.65 lx	0.90	0.86	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	3.61 lx	3.27 lx	3.77 lx	0.91	0.87	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	2.31 lx	2.13 lx	2.40 lx	0.92	0.89	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	1.60 lx	1.50 lx	1.65 lx	0.94	0.91	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	1.17 lx	1.11 lx	1.21 lx	0.95	0.92	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.90 lx	0.85 lx	0.92 lx	0.94	0.92	CG14

Table.5.5. Simulated results of **light scene 4** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	127 lx	16.2 lx	318 lx	0.13	0.051	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	70.0 lx	21.1 lx	106 lx	0.30	0.20	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	41.4 lx	21.8 lx	58.1 lx	0.53	0.38	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	26.5 lx	17.4 lx	33.8 lx	0.66	0.51	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	18.2 lx	13.7 lx	21.7 lx	0.75	0.63	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	13.2 lx	10.7 lx	15.1 lx	0.81	0.71	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	9.95 lx	8.49 lx	11.2 lx	0.85	0.76	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	7.76 lx	6.85 lx	8.56 lx	0.88	0.80	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	6.22 lx	5.62 lx	6.78 lx	0.90	0.83	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	5.09 lx	4.69 lx	5.49 lx	0.92	0.85	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	3.32 lx	3.14 lx	3.52 lx	0.95	0.89	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	2.33 lx	2.22 lx	2.45 lx	0.95	0.91	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	1.72 lx	1.65 lx	1.80 lx	0.96	0.92	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	1.32 lx	1.27 lx	1.38 lx	0.96	0.92	CG14

Table.5.6. Simulated results of **light scene 5** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	95.5 lx	8.77 lx	307 lx	0.092	0.029	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	42.0 lx	12.0 lx	73.6 lx	0.29	0.16	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	23.2 lx	11.8 lx	32.1 lx	0.51	0.37	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	14.3 lx	9.70 lx	17.9 lx	0.68	0.54	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	9.66 lx	7.37 lx	11.4 lx	0.76	0.65	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	6.92 lx	5.64 lx	7.89 lx	0.82	0.71	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	5.19 lx	4.41 lx	5.77 lx	0.85	0.76	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	4.03 lx	3.52 lx	4.41 lx	0.87	0.80	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	3.21 lx	2.87 lx	3.48 lx	0.89	0.82	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	2.62 lx	2.38 lx	2.82 lx	0.91	0.84	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	1.70 lx	1.57 lx	1.80 lx	0.92	0.87	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	1.19 lx	1.11 lx	1.24 lx	0.93	0.90	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	0.87 lx	0.82 lx	0.91 lx	0.94	0.90	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.67 lx	0.63 lx	0.70 lx	0.94	0.90	CG14

Table.5.7. Simulated results of **light scene 6** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	77.7 lx	16.7 lx	194 lx	0.21	0.086	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	32.1 lx	16.7 lx	49.4 lx	0.52	0.34	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	13.5 lx	8.79 lx	19.4 lx	0.65	0.45	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	7.18 lx	5.17 lx	9.54 lx	0.72	0.54	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	4.43 lx	3.35 lx	5.63 lx	0.76	0.60	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	2.98 lx	2.34 lx	3.65 lx	0.79	0.64	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	2.13 lx	1.72 lx	2.54 lx	0.81	0.68	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	1.59 lx	1.32 lx	1.86 lx	0.83	0.71	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	1.23 lx	1.04 lx	1.42 lx	0.85	0.73	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	0.98 lx	0.84 lx	1.12 lx	0.86	0.75	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	0.61 lx	0.54 lx	0.68 lx	0.89	0.79	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	0.41 lx	0.37 lx	0.45 lx	0.90	0.82	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	0.30 lx	0.27 lx	0.32 lx	0.90	0.84	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.23 lx	0.21 lx	0.24 lx	0.91	0.88	CG14

Table.5.8. Simulated results of **light scene 7** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

5.4 RAILWAY FOG LIGHTING DESIGN BY DIALUX, USING HALOGEN LIGHT (THEY ARE USING CURRENTLY):

In this section, I talked about the arrangement that was planned using halogen lamps (currently using as fog light in railway). Using dialux evo 10.1, I simulate the intended setup and record the findings. The setup is depicted in figures 5.14 and 5.15 below.

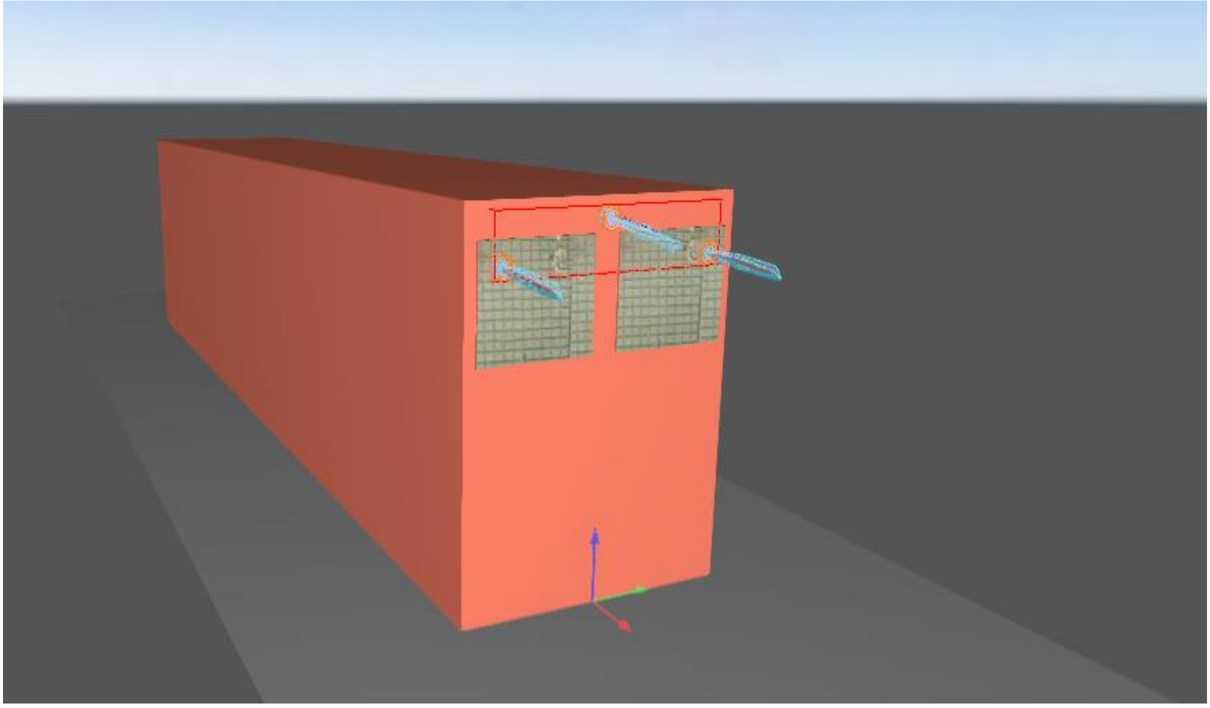


Fig5.14. 3D front view of railway Train with luminaire setup

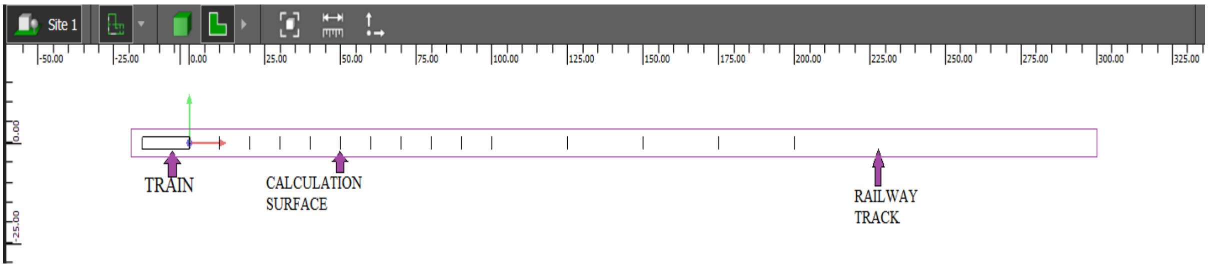


Fig.5.15. 2D floorplan view (top view) of train with track and calculation surface.

5.4.1 DESIGN INPUT PARAMETERS:

- SITE ALIGNMENT shown in below table.5.9

Site alignment	
Location	Calcutta
Longitude	88.40 °
Latitude	22.50 °
North alignment	0.00 °
Time zone	(UTC+05:30) Chennai, Kolkata, Mumbai, New Delhi

Table.5.9. Site alignment

- **Maintenance factor** considered 0.8 for normal environmental condition.
- **Train:** Length: 15.5m
  Height: 3.5m
  Width: 3m
  Train driver's cabin window: Width: 1.25m
  Height: 1.00m
- **Luminaire:**
  3. Upper centre luminaire: Mounting height: 3.324m
  4. Line arrangement with two numbers of luminaire: Mounting height: 3.00m
- **Calculation Surface:** Height: 3m
  Width: 3m

  Same size vertical calculation surfaces are placed in certain distance of 10m, 20m, 30m, 40m, 50m, 60m, 70m, 80m, 90m, 100m, 125m, 150m, 175m, 200m. All calculation surfaces are shown in fig.5.16 below.

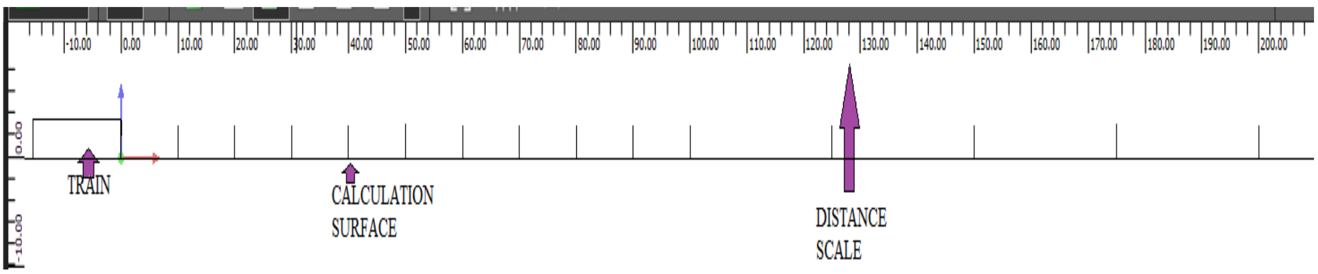


Fig.5.16. 2D Side view of train with track and calculation surface with proper distance

5.4.2 DESIGNED SETUP BY USING HALOGEN FOG LAMP:

I have designed a setup of railway fog lighting that consist 3 numbers of luminaire and single type of luminaire in certain arrangement in the manner shown below.

5.4.2.1 LUMINAIRE USED:

In this designed set up, I have used single type of 3 luminaires:

1. **Currently using halogen lamp as railway fog light**

   - Power: 57.64 W
   - Measurement Flux: 359 lumens
   - Luminaire Efficacy Rating (LER): 6.28

Luminous Intensity Distribution Curve of this luminaire is shown below fig.5.17

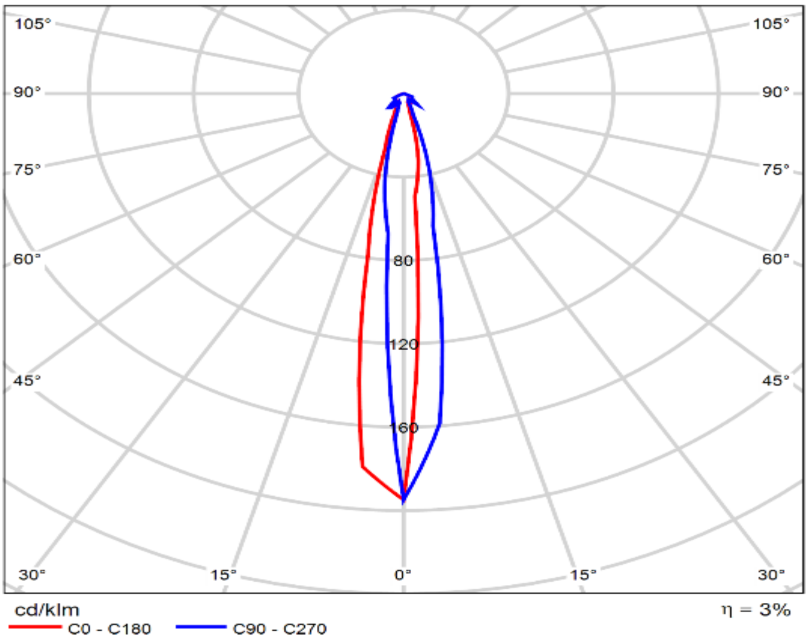


Fig.5.17. Polar Luminous Intensity Distribution curve of currently used(railway) halogen fog light of 58w.

5.4.2.2 LIGHT SCENE:

As I have 3 numbers of halogen fog lights in my set up that's why I simulate my set up in 3 different combinations of luminaire. I made different combinations by grouping luminaires in several light scene, as discussed below:

1. **LIGHT SCENE 1:**

   In this light scene 1 I have 3 numbers of luminaires (all luminaires) in active state (powered on). Simulated results are shown in table.5.10.

   Luminaires: 58W*1 upper one; 58W*2 lower line arrangement

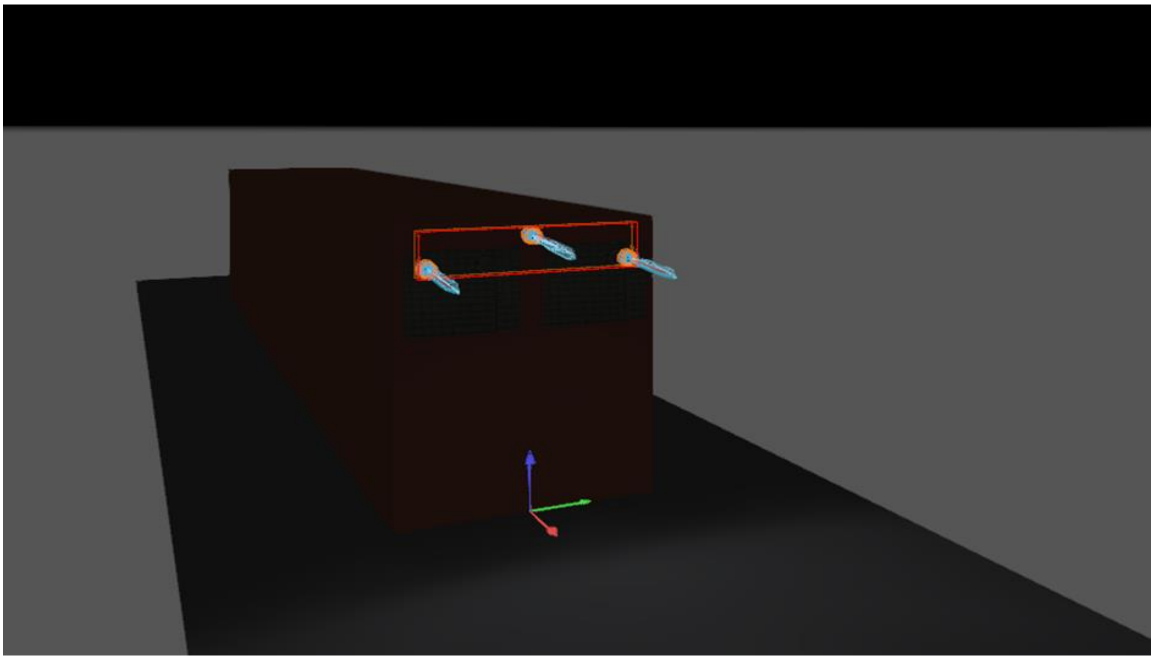


Fig.5.18. Light scene 1

2. **LIGHT SCENE 2:**

In this light scene I have 2 numbers of luminaires in active state (powered on). Simulated results are shown in table.5.11.

Luminaires: 58W*2 lower line arrangement.

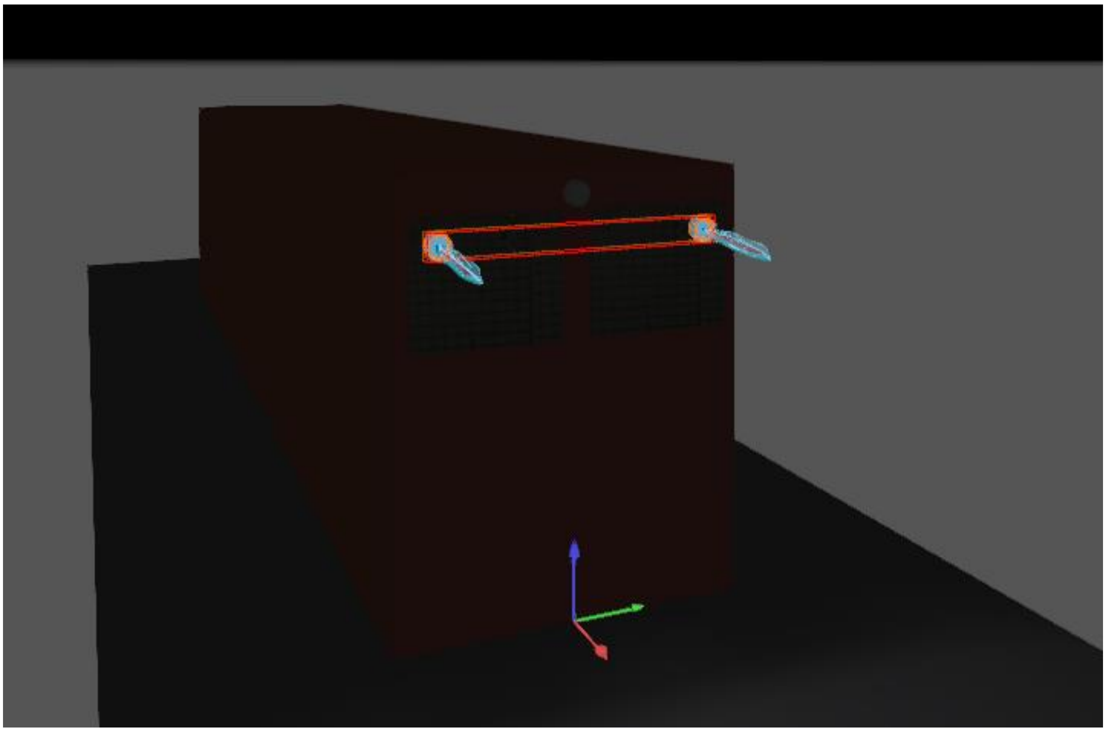


Fig.5.19. Light scene 2

3. **LIGHT SCENE 3:**

In this light scene I have single luminaire in active state (powered on). Simulated results are shown in table.5.12.

Luminaires: 58W*1 upper one.

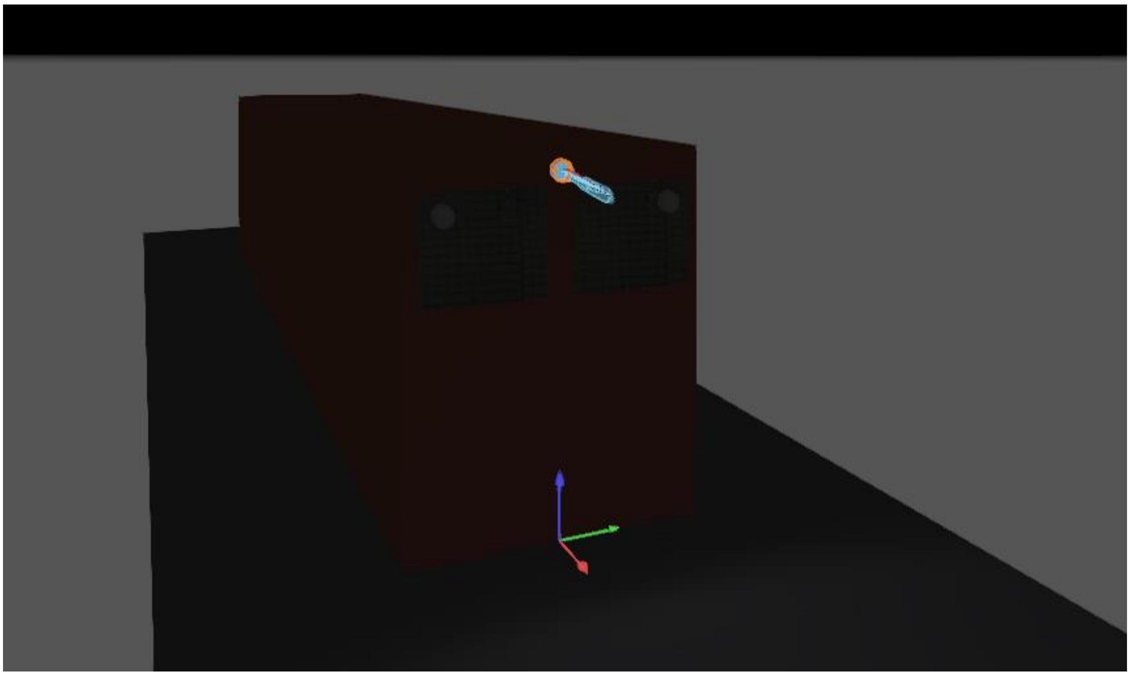


Fig.5.20. Light scene 3

- **SIMULATED RESULTS:**
  Simulated outcomes are presented in tabular style, one by one according to light scenes.

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	20.6 lx	6.49 lx	37.1 lx	0.32	0.17	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	9.34 lx	6.85 lx	11.1 lx	0.73	0.62	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	4.68 lx	3.63 lx	5.29 lx	0.78	0.69	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	2.67 lx	2.13 lx	3.04 lx	0.80	0.70	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	1.69 lx	1.40 lx	1.92 lx	0.83	0.73	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	1.16 lx	0.99 lx	1.30 lx	0.85	0.76	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	0.85 lx	0.73 lx	0.94 lx	0.86	0.78	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	0.64 lx	0.57 lx	0.70 lx	0.89	0.81	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	0.50 lx	0.45 lx	0.55 lx	0.90	0.82	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	0.41 lx	0.37 lx	0.44 lx	0.90	0.84	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	0.26 lx	0.24 lx	0.27 lx	0.92	0.89	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	0.18 lx	0.16 lx	0.19 lx	0.89	0.84	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	0.13 lx	0.12 lx	0.14 lx	0.92	0.86	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.098 lx	0.093 lx	0.10 lx	0.95	0.93	CG14

Table.5.10. Simulated results of **light scene 1** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	11.7 lx	2.96 lx	21.9 lx	0.25	0.14	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	6.03 lx	3.57 lx	7.57 lx	0.59	0.47	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	3.28 lx	2.64 lx	3.74 lx	0.80	0.71	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	1.96 lx	1.67 lx	2.15 lx	0.85	0.78	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	1.28 lx	1.13 lx	1.39 lx	0.88	0.81	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	0.90 lx	0.81 lx	0.97 lx	0.90	0.84	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	0.67 lx	0.61 lx	0.71 lx	0.91	0.86	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	0.51 lx	0.47 lx	0.54 lx	0.92	0.87	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	0.41 lx	0.38 lx	0.43 lx	0.93	0.88	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	0.33 lx	0.31 lx	0.35 lx	0.94	0.89	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	0.21 lx	0.20 lx	0.22 lx	0.95	0.91	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	0.15 lx	0.14 lx	0.15 lx	0.93	0.93	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	0.11 lx	0.10 lx	0.11 lx	0.91	0.91	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.083 lx	0.080 lx	0.085 lx	0.96	0.94	CG14

Table.5.11. Simulated results of **light scene 2** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

Calculation surfaces

Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 10m Perpendicular illuminance Height: 1.500 m	8.87 lx	2.74 lx	17.8 lx	0.31	0.15	CG1
Calculation surface 20m Perpendicular illuminance Height: 1.500 m	3.31 lx	1.42 lx	4.48 lx	0.43	0.32	CG2
Calculation surface 30m Perpendicular illuminance Height: 1.500 m	1.41 lx	0.71 lx	1.99 lx	0.50	0.36	CG3
Calculation surface 40m Perpendicular illuminance Height: 1.500 m	0.71 lx	0.39 lx	1.03 lx	0.55	0.38	CG4
Calculation surface 50m Perpendicular illuminance Height: 1.500 m	0.41 lx	0.24 lx	0.57 lx	0.59	0.42	CG5
Calculation surface 60m Perpendicular illuminance Height: 1.500 m	0.26 lx	0.16 lx	0.36 lx	0.62	0.44	CG6
Calculation surface 70m Perpendicular illuminance Height: 1.500 m	0.18 lx	0.12 lx	0.24 lx	0.67	0.50	CG7
Calculation surface 80m Perpendicular illuminance Height: 1.500 m	0.13 lx	0.087 lx	0.17 lx	0.67	0.51	CG8
Calculation surface 90m Perpendicular illuminance Height: 1.500 m	0.096 lx	0.067 lx	0.12 lx	0.70	0.56	CG9
Calculation surface 100m Perpendicular illuminance Height: 1.500 m	0.075 lx	0.054 lx	0.096 lx	0.72	0.56	CG10
Calculation surface 125m Perpendicular illuminance Height: 1.500 m	0.044 lx	0.033 lx	0.055 lx	0.75	0.60	CG11
Calculation surface 150m Perpendicular illuminance Height: 1.500 m	0.029 lx	0.023 lx	0.035 lx	0.79	0.66	CG12
Calculation surface 175m Perpendicular illuminance Height: 1.500 m	0.020 lx	0.016 lx	0.024 lx	0.80	0.67	CG13
Calculation surface 200m Perpendicular illuminance Height: 1.500 m	0.015 lx	0.012 lx	0.018 lx	0.80	0.67	CG14

Table.5.12. Simulated results of **light scene 3** (results having E_{avg}, E_{min}, E_{max}, g_1, g_2, Index)

CHAPTER 6

EXPERIMENTAL RESULTS AND COMPARATIVE STUDY

6.1 INTRODUCTION:

The major goal of this technique is to improve visibility in foggy conditions, which will benefit both drivers and pedestrians. Accidents will decrease and the average traffic speed will rise as visibility improves. The use of monochromatic LED to improve visibility is covered in this chapter.

In this chapter, we will conduct an experimental comparison of the monochromatic LED and the halogen lamp currently being utilized in the railway fog lighting system.

6.2 INDOOR EXPERIMENT:

6.2.1 122-WATT MONOCHROMATIC AMBER LED LUMINAIRE:

6.2.1.1 LUMINAIRE DETAILS:

- Luminaire Manufacturer: UNILUX
- Luminaire Category: Outdoor
- Luminaire Description: Monochromatic amber LED luminaire
- Number of LEDs: 7*10=70
- **ELECTRICAL DATA:**

  Voltage: 230.5 V   Current: 0.530 A

  Power: 121.59 W   Power Factor: 0.995

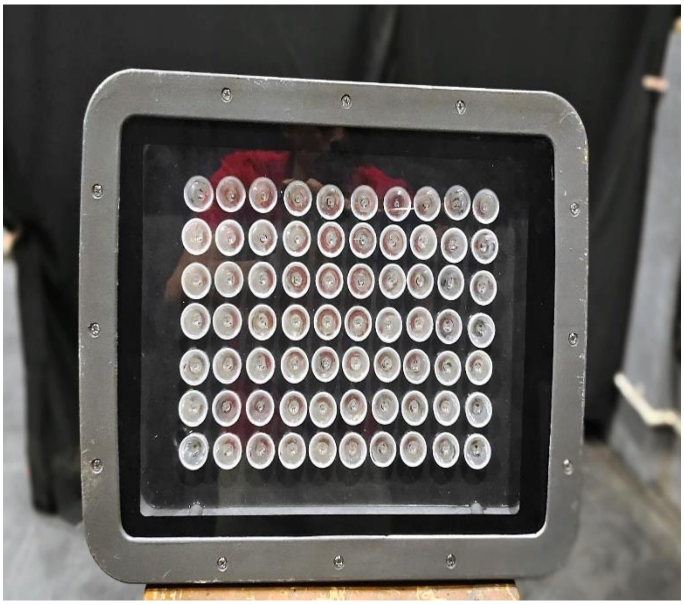


Fig.6.1. (a).122W Monochromatic LED luminaire .

Fig.6.1. (b). 122W Monochromatic LED luminaire in Powered on condition

- **COLOR COORDINATES:**

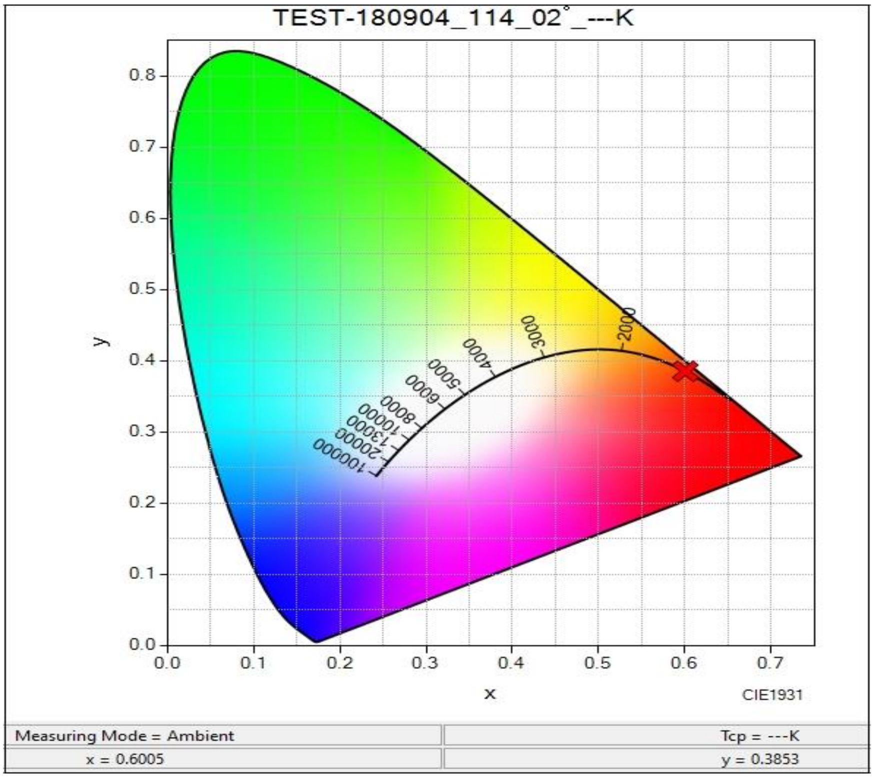


Fig.6.2. (a) CIE 1931 COLOR COORDINATES

(x = 0.6005,

y =0.3853,

z =0.0142)

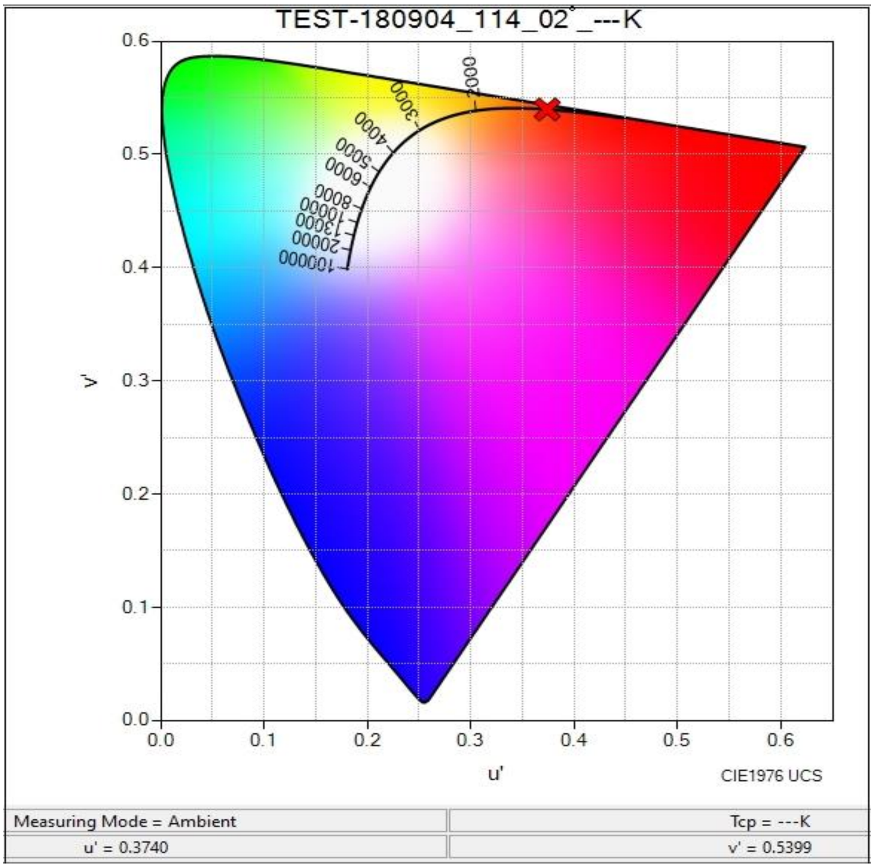


Fig.6.2. (b) CIE 1976 COLOR COORDINATES

(u' = 0.3740,

v' = 0.5399)

- **SPD:** FWHM = 20nm

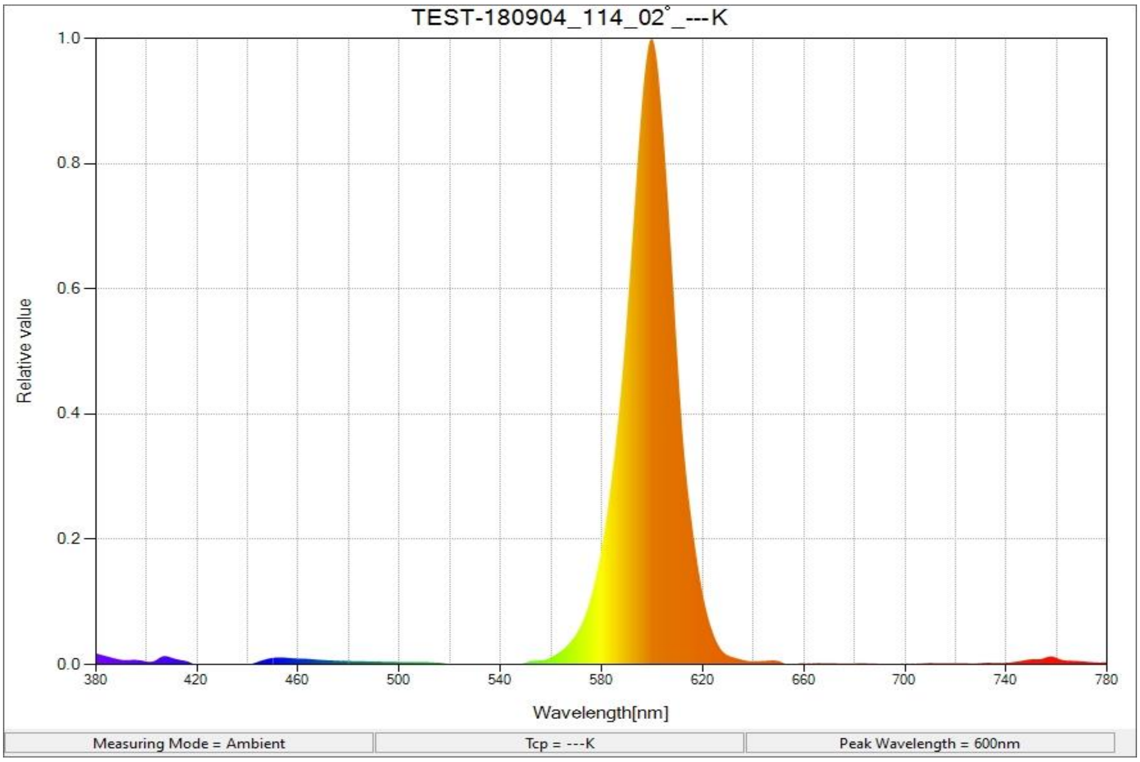


Fig.6.3. SPD of 122W monochromatic amber LED luminaire

6.2.1.2 GONIOPHOTOMETER'S TEST:

All goniophotometer's test are carried out in our Illumination Lab. Of JADAVPUR UNIVERSITY. Details about goniophotometer are given in **ANNEXURE-II.**

6.2.1.2.1 EXPERIMENTAL SETUP:

Fig.6.4. (a) Goniophotometer Experimental setup [Puspasish Mal (me), Samir Mandi (lab assistant) and Pradip Pal (lab assistant) in frame]

Fig.6.4.(b) Goniophotometer experimental setup showing luminaire and light sensor in our JADAVPUR UNIVERSITY ILLUMINATION Laboratory

6.2.1.2.2 EXPERIMENTAL RESULTS:

- **PHOTOMETRIC RESULTS:**

IES NEMA Type: 3H x 2V
Measurement Flux: 2090.4 lm
Field Lumens: 1159.5 lm
Field Angle: H30.4, V25.1
Luminaire Efficacy Rating (LER): 17.24
Max. Intensity: 26671.47 cd

Total Rated Lamp Lumens: 2090.4 lm
Efficiency: 100%
Field Efficiency: 55.47%
Beam Angle: H12.3, V10.2
Central Intensity: 16740.7 cd
Pos of Max. Intensity: H-5 V0

- **LUMINOUS INTENSITY DISTRIBUTION CURVE:**

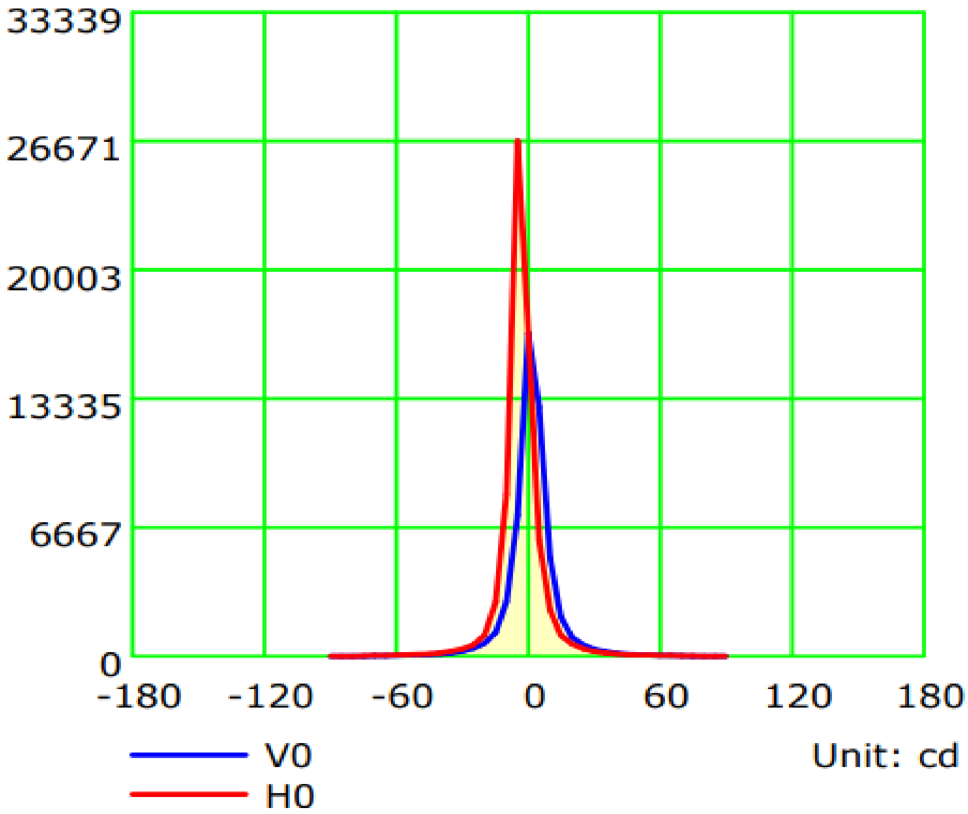


Fig.6.5.(a) Luminous intensity distribution curve

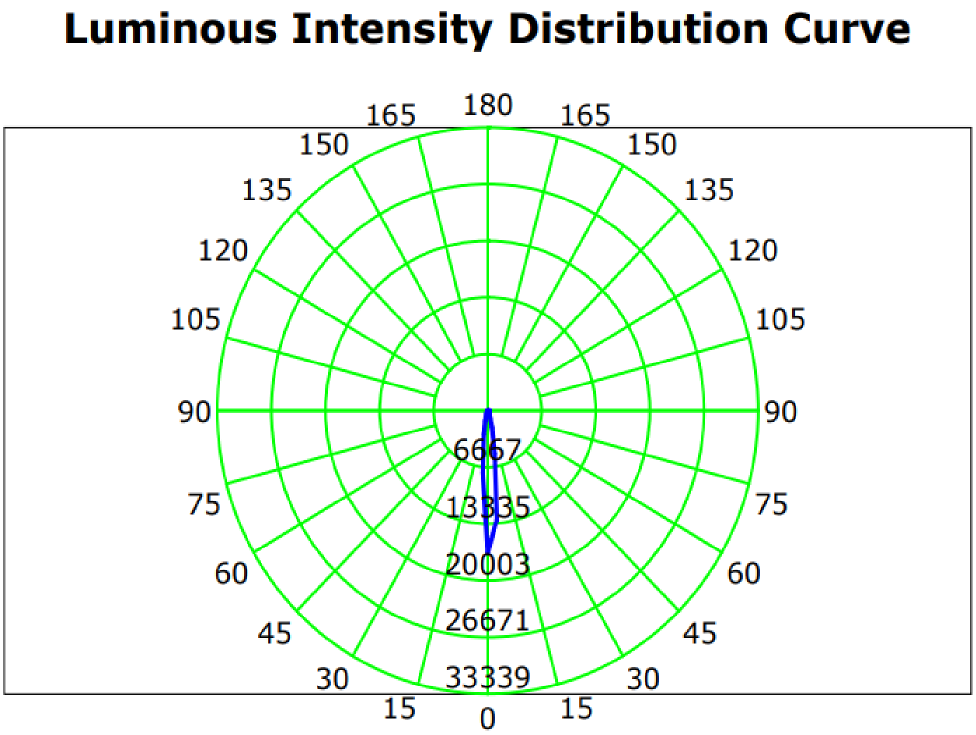


Fig. 6.5. (b)

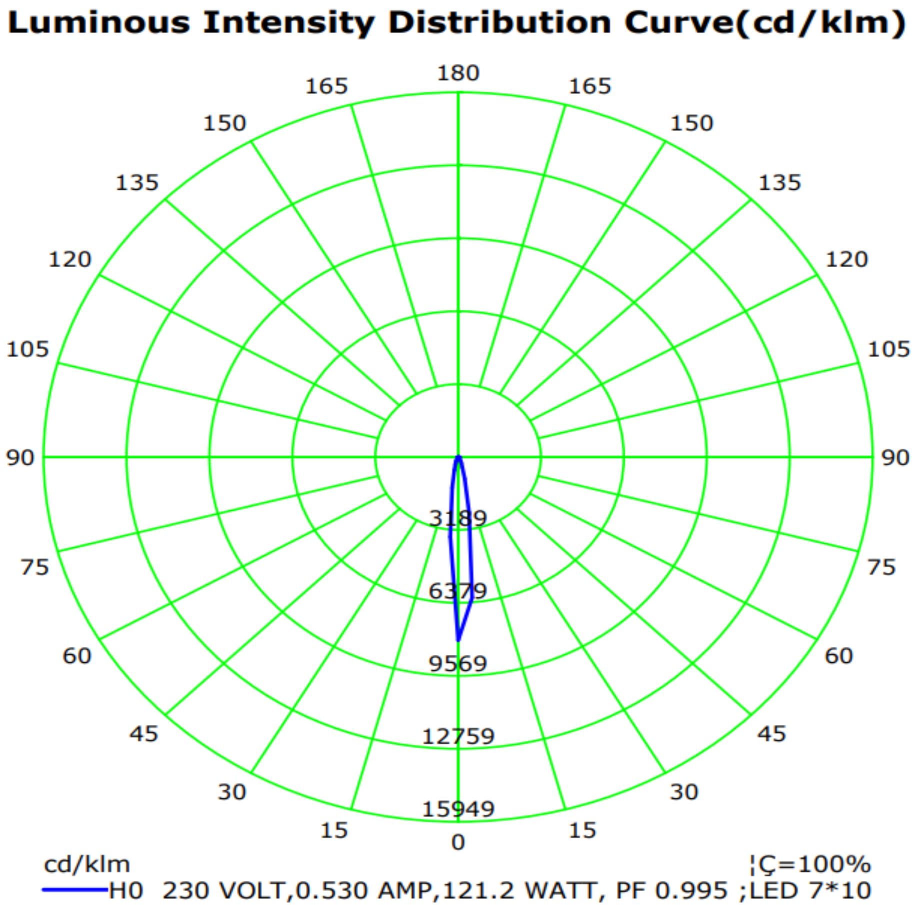


Fig.6.5.(c)

- **ISOCANDELA (RECTANGLE):**

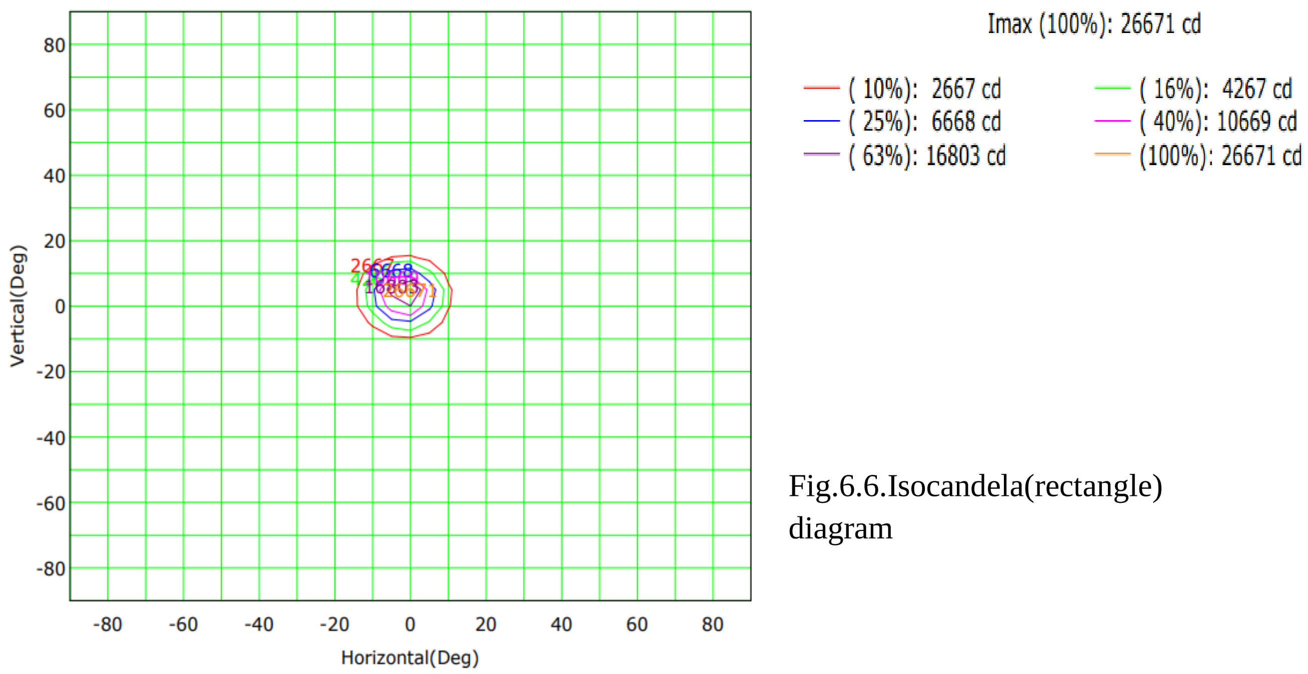


Fig.6.6.Isocandela(rectangle) diagram

- **ISOLUX PLOT:**

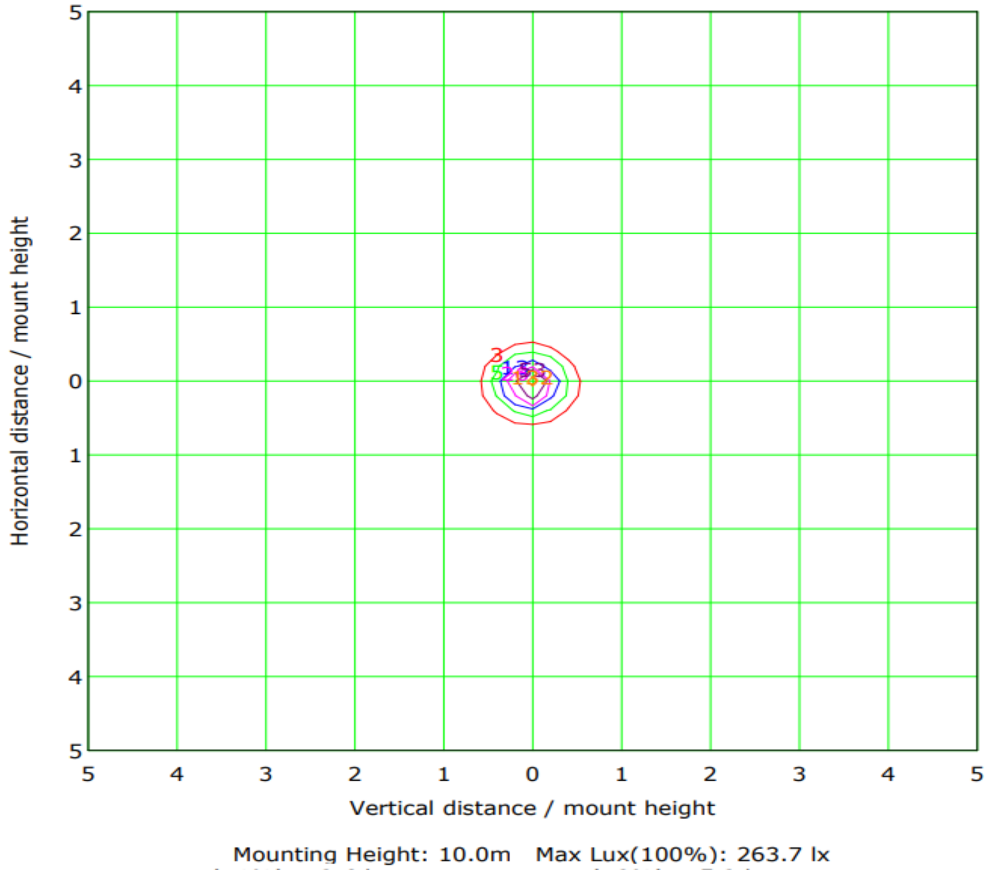


Fig.6.7.(a) IsoLux Plot

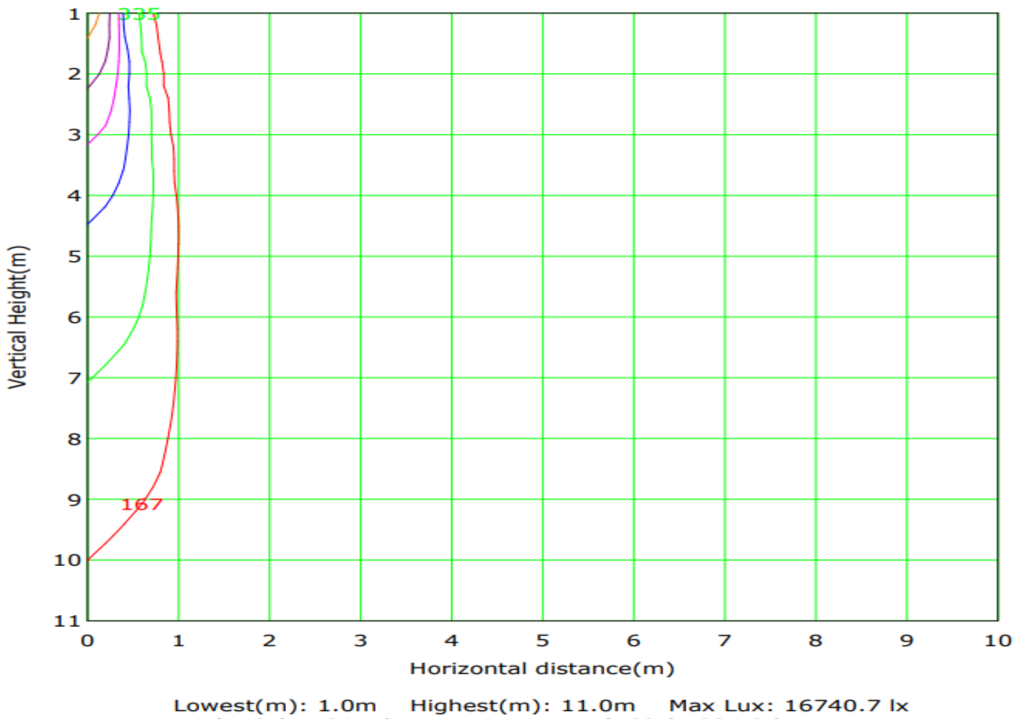


Fig.6.7.(b) Vertical IsoLux Plot

- **ILLUMINANCE AT DIFFERENT POSITION:**

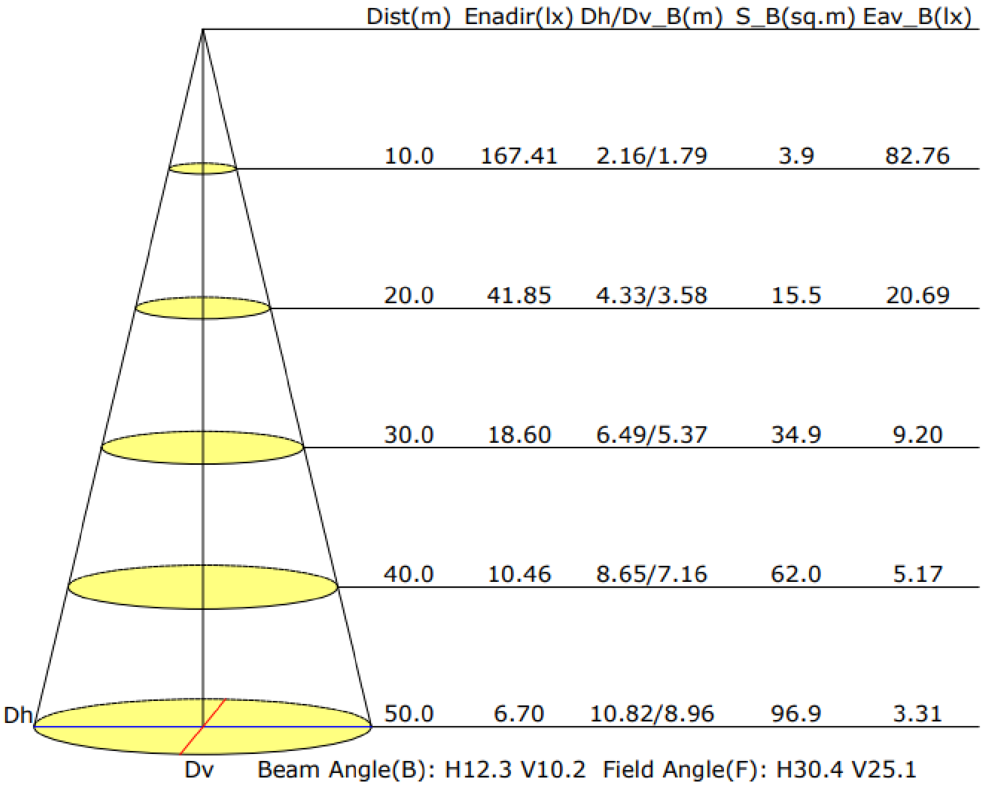


Fig.6.8. (a) Illuminance at a distance

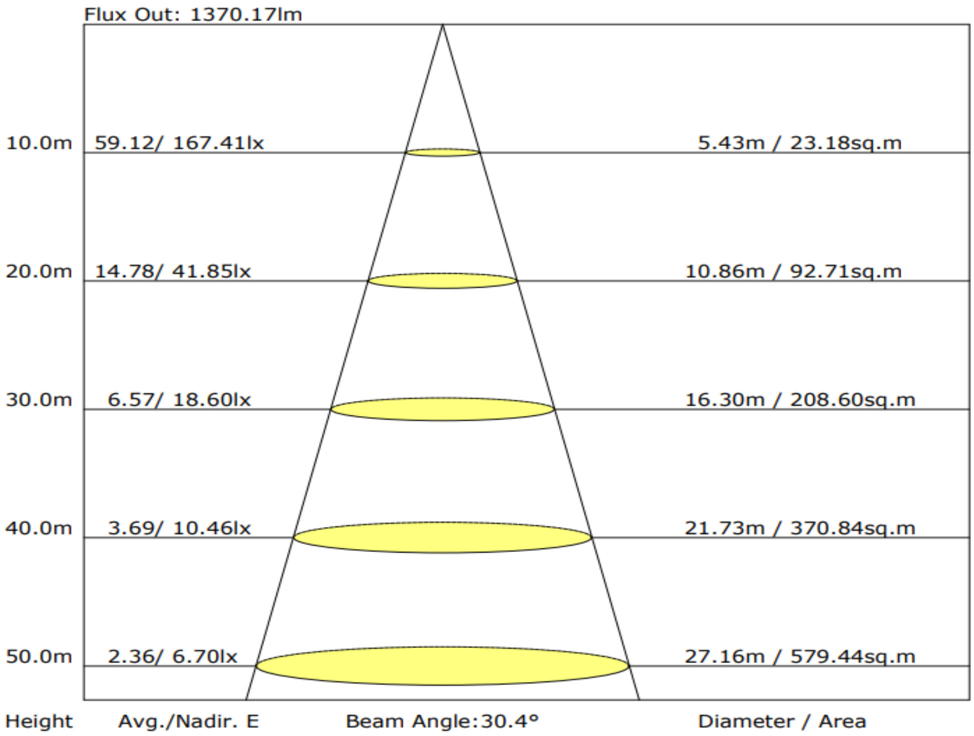


Fig.6.8. (b) The Average Illuminance Effective Figure

- **AREA FLUX TABLE:**

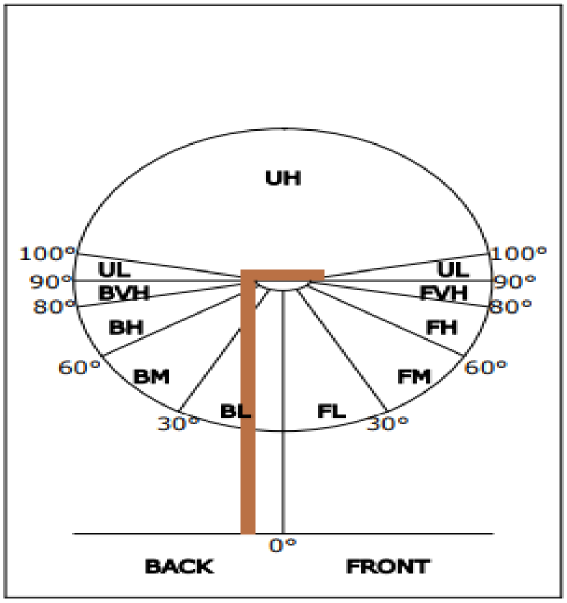
Unit: lm

Vertical plane \ Horizontal plane	-90 to -80	-80 to -70	-70 to -60	-60 to -50	-50 to -40	-40 to -30	-30 to -20	-20 to -10	-10 to 0	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	Flux(T)	Flux(E)
-90 to -80	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
-80 to -70	0.0	0.0	0.0	0.1	0.3	0.5	0.7	0.8	0.9	0.9	0.8	0.8	0.6	0.3	0.1	0.0	0.0	0.0	6.7	0.0
-70 to -60	0.0	0.0	0.1	0.4	0.7	1.1	1.4	1.6	1.7	1.7	1.6	1.4	1.2	0.8	0.4	0.1	0.0	0.0	14.3	0.0
-60 to -50	0.0	0.0	0.2	0.6	1.0	1.5	1.9	2.2	2.4	2.4	2.2	1.9	1.6	1.2	0.7	0.3	0.0	0.0	20.1	0.0
-50 to -40	0.0	0.0	0.3	0.7	1.3	1.8	2.5	3.3	3.9	4.0	3.5	2.7	2.0	1.4	0.9	0.4	0.1	0.0	28.8	0.0
-40 to -30	0.0	0.1	0.4	0.9	1.5	2.4	4.0	6.3	8.1	8.4	6.9	4.6	2.7	1.7	1.0	0.5	0.1	0.0	49.4	0.0
-30 to -20	0.0	0.1	0.4	1.0	1.7	3.3	6.7	12.1	18.2	19.6	14.1	8.1	4.0	2.0	1.1	0.5	0.1	0.0	93.1	0.0
-20 to -10	0.0	0.1	0.5	1.0	2.0	4.3	10.0	24.7	76.0	96.7	35.6	13.1	5.6	2.4	1.2	0.6	0.1	0.0	273.8	112.8
-10 to 0	0.0	0.1	0.5	1.1	2.1	4.9	12.4	42.7	279.9	408.0	72.5	17.1	6.4	2.6	1.2	0.6	0.2	0.0	852.3	735.4
0 to 10	0.0	0.1	0.5	1.1	2.0	4.7	11.4	34.3	140.2	180.3	52.5	15.6	6.1	2.5	1.2	0.6	0.2	0.0	453.2	311.3
10 to 20	0.0	0.1	0.5	1.0	1.8	3.8	8.1	17.2	32.7	36.4	21.8	10.4	4.7	2.1	1.1	0.5	0.1	0.0	142.5	0.0
20 to 30	0.0	0.1	0.4	0.9	1.6	2.7	5.1	8.4	11.7	12.5	9.7	6.0	3.2	1.8	1.0	0.5	0.1	0.0	65.6	0.0
30 to 40	0.0	0.1	0.3	0.8	1.3	2.0	3.0	4.2	5.3	5.5	4.6	3.3	2.2	1.4	0.9	0.4	0.1	0.0	35.4	0.0
40 to 50	0.0	0.0	0.3	0.6	1.1	1.5	2.0	2.4	2.7	2.7	2.5	2.1	1.6	1.2	0.7	0.3	0.1	0.0	21.8	0.0
50 to 60	0.0	0.0	0.2	0.5	0.9	1.2	1.5	1.7	1.8	1.8	1.7	1.6	1.3	1.0	0.6	0.2	0.0	0.0	16.0	0.0
60 to 70	0.0	0.0	0.1	0.3	0.6	0.9	1.2	1.3	1.4	1.4	1.3	1.2	1.0	0.6	0.3	0.1	0.0	0.0	11.6	0.0
70 to 80	0.0	0.0	0.0	0.0	0.2	0.3	0.5	0.6	0.7	0.7	0.7	0.6	0.4	0.2	0.1	0.0	0.0	0.0	5.0	0.0
80 to 90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Flux(T)	0.0	0.7	4.5	10.9	20.1	37.1	72.3	163.9	587.6	783.1	232.3	90.5	44.6	23.2	12.6	5.6	1.2	0.0	2090	
Flux(E)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.9	445.2	647.2	62.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1159

- **ZONAL LUMEN TABLE:**

Gamma [°]	Imean [cd]	Zonal Flux [lm]	Sum Zonal Flux [lm]	Rel Zonal Flux [%]	Sum Rel Zonal Flux [%]
0.0-5.0	14421.6	344.8	344.8	16.50	16.50
5.0-10.0	8517.9	609.4	954.2	29.15	45.65
10.0-15.0	3417.1	405.4	1359.6	19.39	65.04
15.0-20.0	1393.1	229.6	1589.3	10.99	76.03
20.0-25.0	699.2	146.7	1735.9	7.02	83.04
25.0-30.0	423.4	107.2	1843.1	5.13	88.17
30.0-35.0	279.7	82.4	1925.5	3.94	92.11
35.0-40.0	188.4	62.9	1988.3	3.01	95.12
40.0-45.0	129.0	47.8	2036.1	2.28	97.40
45.0-50.0	94.5	38.2	2074.3	1.83	99.23
50.0-55.0	75.3	32.7	2107.0	1.57	100.80
55.0-60.0	62.8	29.1	2136.1	1.39	102.19
60.0-65.0	52.8	25.7	2161.7	1.23	103.41
65.0-70.0	42.7	21.6	2183.3	1.03	104.45
70.0-75.0	30.4	15.9	2199.3	0.76	105.21
75.0-80.0	15.6	8.4	2207.6	0.40	105.61
80.0-85.0	4.0	2.2	2209.8	0.10	105.71
85.0-90.0	0.1	0.1	2209.9	0.00	105.72

- **FLUX DISTRIBUTION TABLE BASED ON THE IESNA LUMINAIRE CLASSIFICATION SYSTEM:**



ZONE	LUMENS	% LAMP LUMENS
FORWARD LIGHT	1224	58.6
FL (0°-30°)	1029	49.2
FM (30°-60°)	157	7.5
FH (60°-80°)	38	1.8
FVH (80°-90°)	1	0.0
BACK LIGHT	913	43.7
BL (0°-30°)	742	35.5
BM (30°-60°)	136	6.5
BH (60°-80°)	34	1.6
BVH (80°-90°)	1	0.0
UP LIGHT	0	0.0
UL (90°-100°)	0	0.0
UH (100°-180°)	0	0.0
TRAPPED LIGHT	NA	NA

BUG(**B**acklight,**U**plight,**G**lare) Rating Base On TM-15-07	
Asymmetrical Luminaire Types (Type I,II,III,IV)	B2 U0 G0
Quadrilateral Symmetrical Luminaire Types (Type V,Area Light)	B2 U0 G0

- **LCS GRAPH:**

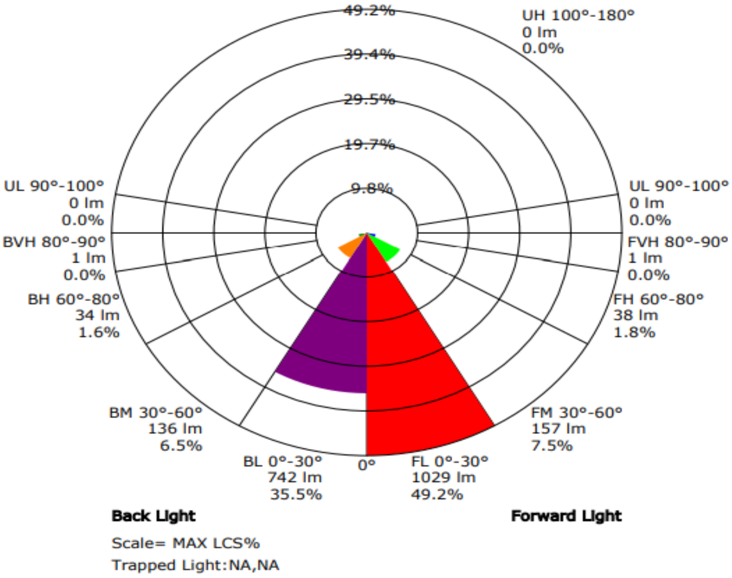


Fig.6.9. LCS Graph

6.2.2 90-WATT MONOCHROMATIC AMBER LED LUMINAIRE:

6.2.2.1 LUMINAIRE DETAILS:

- Luminaire Manufacturer: UNILUX
- Luminaire Category: Outdoor
- Luminaire Description: Monochromatic amber LED luminaire
- Number of LEDs: 54
- **ELECTRICAL DATA:**

  Voltage: 230.3 V   Current: 0.403 A

  Power: 89.80 W   Power Factor: 0.968

Fig.6.10. (a) 90W Monochromatic amber LED luminaire

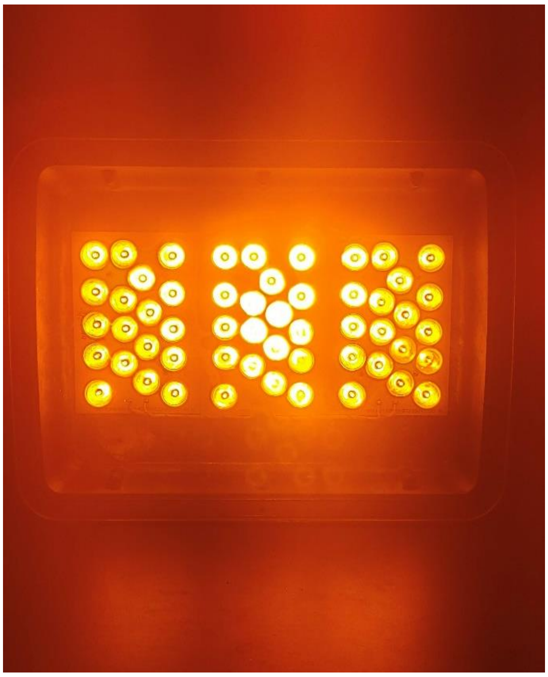


Fig.6.10. (b) 90W Monochromatic amber LED luminaire in Powered on condition

- **COLOR COORDINATES:**

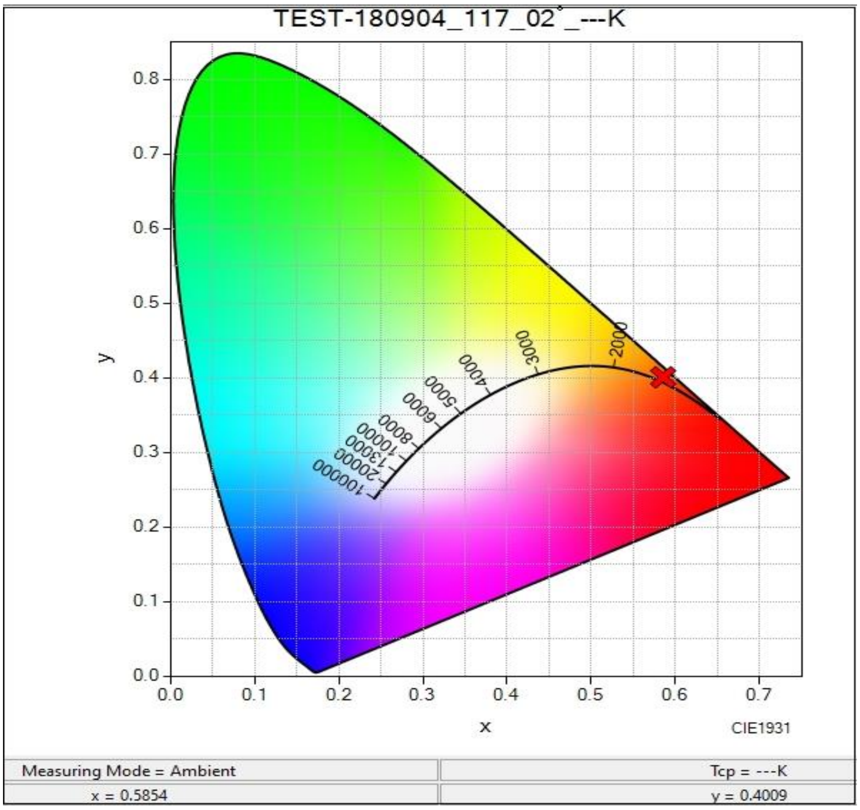


Fig.6.11.(a) CIE 1931 COLOR COORDINATES

(x = 0.5854,

y =0.4009,

z =0.0137)

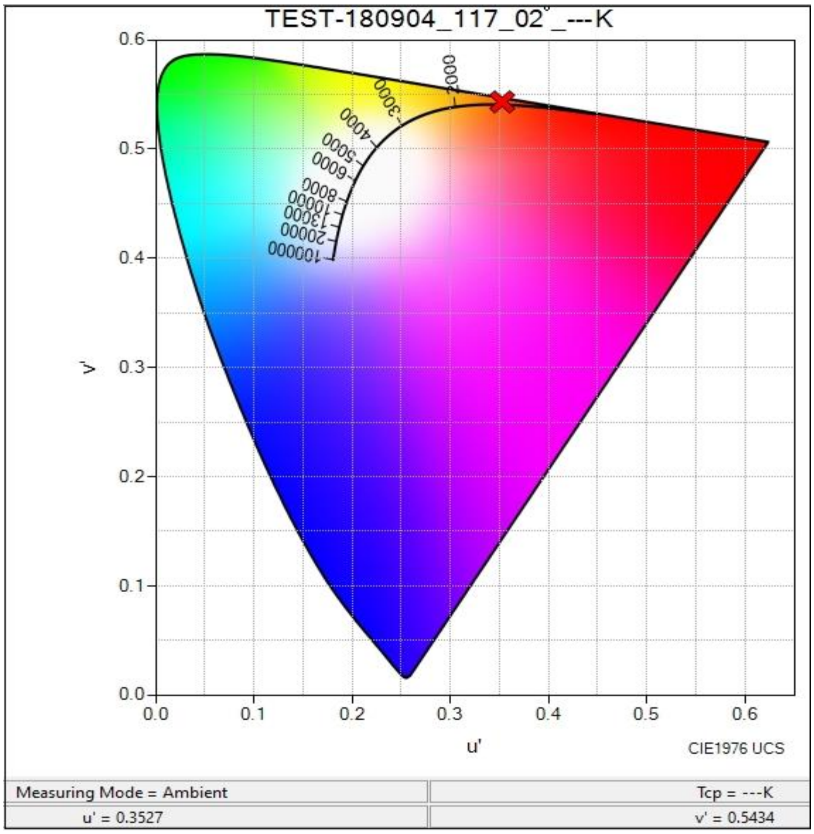


Fig.6.11.(b) CIE 1976 COLOR COORDINATES

(u' = 0.3527,

v' = 0.5434)

- **SPD:** FWHM = 20nm

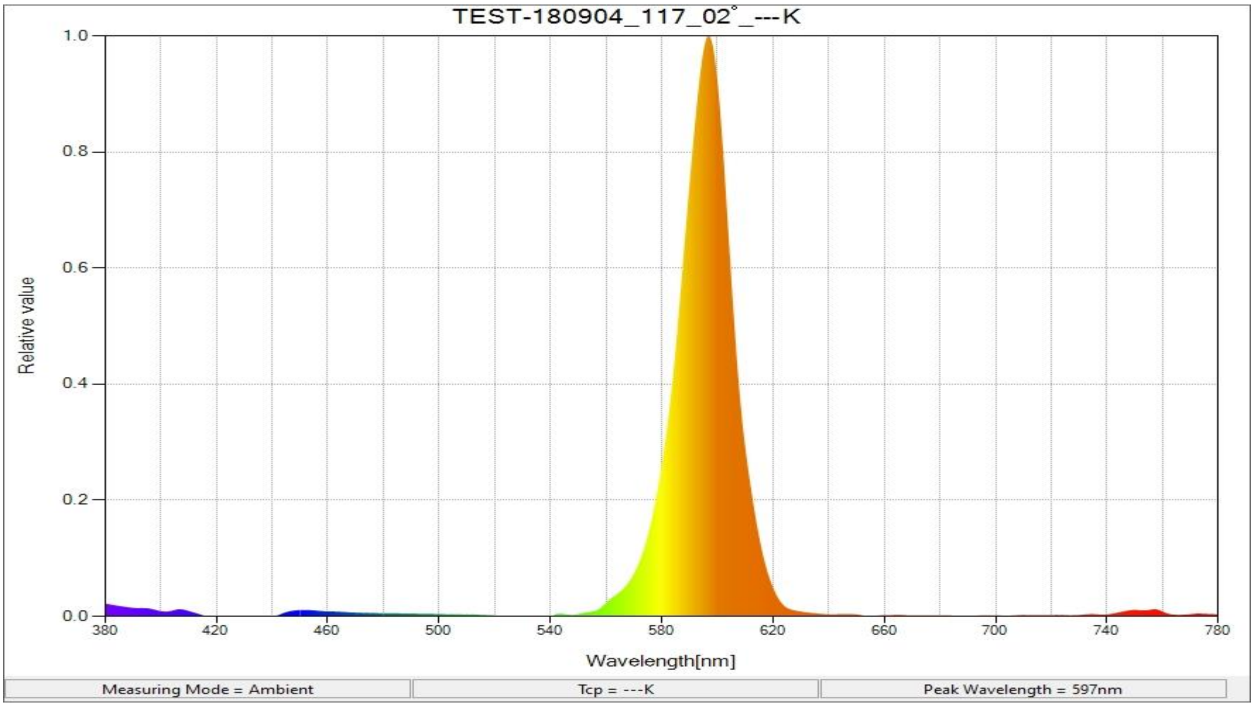


Fig.6.12. SPD of 122W monochromatic amber LED luminaire

6.2.2.2 GONIOPHOTOMETER'S TEST:

6.2.2.2.1 EXPERIMENTAL SETUP:

Fig.6.13. (a)Goniophotometer Experimental setup

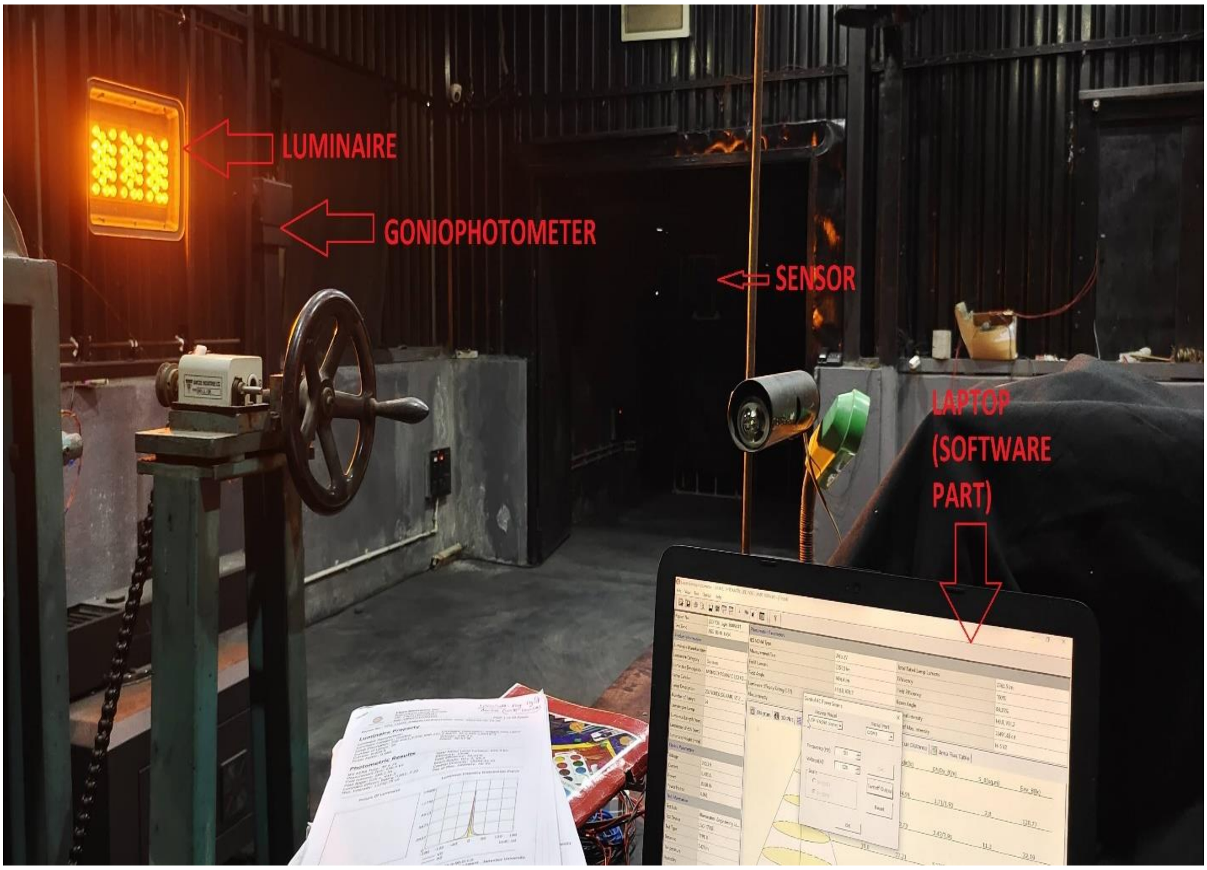


Fig.6.13. (b) Goniophotometer experimental setup showing luminaire and light sensor in our JADAVPUR UNIVERSITY ILLUMINATION Laboratory

6.2.2.2.2 EXPERIMENTAL RESULTS:

- **PHOTOMETRIC RESULTS:**

IES NEMA Type: 2H x 2V
Measurement Flux: 2363.5 lm
Field Lumens: 1426.4 lm
Field Angle: H18.8, V21.7
Luminaire Efficacy Rating (LER): 26.37
Max. Intensity: 39755.88 cd

Total Rated Lamp Lumens: 2363.5 lm
Efficiency: 100%
Field Efficiency: 60.35%
Beam Angle: H9.8, V11.2
Central Intensity: 33491.48 cd
Pos of Max. Intensity: H-5 V2

- **LUMINOUS INTENSITY DISTRIBUTION CURVE:**

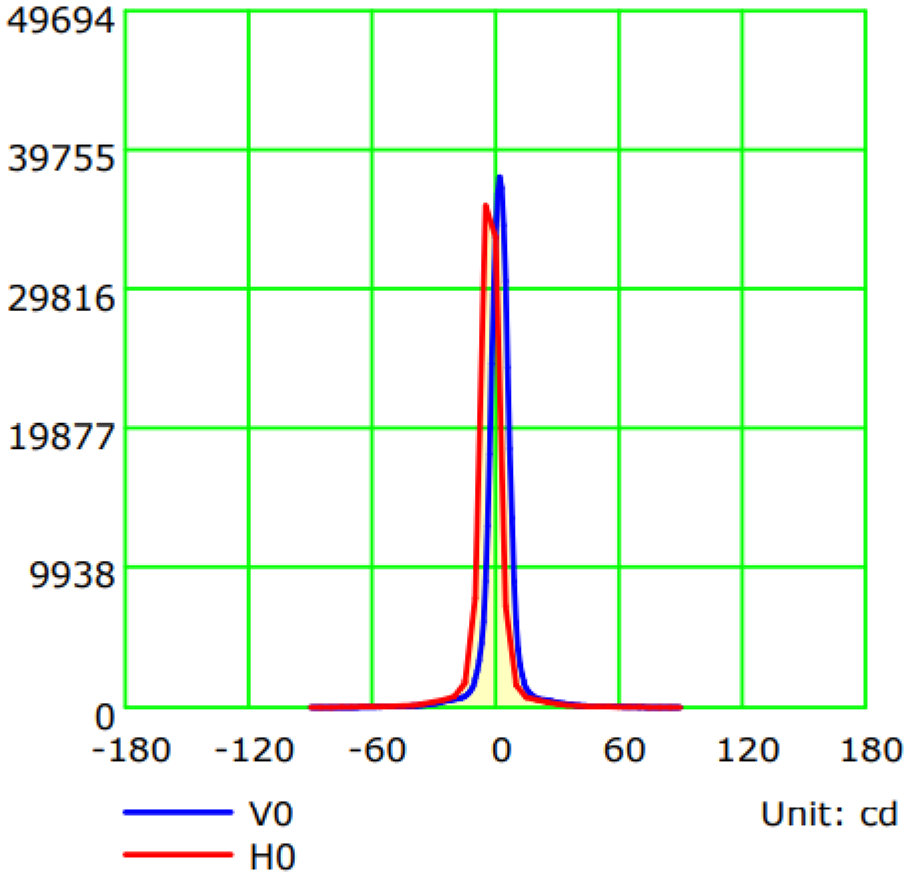


Fig.6.14.(a) Luminous intensity distribution curve

Luminous Intensity Distribution Curve

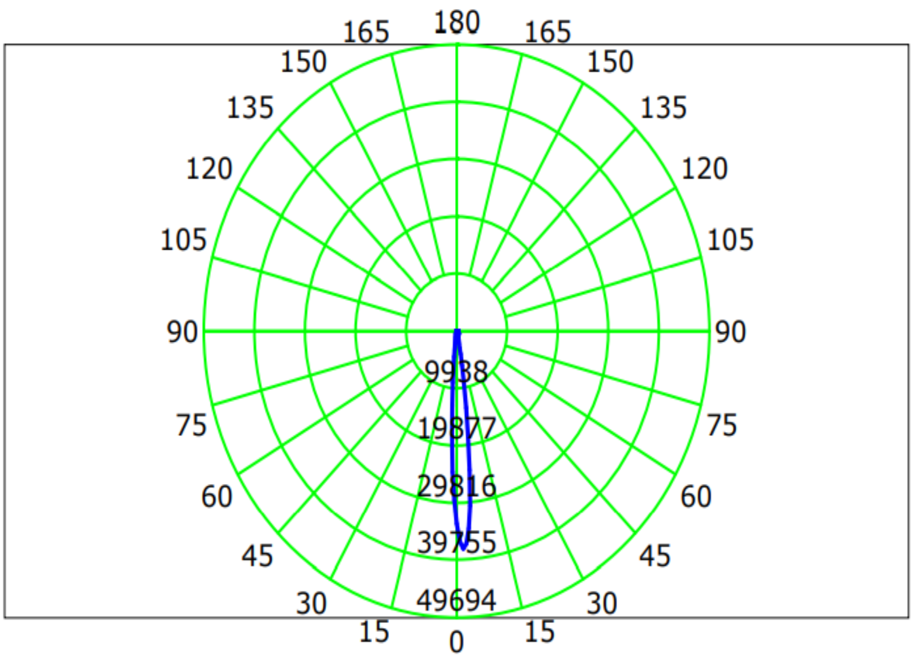


Fig.6.14. (b)

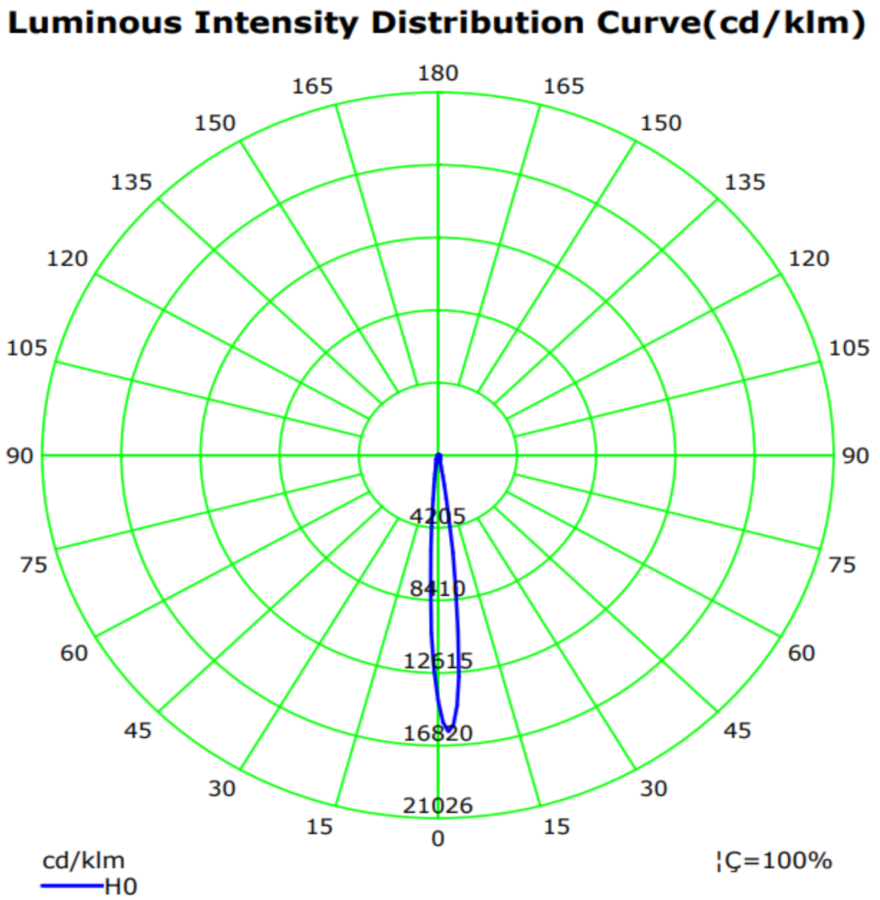


Fig.6.14. (c)

- **ISOCANDELA (RECTANGLE):**

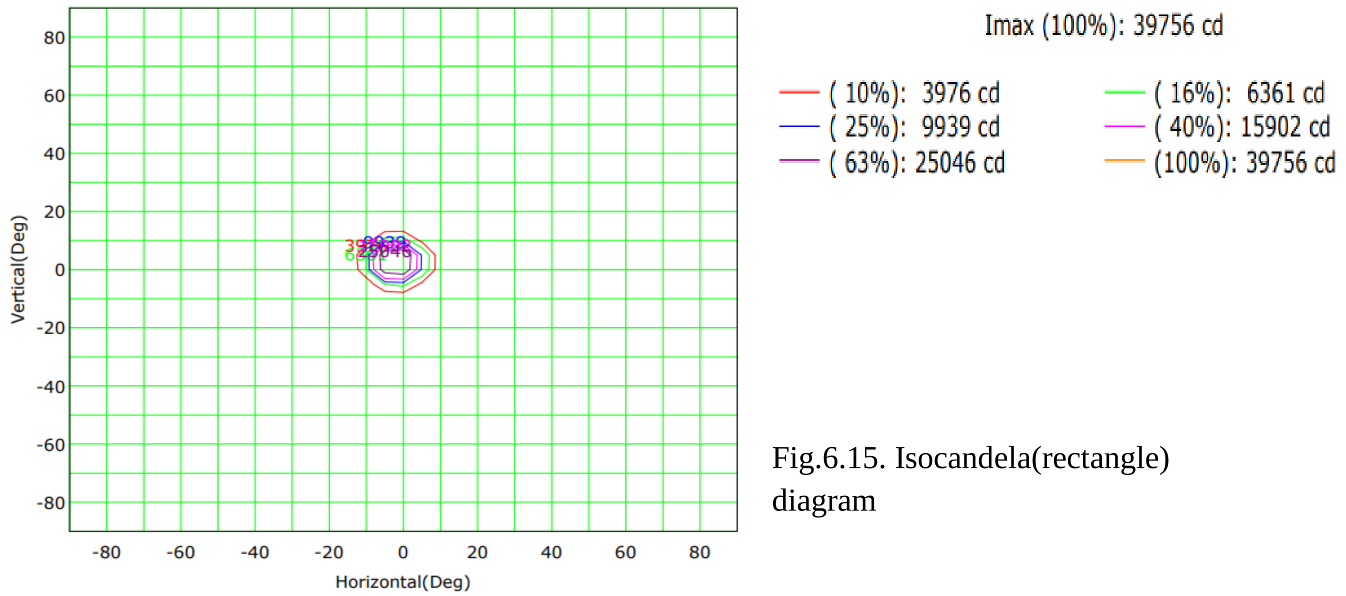


Fig.6.15. Isocandela(rectangle) diagram

- **ISOLUX PLOT:**

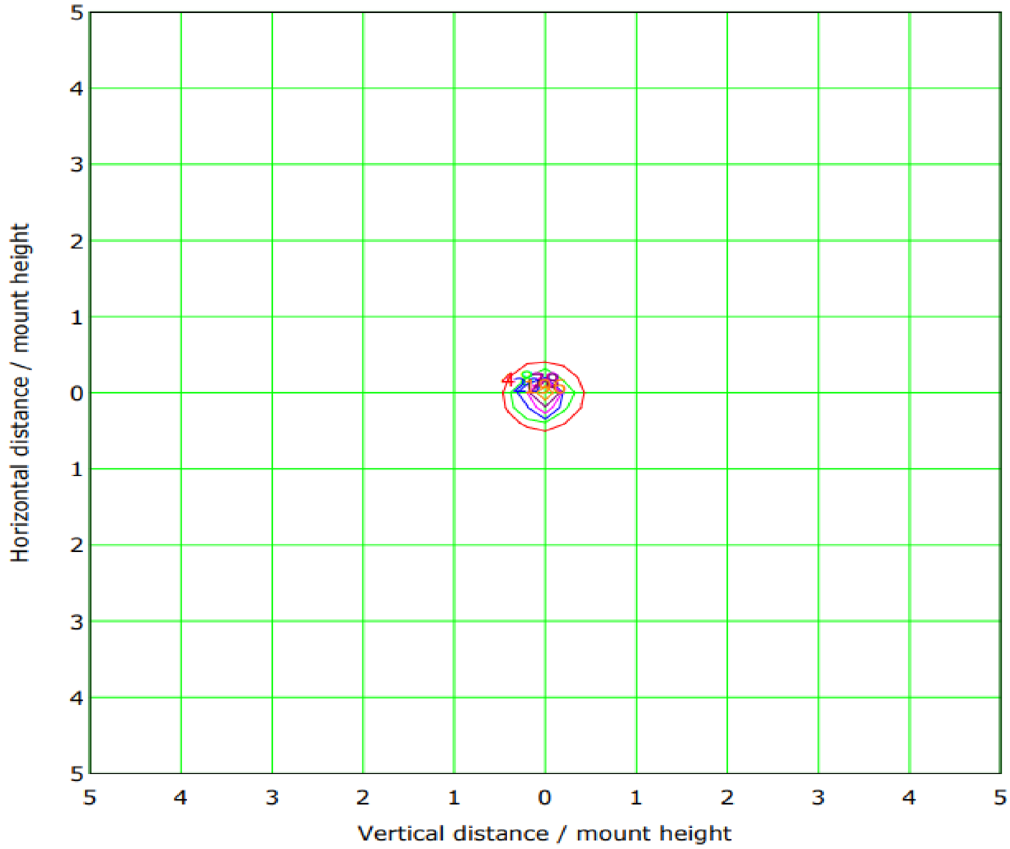


Fig.6.16.(a) IsoLux Plot

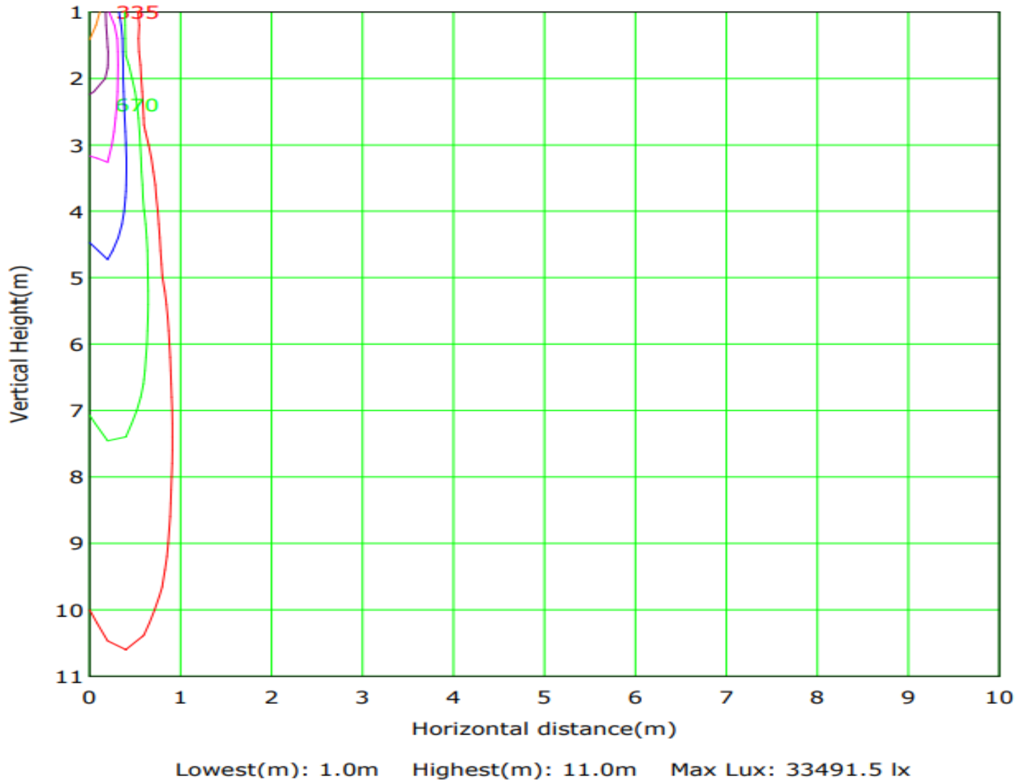


Fig.6.16. (b) Vertical IsoLux Plot

- **ILLUMINANCE AT DIFFERENT POSITION:**

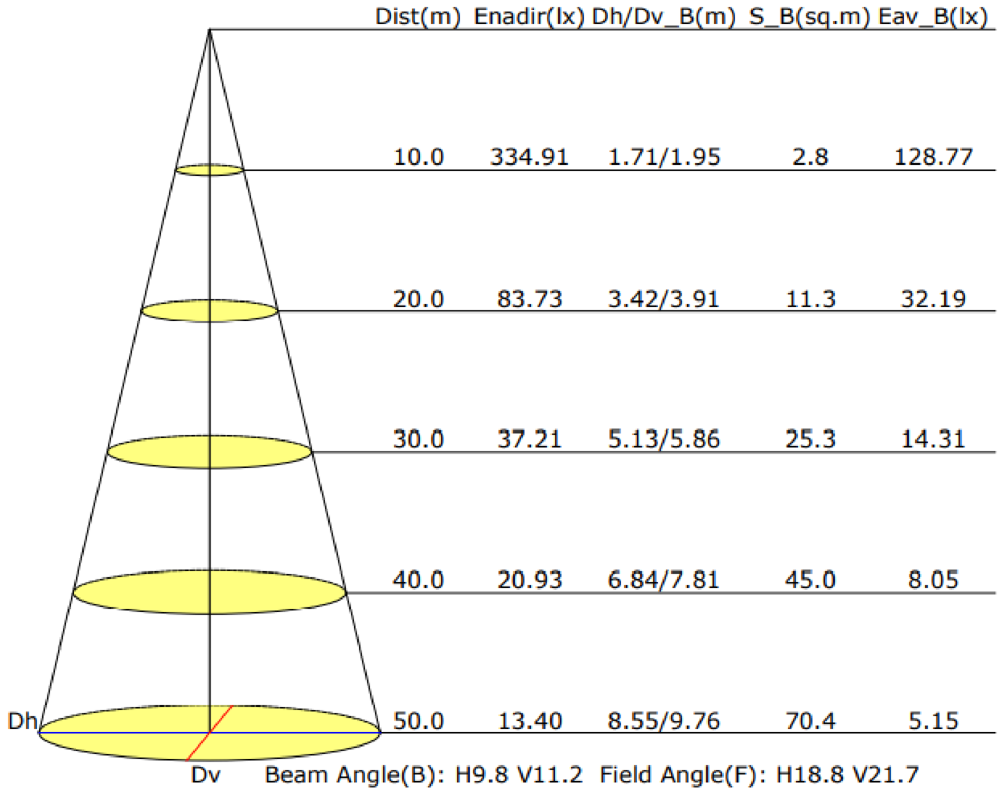


Fig.6.17. (a) Illuminance at a distance

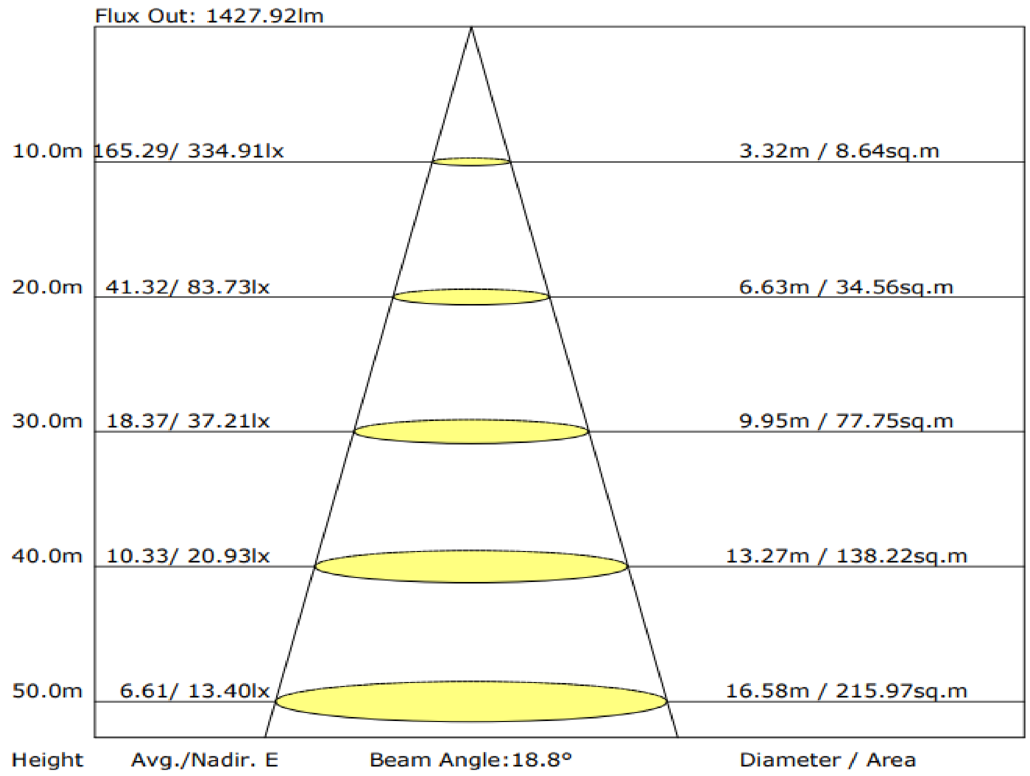


Fig.6.17. (b) The Average Illuminance Effective Figure

- **AREA FLUX TABLE:**

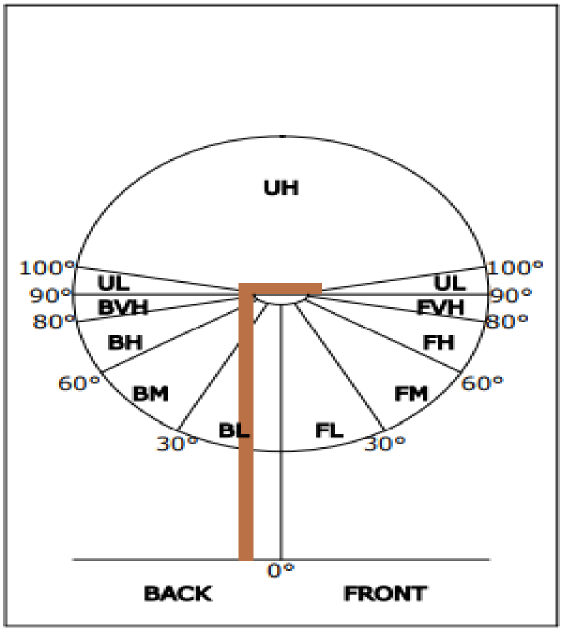
Unit: lm

Vertical plane \ Horizontal plane	-90 – -80	-80 – -70	-70 – -60	-60 – -50	-50 – -40	-40 – -30	-30 – -20	-20 – -10	-10 – 0	0 – 10	10 – 20	20 – 30	30 – 40	40 – 50	50 – 60	60 – 70	70 – 80	80 – 90	Flux(T)	Flux(E)
-90 – -80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
-80 – -70	0.0	0.0	0.0	0.1	0.3	0.6	0.9	1.0	1.0	0.9	0.9	0.8	0.6	0.4	0.1	0.0	0.0	0.0	7.7	0.0
-70 – -60	0.0	0.0	0.1	0.3	0.7	1.2	1.5	1.7	1.8	1.8	1.7	1.5	1.2	0.8	0.4	0.1	0.0	0.0	14.9	0.0
-60 – -50	0.0	0.0	0.1	0.5	1.0	1.5	1.9	2.3	2.5	2.6	2.3	2.0	1.6	1.2	0.6	0.3	0.0	0.0	20.4	0.0
-50 – -40	0.0	0.0	0.2	0.7	1.2	1.9	2.6	3.2	3.7	3.8	3.2	2.6	2.0	1.4	0.9	0.4	0.1	0.0	27.9	0.0
-40 – -30	0.0	0.0	0.3	0.8	1.5	2.3	3.7	5.9	7.9	8.2	6.6	4.2	2.6	1.7	1.0	0.4	0.1	0.0	47.4	0.0
-30 – -20	0.0	0.0	0.3	0.9	1.7	3.0	6.3	11.7	16.1	16.8	13.2	7.7	3.6	1.9	1.1	0.5	0.1	0.0	85.0	0.0
-20 – -10	0.0	0.0	0.3	0.9	1.9	3.9	9.6	18.4	53.6	80.3	24.7	12.1	5.1	2.2	1.1	0.5	0.1	0.0	214.8	52.3
-10 – 0	0.0	0.0	0.4	1.0	2.0	4.6	11.7	26.8	327.8	667.9	54.0	14.2	6.0	2.4	1.2	0.6	0.1	0.0	1120.9	978.2
0 – 10	0.0	0.1	0.4	1.1	2.0	4.4	11.0	23.4	162.1	296.9	37.2	13.3	5.7	2.4	1.3	0.6	0.1	0.0	561.9	396.0
10 – 20	0.0	0.0	0.3	0.9	1.8	3.3	7.9	15.1	23.6	25.7	17.0	9.7	4.4	2.1	1.2	0.5	0.1	0.0	113.7	0.0
20 – 30	0.0	0.1	0.4	0.9	1.6	2.6	4.7	8.2	11.5	11.9	9.3	5.7	3.1	1.9	1.1	0.5	0.1	0.0	63.4	0.0
30 – 40	0.0	0.1	0.4	0.9	1.5	2.2	3.1	4.1	5.1	5.4	4.5	3.4	2.4	1.7	1.0	0.5	0.1	0.0	36.4	0.0
40 – 50	0.0	0.0	0.2	0.6	1.0	1.6	2.0	2.4	2.8	2.8	2.6	2.2	1.7	1.2	0.7	0.3	0.1	0.0	22.1	0.0
50 – 60	0.0	0.0	0.1	0.4	0.8	1.2	1.5	1.8	1.9	1.9	1.8	1.7	1.3	0.9	0.5	0.2	0.0	0.0	16.0	0.0
60 – 70	0.0	0.0	0.0	0.1	0.2	0.5	0.8	1.0	1.1	1.2	1.1	1.1	0.8	0.4	0.1	0.0	0.0	0.0	8.4	0.0
70 – 80	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.4	0.3	0.2	0.1	0.0	0.0	0.0	0.0	2.5	0.0
80 – 90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Flux(T)	0.0	0.4	3.6	10.0	19.2	34.7	69.4	127.5	622.9	1128.6	180.7	82.5	42.5	22.6	12.3	5.3	1.0	0.0	2363	
Flux(E)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	435.0	976.7	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0		1426

- **ZONAL LUMEN TABLE:**

Gamma [°]	Imean [cd]	Zonal Flux [lm]	Sum Zonal Flux [lm]	Rel Zonal Flux [%]	Sum Rel Zonal Flux [%]
0.0-5.0	26496.6	633.5	633.5	26.80	26.80
5.0-10.0	12211.7	873.7	1507.2	36.97	63.77
10.0-15.0	3096.5	367.4	1874.6	15.54	79.31
15.0-20.0	964.4	159.0	2033.5	6.73	86.04
20.0-25.0	565.8	118.7	2152.2	5.02	91.06
25.0-30.0	400.2	101.3	2253.5	4.29	95.35
30.0-35.0	269.1	79.2	2332.8	3.35	98.70
35.0-40.0	176.8	59.0	2391.8	2.50	101.20
40.0-45.0	122.9	45.5	2437.3	1.93	103.12
45.0-50.0	94.0	38.0	2475.3	1.61	104.73
50.0-55.0	77.5	33.7	2509.0	1.43	106.16
55.0-60.0	64.2	29.7	2538.7	1.26	107.41
60.0-65.0	51.5	25.0	2563.7	1.06	108.47
65.0-70.0	40.0	20.2	2584.0	0.86	109.33
70.0-75.0	26.8	14.0	2598.0	0.59	109.92
75.0-80.0	12.0	6.4	2604.4	0.27	110.19
80.0-85.0	2.4	1.3	2605.7	0.06	110.25
85.0-90.0	0.0	0.0	2605.7	0.00	110.25

- **FLUX DISTRIBUTION TABLE BASED ON THE IESNA LUMINAIRE CLASSIFICATION SYSTEM:**



ZONE	LUMENS	% LAMP LUMENS
FORWARD LIGHT	1529	64.7
FL (0°-30°)	1340	56.7
FM (30°-60°)	153	6.5
FH (60°-80°)	36	1.5
FVH (80°-90°)	1	0.0
BACK LIGHT	920	38.9
BL (0°-30°)	758	32.1
BM (30°-60°)	132	5.6
BH (60°-80°)	30	1.3
BVH (80°-90°)	0	0.0
UP LIGHT	0	0.0
UL (90°-100°)	0	0.0
UH (100°-180°)	0	0.0
TRAPPED LIGHT	NA	NA

BUG(**B**acklight,**U**plight,**G**lare) Rating Base On TM-15-07	
Asymmetrical Luminaire Types (Type I,II,III,IV)	B2 U0 G0
Quadrilateral Symmetrical Luminaire Types (Type V,Area Light)	B2 U0 G0

- **LCS GRAPH:**

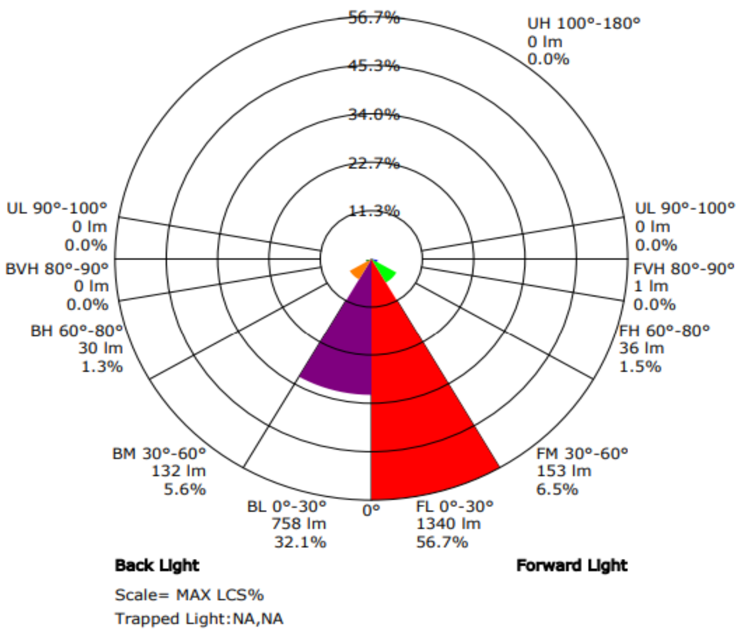


Fig.6.18. LCS Graph.

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6.2.3 CURRENTLY USED RAILWAY FOG LAMP WITH HALOGEN BULB LUMINAIRE:

6.2.3.1 LUMINAIRE DETAILS:

- Luminaire Manufacturer: BAPI PRODUCT
- Luminaire Category: Outdoor
- Luminaire Description: The car rally people (yellow) with halogen bulb.
- Number of halogen bulb: 1
- **ELECTRICAL DATA:**

  Voltage: 23.5 V(DC) Current: 2.458 A

  Power: 57.64 W Power Factor: 1

Fig.6.19. (a) Currently used railway fog lamp with halogen bulb luminaire

Fig.6.19. (b) Currently used railway fog lamp with halogen bulb luminaire in powered on condition.

- **COLOR COORDINATES:**

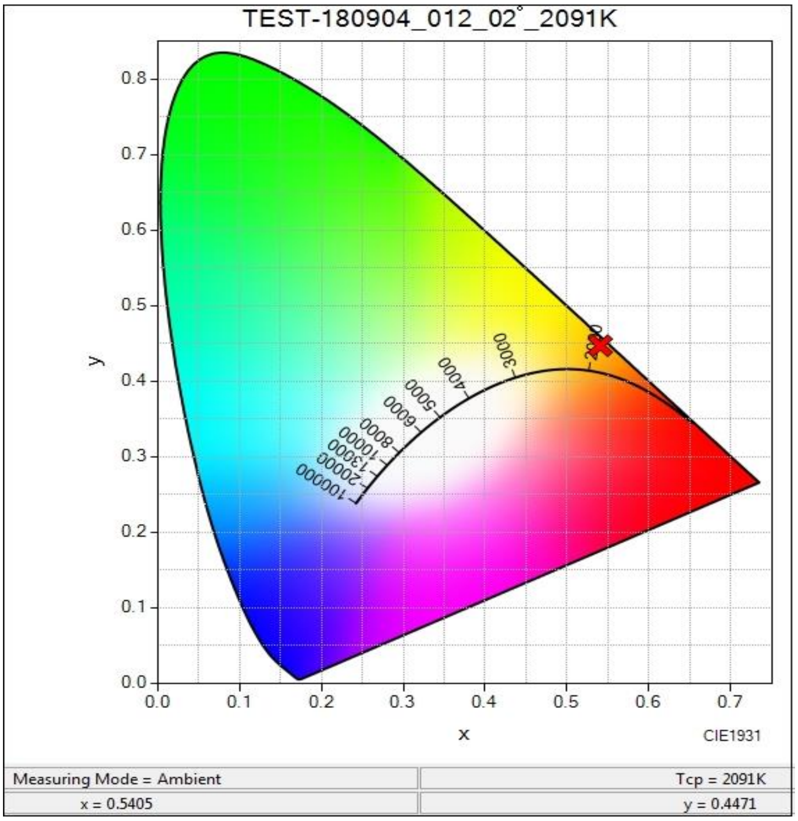


Fig.6.20. (a) CIE 1931 COLOR COORDINATES

(x = 0.5405,

y =0.4471,

z =0.0123)

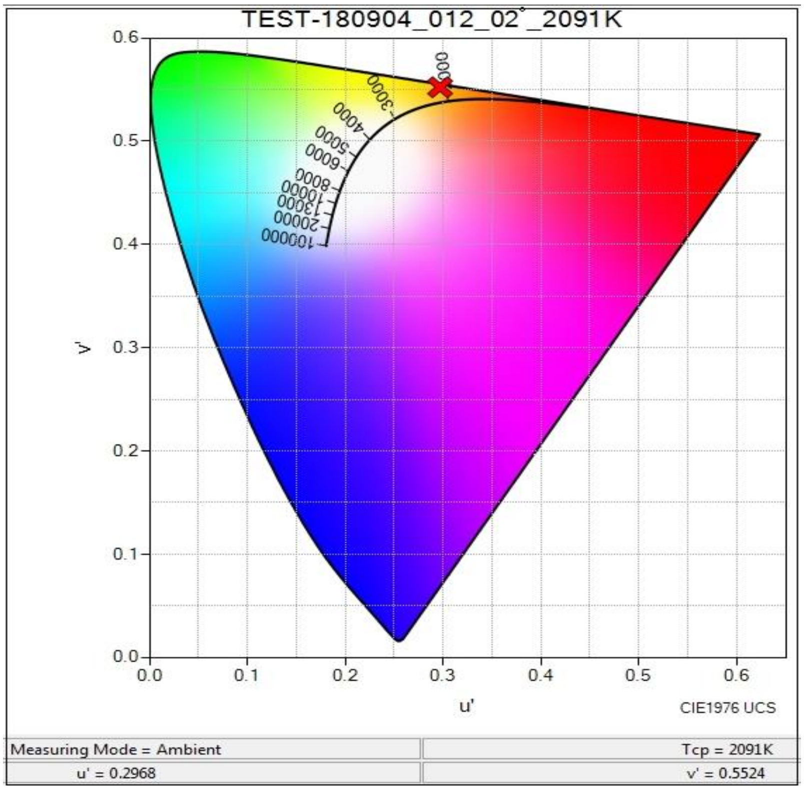


Fig.6.20. (b) CIE 1976 COLOR COORDINATES

(u' = 0.2968,

v' = 0.5524)

- **SPD:** FWHM = 180nm

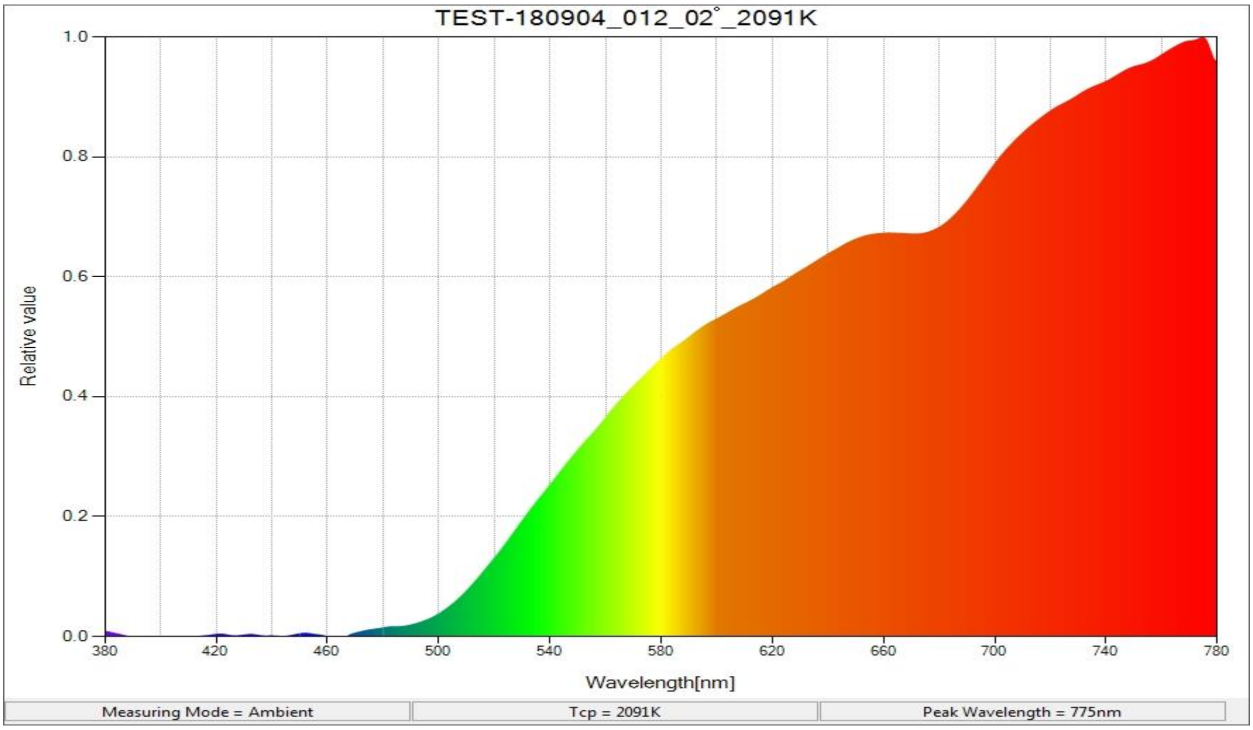


Fig.6.21. SPD of 122W monochromatic amber LED luminaire

- **COLOR RENDERING:**

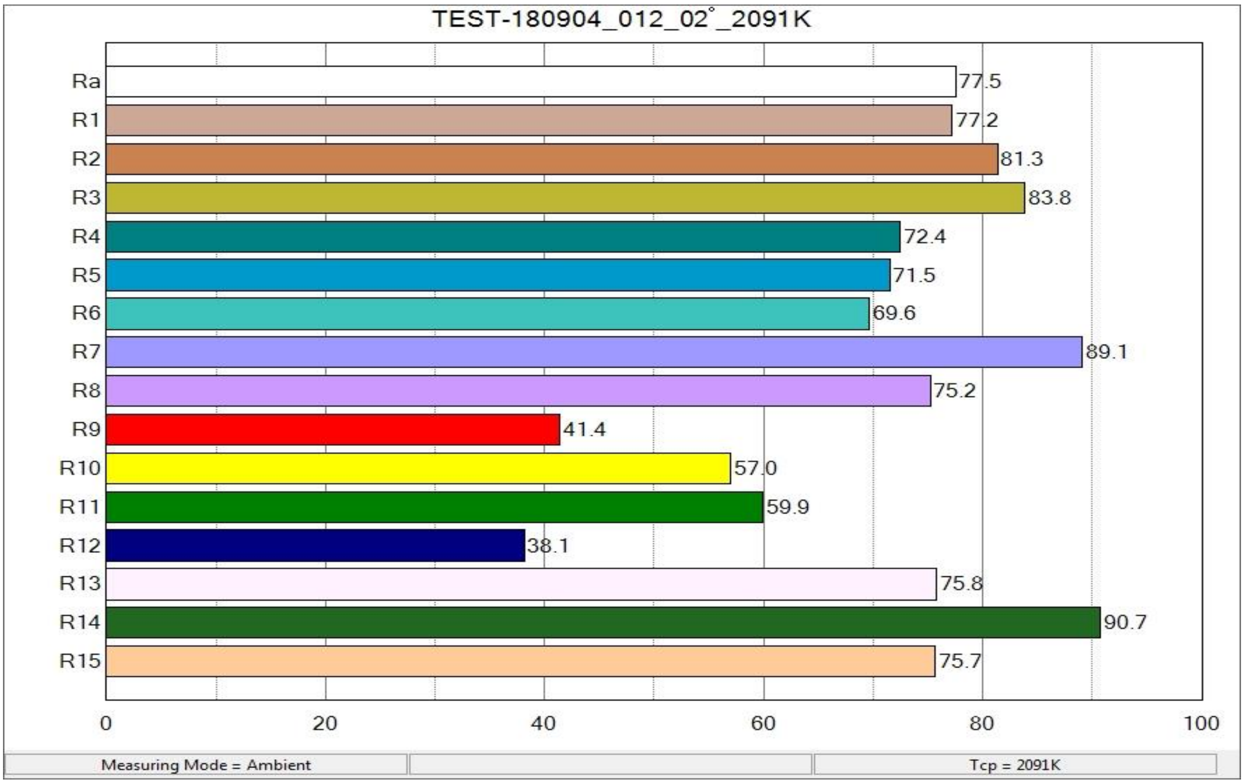


Fig.6.22. Color Rendering

6.2.3.2 GONIOPHOTOMETER’S TEST:

6.2.3.2.1 EXPERIMENTAL SETUP:

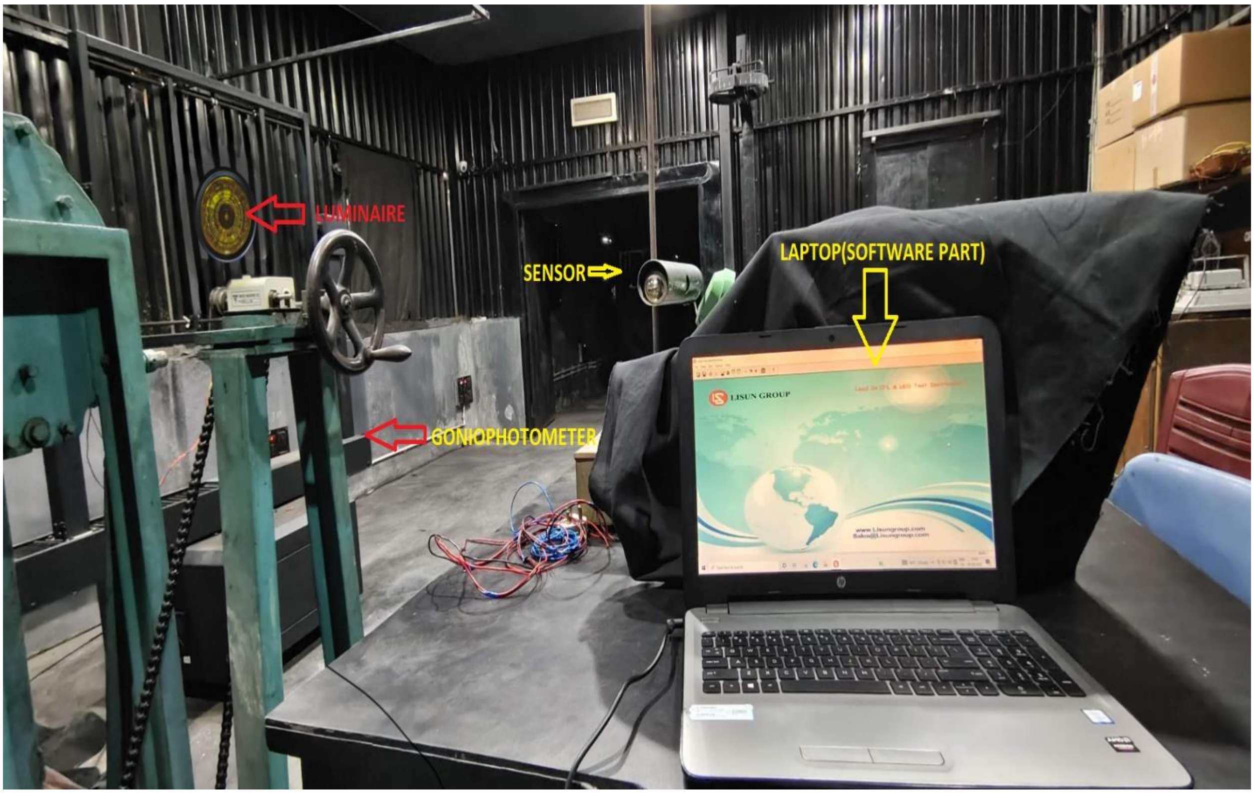


Fig.6.23. Goniophotometer experimental setup showing luminaire and light sensor in our JADAVPUR UNIVERSITY ILLUMINATION Laboratory

6.2.3.2.2 EXPERIMENTAL RESULTS:

- **PHOTOMETRIC RESULTS:**

IES NEMA Type: 3H x 3V	Total Rated Lamp Lumens: 358.9 lm
Measurement Flux: 358.9 lm	Efficiency: 100%
Field Lumens: 162.4 lm	Field Efficiency: 45.27%
Field Angle: H31.6, V30.0	Beam Angle: H12.4, V12.4
Luminaire Efficacy Rating (LER): 6.28	Central Intensity: 2237.86 cd
Max. Intensity: 2248.49 cd	Pos of Max. Intensity: H0 V1

- **LUMINOUS INTENSITY DISTRIBUTION CURVE:**

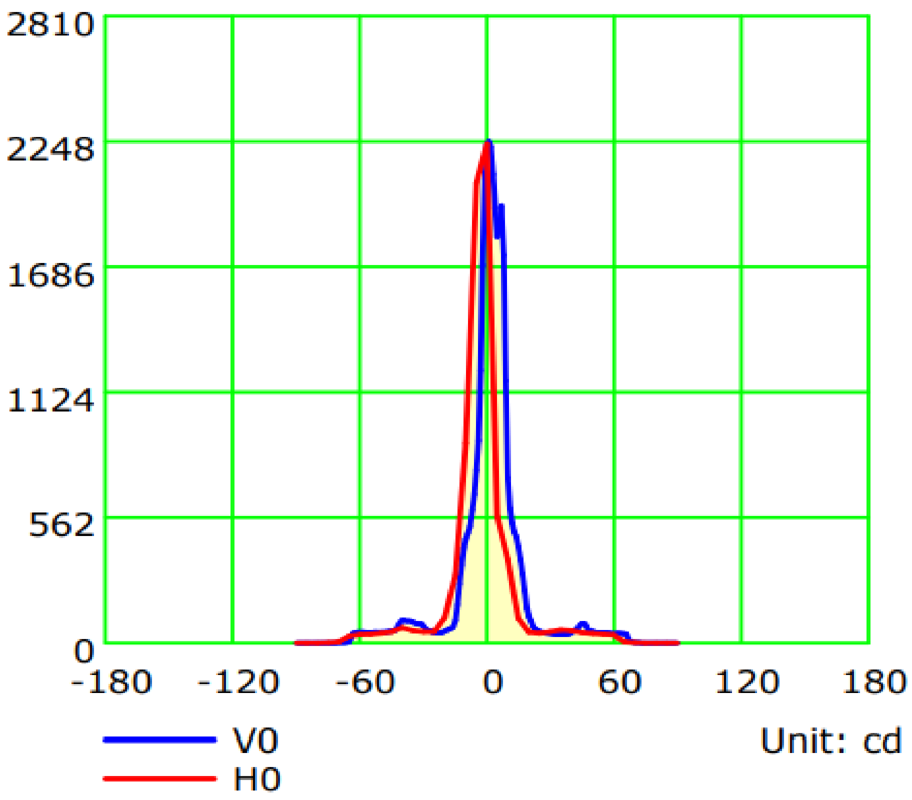


Fig.6.24. (a) Luminous intensity distribution curve

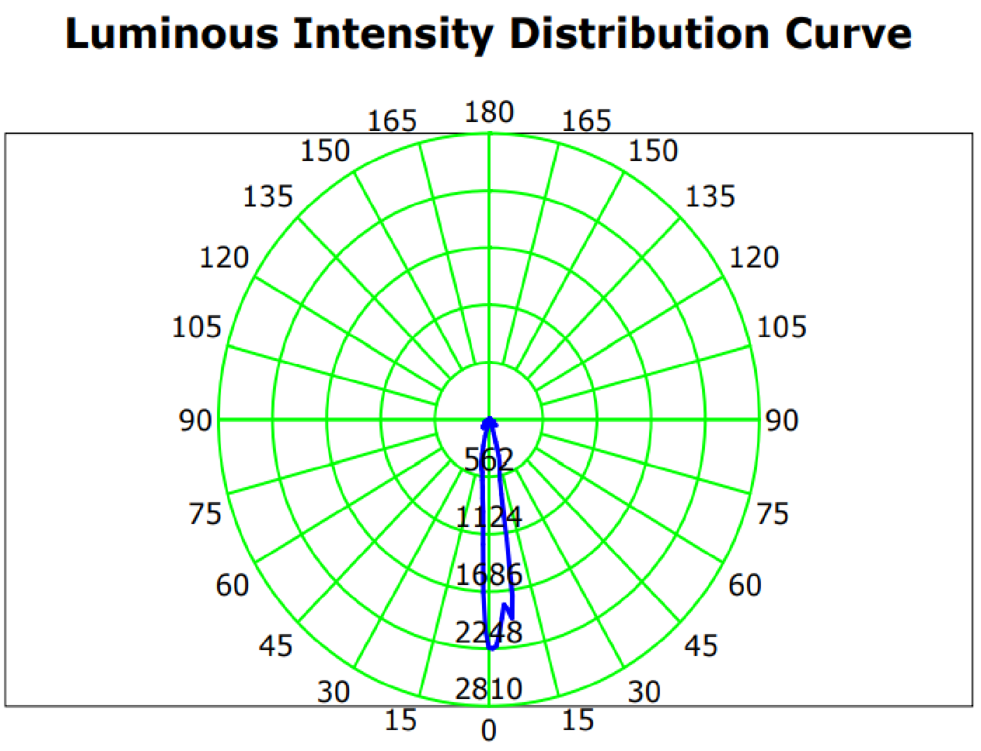


Fig.6.24. (b)

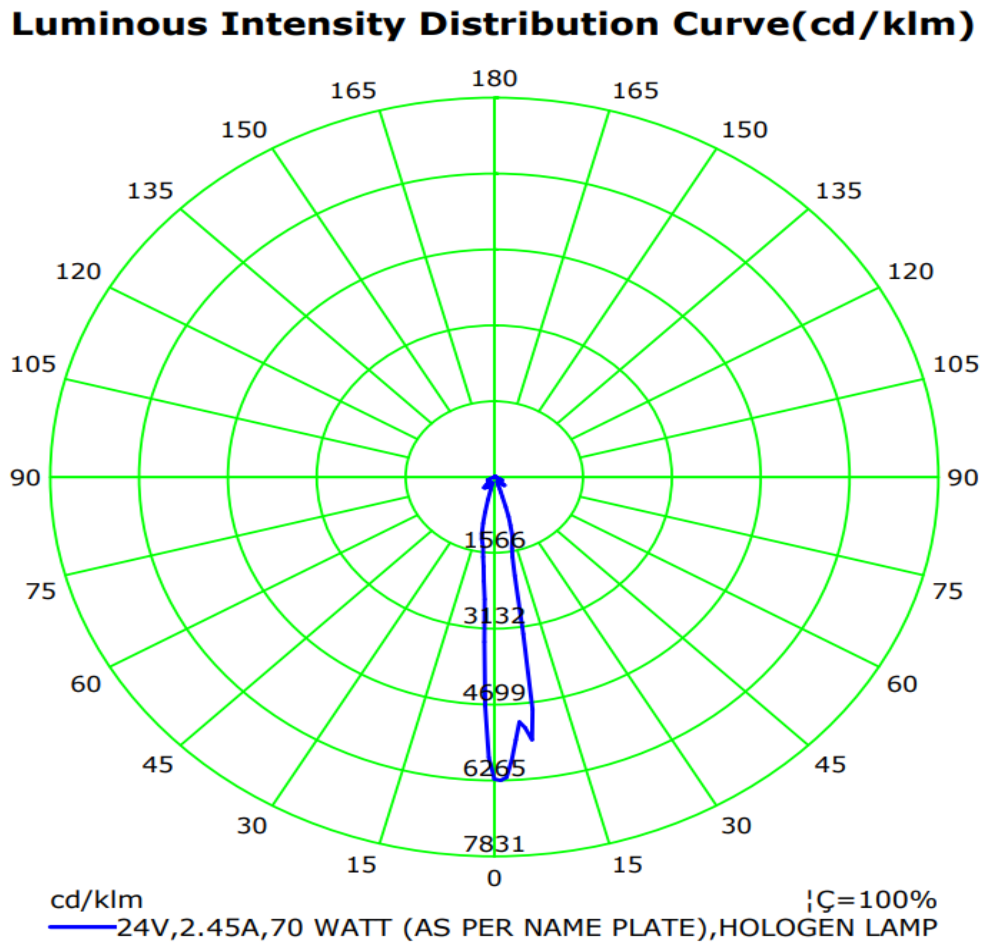


Fig.6.24.
(c)

- **ISOCANDELA (RECTANGLE):**

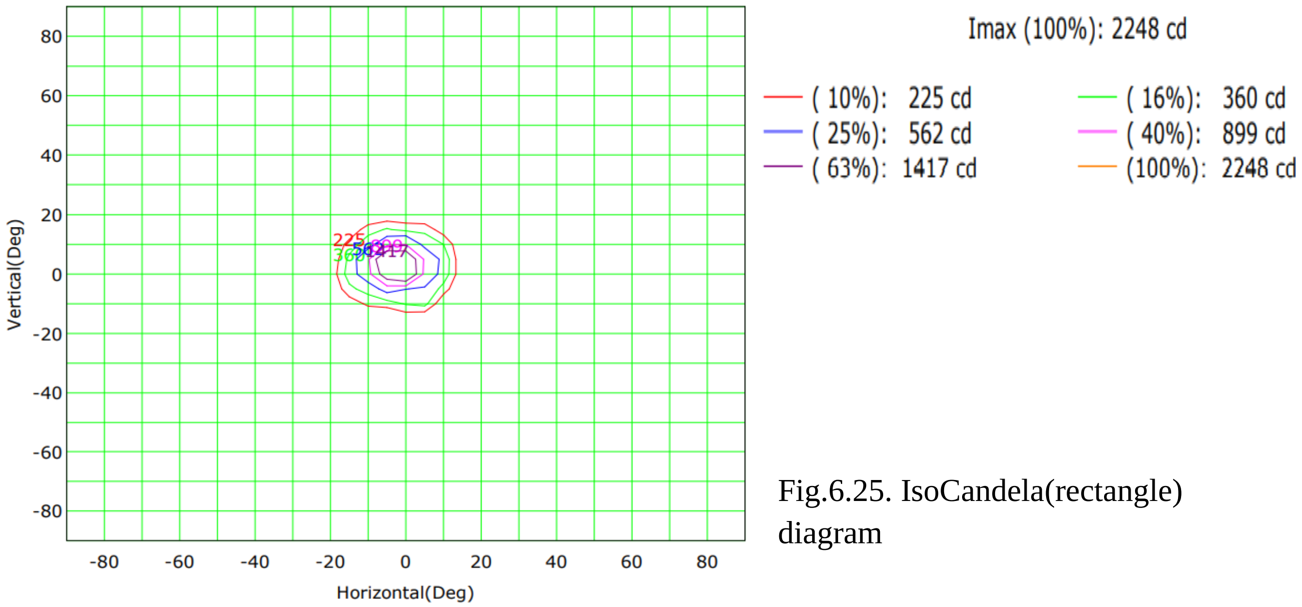


Fig.6.25. IsoCandela(rectangle) diagram

- **ISOLUX PLOT:**

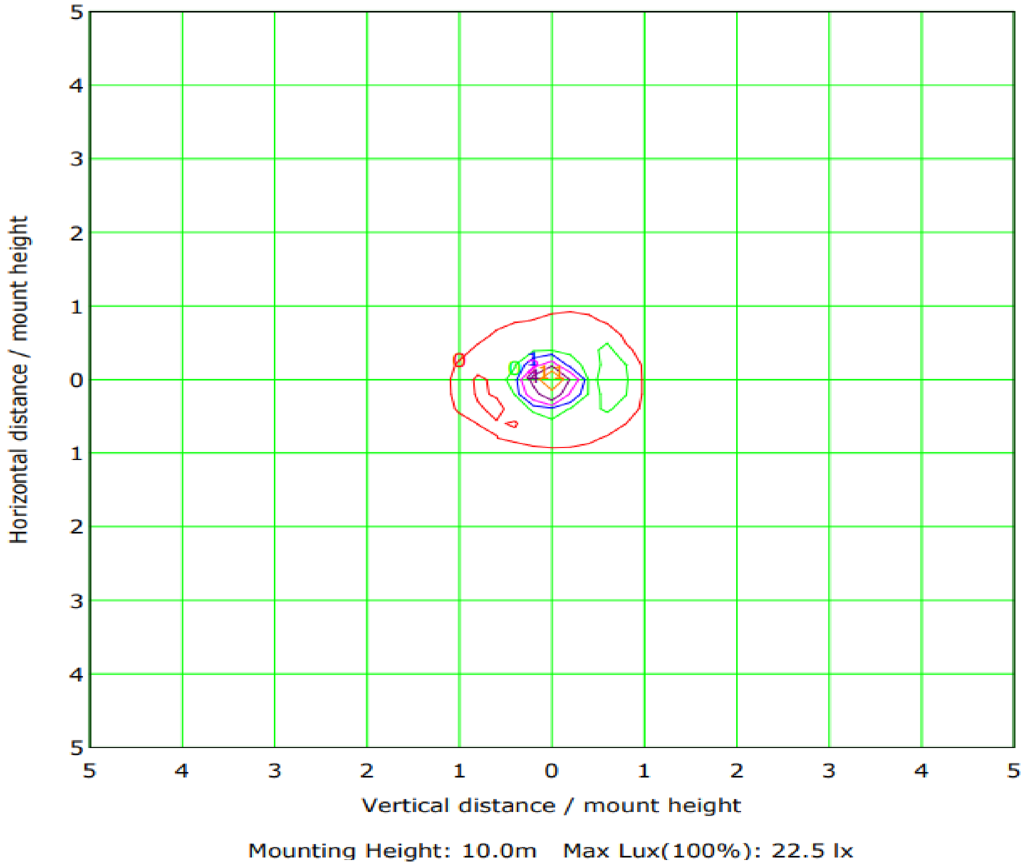


Fig.6.26. (a) IsoLux Plot

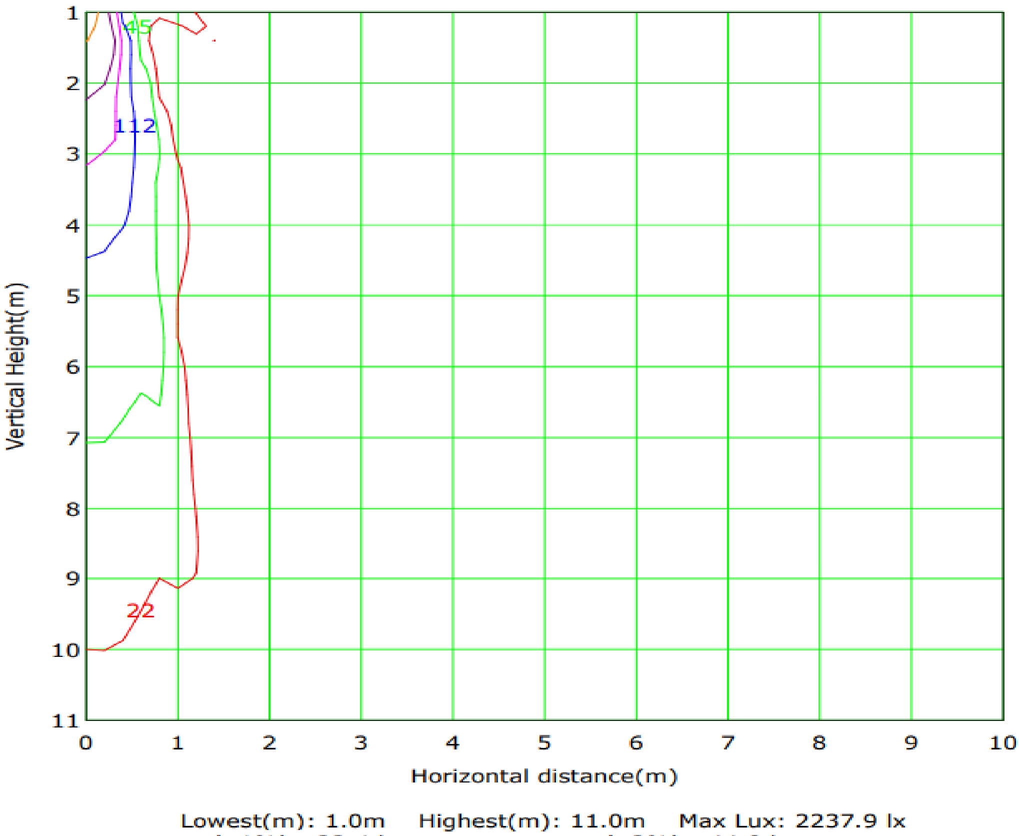


Fig.6.26. (b) Vertical IsoLux Plot

- **ILLUMINANCE AT DIFFERENT PSITION:**

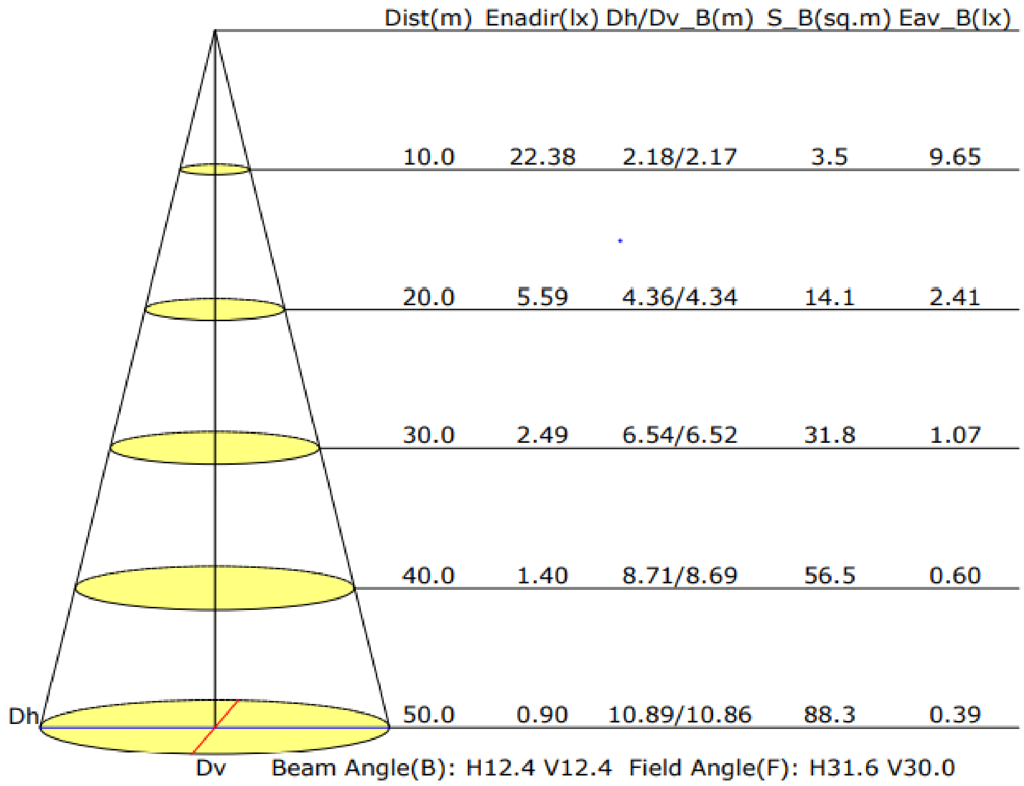


Fig.6.27. (a) Illuminance at a distance

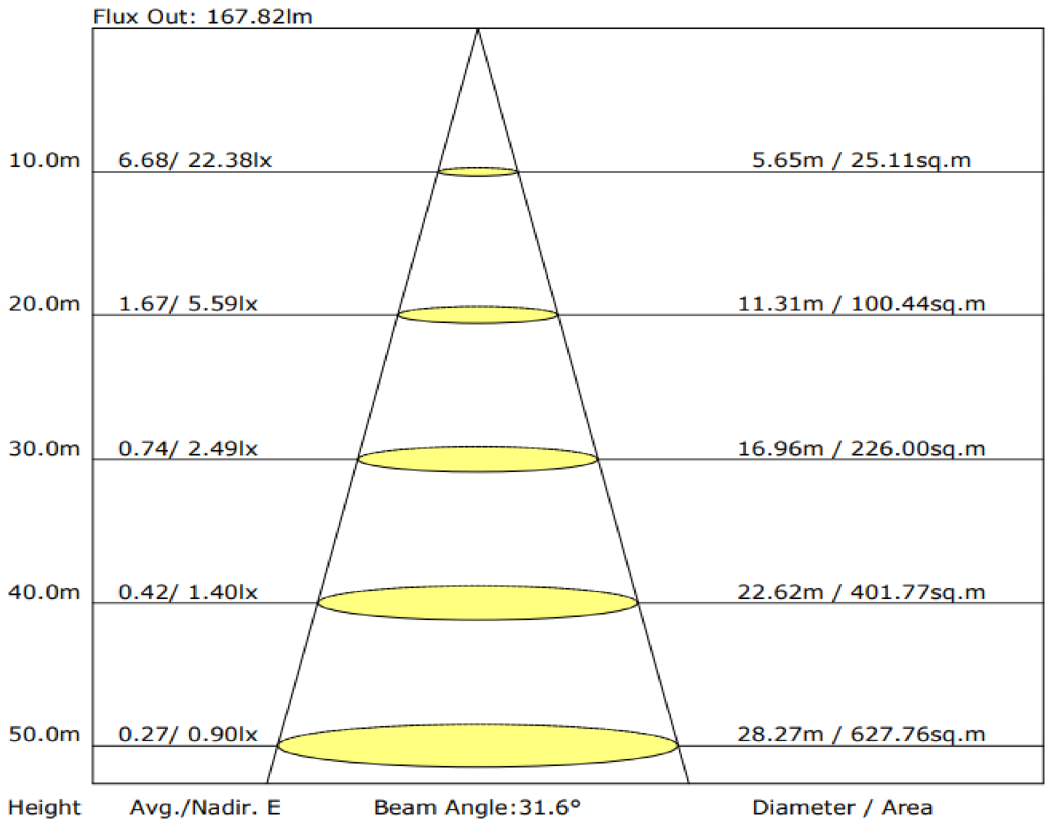


Fig.6.27. (b) The Average Illuminance Effective Figure

- **AREA FLUX TABLE:**

Unit: lm

Vertical plane \ Horizontal plane	-90 to -80	-80 to -70	-70 to -60	-60 to -50	-50 to -40	-40 to -30	-30 to -20	-20 to -10	-10 to 0	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	Flux(T)	Flux(E)
-90 to -80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
-80 to -70	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
-70 to -60	0.0	0.0	0.0	0.1	0.1	0.3	0.6	0.8	0.8	0.9	0.9	0.9	0.4	0.2	0.0	0.0	0.0	0.0	5.9	0.0
-60 to -50	0.0	0.0	0.0	0.1	0.6	1.0	1.1	1.2	1.2	1.3	1.3	1.2	1.1	0.8	0.2	0.0	0.0	0.0	11.1	0.0
-50 to -40	0.0	0.0	0.0	0.5	1.0	1.1	1.3	1.5	1.6	1.6	1.6	1.4	1.2	0.9	0.6	0.1	0.0	0.0	14.3	0.0
-40 to -30	0.0	0.0	0.1	0.8	1.0	1.3	1.9	2.0	1.9	1.7	1.5	1.5	1.5	1.0	0.8	0.2	0.0	0.0	17.2	0.0
-30 to -20	0.0	0.0	0.2	0.9	1.1	2.0	2.1	1.7	1.8	1.8	1.3	1.1	1.5	1.3	0.8	0.4	0.0	0.0	17.9	0.0
-20 to -10	0.0	0.0	0.3	0.9	1.3	2.4	1.8	2.3	9.0	11.5	4.5	1.2	1.1	1.5	0.9	0.4	0.0	0.0	39.0	19.9
-10 to 0	0.0	0.0	0.3	0.9	1.4	2.4	1.5	5.0	28.1	47.3	10.8	1.6	1.0	1.5	0.8	0.4	0.0	0.0	103.0	88.1
0 to 10	0.0	0.0	0.3	0.8	1.3	2.4	1.5	3.4	18.0	25.2	8.2	1.5	1.1	1.5	0.8	0.4	0.0	0.0	66.4	51.0
10 to 20	0.0	0.0	0.2	0.9	1.1	2.3	1.8	1.5	4.0	4.1	2.3	1.2	1.4	1.3	0.9	0.4	0.0	0.0	23.3	3.4
20 to 30	0.0	0.0	0.1	0.9	1.1	1.7	2.4	1.6	1.4	1.5	1.5	1.5	1.5	1.1	0.8	0.3	0.0	0.0	17.4	0.0
30 to 40	0.0	0.0	0.1	0.6	1.0	1.2	1.8	2.1	1.9	1.7	1.6	1.5	1.2	1.1	0.8	0.1	0.0	0.0	16.6	0.0
40 to 50	0.0	0.0	0.0	0.2	0.9	1.1	1.4	1.5	1.6	1.4	1.3	1.3	1.1	1.0	0.4	0.0	0.0	0.0	13.4	0.0
50 to 60	0.0	0.0	0.0	0.0	0.3	0.8	1.2	1.2	1.3	1.2	1.2	1.0	0.9	0.5	0.1	0.0	0.0	0.0	9.7	0.0
60 to 70	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.4	0.4	0.4	0.4	0.3	0.2	0.0	0.0	0.0	0.0	0.0	2.6	0.0
70 to 80	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0
80 to 90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Flux(T)	0.0	0.1	1.7	7.6	12.2	20.2	20.6	26.1	73.1	101.7	38.6	17.4	15.1	13.6	7.9	2.7	0.1	0.0	359	
Flux(E)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	55.1	84.3	18.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0		162

- **ZONAL LUMEN TABLE:**

Gamma [°]	Imean [cd]	Zonal Flux [lm]	Sum Zonal Flux [lm]	Rel Zonal Flux [%]	Sum Rel Zonal Flux [%]
0.0-5.0	26496.6	633.5	633.5	26.80	26.80
5.0-10.0	12211.7	873.7	1507.2	36.97	63.77
10.0-15.0	3096.5	367.4	1874.6	15.54	79.31
15.0-20.0	964.4	159.0	2033.5	6.73	86.04
20.0-25.0	565.8	118.7	2152.2	5.02	91.06
25.0-30.0	400.2	101.3	2253.5	4.29	95.35
30.0-35.0	269.1	79.2	2332.8	3.35	98.70
35.0-40.0	176.8	59.0	2391.8	2.50	101.20
40.0-45.0	122.9	45.5	2437.3	1.93	103.12
45.0-50.0	94.0	38.0	2475.3	1.61	104.73
50.0-55.0	77.5	33.7	2509.0	1.43	106.16
55.0-60.0	64.2	29.7	2538.7	1.26	107.41
60.0-65.0	51.5	25.0	2563.7	1.06	108.47
65.0-70.0	40.0	20.2	2584.0	0.86	109.33
70.0-75.0	26.8	14.0	2598.0	0.59	109.92
75.0-80.0	12.0	6.4	2604.4	0.27	110.19
80.0-85.0	2.4	1.3	2605.7	0.06	110.25
85.0-90.0	0.0	0.0	2605.7	0.00	110.25

6.3 OUTDOOR EXPERIMENT:

In this section I discussed about outdoor experimental setup and results.

6.3.1 EXPERIMENTAL SETUP WITH 4 MONOCHROMATIC LED LUMINAIRES:

Fig.6.28. (a) Railway tower van with fog lighting system setup consisting 4 monochromatic amber LED luminaires

- **APPARATUS USED:**

1. Railway tower van : maximum speed of 60 km/h
2. Luminaire:

   (a)122W monochromatic amber LED luminaires [mounting height: 3.154m] (1 pc.)

   (b) 90W monochromatic amber LED luminaires [mounting height: 2.311m] (in a line arrangement of 3 pcs.)

3. Lux/Fc light meter: Manufacturer- METRAVI
   Model no- 1332
4. Measurement tape of 50 meter

Fig.6.28. (b) Setup in Powered ON condition

Fig.6.28. (c) Measurement taken by me during experiment

.

- **EXPERIMENTAL RESULTS:**

Distance → (meter) / Types of Fog ↓	10	30	50	70	100	125	150	175	200	
No Fog	311	80.3	35.48	18.92	9.21	5.91	4.12	3.38	2.49	**Average Illuminance Values (Lux)**
Haze Fog	233	60.5	25	13.4	6.74	4.36	3.04	2.29	1.72	
Moderate Fog	188	88.8	20.2	10.8	5.44	3.51	2.45	1.81	1.28	
Dense Fog	131	34.2	14.1	7.55	3.81	2.86	1.72	1.27	0.97	

Table.6.1 Avg. Illuminance in certain distance**4 Amber LED fog lighting setups**

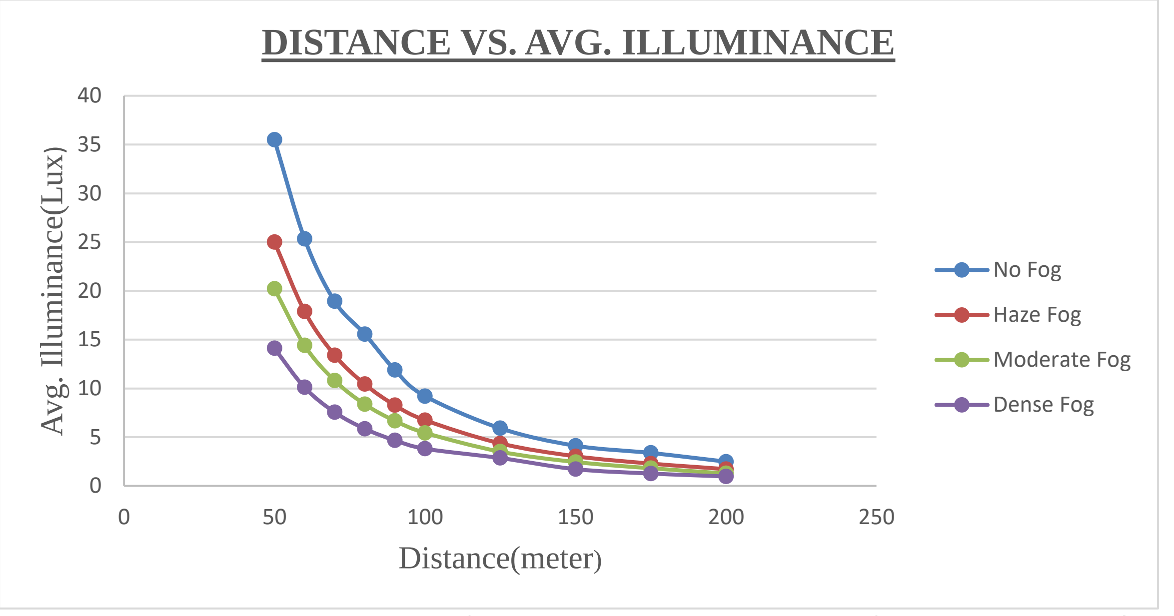


Fig.6.29. Graphical representation of Distance vs Avg. Illuminance for **4 Amber LED fog lighting setups** (For better results I take data from 50 meter to 200 meter).

- **VISIBILITY:** I observed that by this setup we can detect object very far.
  (a) No Fog: 1000meter
  (b) Haze Fog: 650meter
  (c) Moderate Fog: 500meter
  (d) Dense Fog: 250meter

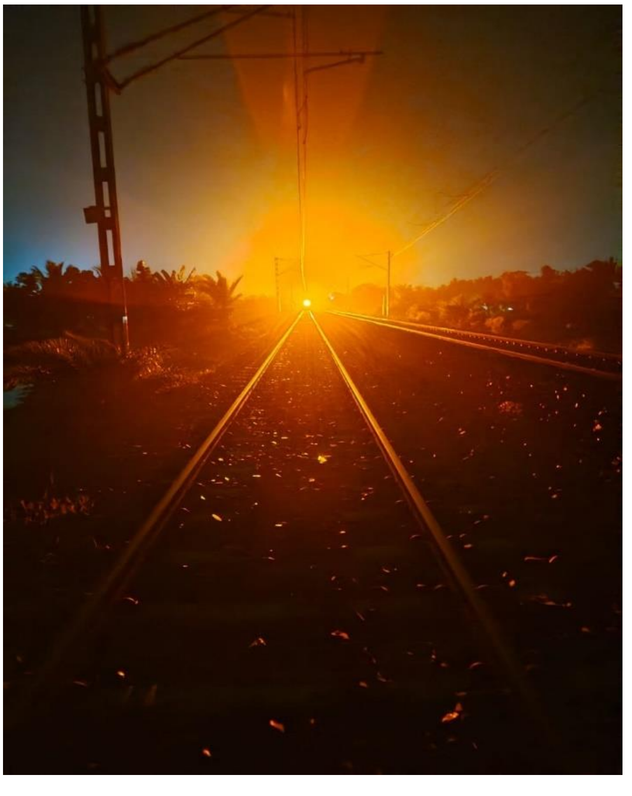


Fig.6.30. (a) Picture taken from 800 meter in normal weather condition

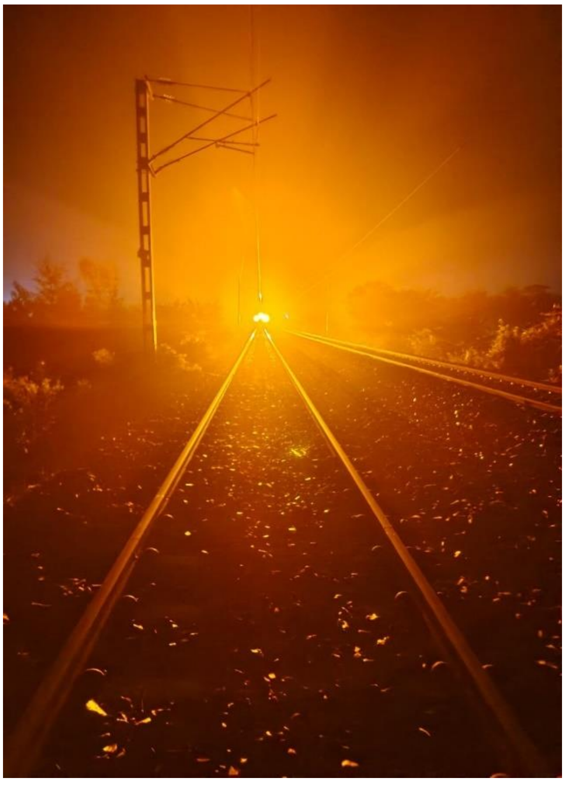


Fig.6.30. (b) Picture taken from 600 meter in foggy weather condition (haze fog).

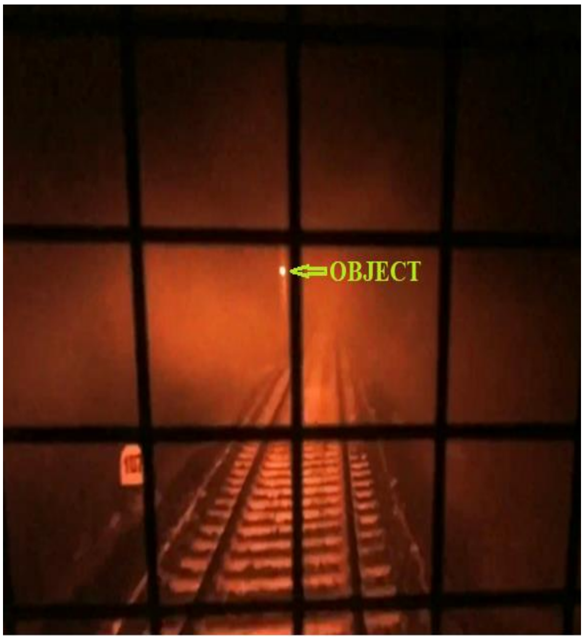


Fig.6.30(c) object detection in amber light
In dense fog(Picture taken from loco pilot's cabin)

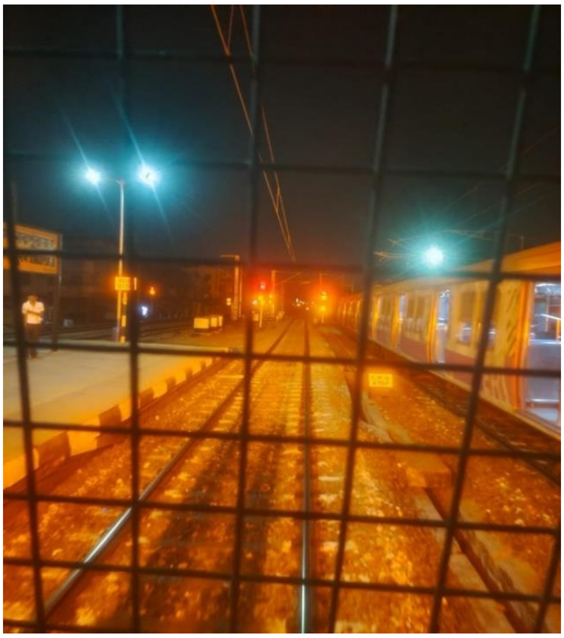


Fig.6.30(d) signal detection in amber light
(Picture taken from loco pilot's cabin)

6.3.2 EXPERIMENTAL SETUP WITH 90WATT MONOCHROMATIC LED LUMINAIRE:

Fig.6.31. Experimental setup with 90watt monochromatic LED luminaire

- **APPARATUS USED:**
  1. Railway tower van : maximum speed of 60 km/h
  2. Luminaire: 90W monochromatic amber LED luminaires
     Mounting height: 2.311m
  3. Lux/Fc light meter: Manufacturer- METRAVI
     Model no- 1332
  4. Measurement tape of 50 meter

- **EXPERIMENTAL RESULTS:**

Distance → (meter) / Types of Fog ↓	10	30	50	70	100	125	150	175	200	
No Fog	105.6	30.2	11.66	6.19	3.62	2.7	2.19	1.7	0.9	**Average Illuminance Values (Lux)**
Haze Fog	74	18	7.48	4.02	2.03	1.32	0.92	0.68	0.52	
Moderate Fog	59.7	14.5	6.03	3.24	1.64	1.06	0.74	0.55	0.42	
Dense Fog	41.8	10.1	4.22	2.27	1.15	0.74	0.52	0.38	0.29	

Table.6.2 Avg. Illuminance in certain distance for **90W monochromatic fog lighting setup**.

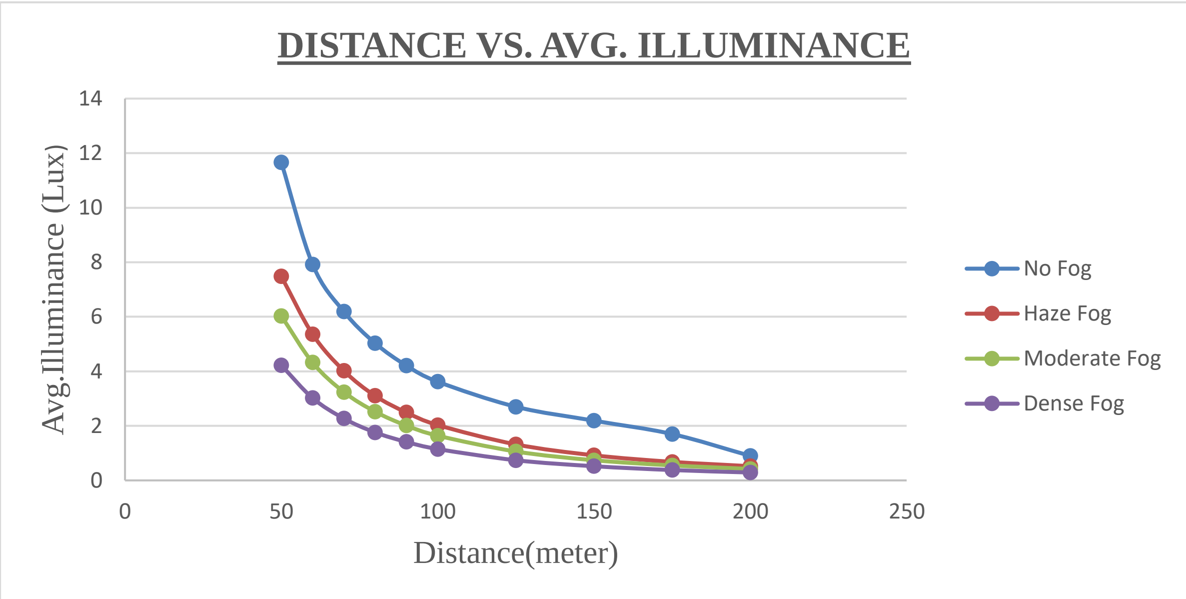


Fig.6.32. Graphical representation of Distance vs Avg. Illuminance for **90W monochromatic fog lighting setup** (For better results I take data from 50 meter to 200 meter)

- **VISIBILITY:** I observed that by this setup we can detect object:
  (a) No Fog: 200M
  (b) Haze Fog: 175M
  (c) Moderate Fog: 150M
  (d) Dense Fog: 125M

6.3.3 EXPERIMENTAL SETUP WITH CURRENTLY USED RAILWAY FOG LAMP WITH HALOGEN BULB LUMINAIRE:

Fig.6.33(a). Experimental setup with currently used fog lamp with halogen bulb luminaire

- **APPARATUS USED:**
  1. Railway tower van : maximum speed of 60 km/h
  2. Luminaire: currently used fog lamp with halogen bulb luminaire
     Mounting height:2.311m
  3. Lux/Fc light meter: Manufacturer- METRAVI
     Model no- 1332
  4. Measurement tape of 50 meter

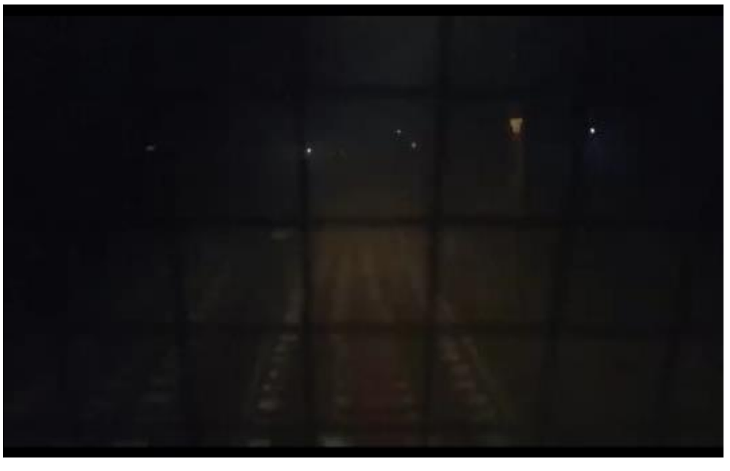


Fig.6.33(b). Picture taken from loco pilot's cabin in **haze fog** condition when **halogen fog lamp** in powered on condition (**light level and visibility is too low**).

- **EXPERIMENTAL RESULTS:**

Distance → (meter) / Types of Fog ↓	10	30	50	70	100	125	150	175	200	
No Fog	9.12	2.11	0.71	0.22	0.1					**Average Illuminance Values (Lux)**
Haze Fog	6.87	1.09	0.42	0.18						
Moderate Fog	5.54	0.88	0.3	0.15						
Dense Fog	3.88	0.61	0.18							

Table.6.3 Avg. Illuminance in certain distances. (Blank spaces represents very low Lux value)

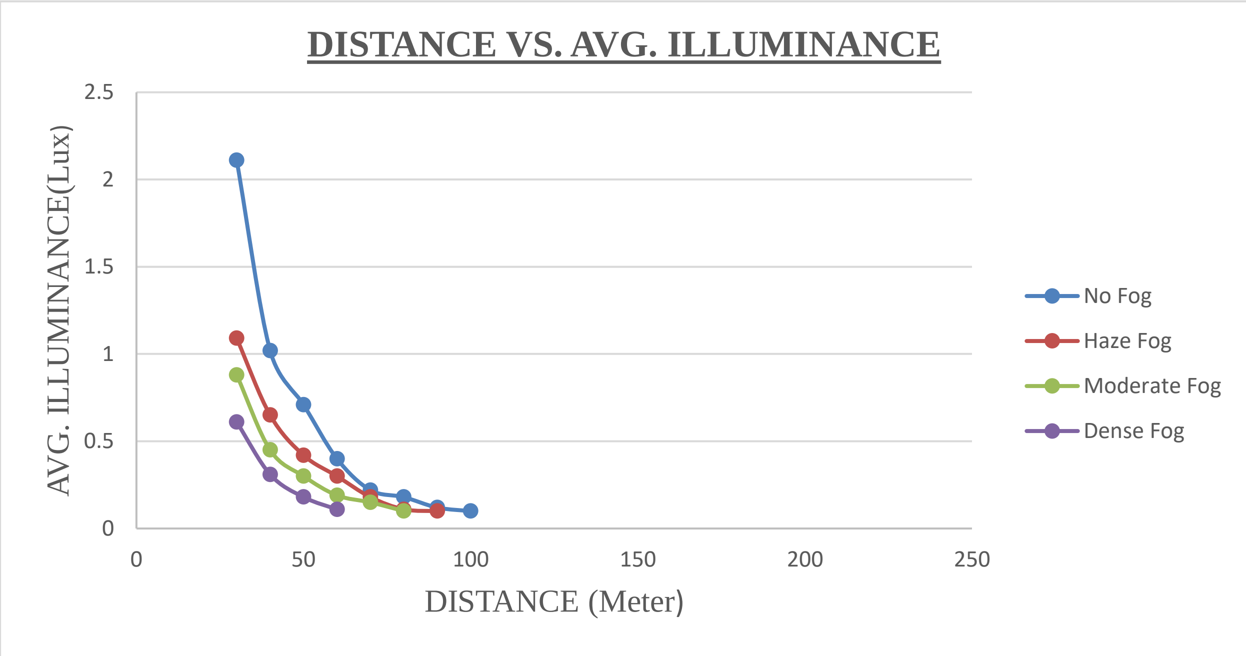


Fig.6.34. Graphical representation of Distance vs Avg. Illuminance for **currently used fog lamp with halogen bulb luminaire** (For better plot I take data from 50 meter to 200 meter).

- **VISIBILITY:** I observed that by this setup we can detect object:
  - (a) No Fog: 40m
  - (b) Haze Fog: 30m
  - (c) Moderate Fog: 25m
  - (d) Dense Fog: 20m

  Performance of this light is very poor.

6.4 COMPARATIVE STUDY:

6.4.1 COMPARISON IN NORMAL WEATHER CONDITION (NO FOG):

I can compare the avg. illuminance values of outdoor experiment with the simulated results of our proposed setup.

DISTANCE (meter)→ FOG LIGHTING SETUP↓	10	30	50	70	100	125	150	175	200	
Single fog light(90W)	95.5	23.2	9.66	5.19	2.62	1.7	1.19	0.87	0.67	AVG. ILLUMINANCE (Lux)
Single fog light(122W)	77.7	13.5	4.43	2.13	0.98	0.61	0.41	0.3	0.23	
Double fog light(horizontally)(180W)	127	41.4	18.2	9.95	5.09	3.32	2.33	1.72	1.32	
Double fog light(vertically)(212W)	173	36.6	14.1	7.32	3.61	2.31	1.6	1.17	0.9	
Triple fog light(horizontally)(270W)	223	64.6	27.8	15.1	7.72	5.01	3.51	2.59	2	
Triple fog light(triangular)(302W)	205	54.9	22.6	12.1	6.08	3.93	2.74	2.02	1.55	
4 fog light(392W)	300	78.1	32.3	17.3	8.7	5.62	3.92	2.89	2.22	

Table.6.4 **Simulated data** of Avg. Illuminance in certain distances.

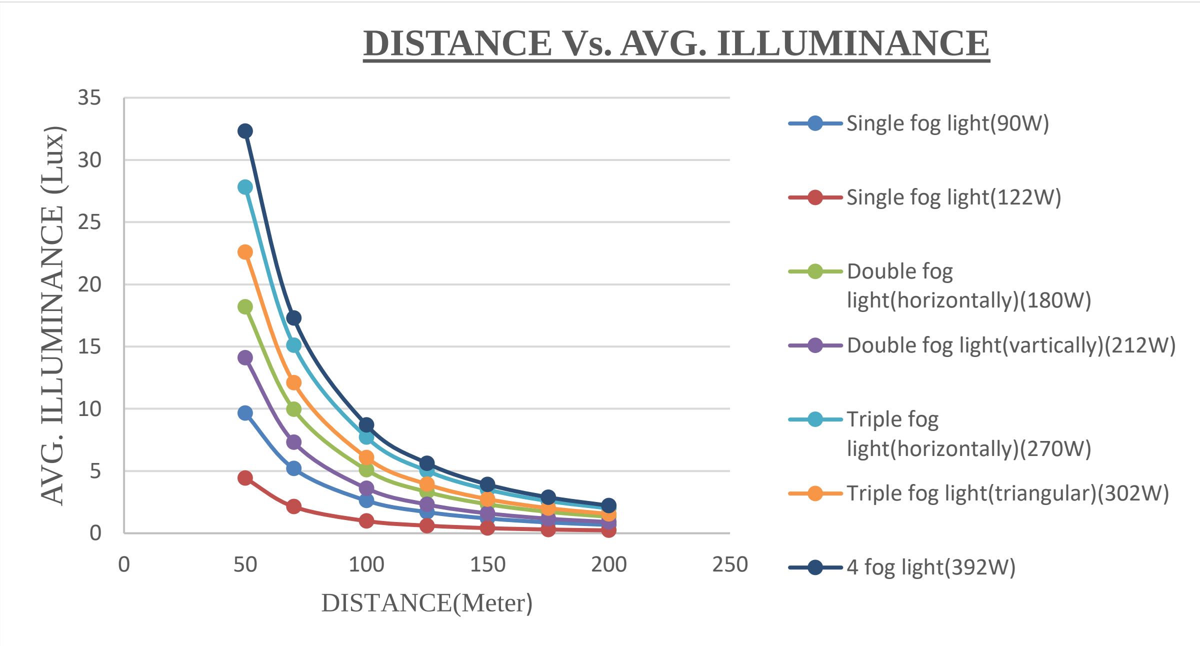


Fig.6.35. Graphical representation of Distance vs Avg. Illuminance of **simulated data** (For better plot I take data from 50 meter to 200 meter)

DISTANCE (meter)→ FOG LIGHTING SETUP↓	10	30	50	70	100	125	150	175	200	
Single fog light(90W)	206	25.7	9.2	4.5	2	1.2	0.7	0.4	0.3	
Single fog light(122W)	26.5	7.9	3.3	1.9	0.9	0.6	0.4	0.2	0.1	
Double fog light(horizontally)(180W)	58	32.1	15.3	8.3	4.2	2.6	1.8	1.3	0.9	**AVG.**
Double fog light(vertically)(212W)	167	29.2	11.4	6.1	3.1	2	1.3	0.9	0.6	**ILLUMINANCE**
Triple fog light(horizontally)(270W)	77.9	38.4	17.7	9.9	5	3.1	2.1	1.5	1	**(Lux)**
Triple fog light(triangular)(302W)	113	52.4	22.8	12	5.5	3.4	2.4	1.6	1.1	
4 fog light(392W)	311	80.3	35.5	19	9.2	5.91	4.12	3.18	2.49	

Table.6.5 **Outdoor experimental data** of Avg. Illuminance in certain distances.

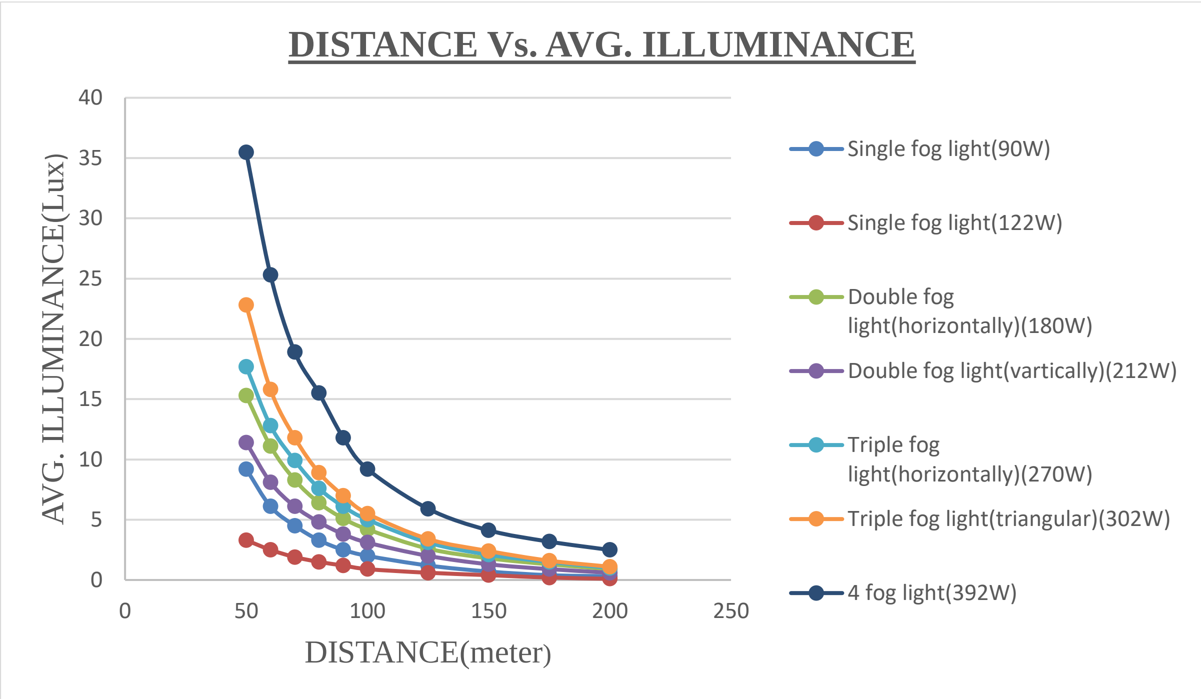


Fig.6.36. Graphical representation of Distance vs Avg. Illuminance of **Outdoor experimental data** (For better plot I take data from 50 meter to 200 meter)

By comparing above table's (table.6.4 & table.6.5) data, I can clearly say that simulated results and outdoor experimental results are almost same but some error is there due to noise during experiment (like stray light effect etc). From this comparison I can conclude that the goniophotometer's generated ies file of luminaire's are properly work and give me the comparable simulated and experimental data of my experimental setup.

From the above plots (fig.6.34 & fig.6.35) I can clearly see that four-fog light setup gives the better results in comparison of other lighting setups. 90W monochromatic amber luminaire gives the far better results in comparison of 122W monochromatic amber luminaire.

6.4.2 COMPARISON IN FOGGY WEATHER CONDITION:

6.4.2.1 COMPARISON IN HAZE FOG WEATHER CONDITION:

Distance → (Meter) / Experimental setup ↓	10	30	50	70	100	125	150	200		Visibility (Meter)
4 Amber LED setup	233	60.5	25	13.4	6.74	4.36	3.04	1.72	Average	650
single 90W Amber LED setup	74	18	7.48	4.02	2.03	1.32	0.92	0.52	Illuminance	175
60W halogen fog lamp setup	6.87	1.09	0.42	0.18					(Lux)	30

Table.6.6 Outdoor experimental data of Avg. Illuminance in certain distances in haze fog for different experimental setups.

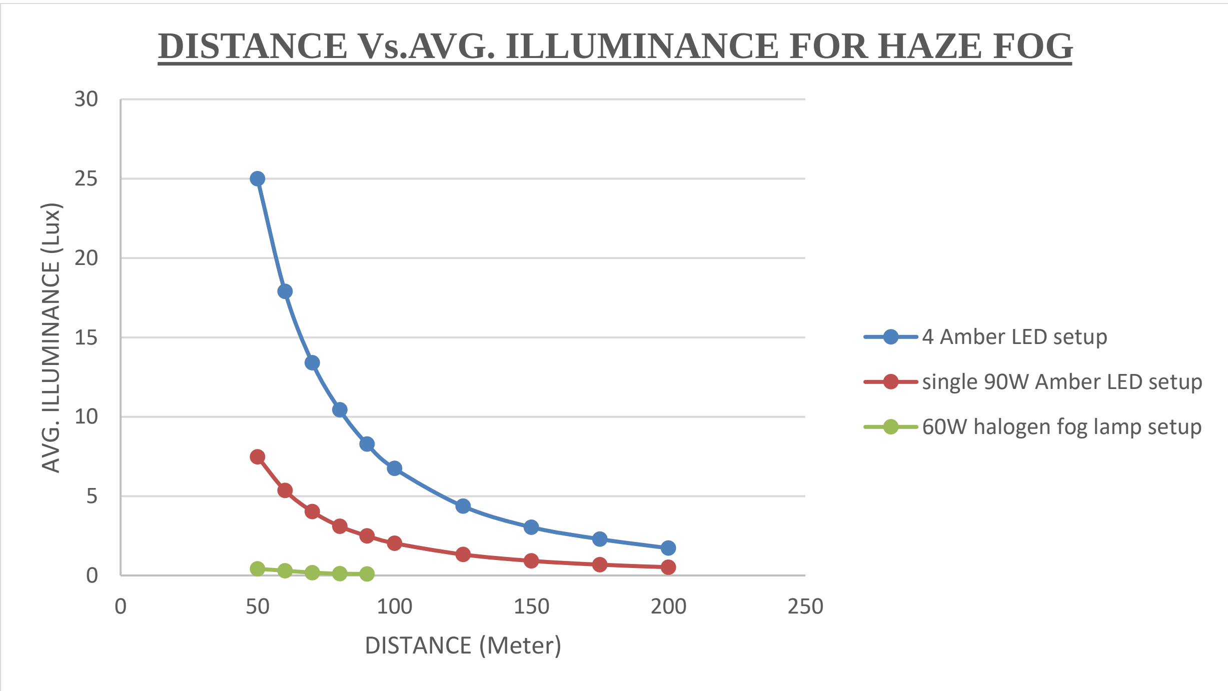


Fig.6.37.Graphical representation of Distance vs Avg. Illuminance of **Outdoor experimental data** in **haze fog** for different experimental setups. (For better plot I take data from 50 Meter to 200 Meter)

From the above analysis it is cleared that performance of currently used halogen fog lamp is very bad with respect to Amber LED luminaire. 4 amber LED setup performs extremely well in every aspect, like it gives the visibility of 650 Meter whereas halogen fog lamp gives the visibility of 30 M.

6.4.2.2 COMPARISON IN MODERATE FOG WEATHER CONDITION:

Distance (Meter)→ / Experimental setup ↓	10	30	50	70	100	125	150	200		Visibility (Meter)
4 Amber LED setup	188	88.8	20.2	10.8	5.44	3.51	2.45	1.28	**Average**	500
single 90W Amber LED setup	59.7	14.5	6.03	3.24	1.64	1.06	0.74	0.42	**Illuminance**	150
60W halogen fog lamp setup	5.54	0.88	0.3	0.15					**(Lux)**	25

Table.6.7 Outdoor experimental data of Avg. Illuminance in certain distances in **moderate fog** for different experimental setups.

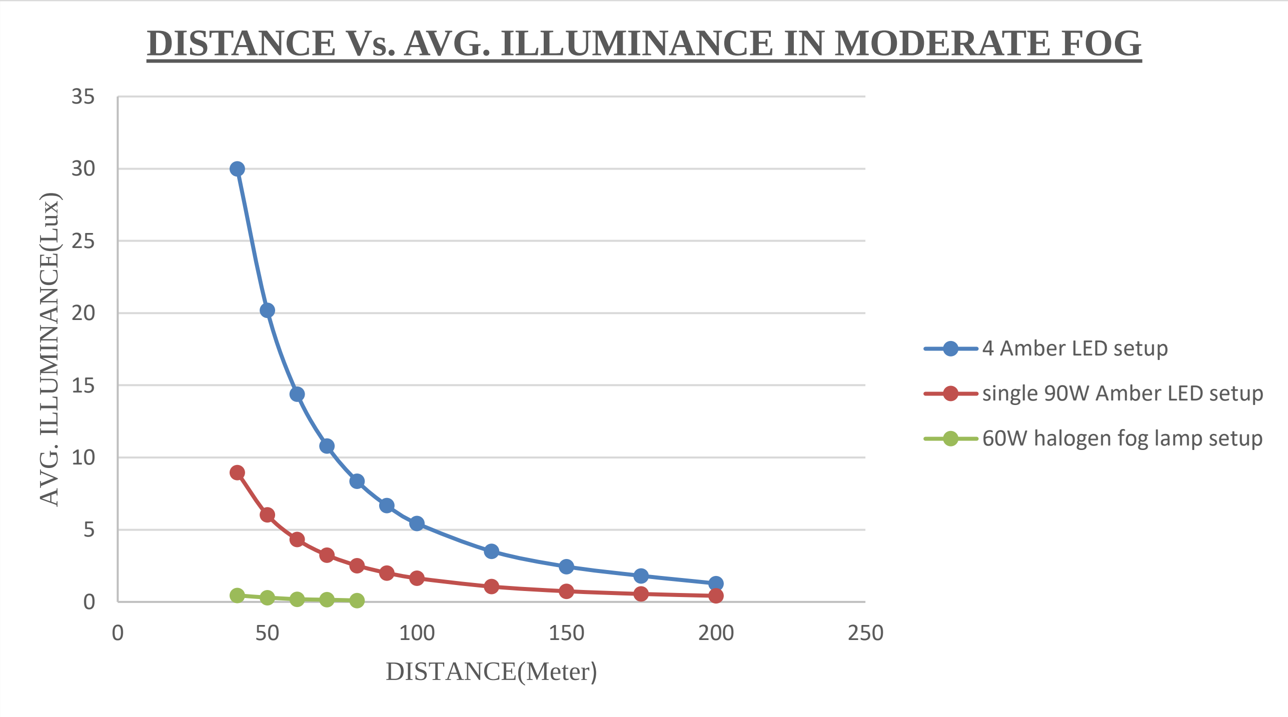


Fig.6.38.Graphical representation of Distance vs Avg. Illuminance of **Outdoor experimental data** in **moderate fog** for different experimental setups. (For better plot I take data from 40 Meter to 200 Meter).

From the above analysis it is cleared that performance of currently used halogen fog lamp is very bad with respect to Amber LED luminaire. 4 amber LED luminaire setup performs extremely well in every aspect, like it gives the visibility of 500 Meter whereas halogen fog lamp gives the visibility of 25 M.

6.4.2.3 COMPARISON IN DANSE FOG WEATHER CONDITION:

Distance (Meter)→ / Experimental setup ↓	10	30	50	70	100	125	150	200		Visibility (Meter)
4 Amber LED setup	131	34.2	14.1	7.55	3.81	2.86	1.72	0.97	Average	250
single 90W Amber LED setup	41.8	10.1	4.22	2.27	1.15	0.74	0.52	0.29	Illuminance	125
60W halogen fog lamp setup	3.88	0.61	0.18						(Lux)	20

Table.6.8 Outdoor experimental data of Avg. Illuminance in certain distances in **dense fog** for different experimental setups.

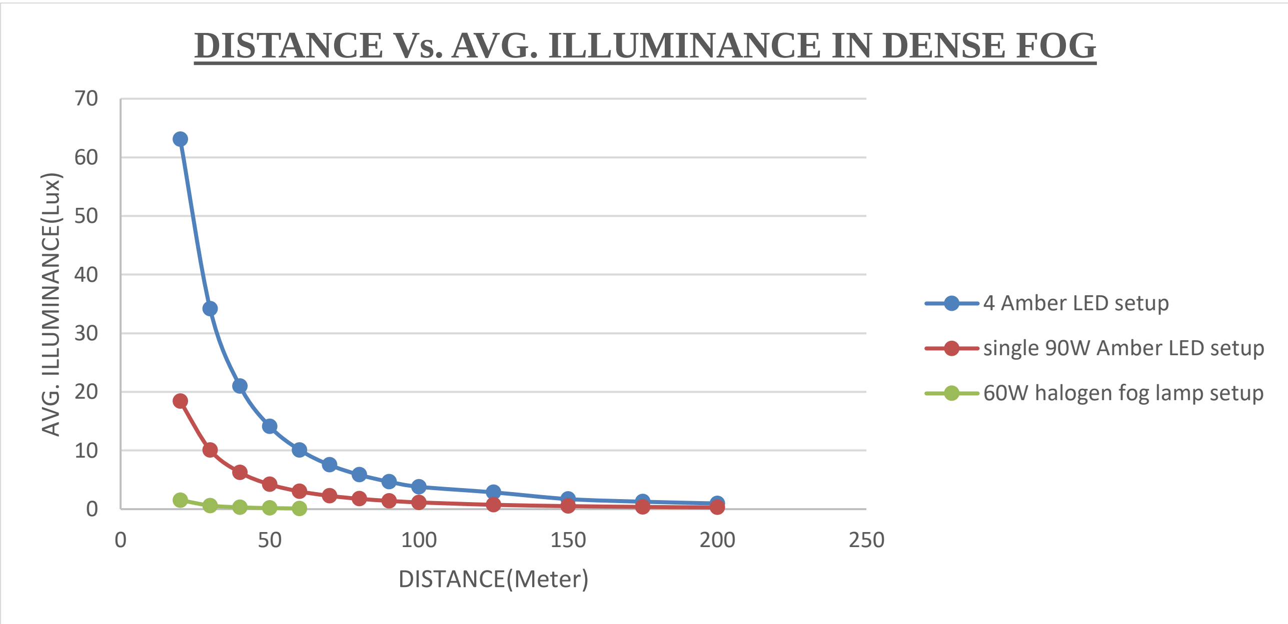


Fig.6.39.Graphical representation of Distance vs Avg. Illuminance of **Outdoor experimental data** in **dense fog** for different experimental setups. (For better plot I take data from 30 Meter to 200 Meter).

From the above analysis it is clear that performance of currently used halogen fog lamp is very bad with respect to Amber LED luminaire. 4 amber LED luminaire setup performs extremely well in every aspect, like it gives the visibility of 250 Meter whereas halogen fog lamp gives the visibility of 20 M.

By DIALUX simulation we can get the approximately comparable results like dense fog condition at the light loss factor of **0.3**.

6.5 ANALYSIS OF EXPERIMENTAL REULTS:

6.5.1 CALCULATION OF MAXIMUM SAFE SPEED:

For this calculation, WAP-5 loco has been assumed. Indian Railways manufactures and operates the high-speed electric locomotive known as WAP-5. In 1995, the first 10 locomotives were brought in from ABB Switzerland. WAP-5 has regenerative braking as one of its major characteristics and is capable of producing 6,000 horsepower (4,500 kW) at its peak. Details about WAP-5 loco are discussed in **ANNEXURE-III.**

Traction System	Control System	3 Phase VVVF	IGBT based
	Traction Power	7200kW or more	
	Starting acceleration	2.6km/h/s ($0.722m/s^2$)	
	Starting Tractive Effort	550KN	
Braking System		Pneumatic and regeneration	
Average acceleration		2.48km/h/s ($0.69m/s^2$)	(up to 80km, on plane and straight line)
Average deceleration		2.61km/h/s ($0.72m/s^2$)	(From 200km/h, Electrical braking on plane and straight line)
Maximum Operation Speed		200 km/h	

Table.6.9 Technical specification of the WAP5 loco

Speed (km/h)	200	160	130	100
Corresponding EBD (m)	1750	1100	700	400

Table.6.10. **Emergency braking distance (EBD)** at different speeds as per Indian standard

In case of danse fog, the visibility level is **250M** (Referred to table 6.8), so calculation of maximum safe speed for avoiding accident is based on dense fog.

The relation between initial velocity, final velocity and deceleration is defined below:

$$v^2 = u^2 - 2as \text{…………………}6.1$$

Where,

u = initial velocity

v = final velocity = **0 m/s**

a = deceleration = 2.61km/h/s = **$0.72m/s^2$**

s = distance = **250m**

so,

$$u^2 = v^2 + 2as$$

$u^2 = 0^2 + 2*0.72*250 = 360$

$$u = \sqrt{360}$$

u = 18.97 m/s = 68.305 km/h

As per above calculation it can be said that the maximum safe speed should be **68 km/h for** avoiding accidents.

We calculate the whole calculation in the basis of avg. deceleration, so, it can be said that for emergency condition the train will stop before the specific distance easily as emergency deceleration much higher than avg. deceleration (referred to table 6.10).

In our experiment a tower van was used which maximum allowable speed is 60 km/h that's why there is no restriction for that tower van in the foggy condition.

6.5.2 IMPROVEMENTS:

1. **LER:**

Total Rated Lamp Lumens (currently used system) = 358.9 lumen
LER (currently used system) = 6.28
Total Rated Lamp Lumens (proposed system) = (2363.5×3) + 2090.4 = 9180.9 lumen
Total power consumed (proposed system) = 390.99 Watt
LER (proposed system) = $\frac{9180.9}{390.99}$ = 23.48

Improvement of LER = $\frac{23.48-6.28}{6.28} \times 100\%$
$= \frac{17.2}{6.28} \times 100\%$
= 273.88%

So, LER value is improved by 273.88% by the proposed system.

2. **FIELD EFFICIENCY:**

Field Lumens (currently used system) = 162.4 lumen
Field Efficiency (currently used system) = 45.27%
Field Lumens (Proposed system) = 1426.4 lumen
Field Efficiency (Proposed system) = 60.35%

Improvement of Field Efficiency = $\frac{60.35-45.27}{45.27} \times 100\%$
$= \frac{15.08}{45.27} \times 100\%$

= 33.31%

3. MAXIMUM INTENSITY:

Max. Intensity (currently used system) = 2248.49 cd

Max. Intensity (Proposed system) = 39755.88 cd

Improvement of Maximum Intensity = $\frac{39755.88-2248.49}{2248.49} \times 100\%$

= 1668.11%

4. FULL WIDTH HALF MAXIMUM (FWHM):

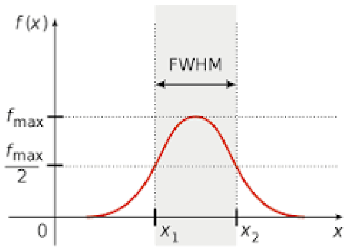
In a distribution, full width at half maximum (FWHM) is the difference between the two values of the independent variable at which the dependent variable is equal to half of its maximum value [29].

FWHM (currently used system) = 180nm

FWHM (Proposed system) = 20nm

Improvement of FWHM = $\frac{180-20}{20} \times 100\%$

= 800%



5. VISIBILITY:

From the table 6.8 analysis it is cleared that performance of currently used halogen fog lamp is very bad with respect to Amber LED luminaire. 4 amber LED luminaire setup performs extremely well in every aspect, like it gives the visibility of **250 meter** whereas halogen fog lamp gives the visibility of **20 meter**.

$$\textbf{VISIBILITY IMPROVEMENT} = \frac{250-20}{20} \times 100\%$$

$$= \frac{230}{20} \times 100\%$$

= 1150%

CHAPTER-7

CONCLUSION

AND

FUTURE SCOPE OF WORK

7.1 CONCLUSION:

This thesis work deals with the comparative study of current fog lighting, used in railways and our proposed monochromatic LED based fog lighting. It is imperative to entirely turn off headlights that emit white light (contains blue in spectrum) and replace them with lights that emit higher wavelengths of light that scatter-less through fog. Because of this, we have decided to use amber LEDs, which produce light that is nearly monochromatic and that has been used for proposed system of railway fog lighting.

It can be said that in every aspect the monochromatic amber LED luminaire is far better than currently used railway fog light with halogen bulb luminaire, like

- **Total rated lamp lumens** is highly improved.
- **LER** (Luminaire Efficacy Rating) is improved by 273.88%
- **Field lumens** is highly improved.
- **Field efficiency** is improved by 33.31%
- **Maximum intensity** is improved by 1668.11%
- **FWHM** (full width half maximum) is improved by 800%
  - **Visibility** is improved by 1150%

According to the experimental results, monochromatic amber LED luminaire performs significantly better than halogen fog light which is currently used in railways. As the halogen fog light uses a yellow filter in front of the halogen bulb, hence, a significant amount of light loss occurs, which makes this system significantly less energy efficient than monochromatic LED luminaires.

In this work, both simulated and experimental results depict that railway fog light (halogen bulb with yellow filter) luminaire have shown very poor performance in every aspect, like LER, Max. intensity, field efficiency, energy efficiency, lighting distribution, visibility etc. in foggy atmosphere as well as normal weather condition. So, it can be concluded that fog lamp, which consists of halogen bulb and yellow filter should be replaced with the monochromatic amber LED luminaire for better performance, train speed and visibility.

The results of the experiments indicate that monochromatic lighting systems are very much effective as fog lighting, which will improve the human’s visibility in foggy condition. As the visibility increases, the occurrence of accident will get reduced, train’s (vehicle) speed will be increased as well as the transportation speed will be improved, which will indirectly help to grow our economy.

7.2 FUTURE SCOPE:

Now a days, most common problem is pollution and pollution is increasing day by day that's why density of fog is also increasing. So, more advanced system has to be developed to overcome these situations. In this project, monochromatic light is used as illuminator but, in future, experiment should be carried out using more developed and advanced fog lighting system for railway as well as road lighting.

In future a better and improved version of this proposed system may be developed by improving the FWHM (narrow FWHM) of the used LEDs. If FWHM reduces, then the LED becomes more absolute monochromatic that can penetrate the fog more easily and scattering become much less.

Also, it would possible to design an automatic fog lighting system which consists of light sensor and also fog sensor. In future this would be the next version of automatic lighting system that will reduce the wastage of electrical energy and a proper energy efficient system.

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ANNEXURE:

ANNEXURE-I

MOSO EHC SERIES-105W LED DRIVER:

BIS CE

Product Feature:

- Input Voltage: 108～305Vac;
- Surge immunity: DM-4KV, CM-6KV;
- THD<10%;
- Protection: Input OVP, Output OVP, SCP, OTP;
- IP67 design for indoor and outdoor applications;
- 5 years warranty.

Application

- LED street lighting, industrial lighting and landscape lighting.

DESCRIPTION

The EHC-105W is a 105W, constant-current, IP67 LED driver that operates from 108-305Vac input with excellent power factor and low THD. It is created for industrial lights, tunnel and street lights. The high efficiency of these drivers and compact metal case enable them to run cooler, significantly improving reliability and extending product life. To ensure trouble-free operation, protection is provided against input surge, input over voltage, output over voltage, short circuit, and over temperature.

Models

Model Number	Input voltage range(Vac)	Max Output Power（W）	Output Voltage Range (Vdc)	Output current (A)	Typical Efficiency	Typical THD	Typical PF	
							120Vac	230Vac
EHC-105B150	200-305	105	75-150	0.70	91%	10%	0.99	0.97
	108-200	80	75-115					
EHC-105B122	200-305	105	61-123	0.86	90%	10%	0.99	0.97
	108-200	80	61-94					
EHC-105B100	200-305	105	50-100	1.05	90%	10%	0.99	0.97
	108-200	80	50-77					

Remark: All specifications are measured at 25℃ ambient temperature, if no specific note.

INPUT SPECIFICATIONS

Parameter	Min.	Typ.	Max.	Notes
Input Voltage	120Vac	120-277Vac	305Vac	Please refer to the Derating curve
Input Frequency	47Hz	50/60 Hz	63Hz	
Leakage Current	-	-	0.75mA	277Vac/50Hz
Input AC Current	-	-	1.2A	120-277Vac with full load
Inrush Current(I^2t)	-	-	$0.01A^2S$	230Vac input，Ta＝25℃（cold start）
Power Factor	0.97	0.98		120Vac, 80W
	0.95	0.97		230Vac, 105W
THD	-	10%	20%	200-230Vac, 80-105W Load
	-	10%	15%	200-230Vac, 105W Load
	-	10%	15%	120-200Vac, 80W Load

OUTPUT SPECIFICATIONS

Parameter	Min.	Typ.	Max.	Notes
Output Current Tolerance	-8%Iset	-	8%Iset	Full load
Total Output Current Ripple(pk-pk)	-	150%	200%	Full load & LED Load, ripple is different with difference LED load. 20MHz BW
Startup Overshoot Current	-	-	10%	120~277Vac & Full load, LED Load
No Load Output Voltage EHC-105B150 EHC-105B122 EHC-105B100	-	-	200V 180V 160V	
Line Regulation	-	-	8%	25℃±10℃ ambient temperature, input voltage changes from 200Vac to 277Vac.
Load Regulation	-	-	8%	25℃±10℃ambient temperature, 230Vac input, load changes from 60% to 100%.
Turn-on Delay Time	-	-	3S	120Vac, 80W
	-	0.5S	1S	230Vac, 105W

GENERAL SPECIFICATIONS

Parameter	Min.	Typ.	Max.	Notes
Efficiency@120Vac EHC-105B150 EHC-105B122 EHC-105B100	87% 87% 87%	89% 89% 89%		Measured at 80W load and 25℃ambient temperature
Efficiency@230Vac EHC-105B150 EHC-105B122 EHC-105B100	89% 89% 88%	91% 90% 90%		Measured at 105W load and 25℃ambient temperature

Efficiency@277Vac EHC-105B150 EHC-105B122 EHC-105B100		87% 87% 87%	89% 89% 89%		Measured at 105W load and 25℃ambient temperature
Dielectric Strength	Input-Output	-	3750Vac	-	10mA/60S
	Input-PE	-	1600Vac	-	
	Output- PE	-	1600Vac	-	
Grounding Resistance		-	-	0.1Ω	25A/60S
Insulation Resistance		50MΩ	-	-	Input-Output, Input-PE, Output-PE, 500Vdc/60S/25℃/70%RH
MTBF		-	200000Hours	-	230Vac,80% load (MIL-HDBK-217F)
Lifetime		-	50000Hours	-	230Vac&100% load,70℃case temperature, refer to lifetime VS Tc curve for details
Operating Case Temperature for Safety Tc_s		-40℃	-	+85℃	
Operating Case Temperature for Warranty Tc_w		-40℃	-	+75℃	5 Years Warranty Humidity：10% to 95% RH
Storage Temperature		-40℃	-	+85℃	Humidity：10% to 95% RH
Dimensions (L×W×H)mm		164mm*68mm*39mm			
Net Weight		650±100g/PCS			
Package		L500*W310*H60mm; 10pcs/Ctn.			

Note: All specifications are tested by Cree XLamp XP-G2 and typical measured at 230Vac and 25℃ unless otherwise stated.

SAFTY STANDARDS

Safety Category	Country / Territory	Standards
CCC	China	GB19510.1, GB19510.14
CE	China	EN61347-1, EN61347-2-13
CB	CB Countries	IEC61347-1, IEC61347-2-13
BIS	India	IS 15885(PART 2/SEC 13)
UL	USA	UL 8750
CUL	Canada	CSA C22.2 No.250.13
KC	South Korea	K61347-1, K61347-2-13, K62384
PSE	Japan	J61347-1, J61347-2-13
SAA	Australia	AS/NZS IEC 61347-2-13
		AS/NZS 61347.1

EMC COMPLIANCE

EMC Category	Country / Territory	Standards
CCC	China	GB 17743, GB 17625.1
CE	Europe	EN 55015, EN 61000-3-2, EN 61000-3-3
		EN61000-4-2,3,4,5,6,8,11
		EN 61547
KC	South Korea	K61547
		K00015
PSE	Japan	J55015
FCC	USA	FCC part 15

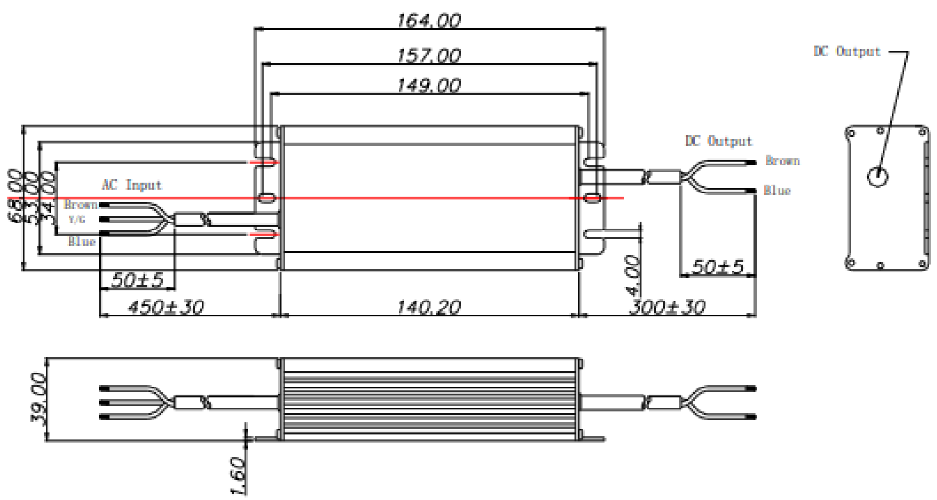
NOTE:

This LED driver meets the EMI specifications above, but EMI performance of a luminaire that contains it depends also on the other devices connected to the driver and on the fixture itself.

PROTECTIONS

Parameter		Min.	Typ.	Max.	Notes
Input Over Voltage Protection	Input Protection Voltage	320Vac	330Vac	360Vac	Turn off the output when the input voltage exceeds protection voltage.
	Recovery Voltage	300Vac	320Vac	360Vac	Auto Recovery. The driver will restart when the input voltage falls below recovery voltage.
	Max. of Input Over Voltage	-	-	440Vac	The driver can survive for 48 hours with input over-voltage of 440Vac.
Over Temperature Protection		Decreases output current, returning to normal after over temperature is removed.			
Short Circuit Protection		Hiccup mode and auto recovery. No damage will occur when any output is short circuited. The output shall return to normal when the fault condition is removed.			
Output Over Voltage Protection		Limits output voltage at no load and in case the normal voltage limit fail			

MECHANICAL OUTLINE



ANNEXURE-II

HIGH PRECISION ROTATION LUMINAIRE GONIOPHOTOMETER (LSG-1890B/LSG-1800A):

System Configuration

A. Goniophotometric System:

- Goniometric Rotating Console:
  1) LSG-1890B: Japanese Mitsubishi Motor and German Angle encoder System to keep the test accuracy to 0.1degree
  2) LSG-1800A: Taiwan Motor and Angle encoder System to keep the test accuracy to 0.2degree
- The LSG-1890B has Goniometric Rotating Control Instrument in 19inch cabinet: It connects to the PC and was controlled by the software.
- The LSG-1890B/LSG-1800A has Goniometric Rotating Control Android App which can control it to rotating angle in the dark room easily.
- High Precision Photometer with Class A Constant Temperature Photo Detector (Option is Class L)
- Cross-beam Laser System for Calibrating
- English Measuring Software
- Three sets of luminaries Clamps: multi-functions
- Oversea Delivery and Packing: all of the instruments and accessories will be packed with Fumigation free three plywood, include the delivery cost to Shanghai sea port

B. SLS-150W DC Standard Light Intensity Lamp

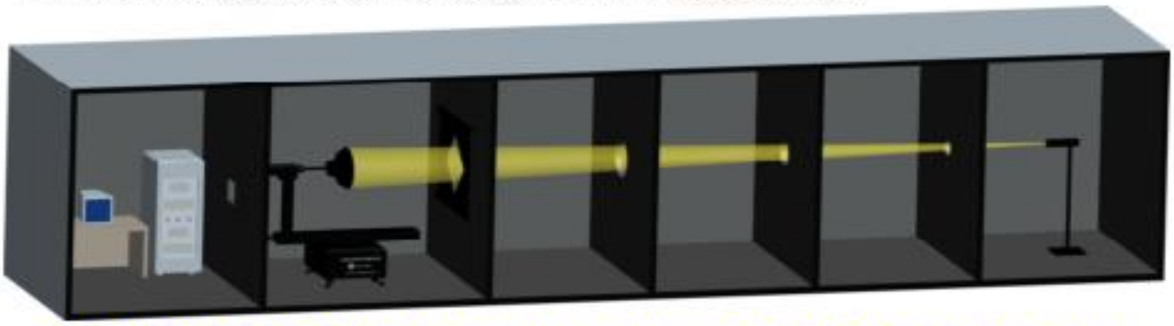
C. Digital Power Meter:

1) LSG-1890B has LS2050B Digital Power Meter: With LCD screen display, it is used to test AC/DC voltage, current, power, PF, DF and Harmonic
2) LSG-1800A has LS2012 Digital Power Meter: It is used to test AC/DC voltage, current, power and PF

D. DC3010 CC & CV DC Power Source: DC3010 output is 30V/10A, Option can be DC6010 (output is 60V/10A) and DC12010 (output is 120V/10A)

E. AC Power Source: LSP-500VARC Pure Sine Wave AC Power Source with LCD Screen: 500VA Output. It can communicate with PC via software

F. CASE-19IN 19inch Standard Instruments Cabinet.



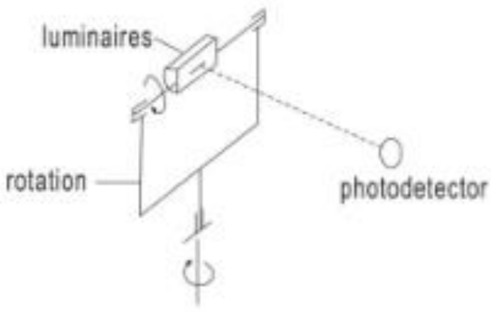
Full View for High Precision Rotation Luminaries Goniophotometer

2. Working Principle

Goniophotometric System carries out measuring methods of fixed location and rotating luminaries. The measured luminaries is installed on the rotating supported, the center of which is in line with the rotating supporter center with the help of Laser sight. The fixed photometry detector is testing the luminous intensity in various horizontal directions, while the light source rotating. The mechanical equipment allows turning the tested luminaries around a vertical axis and a horizontal axis. When the luminaries under test turn around horizontal axis, the detector which is at the same level with rotating table will measure the intensity of each direction at this surface. When rotating with vertical axis, the detector will measure the intensity at the vertical surface. The vertical and horizontal axis can be rotated continuously at -180° ～ +180° . According to the measurement requirements, the system can be operated in B-β , A-α and C-γ coordinates. When getting intensity distribution data, computer will calculate other photometric parameters automatically.

Double pillars structure (B-β, A-α coordinate system)

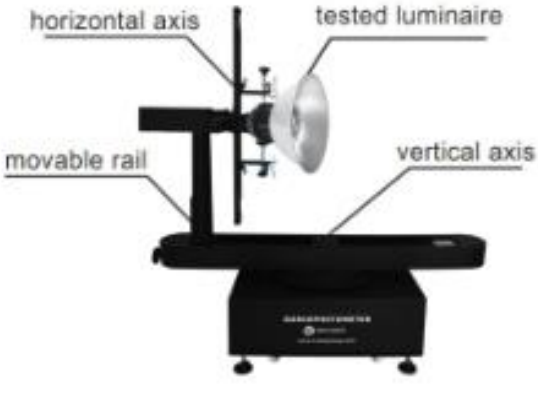
This type is applied to fixed grille lamp. The symmetry axis of lamp and the horizontal of rotating supporter is coaxial in the B-β coordinate system, and the two is vertical Cross in the A-α coordinate system.

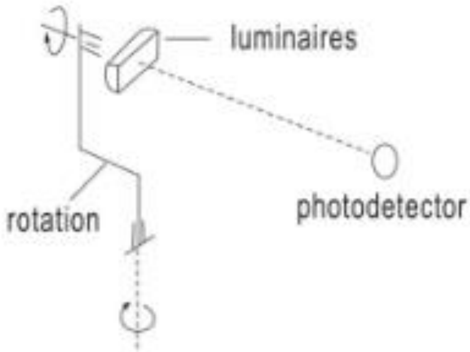


Double pillars structure

Single pillar structure (C-γ coordinate and Conic coordinate)

The single column structure will be gotten when the assistant column is taken down from double columns structure. This type is applied to fixed tube lamp, spot lamp etc. The axis radiation of lamp and the horizontal of rotating supporter is coaxial.





3. System Functions

LSG-1890B/LSG-1800A Goniophotometer is high precision automatic goniophotometric instrument for luminous intensity distribution measurements with facility for turning the light source. The LSG-1890B uses a constant temperature detector, Japanese Motor and Germany precision angle coder which keep high test accuracy. It is for industrial laboratory measurements the photometric data of luminaries.

Be utilized to measure photometric parameters of luminaries for LED road lighting fixture, room lighting fixture and projecting lighting fixture, such as spatial intensity distribution curve, spatial iso-intensity curve, intensity distribution curve on each section (represent by right-angled coordinates or polar coordinates, luminance limitation curve, luminaries efficiency, glare grade, effective beam angle, upward luminous flux ratio, downward luminous flux ratio, total luminous flux, effective luminous flux, utilization factor and electric parameters voltage, current, wattage, power factor and etc. The measured data meets IES standard format and can be applied for lighting design by lighting design software. The measurement system fully satisfies the requirement of lighting design work.






4. Specifications

- Meets the requirements of CIE, IEC, IES LM-79 & GB standards
- Reaching many measurement ways such as B- β and C- γ
- Test Max Luminaires size and weight: LSG-1890B is 2000mm/60kg and LSG-1800A is 1600mm/50kg
- The tested luminaries rotates around an angle of (γ)±180°(or 0-360°) and the tested luminaries rotates around itself with an angle of (C)±180°(or 0-360°)
- Luminosity Testing Range: Illuminance 0.001lx~99,999lx; Light Intensity 1.0cd~10^7cd(detector)
- Angle accuracy: LSG-1890B is 0.1°, LSG-1800A is 0.2°
- Photometry Accuracy: CIE Class A (Class L is option)
- Testing Accuracy: 2%(Under Standard lamp); Stray Light: less than 0.1%
- English version software can run in Win7, Win8 or Win10, Win11

5. Laboratory Requirements

LISUN MODEL	Center Height (A)	Total Height (B)	Total Depth (C)	Total Width (D)	The max size for the Testing Lamp: Diameter(E)*Depth(F)	The max diameter of the mast rotating(G)	Max Testing Weight
LSG-1890B	1510	1600	922	1750	⌀2000×600max *	⌀2000	60kg
LSG-1800A	1370	1420	750	1650	⌀1600×600max	⌀1700	50kg

Table 1 The Diamensions of the Goniophotometer Master

*Note: The max testing lamp size depends on the dark room height and special design jig (option)

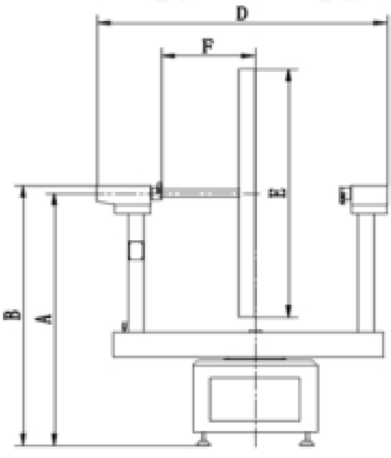


Figure 1 The Side View

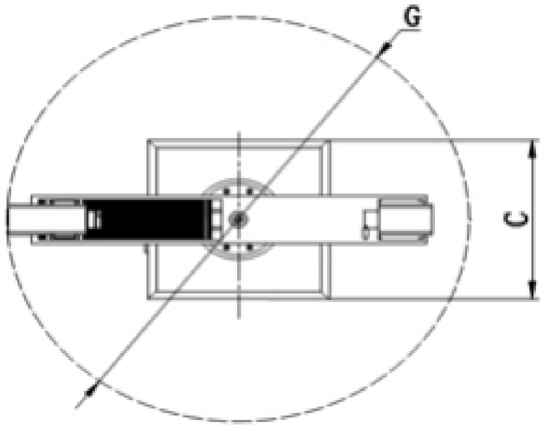
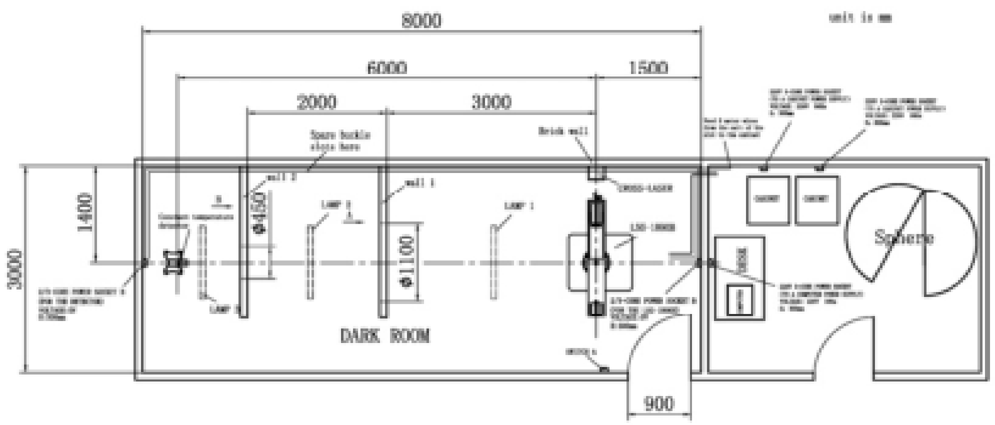


Figure 2 The Vertical View

- Dark Room size request (The G, A and E please refer to the above table 1 and figure 1 and 2): The darkroom Width W=G+X (It recommends the X is min 500mm which can allow one person pass). The darkroom Height H=A+0.5*E+Y (It recommends the Y is min 100mm to the ceiling). The darkroom Length L=6*E (According to CIE, it requests at least 6times than the testing lamps).

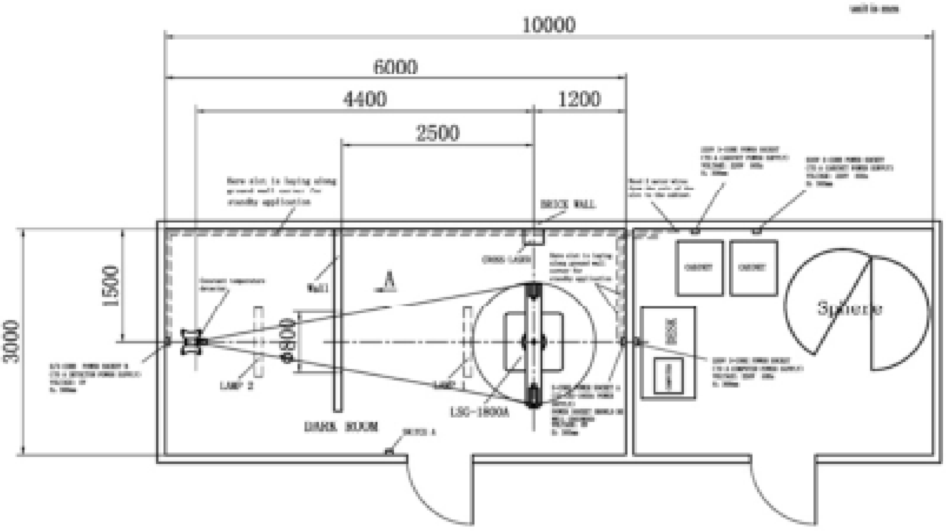
- Control Room size request: min=2000*2000*2000mm
- The wall, ceiling and floor should be all coated with dull black paint or be covered by black cloth and black carpet.
- Air-conditioner should be set in the dark room to control the temperature around lamps to the standard value upon the CIE requirements
- LISUN engineer dept will submit the Lab Design support documents according to the customer's lab size after the purchase order was confirmed (The below are two Typical Lab Design reference for LSG-1890B/LSG-1800A). NOTE: The longer dark room, the better test accuracy. LISUN recommends you to prepare as longer dark room as you can (max 30m)

LSG-1890B DARK ROOM VERTICAL VIEW



Technical requirements:
1. The walls and ceiling of the darkroom need to be painted matte black. Cover the floor with black carpet.
2. The wires for 3-core power socket A and 2/3-core power socket B are inside of the buckle slot from the cabinet. Need 2 meter wires from the exit of the slot to the cabinet. Another buckle slot at the same place for backup.
3. Switch A is for lamp 1、lamp 2 and lamp3. Lamps should be installed on the ceiling.
4. The 3-Core power socket for LSG-1890B must be well grounded or connected with the separate earthing terminal.
5. The dotted line buckle slot need to be easy tear open outfit and matte black.
6. The wall for cross laser is better to be brick. The cross laser togther with the holder is about 5kg and need to be fixed on the wall.
7. Diameter of all wires are at least $2mm^2$.
8. The air conditioner outlet must not close to the luminaries being measured or the light path.
9. The windows need to be blocked or covered by matte black curtain.
10. The width of dark room door above 900mm, so that LSG-1890B could enter into dark room.

LSG-1800A DARK ROOM VERTICAL VIEW



Technical requirement:

1. **The walls, floors and ceilings of dark room must painted matt black paint and the ground spreads black carpet .**
2. The power lines of three-core power socket A and two / three-core power socket B laying along the wall and into the operating room, **requires power line head exposed ground 2 meter**, the other slot laying along and enter into operating room for standby application.
3. SwitchA used to control lamp 1、lamp 2 , Lamp installed in the ceiling.
4. **Three-core power socket A (Power to LSG-1800A) must be well grounded, or separate ground terminal .**
5. The slot where is refering by dotted line should be detachable ,and the width of the slot should be not less than 50mm .
6. The wall to install cross laser must be brick wall.
7. The windows are sealed off in the darkroom to make sure light cannot leak absolutely.
8. In the dark room where LSG-1800A main machine placed ,the air outlet of air set should not directly face to the tested lamp and the optical path.
9. All wire diameter ≥ 2mm².

6. Typical oversea market customers:

There are many world famous companies and lab institute choose Lisun Goniophtometer, Please get the reference customers' information from Lisun Group Oversea Sales Dept.

7. Design Standard of Device

The construction, technical parameter, test & operate steps as well as data processing software of goniophotometer meet the following requirements:

- CIE Pub. NO.70,"The Measurement of Absolute Luminous Intensity Distributions"
- CIE DIV. Ⅱ-TC10,"Photometry of Luminaires"
- IES LM-35-1989,"IES Approved Method for Photometric Testing of Floodlights"
- IES LM-31,"IES Approved Method for Photometric Testing of Roadway Luminaires"
- IES-LM-79-19, "Electrical and Photometric Measurements of Solid-State Lighting Products"
- GB/T 7002-1986,"Luminosity Test of Flood Luminaires"
- GB/T 9467-1988, "Luminosity Test of Indoor Luminaires"
- GB/T 9468-1988, "Luminosity Test of Street Luminaires"
- IES 61341 "Method of Measurement of Center Beam Intensity and Beam Angle(s) of Reflector Lamp"
- CIE Pub.NO.76, "Photometry-the CIE System of Physical Photometry"

8. Application Software

All control of the goniophotometer operations can be realized by the software, including gonophotometer movement, data acquisition and processing, real-time display on screen, report print and etc, thus enabling the measurement easy and secure.

This system can export data files as following formats:

IESNA Files (*.ies)
EULUMDAT Files (*.ldt)
CIEBSE TM14 Files (*.cib)
CIEBSE TM14 Files (*.tm4)
CIE Files (*.cie)
DIN CEN Files (*.cen)
Excel File(*.csv)

This kind of format files can be transferred by other illumination and luminaries design software such as DiaLux

Application software can also implement essential calculation for lighting design as iso-illuminance distribution curve on a working plane, luminance limitation curve, luminary's efficiency, effective beam angle, upward luminous flux ratio, downward luminous flux ratio, effective luminous flux, utilization factor curve etc.

ANNEXURE-III

TECHNICAL SPECIFICATION OF THE WAP5 LOCO:

Technical Information	
Gauge	Broad gauge 1,676 mm (5 ft 6 inch)
Line voltage	25 kV
Type of current	Alternating Current (AC), 50 Hz
Axle load	19.5 Tonnes ±2%
Weight	78 Tonne±1%
Bogie Arrangement	Bo-Bo
Length over head-stocks	16,880 mm
Length over buffers	18,162 mm
Bogie wheel base	2,800 mm
Wheel Base	13,000 mm
Body width	3,144 mm
Pantograph locked down height	4,255 mm
Bogie center distance	10,200 mm
Starting Tractive Effort	258 kN (26.3 Tonne)
Continuous Rated T.E.	220 kN (22.4 Tonne)
Max. Re-generative B.E.	160 kN
Coupling	Central Buffer Couplers (CBC)
Traction motors	
Type	6FXA 7059 3-phase asynchronous motors, 1,150 kW, 2180V, 370A-Continuous, 396A for 1 hr, 540A max, 1585 rpm continuous, 3174 rpm max, Weight 1990 kg. Forced-air ventilation, fully suspended. Torque 6930/10000 N-m. 96% efficiency.
Make	ABB
Class of Insulation	Class 200
Number of Traction Motors	4
Gear Ratio	67:35:17 (160 km/h) 59:35:19 (200 km/h)
Transformer	
Type	ABB LOT-7500/LOT-7775: {7475 kVA/7775 kVA, 25kV, 299A-primary/311A}- Traction winding- {4x1269V, 4x1450 kVA, 4x1142A}-Auxiliary Winding, {1000V, 334kVA, 334A}- Hotel Load- {960 V, 2x622.5 kVA, 2x648 A}- Filter {1154 V, 400 kVA, 347 A}-
Insulation Class	Class A
Weight	10000 +/-3% kg
Hotel Load Converter	
Make	Siemens / Medha / ABB
Rating	2x500 kVA
Voltage	750V +/- 5%, 3 phase
Bogie	
Type Un-Sprung Mass	Bo-Bo Henschel Flexifloat bogies with quill drive. Per axle: 2.691 t
Drive Arrangement	Gear coupling and 3-stage gears
Design	2-axle fabricated
Primary suspension	Coil
Secondary suspension	Coil
Pantograph	
Type	AM-92
Pantograph Weight	231 kg
Batteries	110 V, 199 AH, Ni-Cd.

Main Specification of METI proposed Train-Set:

Item		Characteristic	Remark
Train set		EMU 12 Cars	6 Driving Cars + 6 Non Driving Cars
Maximum Operation Speed		200 km/h	
Passenger Capacity		Seating Car train - 821 Sleeper Car train - 651	
Weight (average axle load)		Seating Car around 13.6t* Sleeper Car around 15.6t*	Components of weight of 'ventilation only battery' & passenger weight @80kg/seat have been added to 12t & 14t, as these are only average Tare weights. Being average tare axle loads, actual maximum axle load will be higher than these figures.
Car Body	Structure	Aluminum alloy	
	Length over all	Leading car 24450mm Intermediate car 23500mm	
	Width	3250mm	
	Height	4015mm	From rail level
	Distance between bogies	16100mm	
	Compressive Force	1500KN	According to EN 12663, Category – P2
Bogie	Car body suspension	Bolster-less Air Spring	With anti-rolling device
	Gauge	1676mm	
	Wheel base	2500	
Traction System	Control System	3 Phase VVVF	IGBT based
	Traction Power	7200kW or more	
	Starting acceleration	2.6km/h/s (0.722m/s^2)	
	Starting Tractive Effort	550KN	
Braking System		Pneumatic and regeneration	
Average acceleration		2.48km/h/s (0.69m/s^2)	(up to 80km, on plane and straight line)
Average deceleration		2.61km/h/s (0.72m/s^2)	(From 200km/h, Electrical braking on plane and straight line)
Ride Index		2.55	At 200 km/h, By simulation using worn profile in India
Energy Consumption		27.9 Wh/km/person	In case of seating car

(Source METI Study Report)