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Safer and innovative traffic lights with minilenses and optical fibers

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A B S T R A C T

When an array of LEDs has to be repaired in or removed from a traffic light, it is necessary interrupt traffic. A lift has to elevate workers to the traffic-light disks, entailing job-safety dangers, high costs, and traffic disruption. To allay some of these problems, we have designed a new illumination system with LEDs, using minilenses set into the base of the traffic light, from which a bundle of optical fibers emerge to feed the disks, and these optical fibers transport the light from the array of LEDs to the disks. The new traffic lights will improve traffic and worker safety because the repairs are made on the ground.

1. Introduction

Roads and streets pose a constant threat to pedestrians and drivers because of the increasing traffic density. This necessitates control and regulation to ensure efficient signaling and speed limits for the vehicles. Signaling needs to be clear, visible, and always operative (especially in the daylight) and it has to facilitate driving.

Urban traffic density varies constantly, not only between days, but depending on the hour of the day and according to the size of the city and its growth. The main causes of accidents and fatalities include traffic-signal failure, bad street maintenance, and natural catastrophes.

The OECD's report *Safety on the Road: What's the Vision?* [1] established a goal of improving the road safety, and subsequent studies have shown that countries that failed to set this target had more accidents [2]. According to the World Health Organization, more than a million people are killed on the world's roads each year [3], indicating that the society and the government should make an effort to increase the level of safety and prevention [4]. The consequences of traffic accidents are varied, affecting public health, public safety, and the economy [3]. Approximately, 1.2 millions of persons die each year in traffic accidents and about 50 millions are injuries. Traffic is the third cause of die in the world after cardiovascular illness and cancer [3], thus traffic signals are essential for drivers and pedestrians.

According to General Traffic Administration of Spain, in 2008, 634 people died in urban areas, 5411 were seriously injured, and 58,237 slightly injured. Some 38% of these casualties were pedestrians, while 24% involved lateral or frontal crashes, and 14% were accidents leaving the driveway. In 2007, multiple crashes and back ending decreased by 40%, but frontal or lateral crashes increased in 2% [3,4].

In this context, governments should have two essential goals for traffic: safety and fluidity. For both aspects, streets need improvement and vehicles need to follow safety standards to reduce the number of accidents. Also, it is necessary to raise citizen awareness of the driver's responsibility in following traffic regulations, and traffic signs need to be improved. It should be promoted the collaboration between citizens and a correct regulation of the traffic, especially in urban zones, for instance, to improve the signs to direct the traffic. In some ways, traffic safety and fluidity have opposite needs, so that an equilibrium between them needs to be established.

An essential aspect is to improve the flow of vehicles through the cities [5–8] by, for example, the use of traffic simulators [9–24].

In this regard, three fundamental interacting factors have been established: people, vehicles, and roads thus, the traffic is a

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multifactorial system in which all factors interact. Vehicles and roads are instruments used by the driver, who ultimately determines safety and fluidity. At the moment, signals are not widely deemed essential to safety and fluidity, but, in this work, we consider signals (especially traffic lights) to be essential to maintain these two qualities, particularly in urban areas.

The invention of the LED and the arrays has been a revolution in our modern society in everything from home lighting to traffic signals. Electronics and optics of LED arrays are more expensive than incandescent lamps but the advantages are significant: the illumination is quasi-instantaneous, energy consumption is lower, there are environmental benefits, less maintenance is required, there is no ghost effect, reliability is greater, and luminosity control (dimming).

LED arrays for signal lights were introduced in 2008. These signal lights comply with the European guidelines [25–27]. Although LEDs have improved traffic light, when a great number of them fail to emit, the array must be removed and replaced. The presence of a number of technicians for the repair and vehicles (lifts) in the streets reduces traffic fluidity, disturbs drivers, and endangers the technicians, drivers, and pedestrians.

Clearly, correct traffic signals help to minimize human error, encourage fluidity, increase the speed of vehicles, and consequently reduce the likelihood of catastrophic situations. Every time a failure occurs in a signal light at an intersection, it is necessary for the police to direct traffic, to interrupt the flow in a lane or even stop the traffic. The delays, instigating driver impatience, exacerbate accident risks.

Although LEDs, LED arrays, and traffic lights have developed greatly, traffic lights are still not as safe as needed. For this reason, in the present work, we have designed a new, safer, traffic light. This system can be adapted to the current traffic light, so it is not necessary to manufacture a new apparatus. The new ones have the LED arrays at the base of the traffic light, minilenses, and a bundle of optical fibers to carry the light to the top of the traffic light, to the disks. The traffic light is designed in such a way that the optical fiber bundle can be inserted into the tube of the traffic light, making it unnecessary to make any modification.

2. Materials: LEDs, minilenses and optical fibers

2.1. LEDs

The LED chosen for our design is the Hebei I.T. 520PG0C because its luminous characteristics comply the UNE-EN 12368:2008 [26]. It has a forward current of 20 mA and a forward voltage of 3.2 V, the luminous intensity is 9000 mcd, the Spectral Line half-width is 35 nm, and the viewing angle 20°.

The dimensions of the LED are shown in Fig. 1 and the graphic depiction of the relative luminous intensity vs. radiation angle appears in Fig. 2.

The schematics provided by the manufacturer (Fig. 2) show that the LED is not a Lambertian emitter because it violates the cosine rule. The value of the relative intensity vs. angle is given in Fig. 2.

2.2. Minilenses

The minilenses used in this design are from Newport, model KGA022-A for LEDs emitting wavelengths between green and amber, and KGA0022-B for LEDs emitting red wavelengths, aspherical, and manufactured by Corning C0550 glass, 5.42 mm in diameter, 5 mm thick, 4.47 mm in focal length (f'), numerical aperture (N.A.) 0.47, and a work spectrum of 400–600 nm. Minilenses were chosen because they have the characteristics that adapt very well to our design and also minimize the spherical and chromatic aberrations.

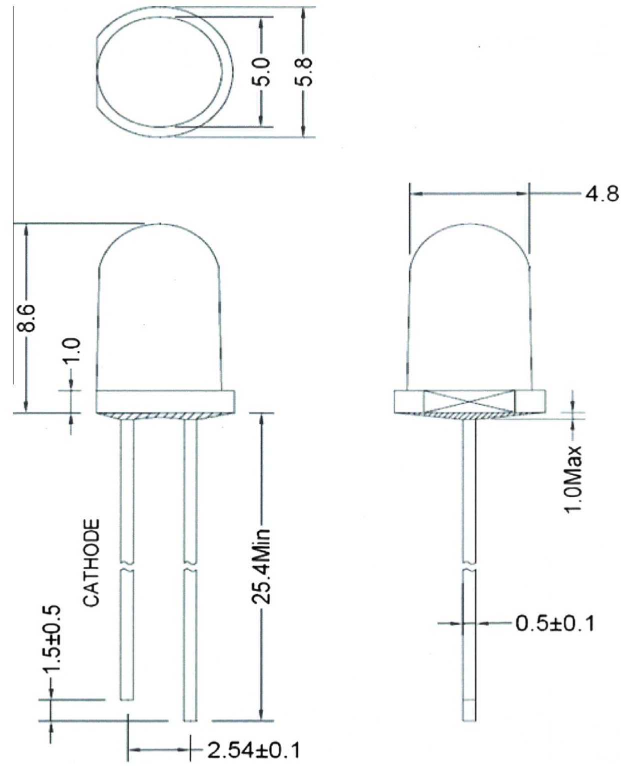

Fig. 1. Dimensions and uncertainties (in mm) of the LED. Data sheet of LED Hebei I.T. (Shanghai) Co., Ltd. 520PG0C.

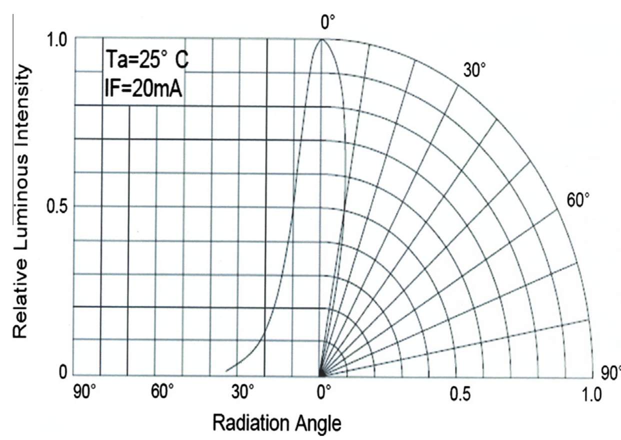

Fig. 2. Relative luminous intensity vs. radiation angle Data sheet. Data sheet of LED Hebei I.T. (Shanghai) Co., Ltd. 520PG0C.

According to the manufacturer, the transmittance of a minilens is 100% in our range of wavelengths. In nature, no material is completely transparent (only the vacuum has 100% transmittance) and therefore we considered the transmittance of each minilens to be 90%.

2.3. Optical fiber

The optical fiber, chosen for its characteristics, is the plastic optical fiber (POF) PGU-CD1001-22E, manufactured by TORAY RAYTELA®.

The optical fiber has a step index profile, core of polymethyl methacrylate (PMMA), and of fluorinated polymer cladding. The