Antiglare Traffic Signal by Natural Lighting

Antonio ALVAREZ FERNANDEZ-BALBUENA*
Researcher, E-mail: antonioa@opt.ucm.es

Daniel VAZQUEZ-MOLINÍ*
Professor, E-mail: dvazquez@fis.ucm.es

Berta GARCÍA-FERNADEZ*
Researcher, E-mail: bertagf@opt.ucm.es

Eusebio BERNABEU**
Professor, E-mail: ebernabeu@fis.ucm.es

* Dept. of Optics, School of Optics, University Complutense of Madrid, c/ Arcos de Jalón nº118., Madrid, 28037, Spain, Phone +34 91 394 6893
** Dept. of Optics, Faculty of Physics, University Complutense of Madrid, Ciudad Universitaria s/n., Madrid, 28040, Spain, Phone +34 91 394 4555

ABSTRACT

The actual technology has not resolved a vision problem in vertical traffic signal when sun that is in the back of the vertical panel glares drivers and makes vertical traffic panels difficult or impossible to read. In this work authors have designed a nonimaging optical unit that collects and redirect sun light towards the driver’s eye with luminance values near $10^4 \text{ cd/m}^2$. The unit is disposed in an array format to conform letters or symbols. Natural light guided with this new device is enough to make this panel visible in the worst sun conditions. Light angle is directed to the road so less lighting is reaching outside it to prevent outdoor troubles. The device is not powered by electricity, for this reason the device is landscape respectful because not civil building is necessary so it is ecological. No mobile parts are present so is more resistant to outdoor weather with less maintenance.

Keywords: Natural Lighting, Sun Glare, Traffic Signal

1. INTRODUCTION

The application of new technology to vertical traffic sign is continuously increasing. The actual technology, LED [1], retroreflective tape and louvers [2], has not solved a vision problem in vertical traffic signalization when the sun glares
drivers and makes the panel unreadable. This situations occurs when the road direction is facing east at dawn and west at dusk. Natural light, guided with this new nonimaging optical device [3], makes the panel visible in the worst conditions. Because the device is not powered by electricity and has no mobile parts, it is ecological and also resistant to outdoor weather. The installation and the device itself are both electricity free. The angle of the light is directed to towards the road reducing light pollution. Computer simulations and a make-up are studied.

In figure 1 the sun is very high and light in panel on the front side so it can be read but the same panel in the other direction is lighted backwards at the same time, there are clouds that minimize the contrast effect, but even with these conditions it is not possible to read the panel.

In this paper the authors have developed a device that could solve visibility of vertical panel when they are seen with very high luminance contrast ratio. To solve the problem the use of direct solar light is necessary to obtain the luminance levels to permit the reading of the signals when surrounding luminance is such that we cannot read the signal text with standard technology.

The developed device is a passive solar system, as consequence it will not have energy consumption and it will have reduced maintenance. This device gets solar direct light, when radiation falls onto the panel with a determined angle, and the light is guided towards other board side, where people need to read the panels.

The panels have an optical unit to get light from determinate angles from the back. This uses an optical guide to address light to the other side of panel with an optical unit to lead light to drivers.

The system can incorporate more complex systems such as opto-mechanical or electro-optical devices to improve efficiency or to permit changes to the message, but the main and essential character of this device is to use direct light and to avoid glare that this light gives.

2. DEVELOPMENT OF A SPECIFIC OPTICAL UNIT

When drivers see vertical traffic signals with the sun in the same direction as their vision it is not possible to read any
message written on them because the human visual system is adapted to very high contrast luminance levels, and the panel is seen as black. This is an experience that all people can test in their everyday life, mainly when sun is rising or setting. Since the size of panel cannot be very big for obvious reasons, there are only two ways to solve the problem:

1. - To assume that at certain hours the vertical signal panel cannot be read facing west or east.
2. - To give a very high luminance level to alphanumerical characters. By doing this with artificial light it will be needed light sources with an expensive energy cost, but these lights will be put on only for a reduced period of time in the day. Researchers propose to use the sun light to solve the problem that it originated, fig 3. Sun light coming from good directions, from the back of the panel, would not look very difficult to read for the driver. When sun is not in front of driver the light readress will be necessary since visibility contrasts is low.

2.1 Optical Unit

A compound parabolic concentrator (CPC) [4, 5] is an optical design that is widely used in the concentrator industry because it has a high efficiency with good light control. The CPC is a tilted parabolic profile that can be designed with different light angle acceptances.

The authors designed a specific optical unit composed of two CPCs, Fig 4.

The entry CPC is designed with a 30° semiangle caption to obtain the natural light in the necessary range of solar movement. In this case the unit is tilted 10° over the horizontal so when the sun height is 40° above from the horizontal the unit will reject that light backwards. The aim of this rejection is to switch off –without moving parts- the panel when the sun is above that angle because if the sun is at this elevation the glare over the panel is almost imperceptible.

The entry CPC redirects all the natural light over the union as a standard CPC in a 2π solid angle. The output CPC (20° design) works in inverse mode, instead of concentrating it collimates light, and is able to redirect all radiation that is on the union to the output fulfilling the condition that all radiation is inside the design angle cone. The design can be done in dielectric material and also with specular surface.
2.2 Simulation

To simulate the optical unit a typical road of 3 lanes is evaluated. This road is 9 x 50 m and the optical unit is situated at the beginning of the road centered on all lanes, Fig 5.

Raytracing [6] is done from 0º to 50º solar height, efficiency and distribution over the road is evaluated. The azimutal angle of the sun is not evaluated. The output surface has an optics surface treatment with specific calculated roughness on it to redistribute uniformly the flux on the road. This surface is simulated with a bidirectional transmittance distribution function (BTDF) of 0.89, parameter A=0.1181, B=0.1 and g=2. BTDF has a specular reflection of 0.1 and a specular transmission of 0.01. The surface of the unit is analyzed with a perfect mirror on it. The efficiency is calculated as:

\[
\eta = \frac{\Phi_{\text{road}}}{\Phi_{\text{unit entry}}}, \text{ where } \Phi_{\text{road}} \text{ is the flux that reach the } 9 \times 50 \text{ m surface that is the road and } \Phi_{\text{unit entry}} \text{ is the flux that reach the entry aperture of the designed unit. In figure 6, efficiency is evaluated showing that the unit rejects light above 40º because of the designed properties.}
\]

Mean efficiency is defined as:

\[
\bar{\eta} = \frac{1}{M} \sum_{0}^{\theta_{\text{max}}} \eta(a), \text{ the mean efficiency obtained for the range from 0º to 40º is 24.4%.}
\]

The 10º optical unit tilt not only make the first CPC reject the light above a 40º height, but also the iluminance distribution over the road will be optimized. There is no flux on the road when sun is above 45º, Fig 6.

Iluminance map for 10º is presented in Fig 7. Due to the direct solar light that enters and exits the unit without suffering refraction in the profile there is a high iluminance point that also is observed in the luminance profile.

The quantity of light that the eye detects is the luminance, with iluminance data the intensity is calculated with the inverse square law:

\[
E = \frac{I \cos(b)}{d^2} \text{ with the area of the exit surface is simple to calculate luminance on the road that is coming from the unit.}
\]
The profile of luminance, Fig 8, shows good stability with regard of sun movement.

3. PROTOTYPE PANEL
Authors have made a prototype of the whole panel in order to evaluate the general performance of the proposed device. The prototype is a panel of 90 cm by 40 cm, and it has a single letter “E” (13x17cm) drawn on it in white on a blue background, as it is common in signal traffic panels. In Fig. 9 a photograph of the panel prototype is presented. In this prototype is placed an optical rectangular 7 x 5 array composed by optical units inside the panel. On the back side of the panel there is inserted a mask to form the letter: in this case an “E”. The objective of the rectangular array is to use a standard traffic unit which can be adapted to any symbol or letter. According to visual necessities, the array size can be adapted by just increasing the optical units.

When the panel is observed with the sun near the visual driver line, the alphanumerical characters can be read because the optical array starts to work and leads light towards the drivers. Fig. 9 (right) show a sample of this effect using the prototype. In this case the letter “E” that is painted in the panel is not visible; driver can deduce the “E” because the optical units are transmitting natural sun light.

3. RESULTS AND DISCUSSION
Computer simulation gives an advantage in optical design because optimization can be done without the need of making any prototype. Prototyping is also necessary to evaluate concordance of simulation to the real behaviour of the system. In this paper authors have designed and simulated an optical unit to redirect light to the road surface. A prototype is made to check real visibility with sun light, but the next step is to assemble a prototype in a real road signal and test different symbol visibility. Also needed is a landscape evaluation as stray light could cause trouble in neighbourhood surroundings glaring on people away from the road.
4. CONCLUSIONS

In this paper authors have developed a new antiglare panel system to make visible vertical traffic signals when sun light is in visual direction, using the own sun light which causes the glare. This very dangerous effect appears mainly in west and east roads. When sun light falls with a specific angle on the back of the panel this light is directed toward drivers that otherwise would not see the signal. Luminance values of $10^4$ cd/m$^2$ are obtained, so contrast ratio with the panel surface is high and visibility of the panel is guaranteed.

Due to the modularity of the array and due to the electricity free device, it could be easily implemented in present vertical panels at a low cost in time and work. This could reduce road accidents because cars actually slow down when drivers try to read a non visible message.

The optical design is optimized to concentrate all the obtained flux on the road to improve visibility of the unit and also to avoid glare away from the road.

REFERENCES