INTEGRATION OF A MULTIFUNCTIONAL AND MULTISPECTRAL OPTICAL SENSOR FOR AUTOMOTIVE APPLICATIONS USING SURFACE MOUNTABLE PLANAR OPTICAL INTERCONNECT

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In this paper we present the design and fabrication of a low cost surface mountable planar optical interconnect and the integration in a low-cost multifunctional and multispectral CMOS vision sensor to detect critical environmental parameters providing, at the same time, information on the driving scenario.

1. Introduction

Nowadays a lot of sensors are used on vehicle or are being developed to detect environmental parameters (luminance, rain, dimming) and the driving scenario (oncoming vehicles, approaching tunnels, lane detection, VRUs in night condition). These sensors provide the necessary input for comfort and safety assistance systems: illumination adapting to the visibility conditions, fog lamp lighting, turning on (off) lamps before tunnel entrance (exit), illumination adapting when crossing other vehicles, automatic activation of windscreen wipers, automatic demisting, automatic speed control, lane warning, etc. Car makers have to manage this increasing number of sensors which means complexity in terms of sensor housing, cabling, electronic interfaces and actuation strategies. For this reason, component suppliers are working toward the integration of more functions. The monitoring of the area in front of the vehicle with one or more cameras allows to collect useful information on the scenario (kind, dimensions and shape of objects and obstacles) to implement comfort and safety functions. For instance, lane warning and lane keeping systems, are based on the use of a camera (CMOS array) placed close to the internal rear-view mirror. The format of the camera is often redundant for the function (e.g. VGA area is not completely used in lane warning function). The former needs (combination of imaging and non-imaging functions and reduction of number of sensors) can be successfully addressed by a multifunctional integration on a multispectral CMOS array [1]. The advantages stemming from this solution are: increased reliability, easy-to-use functions control, reduction in number of sensors and components, lower size, easier mounting on vehicle and reduced total costs. The ADOSE project aims at developing a multifunction automotive sensor with the integration on a single CMOS array of part or all the above mentioned functions, presently performed by different sensors. The approach is to utilise the array as the photo-sensitive element and to divide it into sub-areas, each one being dedicated to one or more functions. The solution proposed by CRF will allow going far beyond in terms of both number and type of integrated functions, thus reducing system costs significantly. The acquisition and processing of each area can be optimised by the use of *windowing* (i.e. reading of sub-areas of the pixel array) and the use of the suitable frame rate and sensor parameters (e.g. gain).

To reduce the amount of detectors for such sensing applications and collect light from special directions an optical interconnect and collecting optics were developed by Fraunhofer IZM to gather and guide light to special region of interest (ROI) on one CMOS imager chip. The optical interconnect is a hollow lightpipe fabricated by hot embossing in

Polymethylmethacrylate (PMMA) and coated with a thin layer of aluminum for enhanced reflection. The collection optics consists of Fresnel lenses to collect light from FOVs up to 60° and a condenser lens system to reduce the beam sizes for coupling into the waveguide. The Fresnel lenses have been specially designed for environmental sensing applications and fabricated by hot embossing in polymer substrates. The optical system, designed to integrate two functions (twilight and fog) is schematically presented in Fig. 1. The optical interconnect has been characterized by measuring the transmission of each channel in the visible and near-infrared spectral ranges. A transmission of up to 48% was measured, depending on the wavelength and the number of deflection elements in the channel. The optical system has been simulated using ray tracing software and a tolerance analysis was carried out which assured the passive assembly approach to meet the low cost requirement.

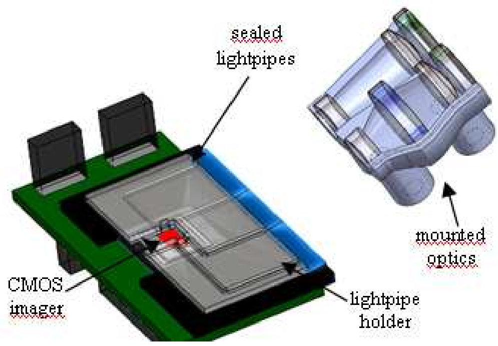

Fig.1. Schematic of the optical system

2. Optical design

The schematic of the optical system for the twilight function is shown in Fig. 2. A Fresnel lens with a diameter of 7mm and different facet angles samples the FOV of 60°. Each facet samples two degree of the FOV and collimates the so collected light. The collimated light beam is focused through a standard plan convex lens (Ø=9mm), which is directly placed behind the Fresnel lens to reduce the beam diameter and the light is then nearly collimated by a standard bi concave lens (Ø=6mm) after 12mm. The reduced beam is reflected by an aluminum coated surface and coupled into the also aluminum coated lightpipe with edge length of 600µm and an overall length of 15mm. The lightpipe guides the light to the ROI with an edge size of 800µm placed at the corners of the CMOS imager.

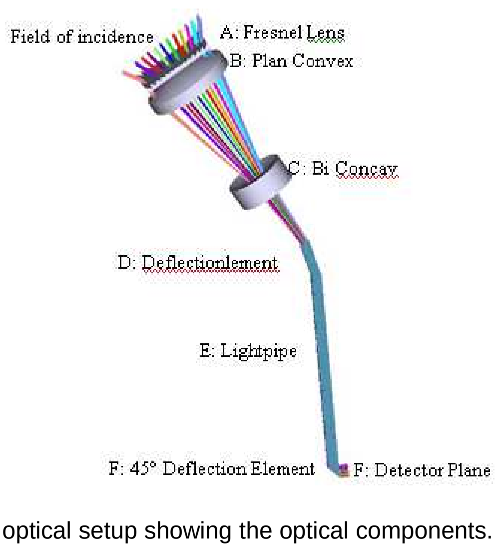

Fig. 2. Schematic diagram of the optical setup showing the optical components. The lightpipe is coated with a thin film of aluminum for enhanced reflection

To ensure the functionality of the optical design a non sequential simulation has been conducted using optical design software Zemax® to calculate the spot size on the imager and the transmission of the optical system for VIS and NIR. Moreover, to evaluate the possibility of passive assembly a tolerance analysis was carried out vary the distances between the plan convex lens and the bi concave lens and the gap between the bi concave lens and the lightpipe in all three spatial directions.

3. Fabrication and Packaging

The lightpipes which couple the collected FOV to the ROI on the sensor chip are hollow lightguides embossed into a polymer substrate which is subsequently metalized to ensure reflection at all incident angles. Furthermore, the Fresnel lenses are also hot embossed in polymer substrates. To ensure the required optical quality of the surfaces of these structures, special high precision milling methods have been employed to produce the master stamps with a surface roughness of R_a=15nm. After embossing, the lightpipes were metalized with Aluminum Al using a PVD process with careful attention paid to the angle of incidence of the evaporation beam to ensure that all the fine structures and deflection surfaces are properly coated. Fig. 3 displays a laser cutted and Al coated PMMA substrate with lightpipes. The lightpipe structure was sealed by an Al coated 300µm thick PMMA foil using adhesive bonding.

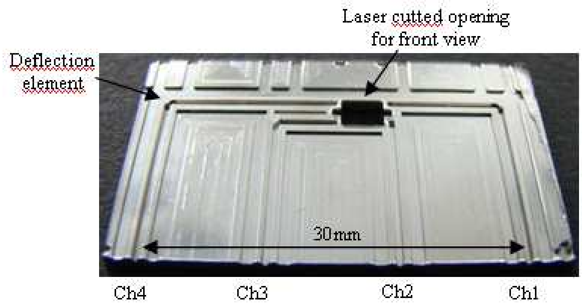

Fig. 3. Aluminum coated PMMA lightpipes with an opening for frontal vision function fabricated by laser cutting

To meet the requirements of low cost fabrication the lightpipes and the packaging concept were developed with regards to a possibility of surface mounting. The planar structure of the lightpipes, sealing foil and the lightpipe holder makes it possible to assemble the parts by surface mounting onto the CMOS Imager PCB using adhesive bonding and clip features, Fig. 4.

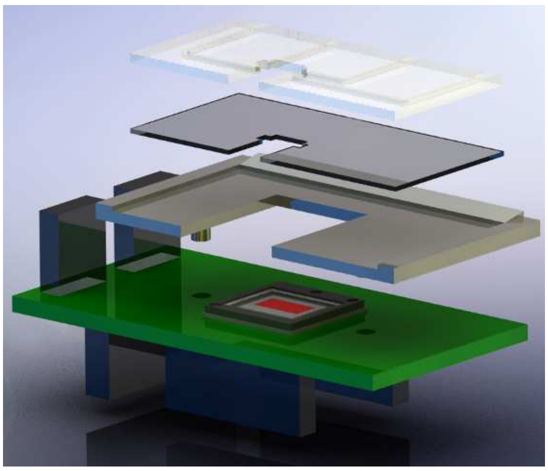

Fig. 4. Schematic of surface assembly of the lightpipes. From top to bottom: PMMA lightpipes, sealing foil, lightpipe holder with deflection element, CMOS imager mounted on PCB.

4. Characterization

The optical system for the fog and twilight function was characterized. The Fresnel lenses were illuminated by a white light and a NIR LED focusing the light through a plan convex lens generating the special FOV for each function. After reducing the beam diameter through the condenser optics the light were coupled via the first deflection element on the lightpipe holder into the lightpipe. The light intensity was measured using a calibrated photodiode before the lens system and at the output of each of the four lightpipe channels (Table 1). The highest transmission of 48% ± 4% was measured for the lightpipe channel with one deflection element. The simulation with one deflection element showed a calculated transmission of 46% which is an excellent match to the measured transmission showing the accuracy of the ray tracing simulation. The transmission decreases for channels with two deflection elements due to losses caused by reflection at aluminum surfaces. Channel 4 showed the lowest transmission.

Channel	Transmission (VIS) ± 4%
1	37%
2	48%
3	41%
4	29%

Table 1. Measured Transmission

5. Conclusions

In this paper we presented the development of a low cost surface mountable optical interconnect for a multifunctional and multispectral CMOS vision sensor for automotive applications. The need for integrate more and more sensors providing data about the driving environment led to a combination of imaging and non- imaging functions on one CMOS chip. The working principle of a fog and a twilight (diming) sensor were presented giving information about the visibility and the luminance around the vehicle. The collection optics was designed to cover a special field of view using Fresnel lenses and a condenser optics to collimate the light and couple into the optical interconnect which uses aluminium coated lightpipe channels to guide the light to the partitioned CMOS chip matrix. To meet the requirements for this application the optical system was designed for passively assembly and the possibility to assemble the optical interconnect by surface mounting. A Ray tracing simulations as well as tolerance analyses were carried out to ensure a configuration with high transmission in the VIS and NIR region and the passive assembly approach. A transmission of up to 48% was achieved which could be further enhanced in the future by using anti reflective coating for each sensor part.

Acknowledgments

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