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Applications of Optical Fibers in Automobiles

Simarpreet Kaur Aulakh

Abstract-In past decade broadband communication technology using optical fibers has spread quickly through internet lines and cable TV lines to the home. All this is due to cheaper cost of optical fiber that realize the transmission speed required by those services. It is now believed that amount of information that will need to be transmitted in field of automobile technology will increase rapidly in near future ,not only in information systems but also in control systems and safety systems. The MOST and IDB1394 standards are an example for automotive infotainment systems. Many European car manufacturers have already adopted the MOST system. The Byte flight system of BMW is pioneering the usage of fiber optic links in their airbag control system. Since the bandwidth-distance product required is smaller, one can use large core fibers such as the plastic optical fiber (POF) and polymer cladded silica (PCS) fiber.

Index terms - Fiber Optic Sensors, Pedestrian-Protection Systems, Polymer Optical Fibers, Seat Occupancy Detection, VCSEL.

1 INTRODUCTION

In several European vehicles, the provision of optical networks has already started in luxury grade models. And it is considered that a sharp turning point from metal networks to optical networks will arrive in near future. Since the beginning of this millennium new applications have emerged in the fields of automotive, industrial control, consumer electronics, home networking and optical backplane interconnects. Since the bandwidth-distance product required is smaller, one can use large core fibers such as the plastic optical fiber (POF) and polymer cladded silica (PCS) fiber. The core diameters of these fibers are normally 0.2mm to 1mm [3]. The large optical core of POF or PCS fibers greatly relaxes the mechanical alignment tolerances of the optical components. As a result, passive alignment can be realized. Conventional electronics packaging technologies such as automatic pick-and-place and transfer molding can be employed in mass production of optical transceivers. The manufacturing cost of optical interconnects can be substantially reduced. There are three principle networks used in cars known as information, control and body systems [3]. Today, commercial applications of POF can be found in short distance communication, in low speed communication between amplifiers with built-in digital to analog converter and digital audio appliances, and in communication systems between numerical controls and high dynamic digital drives for industrial machines and robots [2]. Currently plastic optical fiber (POF) and 650nm LEDs are used in the fiber optics systems . These systems exhibit a power budget of around 14dB and an operating temperature up to +85^{o}C or +95^{o}C. Therefore the current fiber systems are limited to the passenger compartment. Roof top implementations require a maximum temperature of +105oC and the engine compartment takes it up to +125^{o}C. Polymer cladded silica (PCS) fiber is under consideration to overcome the current operating temperature limitations. This type of fiber can operate even at +125^{o}C. Vertical-cavity surface-emitting lasers (VCSELs) are suitable light sources for the new PCS fiber. The VCSEL has a very narrow beam emission angle. Therefore the light output of the VCSEL can be easily coupled into the 200µm core of the PCS optical fiber. Since the VCSEL is a laser element its maximum modulation speed is very high (>>GHz). VCSELs provide data transmission bandwidth in the Gb/s range. Thus, optical systems with VCSELs are future proof for higher speed requirements in new systems. This is an advantage in particular for video type applications [3].

In this paper an overview of recent developments affecting in-vehicle optical networks is discussed along with the use of POF (Plastic optical fibers) in car safety systems and information systems .In particular, key devices used here are visible light sources, optical fibers, and optical circuits and transceivers modules.

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2 PLASTIC OPTICAL FIBERS

Plastic core/plastic clad optical fiber (POF) consisting of the plastic polymethylmethacrylate (PMMA) are used in automobiles. Increasing demands regarding temperature performance, transmission losses, and bandwidth have pushed the current limits of the POF fiber, and the automotive industry is now moving towards an optical domain.

2.1 Car Networks Based On Polymer Optical Fibers

Polymer optical fibers consist of a polymer core and a lower index polymer cladding. Fibers with a polymethylmethacrylate (PMMA) core and an extruded fluorinated acrylic polymer cladding have found interest as light guides for illumination and display elements as well as to transmit optical signals over short distances 100 m. In several ways, POFs are superior to silica-based inorganic glass fibers: they have an acceptable flexibility due to their good ductility, allowing the realization of large and still-flexible core diameter fibers (e.g.1 mm). The main Today, commercial applications of POFs can be found in short distance communication, in low speed communication between amplifiers with built-in digital to analog converter and digital audio appliances, and in communication systems between numerical controls and high dynamic digital drives for industrial machines and robots [2]. The large optical core of POF or PCS fibers greatly relaxes the mechanical alignment tolerances of the optical components. As a result, passive alignment can be realized. Since the bandwidth-distance product required is smaller, one can use large core fibers such as the plastic optical fiber (POF) and polymer cladded silica (PCS) fiber. The core diameters of these fibers are normally 0.2mm to 1mm. Conventional electronics packaging technologies such as automatic pick-and-place and transfer molding can be employed in mass production of optical transceivers. The manufacturing cost of optical interconnects can be substantially reduced. From telecom to datacom to bitcom the typical cost of fiber optic transmitter components can be reduced by about a factor of ten depending on specifications and requirements. POF offers a high operating bandwidth, increased transmission security, low weight, immunity to electromagnetic interference, and ease of handing and installation. Crucially, it is also a low-cost option, with both the fiber itself and the associated components coming in at a fraction of the cost of their pure silica counterparts .And it's not just navigation and entertainment functions that can exploit POF.

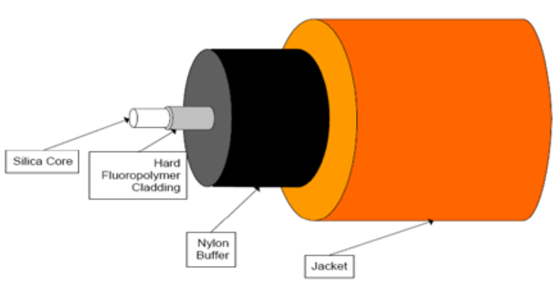

FIG: 1 Automotive PCS Structure [1]

3 AUTOMOBILE INFOTAINMENT AND SAFETY NETWORKS

3.1 Optical Fiber Transceivers for Automobile Information Networks

Fiber optic transceivers (FOT) based on lead frame and plastic molding technologies for large core plastic optical fiber (POF) and polymer clad silica (PCS) fiber systems. The transmitter module contains a VCSEL light source, an electronic driver chip, and passive electronic components. The laser transmitter emits in the near infrared at 850nm. The normal operating speed is 50Mb/s for applications in the automotive infotainment system. Eye diagrams are wide open for all ambient conditions. For higher data rates up to the Gb/s range, a GaAs metal-semiconductor-metal (MSM) photo detector is used in the receiver module. The technology is well suited for ultra low cost applications in automotive, industrial links, consumer electronics, home and office networking. Currently plastic optical fiber (POF) and 650nm LEDs are used in the fiber optics systems . These systems exhibit a power budget of around 14dB and an operating temperature up to +85°C or +95°C. Therefore the current fiber systems are limited to the passenger compartment. Polymer cladded silica (PCS) fiber is under consideration to overcome the current operating temperature limitations. This type of fiber can operate even at +125°C. Vertical-cavity surface-emitting lasers (VCSEL) are suitable light sources for the new PCS fiber. The VCSEL has a very narrow beam emission angle. Therefore the light output of the VCSEL can be easily coupled into the 200μm core of the PCS optical fiber. Since the VCSEL is a laser element its maximum modulation speed is very high (>>GHz). VCSEL provide data transmission bandwidth in the Gb/s range. Thus, optical systems with VCSEL are future proof for higher speed requirements in new systems. This is an advantage in particular for video type applications. [3]

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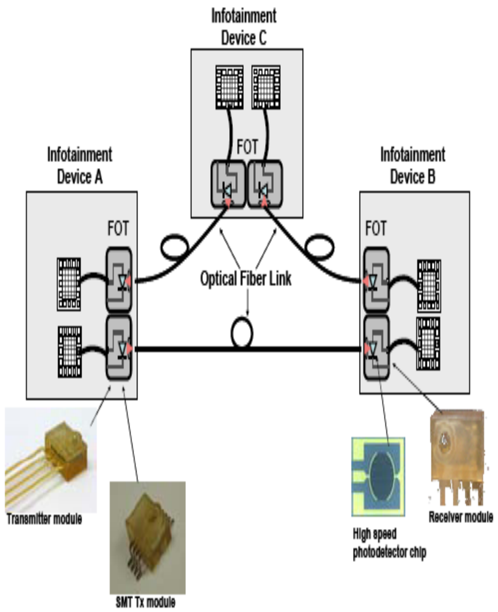

FIG: 2 Transmitter and receiver components for the infotainment system in automobiles. The various infotainment devices (such as for example: radio "A," CD player "B," navigation system "C") are connected in a fiber optic ring. [3]

The important cable characteristics of plastic optical fibers that need to be properly set are core diameter, cladding diameter refractive index profile, attenuation. The standard values of these parameters are given in Table 1.

TABLE: 1

IMPORTANT CABLE CHARACTERISTICS OF PMMA POF IN CAR NETWORKS [2]

core diameter	µm	980
cladding diameter	µm	1000
refractive index profile		step-index
numerical aperture		0.5
attenuation between 630 nm and 685 nm [a]	dB/m	<0.4
bandwidth [b]	MHz·km	3
inner jacket		polyamide
diameter of inner jacket	µm	1510
outer jacket		polyamide
diameter of outer jacket	µm	2300
operation temperature	°C	-40...+85
tensile strength	N	100
elongation at 100 N	%	< 2.5
minimum bending radius	mm	25

3.2 Optical Fiber use in Automobile Safety Systems

3.2.1 Passenger Safety

The most important use for POF in automobiles is for the crucial purpose of passenger safety. In many instances, safety requires communication between sensors embedded in the vehicle and other devices, such as air bags, that are used to ensure safety. While using POF for other non-safety-oriented applications is becoming more prevalent, automakers typically reserve these uses for the automotive aftermarket-those (usually optional) devices that replace initial factory-installed equipment. The first serious intravehicle communication application for POF sensors can be found in BMW automobiles. BMW has developed a POF optical network for internal use operating at 10 Mbit/s-a star networks that is used to communicate with the air-bag sensors. This network uses the same components and technology developed for the MOST standards. When a vehicle collision occurs, information from force sensors within the vehicle is interpreted and communicated over the POF network to the individual air bags to control their inflation. This is the first time that POF has been used for such a mission critical application.

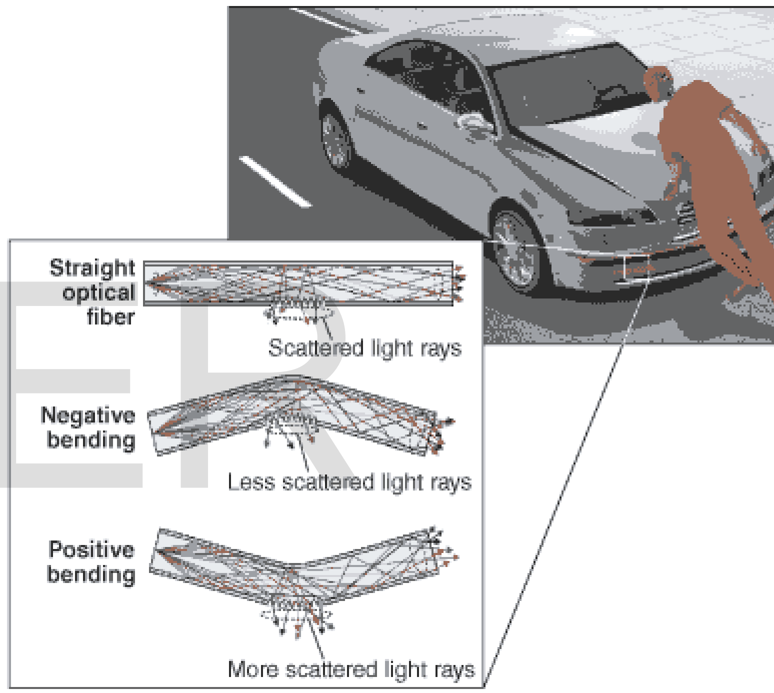

FIG: 3 Sensors using plastic optical fiber embedded within the framework of an automobile can be used to provide pedestrian protection. The transmission signal changes when a surface-treated zone on the fiber is bent. Analysis of the signal from several parallel fiber strands allows the system to determine the nature of the object impacting the vehicle. The sensor can distinguish between a human and an inanimate object, triggering the hood to lift and softening the impact if a human is struck.[6]

3.2.2 Pedestrian-Protection Systems

In addition to protecting vehicle occupants, POF is being used for pedestrian-protection systems. Active methods can be sensors that identify impact with a pedestrian and then trigger protective action such as using actuators to lift the hood. The basic principle behind the active pedestrian protection systems is a cladding surface treatment of the fiber at discrete zones along the fiber. Bending the fiber in one direction leads to a better transmission whereas bending in the other direction leads to a lower transmission, compared to the straight position. The spatial resolution is achieved by incorporating several fiber strands in parallel and using numerical signal analysis of the treated zones. Due to its high bandwidth, the sensor is able to distinguish between positive and negative bends and can determine the source of an impact with high temporal resolution. High resolution is necessary to distinguish between a human leg, an animal, or a lamp pole-an important distinction in determining whether to lift the hood of a vehicle in the event of a pedestrian or animal collision, or activate air bags or other safety features in the case of a non-pedestrian collision.

A pedestrian protection system was developed by the consortium IPPS, Intelligent Pedestrian Protection Systems. In this safety concept the companies co-operate since 2001 [8].The concept of these companies contains a give-way bumper, fiber-optical sensors and an active hood, raised by a pneumatic muscle instead of pyrotechnical actuation. The result is a drivable prototype in which the companies combined their know-how. To decrease the risk of leg injury, a design was developed with a soft foam that is situated between bumper cover and bumper cross beam. In addition to this, new sensors were also integrated into the bumper. The functional principle of these fiber-optical contact sensors acts in different stages. In parts the plastic sheath of the light wave conductor is removed. If the fibers are bent, a part of the light there reflects from the fiber. This reflection is depending on the bending intensity and therefore the light loss registers how strong the fiber has been bent. By laying several preserved fibers horizontally above the bumper and removing different segments of the sheath, a distortion picture of the vehicle front arises. Through this the control module can recognize if a pedestrian is going to crash into the bumper. Then it sends an impulse for lifting the modified bonnet to catch the full

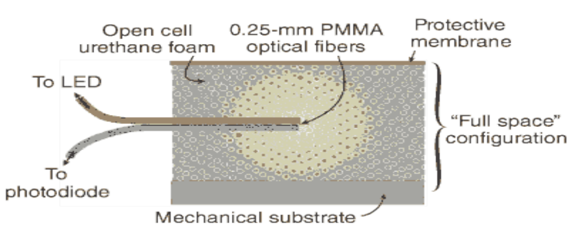

FIG: 4 Seat occupancy detection[6].

pedestrian's head softly [8].Plastic optical fiber can also be used for seat-occupancy recognition, resulting in cost reduction as well as increased safety. A sensor in the seat identifies whether the seat is occupied. If the seat is empty in the event of a collision, for example, the air bag will not deploy, saving the expense of repair and replacement. Seat-occupancy recognition could also be used to lower the headrests for improved driver visibility if the surrounding seats are not occupied.

Seat occupancy detection is useful to prevent expensive repair and replacement of air bags in the event of a collision. If the seat is unoccupied, for example, the air bag will not deploy. One available method is the use of special foam that responds to pressure, changing the amount of light transmitted to a plastic optical fiber for occupancy detection. [6].

One approach for seat-occupancy recognition is the Kinotex cavity sensor from Canpolar East (St. John's, NF, Canada). The principle behind this method is light-scattering that is dependent on the compression of the scattering medium, such as special rubber foam. The transducer operates by detecting a change in energy intensity in and around an illuminated integrating cavity. Deformation of the integrating cavity by an external influence, such as pressure, results in a localized change to the illumination energy intensity, which can be transmitted by a plastic fiber and then measured In addition to single-point occupancy detection, an embedded array of point sensors within the seat can be used to reveal information on the pressure load distributed over the area, allowing seat-pressurization and/or cushioning to maximize the occupant's comfort. Many consumers are probably aware of the use of tactile sensors that can stop a car window if an object is in the way. While many of these sensors are nonoptical, the evanescent field of an optical fiber can also be exploited in this application. [6].

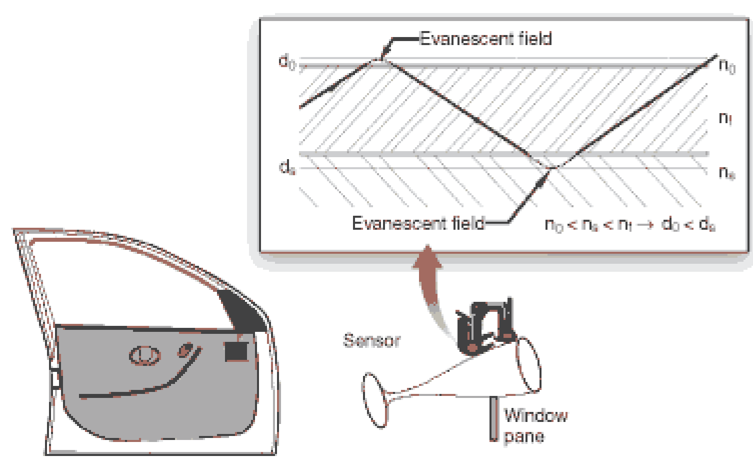

FIG: 5 the well-known phenomenon of the "evanescent field" within an optical fiber can be used as a tactile sensor. If an object disrupts the evanescent field, the light transmitted through an optical fiber shifts within its core. This shift can be detected with very high sensitivity, allowing the motion of a window to be stopped if an object is in its path. [6]

CONCLUSION

From this study on use of optical fibers in automobiles we conclude that Photonic technologies are superior to electronic solutions in terms of data rates, bandwidth, reliability, and robustness. However, it is not easy to achieve integration and miniaturization in photonics as easily as in electronics. Although optical sensors and communication protocols have demonstrated their performance capabilities, they still need to prove they are capable of replacing their electronic counterparts. The industry is relying on light/image or optical sensors to develop a wide range of safety technologies for occupant safety, intruder detection, lane departure warning, and blind spot detection notes the analyst. Meanwhile, fiber optic sensor's rigidity and resistance to electromagnetic interferences have made them well suited for automotive applications. The major application areas of optical sensors are driver assistance systems and traffic monitoring systems. Optical sensors (rain sensors), used as automatic wipers in cars, is a typical illustration of the suitability of optical sensors for hostile environmental conditions, observes the analyst. In the case of driver assistance systems, cameras with image sensors are used to alert the driver about the driving environment and the possibility of collision with other vehicles. Photonic technology has also been associated with lighting systems in automobiles. It not only aids the development of anti-glare lighting but also night vision systems for safety in harsh driving situations such as darkness, fog, and exposure to blinding light.

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