

Fiber Optic Systems for Avionics Illumination

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ABSTRACT

Fiber optics has been a viable technology for data communication applications in many environments including aircrafts, providing higher bandwidth, longer transmission distances, EMI/RFI immunity, and lower weight than copper cables. Until recently however fiber optics was not a viable transmission medium to efficiently distribute light for illumination on aircrafts.

Fiber optic lighting systems, referred to as the Remote Source Lighting technology have been installed on US Navy vessels including the LPD 17 class, the Italian Multi-Mission Frigate FREMM class, and the DDG 1000 class. Optical fibers can offer advantages over conventional lighting systems that use copper cables due to safety, lower maintenance, EMI/RFI immunity, no possibility of short circuits or sparks, lightweight, and low operating costs. Higher procurement costs, primarily driven by the 37 fibers optical cable, have prevented a broader usage on naval vessels and for other applications including aircrafts.

Systems utilizing visible Lasers as light sources are being developed under a number of US Navy sponsored programs, enabling the use of single fiber cables to transport light. This critical transition to a laser system capable to couple more light into a single fiber can drastically change the way lighting systems are designed on aircrafts. The single fiber cable will provide significant benefits including 70% lighter weight than copper cables, 80% lower cost than the existing Navy cables, immunity to EMI/RFI, and the possibility to adapt fiber optic components and procedures developed for fiber data transmission applications, such as switches, connectors, installation procedures, and methods to illumination applications.

CITATION: Tomasi, G., "Fiber Optic Systems for Avionics Illumination," *SAE Int. J. Aerosp.* 5(1):2012, doi: 10.4271/2012-01-2127.

INTRODUCTION

Silica fibers have the potential to transport more energy than equivalent sized copper cables. A 100µm core fiber could theoretically transport over 25,000 Watts of energy.

Fiber optic illumination systems offer advantages over conventional lighting systems in situations where the lights are difficult to access and maintain, the luminaires and cables have to be located next to sensitive electronic equipment that may be affected by the electrical emissions, the space for the lighting device is very limited, where the lights will experience extreme mechanical and environmental stresses, and in any other application where reduced weight, small size, and durable, electricity-free lighting is desirable.

Fiber optic lighting has been used for the navigation and signaling lights on the USS San Antonio LPD 17 class since 2005 and is being installed on the new class of DDG 1000 destroyers for all topside navigation, signaling, and illumination lights. These systems use a proven technology consisting of a light engine (illuminator) with high intensity metal halide lamps coupled to a fiber optic cable with 37

bundled optical fibers. The cable transports the light to a luminaire that shapes and diffuses it in the required pattern. Although suitable for many shipboard applications, the size of these illuminators and cables makes them too large and bulky for practical avionics applications.

Recent advances in LED's have made them a feasible alternative to metal halide lamps, increasing the longevity of the light from 2,500 hours of metal halide to more than 50,000 hours for LED's. LED based systems however require the use of the same 37 fibers optical cable to insure that sufficient light energy is transported to the luminaires. Fiber optic lighting systems using LED's are being installed on the new Italian FREMM Frigate class for navigation and signaling lights and will be installed on the LPD 17 class to replace the metal halide illuminators.

High power lasers coupled into optical fibers have been utilized for many years in manufacturing for cutting and welding, and in defense for target illumination, proving that high levels of photonic energy can be coupled and transported efficiently and safely in glass fibers. Recent advances in the areas of visible lasers driven primarily by the



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high definition projection industry have opened the possibility of coupling the laser and fiber optic technology to illumination, reducing the overall systems' costs, size, and weight, while retaining the combined benefits of fiber optic illumination and the longevity of solid state light sources.

In a trade study⁽¹⁾ being performed for the US Navy Office of Naval Research, it is estimated that Laser based illumination systems will provide a reduction in weight of 30% from the metal halide and LED systems and an acquisition cost reduction of over 50%. Additional cost reductions will be realized thru the lower weight and the smaller cable, about 1/3 the size of the existing illumination cable, thus easier to install. Given that each one (1) additional pound of cable on a Boeing 747 costs an additional \$300 per year⁽²⁾, replacing 1,000 feet of 14 AWG wire per MIL-W-16878/4 with a fiber optic cable could save over \$3,000 in fuel cost per year.

This paper examines the benefits that would be derived thru the implementation of a fiber optic lighting network on aircrafts in areas of weight savings, installation cost reduction, and lower maintenance.

TECHNOLOGY OVERVIEW

A fiber optic illumination system consists of three basic components: 1) illuminator, 2) fiber optic cable assembly, and 3) luminaire.

Illuminator

The illuminator contains the light source and is the only electrical component of the system. The light is generated by a high intensity light such as a metal halide lamp, LEDs, or lasers. The light is coupled into the optical fibers utilizing a system of optics. The illuminator provides mechanical and environmental protection to the light source and is controlled via an interface to the control system. Functions including flashing, dimming, and color changing are incorporated into the unit. An active cooling mechanism insures that the light sources operate in the optimal range regardless of the external temperature.

Illuminators are designed to meet the specific requirements of the application where they will be installed. Illuminators used on US Navy vessels meet all the requirements imposed on electrical equipment including shock, vibration, EMI, E3, and water resistance while those designed for use on coal mining equipment comply with MSHA safety standards.

Fiber Optic Cable Assembly

The fiber optic cable transports the light energy from the illuminator to the luminaire. Most commercial fiber optic illumination systems utilize plastic optical fibers that limit the transmission distance to under 15 meters. The fiber optic illumination systems used on US Navy vessels utilize cables manufactured with glass optical fibers, allowing for distances over 300 meters. These cables consist of 37 fibers each with a

core/clad size of 600/630 μ m and a low smoke, zero halogen outer jacket. The high fiber count is required to insure that sufficient light energy is coupled from the illuminator into the cable. Special connectors are applied utilizing the epoxy and polish method similar to what is used for standard fiber optic communications cables. The cable is designed to withstand mechanical and environmental stresses similar to other fiber and copper cables installed on Navy ships. The cables are completely non-metallic.

The laser based systems will utilize single fibers, reducing the cost, size, and weight of the cables.

Luminaire

The luminaire receives the light from the illuminator via the fiber optic cable and shapes it into the pattern required by the application. Since the luminaires do not contain the light source and the related power and thermal management hardware, they can be very small and constructed entirely of non-metallic components. Most luminaires designed for use on Navy vessels and other exterior applications are hermetically sealed and Nitrogen charged to prevent contamination of the internal optical components. Luminaires have been designed completely flush to the ship's hull with a hull penetration as small as 0.5 inches (1.25 mm) in diameter. The existing lighting systems allow up to four (4) luminaires to be connected to one (1) single illuminator.

LASER BASED SYSTEMS

Laser light sources are the critical enabler that will allow the utilization of optical fibers for lighting networks on aircrafts, marine vessels, and eventually commercial and industrial facilities.

Fiber optic illumination systems on US Navy vessels and in mining applications utilize illuminators using either metal halide lamps or high power LEDs as light sources. In the last three years visible lasers have become available providing light intensity levels surpassing those of the metal halide and of the LED sources. [Table 1](#) compares a fiber optic illumination system using the different light sources.

Table 1. Light Sources Comparison (White Light)

	METAL HALIDE	LED	LASER
Fibers in Cable	37	37	1 or 3
Fiber Size - core/clad (μ m)	600/630	600/630	1000/1040 or 600/630
Flux at Luminaire (lumens)	- 1,000	~ 400	> 2,000
Source life (hrs)	~2,500	$\geq 50,000$	$\geq 50,000$
Brightness (W / mm ² str)	~ 1	~ 1	~ 10 ⁵
Coupling Optics Required	Yes	Yes	No