REMOTE SOURCE LIGHTING FOR EXTREME ENVIRONMENTS

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Technology Overview

The remote source lighting (RSL) technology consists of transmitting light generated by a high intensity light engine (illuminator) through a length of fiber optic cable and emitting it at a distance from a light diffusing device (Luminaire). This technology has been widely used in applications ranging from illumination for medical procedures, automotive instrumentation lighting, and architectural illumination. Some of the advantages offered by RSL systems over conventional local lighting include:

- Ability to place the light engine in an area where maintenance functions will be facilitated (closets, basements)
- Elimination of potentially damaging infra-red and ultra-violet emissions via the use of filters in the illuminator
- Ability to place small, maintenance free luminaires in hard to reach locations
- Ability to change light color and intensity instantaneously via filter wheels and light dimmers in the illuminator
- Utilization of a single light source for multiple luminaires
- Improved illumination pattern distribution

These benefits had been of interest to the military naval sector since the first inception of the RSL technology; however, the limitations of commercial RSL systems prevented the implementation aboard naval combatants.

Most of the commercial RSL systems utilize cables manufactured using two basic types of fibers: a) one single large core PMMA plastic optical fiber; or b) bundles of smaller PMMA fibers stranded and encased in an outer jacket. A third option: c) bundled quartz fibers, with individual diameters of about 50µm or less offer a viable option to PMMA in applications where the distance between the illuminator and the light emission point are less than 15 feet and high flexibility is required.

The PMMA and quartz fibers work well for the intended applications where long distances between the light source and the emission point are not required or high attenuation losses as light travels through the cable are acceptable.

The illuminators used in conjunction with these fibers are typically designed to function in relatively benign environments, such as operating rooms, buildings' basements and closets, pool houses, and outdoor in landscaping applications; all areas where stresses from high vibration, mechanical shock, and EMI are not typically experienced. The same applies to luminaires, designed for a variety of applications where extreme stresses are not experienced.

Military Applications

The naval combatant environment requires equipment designed, built, and tested to withstand a variety of conditions including high vibration, strong shock forces, high EMI environments, high humidity, salt spray, and wide temperature ranges. In addition, the cables have to meet the very strict flammability, low smoke, and low toxicity requirements in order to insure the safety of personnel in the event of a fire.

Conventional RSL components would not survive in a typical US Navy shipboard environment nor would PMMA plastic cables meet the cable safety requirements. In addition, the high losses of PMMA fibers and light chromaticity shift experienced over longer lengths would make these cables unsuited for applications where the distances exceeded 40 – 50 feet and the output had to meet strict Coast Guard navigation rules (COLREGS 72).

The US Navy determined that RSL was a technology offering considerable potential in the areas of low radar cross section design, improved lighting efficiency, low infra-red signature, improved illumination pattern distribution, and reduced cost of maintenance. Additional work needed to be done in areas of cable and components design. A program to evaluate and advance the technology was initiated. A team led by Northrop Grumman Ship Systems was partially funded through a US Navy ManTech (Manufacturing Technology Improvement) program sponsored by the Office of Naval Research (ONR), through the Penn State Electro-Optics Center (EOC) to create the baseline for a new family of RSL systems combining the benefits of silica fibers, typically used for communication applications, with the advantages of high definition lighting.

<u>RSL Systems for US Navy Applications</u>

RSL Fiber Systems, LLC a ManTech team member, further evolved the RSL technology into new, Advanced RSL systems for naval combatant applications. The resulting RSL systems are being installed aboard a new class of US surface combatants and are being designed in several new US Navy vessels. These same designs have the potential to find applications in many commercial applications as well, where rugged construction, high definition lighting, and long distances between light source and emission point are required.

Some of the benefits of these new Advanced RSL systems include:

- Improved Lighting Efficiency
- Cable losses of < 25dB/Km (PMMA > 180 dB/Km)
- Cable meeting all Navy safety and flammability requirements
- Ability to embed the lighting fixtures in the ship’s structure (Stealth Design)
- Low Radar Cross Section Lighting Fixture design
- Ability to remote the light emission point from the light source by up to 200 meters
- Improved Illumination Pattern Distribution
- Night Vision Device Compatible lighting
- Integrated System Controls
- Ease of maintenance with basic tools
- Fully encased optical components to prevent contamination

A unique feature of these new Advanced RSL systems is the fact that they were certified for use aboard US Navy vessels through stringent testing to Medium Weight Shock, Vibration, EMI, and UL-1104, COLREGS 72 requirements. This was accomplished without the use of Shock Mounts to qualify for Shock and Vibration requirements.

- Medium Weight Shock to MIL-S-901D
- Vibration to MIL-STD-167-1
- EMI Emission and Susceptibility to MIL-STD-461E

- UL 1104, COLREGS 72 Requirements for Navigation Lights

System Highlights

The most significant aspects of the Advanced RSL system are:

Silica Glass Fiber Optic Cable: Typically, RSL systems use fiber optic cables manufactured using plastic (PMMA) fibers. These fibers exhibit very high losses in the visible range (>180 dB/Km), with very high absorption in the red portion of the spectrum, giving the light a green hue. The ManTech program developed a cable made with silica fibers, with attenuation values of <25 dB/Km, and with flat spectral absorption throughout the visible range. This cable has become the standard for RSL applications aboard US naval combatants.

Illuminator Construction: The Advanced RSL system illuminators incorporate several of the technological innovations of the RSL ManTech program in addition to new design concepts that evolved from the experience gained by reviewing previous RSL shipboard installations.

A double clamshell and steel mounting base design was developed to facilitate the maintenance process while providing a solid structure on which to mount the optical components for best shock and vibration resistance. The illuminators passed Medium Weight Shock to MIL-S-901D and Vibration to MIL-STD-167-1 *without the use of shock mounts*.

The upper portion of the illuminator, easily accessible through the top cover, houses the lamps with the related optics and electronic controls, including an error code indicator. The bottom portion acts as cooling plenum and contains the parts that are not typically serviced, including the slide motor assembly.

Figure 1: Advanced RSL System Illuminator – Top View

Figure 2: Advanced RSL System Illuminator – Front View

Optical Cassette Design: RSL systems typically use filter wheels to position the optical filters and wire mesh screens to dim the light output. The resulting dimming can be non-linear, resulting in inadequate light level adjustment for the pilots when landing the aircrafts. Filter wheels, additionally, are prone to damage during high shock forces. RSLFS developed an optical cassette containing the optical components and allowing for infinite dimming capabilities from 0 to 100%.

Optical Deck and Collection Unit: The lower optical losses of the glass fiber allow for a smaller cable than the one produced with the PMMA plastic fiber. Although the cable is lighter and easier to install, the active light coupling area is nearly 10 times smaller. A light collection and coupling mechanism, able to capture nine times (9X) more light than the older system into the smaller coupling area was developed for the Advanced RSL system.

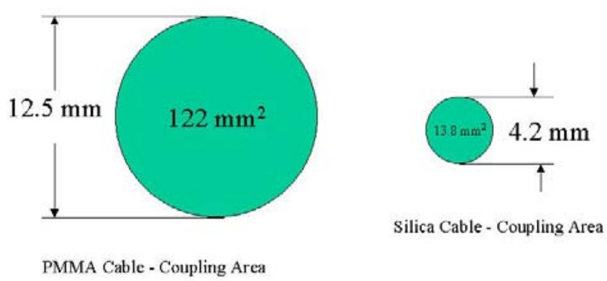

Figure 3: PMMA vs. Silica Cable Coupling Area

Self-Contained Lamp Housings: One of the issues with any lighting system installed in potentially hostile environments is the level of difficulty that may be encountered when replacing the lamps. RSLFS developed fully enclosed lamp housings, containing an integral heat filter. The units are easily unplugged and removed by undoing two retaining screws. The new units are already pre-aligned and easily fit into the illuminator. The old units can then be serviced in a more convenient location or sent back to the factory for repair.

Figure 4: Lamp Housing

Integrated Cable Splitters: When an illuminator is used to drive two or more luminaires, cable splitters serve the function to divide the light output and route it to each respective cable. Conventional splitter designs consist of a device with one input receiving light from the illuminator, and multiple outputs coupling the light into separate RSL cables. The device adds bulk to the system in addition to increasing the overall optical losses. An Integral Splitter was developed for the Advanced RSL system, where from two (2) up to nine (9) cables to be mated into a single connector, considerably reducing the bulk of the system and the optical losses.

Low Loss, Re-Usable Connectors: Connectors are often the weakest point of a communication link and, in an optical system, one of the primary contributors to the optical losses.

Connectors used in an RSL system have to encase multiple fibers, minimizing the “voids” between the fibers, while preventing any longitudinal movement or “pistoning” of the individual fibers. RSLFS, in partnership with Wire-Pro Incorporated (WPI), an RSLFS partner with over 30 years experience in connector and wire harness manufacturing for the Military market, developed a line of high precision RSL connectors for the Advanced RSL system. These optical connectors utilize the epoxy and polish method to secure the 37 optical fibers in a tight package with minimal coupling losses. In addition, the WPI developed optical connectors address the issue of field re-termination. Typically, optical connectors have to be completely scrapped in the event that the RSL cable has to be re-terminated. These connectors utilize a modular design where only the inner sleeve needs to be scrapped should re-termination be necessary. The entire outer shell and housing can be reused.

Figure 5: 1:2 Integral Splitter showing Re-Usable Design

<u>Advanced RSL System Evaluation – RSL Waterline Security System</u>

A direct comparison between an older RSL system using cables containing PMMA plastic fibers (legacy System) and the Advanced RSL system consisted of a ship's Waterline Security (WLS) lights.

When anchored or docked, US Navy ships have the ability to illuminate the water perimeter around the vessel to detect possible intruders by hanging several high intensity lights off the sides. The Legacy System RSL installation aboard a Navy vessel included 32 WLS Luminaires, 16 on the port side and 16 on starboard side, permanently mounted in the ship's hull. One illuminator was used to drive every two luminaires.

The RSL WLS system was selected for its ability to immediately turn the lights on without incurring the tedious, and often lamp-damaging, task of hanging individual lights off the sides of the ship. The intensity of this RSL system however did not equal that of the conventional, manually installed WLS lights, and the light output had a greenish hue, caused by the PMMA fibers filtering out most of the red portion of the lamps' spectral output.

RSLFS designed an upgrade that consisted of replacing the illuminators, the cables, and the luminaires with the components of the Advanced RSL system.

<u>Luminaire Design:</u> The WLS luminaire output pattern consists of a wide beam in the X-axis (100^o) and a narrower beam in the Y-axis (30^o). An angle bracket is incorporated to compensate for the angle of the ship's hull, and a purge line to maintain a positive Nitrogen charge to prevent contamination from moisture.

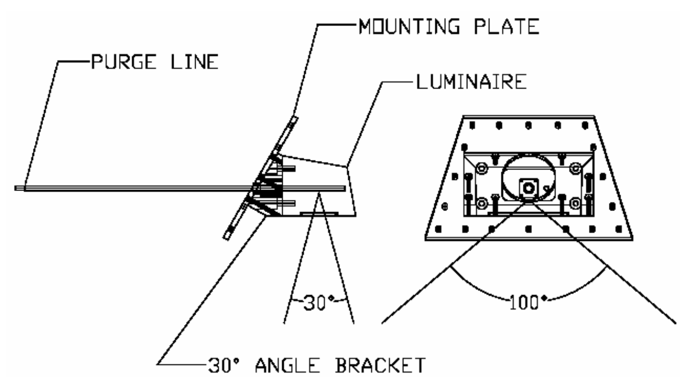

Figure 6: Waterline Security Luminaire Design and Output Pattern

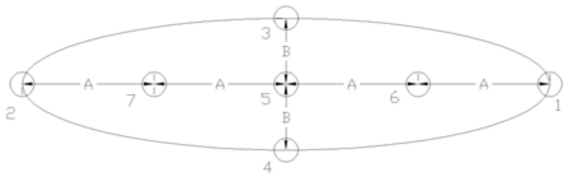

Figure 7: Waterline Security Luminaire Beam pattern and Data Points

Advanced RSL System Testing: Testing performed at the RSLFS facility in Salem, New Jersey compared the existing, PMMA based WLS Legacy RSL system with the Advanced RSL system. ***The results indicated that, on average, a sixteen times (16 X) increase in light output intensity, with a very white light, are realized through the upgrade.***

Table 1 illustrates the foot-candle (fc) values calculated for a distance 15 feet from the luminaires, taken at the data points shown in Figure 7.

Data Point	Advanced RSL Intensity (fc)	Legacy RSL Intensity (fc)	% Improvement
1	0.84	0.05	1622%
2	0.25	0.04	597%
3	2.06	0.08	2524%
4	0.87	0.09	877%
5	6.33	0.32	1896%
6	4.03	0.19	1990%
7	1.96	0.15	1168%
Avg.	2.33	0.13	1682%

Table 1: Advanced RSL vs. Legacy RSL System Light Intensity

Illuminator	Intensity (Lumens)
Advanced RSL System	808
Legacy RSL System	280

Table 2: Advanced RSL vs. Legacy RSL System – Illuminator Output Intensity

Conclusions

The significant design advances made in the RSL technology, as demonstrated by the performance of Advanced RSL System, have addressed the shortcomings of previous RSL systems and have made the technology ideally suited for implementation aboard naval combatants. In addition, these Advanced RSL components can now be utilized in commercial applications where extreme mechanical forces may be experienced, long distances between light sources and luminaires are required, and high intensity illumination is needed.

COMPANY OVERVIEW

RSL Fiber Systems, LLC based in Salem, New Jersey is a joint venture of Wire-Pro, Incorporated and The Skyler Technologies Group, Inc. The Company develops and sells lighting systems utilizing the Remote Source Lighting (RSL) technology as well as other advanced lighting technologies. RSL FS acquired the assets pertaining to this product line from Winchester Electronics, a division of Northrop Grumman, in 2001 and, since then, has continued the development of RSL components and systems. RSL FS products are currently being installed on a number of US naval combatants.

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