Remote Source Lighting for the Shielded Environment

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RSL gives the chamber designer, installer, and user the option of controlled and flexible lighting for RF-free environments.

INTRODUCTION

Lighting the interior of an anechoic or RF shielded chamber can be challenging. Because of the need to keep the chamber isolated from electrical fields, magnetic fields, and metallic surfaces, there are many constraints on lighting equipment. The lighting fixtures may have to be covered during tests. Portable lighting may have to be brought in during equipment installation and then removed when the chamber is in operation. The results can be a dim interior or dark spots. The light that is in the chamber is usually uneven and some surfaces may be impossible to illuminate. Poor quality lighting can make filming of tests difficult. These and other problems can be alleviated by a new lighting technology already in use in hazardous areas.

RECENT DEVELOPMENTS

Recent progress in developing efficient light sources and in manufacturing optical fiber has given rise to a new kind of illumination system in which optical fiber is used to deliver light from the light source to a remotely located point or points. Fiber optic cables do not emit electromagnetic radiation because they carry no current. This type of lighting is called Remote Source Lighting (RSL). RSL systems consist of three subsystems (Figure 1). They are:

- The illuminator, in which light is generated, collected into a small spot coupled into the fiber bundle, and split among several fibers.
- The light pipe (usually large-diameter, cabled, plastic optical fibers) which deliver light from the illuminator to remote lighting points.
- The luminaires (distal end devices) that shape and color the outgoing light.

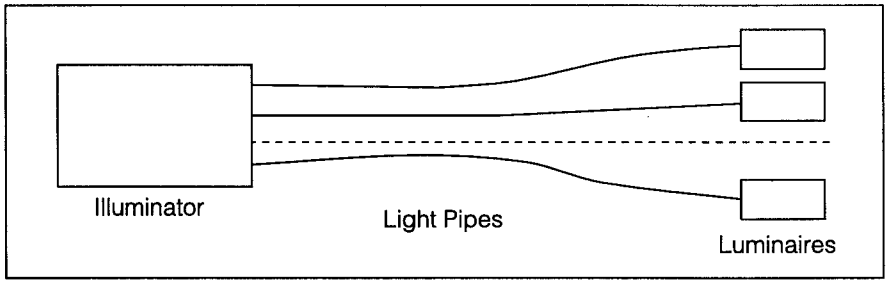

Figure 1. *Remote Source Lighting Concept.*

The illuminator is installed outside the RF chamber. Light pipes carry light from the illuminator into the chamber. Each illuminator has an output cable or several cables carrying light to one or several lighting points. The plastic luminaire is a nonmetallic fixture well-suited to the nonreflective needs of the anechoic environment. In RSL systems that use a holographic diffuser in the luminaires, uniform light can be precisely directed to the target with sharp cutoffs so that light is directed exactly and only where it is needed, resulting in uniform, bright light. This is useful wherever light control is mandatory.

BASIC DESIGN

The components of the RSL system are designed to complement each other. They can be combined to achieve very high light transmission efficiencies. A white light source (usually metal halide, although sometimes xenon or halogen) generates light which is coupled into plastic optical fiber (large core or a bundle of smaller diameter fibers). The length of the fiber is determined by the application. At the distal end of the fiber is a beamformer or luminaire, which conditions, shapes, and homogenizes the light.

The light from each cable can be different. For example, a system with three cables exiting the illuminator might be designed so that one cable carries 1/2 of the light and outputs it in a 10° circle, the second could carry 1/8 of the light and output it in a 30° by 40° ellipse, and the third could carry 3/8 of the light and output it in a 10° by 60° ellipse. In this way, a single lamp located outside the chamber can supply three different spots of uniform light to the interior of the chamber. It would be possible to precisely light the quiet-zone of an anechoic chamber while leaving the rest of the chamber in darkness.

ILLUMINATORS

Illuminators for use in RSL systems usually consist of several components:

a light source in combination with light collection optics (a reflector) to collect generated radiation into a relatively small diameter spot (millimeters); filters to separate the visible portion of the radiation from the UV and IR radiation; a coupler to effectively couple light into the delivery system; a splitter to split the light among several optical fibers; and optical connectors to connect the optical fibers to the port of the illuminator.

For best RSL performance, the illuminator should have:

- Maximum outgoing light flux so that multiple luminaires can be illuminated
- Maximum light source efficacy for lowest power consumption
- Highly efficient light collection, coupling, and splitting
- Maximum outgoing light flux concentration (high luminous excitance).

A family of illuminators are available to suit a variety of needs (Table 1).

Illuminators designed for high definition lighting, or lighting where specific illumination requirements must be met, combine a highly efficient light source and proprietary light coupling and splitting technologies. This means that:

- Outgoing light can be delivered to a number of ports (from 2 to 16 are standard, other options are available)
- Outgoing light can be split evenly among the ports or the distribution can be customized to the application.

LIGHT PIPE

Effective remote source lighting strongly depends on the light transmission medium used to carry the light from the light source to the desired output location. The light transmission medium can be either a liquid or a solid material that relies on total internal reflection to transmit light from the source to the output device. For RF applications,the light guide will be plastic optical fiber. To achieve total internal reflection, the fiber core is usually encased in a tube of lower refractive index material.

The range of applicability of optical fibers to RSL depends on the amount of light that can be transmitted through them. Several factors influence the transmission efficiency of an optical fiber. These include its inherent light absorption at the wavelengths being transmitted, light absorption by impurities present in the plastic, and light scattering losses due to particulate materials, interfacial roughness, defects located between the fiber core and the lower refractive index encasing material, and density fluctuations.

The best plastic optical fiber on the market has an attenuation of approximately 0.150 dB/m. In other words, the amount of useful light out of the cable is directly related to the length of the cable. Figure 2 gives an indication of cable lengths that might be suitable for use in a given chamber.

LUMINAIRES

The distal end of the fiber can be used for illumination directly or in combination with lenses, to provide the light distribution required by the system application. Typically, the open end of the plastic optical fiber produces a light cone with a solid angle between 50° and 80°, depending on the core and cladding materials of the fiber. Using a lens to shape light at the distal end causes light loss and necessitates overly complicated lens designs. These considerations have previously limited conventional RSL use to areas where highly precise illuminance distribution is not required or where light does not need to be shaped into a particular pattern.

These limitations have been overcome by the introduction of a beamformer in the optimal luminaire of the RSL system. The light exiting the optical cable is conditioned and shaped by this device. Inside the beamformer, the light is directed into the desired angular output. Then it is shaped and evenly distributed by a holographic light shaping diffuser. This diffuser has the unique ability to output light in a specified pattern tailored to application-dictated specifications, from simple circular to extreme elliptical. Square or rectangular shapes can be produced, as can a pattern with a particular light distribution from more intense at the center to perfectly uniform up to the abrupt cutoff.

The light transformer/holographic diffuser combination permits a wide range of illumination patterns from a 100° angle for general illumination to a 1° angle or less for an intense spotlight. Diffusers can be combined to produce overlapping patterns, resulting in an elliptical, linear, or even square illumination pattern. Light coloring is possible simply by using a colored filter as the diffuser substrate. For sophisticated light distribution requirements, several beamformers can be combined in one luminaire. Figure 3 illustrates the light output by a bare fiber, a circular beamformer and an elliptical beamformer.

Parameters			
Light Source Operating Electrical Power	500 to 1,000W	150W	60W
Maximum Total Output Luminous Flux	10,000 lumens	4,800 lumens	1,500 lumens
Light Source Color Temperature	5,600K	4,000K	4,000K
Light Source Life Time	5,000 hrs	6,000 hrs	4,000 hrs

Table 1. *High Definition Lighting Illuminator Parameters.*

BENEFITS OF RSL

The lighting requirements of anechoic and RF chambers, MRI suites, and control rooms are different. In fact, each individual chamber has its own requirements depending on size, intended use, and internal equipment. In general, however, all of the chamber types have a need for two lighting scenarios – lighting for noncritical periods such as equipment setup or repositioning, or during chamber maintenance. Conventional practice is to use incandescent lights during critical test periods and fluorescent lighting during noncritical periods. The performance of the ballast required by fluorescent lights prohibits their use during critical testing periods.

The use of RSL simplifies light control in one of two ways; dimmable illuminators can be used or multiple illuminators can light an intermingled arrangement of luminaires. Figure 4 shows the latter arrangement. Illuminator A provides light to four luminaires located over particularly important test or monitoring equipment. Illuminator B could provide more lighting points for maintenance or equipment installation or repositioning.

Illuminator C is an optional lighting system that provides a light "spigot." The connection for the requisite number of cables is always present in the chamber. Light "hose" can be installed and positioned as needed. This precludes the need for flashlights or the addition of spot lights. When additional light is called for, the cable hose is connected and the luminaires at the end of these cables are handheld or positioned and repositioned as needed. The hoses have no heat, no electricity, no magnetic or electric field, and are not made of metal. Depending on the chosen end device, light of a particular pattern can illuminate the test or monitoring equipment.

The installation of RSL simplifies lighting acquisition in several ways:

- The lighting points need no RF isolation.
- The lighting points are permanently installed. Light source change is done at the illuminator, outside the chamber.
- The dimensions of the lighting point luminaires are much smaller that those of conventional high-hat lights — a 3-inch diameter cylinder as opposed to a 1-1/2 ft. on a side high-hat.
- Illuminator and luminaires are installed on the outside walls of the chambers; therefore, no floor removal, catwalk or scaffolding is needed to install light fixtures from the interior of the chamber.
- Since RSL systems are very efficient, the number of illuminators needed to provide light levels equivalent to conventional systems on selected surfaces may be two to three times lower than the number of conventional light fixtures now required.

The life cycle cost of the lighting in a chamber or control room is improved through the use of RSL because:

- Light source life times are from 4000 to 10,000 hours.
- Lighting points never need servicing.

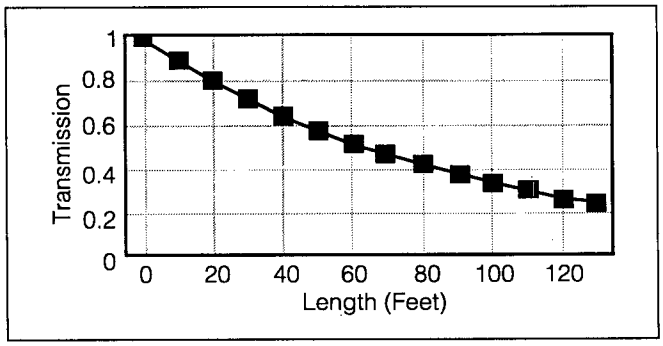

Figure 2. *Amount of Light Transmitted by Plastic Optical Fiber whose Attenuation is 0.15 dB/m.*

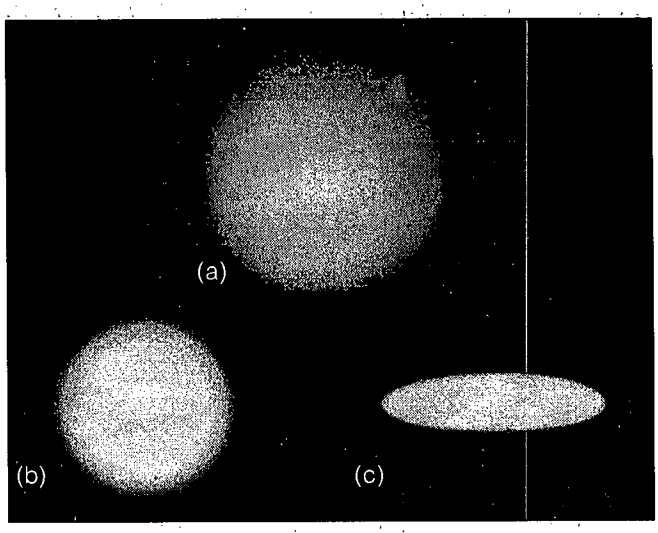

Figure 3. *Light shapes produced by a bare fiber (a), a circular beamformer (b) and an elliptical beamformer (c).*

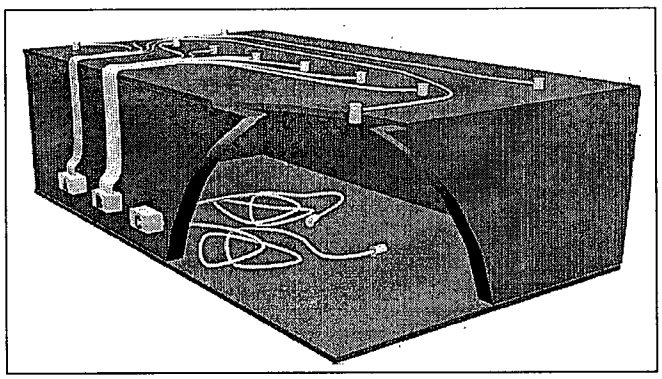

Figure 4. *Schematic of Sample RSL Lighting System Configuration.*

- Energy usage will be lower because of the high efficacy of RSL light sources.
- RF isolation remains permanently in place and is not affected during light source change-out.