# POWER-OVER-FIBER FOR LOW POWER, REMOTE SENSOR SYSTEMS

BY KJERSTI MARTINO

Director of Product Management

**Low power, low cost sensors are commonly available for system monitoring, including temperature, pressure, humidity, proximity, and voltage. However, in certain applications — such as high voltage areas of industrial and manufacturing plants, mining sites, energy generation facilities, utility substations, and even sensitive medical equipment — simply connecting the wires needed to implement the remote sensing and monitoring creates the potential for problematic ground loops, stray voltage, and signal disruption simply due to that electrical pathway. So much so, that the potential issues the electrical interconnect can create outweigh the benefits of remote monitoring. Implementing a low-power remote monitoring sensor solution using power-over-fiber (PoF) eliminates these risks and offers a low-cost implementation with complete galvanic isolation.**

A PoF solution uses a standard optical fiber to deliver power to the remote sensor system, which then also uses fiber to transmit the data back, thus not requiring remote power or any electrical connectivity [1]. Optical fiber is immune to electromagnetic interference (EMI) and therefore can be run in virtually any environment without risk of signal degradation due to the surrounding systems or compromising nearby highly-sensitive equipment. Industry-standard fiber cables themselves are available with a wide range of jacketing materials conforming to environmental requirements, including low- and high-temperature, submersion, radiation, and low-smoke, so sourcing the fiber cable for a specific application should be straightforward.

A remote sensor PoF implementation consists of only a few key components: a high-power laser source, fiber cable, a photo-voltaic converter, a low-power sensor, a low-power laser source, and a signal photodetector [2]. A schematic of this is shown in Figure 1.

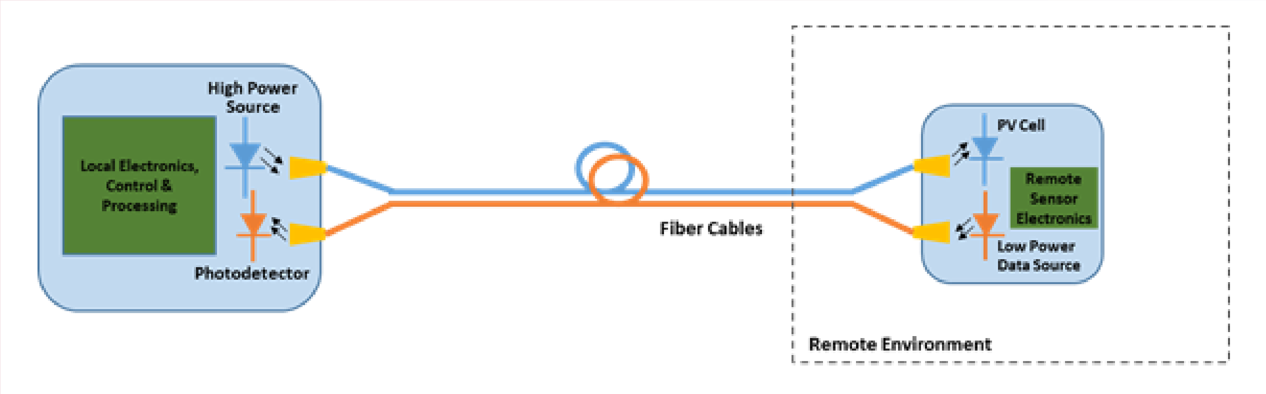


**Figure 1 - Power over fiber system schematic**

There are a few key considerations in designing a PoF solution: the power required for the remote sensor, the total power available to the system, the space constraints and length requirements of the fiber interconnect, and cost target. These limitations lead specific options for the development of a link budget that then, along with the space and cost constraints, drives the requirements for the system solution. Let's look at this in more detail.

The high power laser source will need to output sufficient power and efficiently couple that power into the optical fiber for transmission to the remote sensor module. A vertical-cavity surface-emitting laser (VCSEL) offers a very compact laser source with a circular-shaped emission pattern, allowing for easy coupling into an optical fiber. Figure 2 illustrates the light emission patterns of a light-emitting diode (LED), VCSEL, and edge-emitting laser (EEL), showing the small, circular shape of the VCSEL emission that allows for high-efficiency, low-cost coupling into a standard multimode fiber. Inneos has single aperture 850nm VCSEL components capable of up to 15mW output power over an industrial temperature range of -20°C to +60°C that can be easily coupled into a 50µm or 62.5µm multimode optical fiber.

Fiber cables and connectors are another important aspect of the remote sensor system. Fiber cables are immune to EMI, lightweight, and flexible. This means that fiber interconnects do not emit radiation nor are they susceptible to radiation. They don't create ground loops and they won't spark; therefore, fiber interconnects open a wide range of options for adding remote sensor systems that are not even an option with copper cables. Fiber cable and connector manufacturers test and qualify components to support a wide range of applications and environmental conditions.

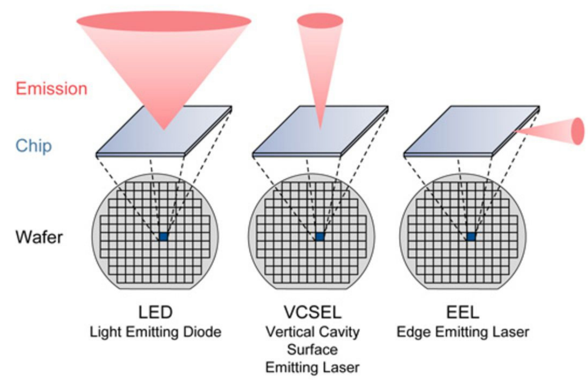


**Figure 2 - Emission patterns of an LED, VCSEL and EEL, illustrating the small circular pattern of the VCSEL that enables easy fiber coupling**

Image from Instrument Systems [3].

Fiber cables will incur wavelength-dependent attenuation along the distance of the fiber run, which is a specification provided by the fiber cable manufacturer. Typically, OM3 multimode fiber has an attenuation < 2.4 dB/km at 850nm and < 0.6 dB/km at 1300nm. Each connector in the link will also incur a slight loss that must be accounted for in determining the amount of power available for the remote sensor, typically 0.25 – 0.5 dB per connector for a multimode fiber connector.

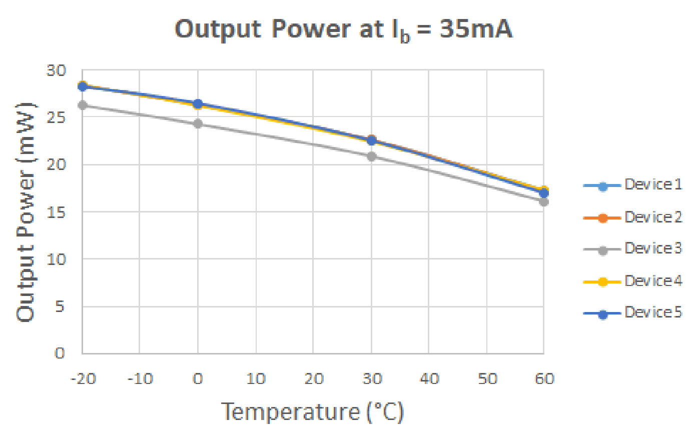


**Figure 3 - High power single aperture 850nm VCSEL output power**

The distance from the laser power source to the remote sensing unit, as well as the number of connectors required, should be known parameters for the remote sensing system. The plot in Figure 4 illustrates the power distributed to the remote sensor system with a 20mW fiber launch power for various in-line connectors, assuming there is a 0.5 dB loss per connector and a worst-case 2.4 dB/km attenuation for an 850nm source wavelength. Once these basic parameters are known, the power available for the remote sensing unit is known and the actual sensing components can be chosen from the vast array of available low-power sensing modules commercially available.

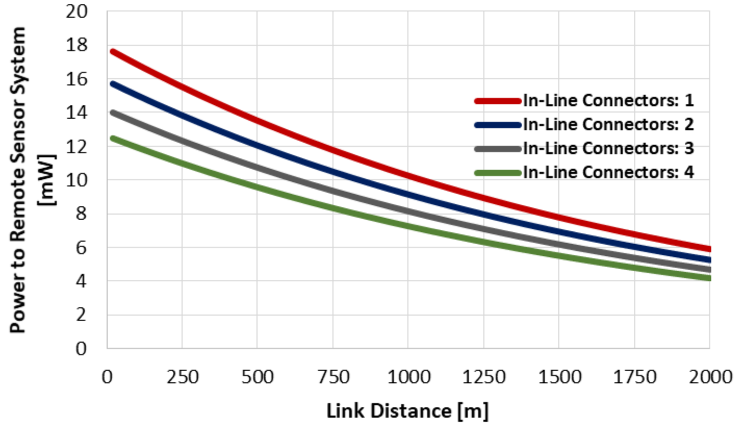


**Figure 4 - Power distributed to remote sensor with a 20mW launch power at 850nm for varying numbers of in-line connectors.**

A remote power sensing solution can be implemented over one or two fibers. If a system does not need to go through a fiber optic rotary joint or have weight or size constraints, it may be more cost effective to run the power to and return signal from the remote system on separate fibers. Alternatively, the system can be implemented over just one fiber, as illustrated in Figure 5, using a novel property of light called wavelength division multiplexing (WDM), where light of different wavelengths can simultaneously travel bi-directionally in the fiber without interference, an interesting and distinct difference from electrons in a wire! If a WDM implementation is required, Inneos offers 910nm, 940nm or 980nm VCSELs that can be used for the low power return channel in conjunction with the 850nm high power VCSEL.

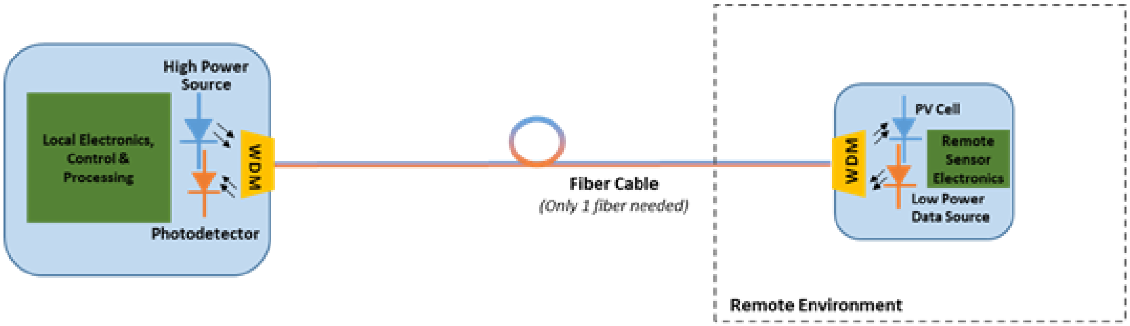


**Figure 5 - Remote sensing system using only one fiber, which also allows for the use of fiber optic rotary joints and low-cost connectors.**

PoF interconnects and wide-temperature range, low-power VCSELs offer novel opportunities for low power remote sensing and monitoring to make real-time adjustments to improve efficiency and system performance. This simple solution offers a low-cost implementation of a remote sensor system that is completely galvanically isolated, a critical requirement for safety and reliability in medical, industrial, and energy applications.

References:
[1] J. Fisher, et al, Journal of Sensors and Sensor Systems, 27 March 2018
[2] Rosolem, J. B., Optical Fiber and Wireless Communications, 21 June 2017
[3] https://www.instrumentsystems.com/en/applications/vcsel-laser