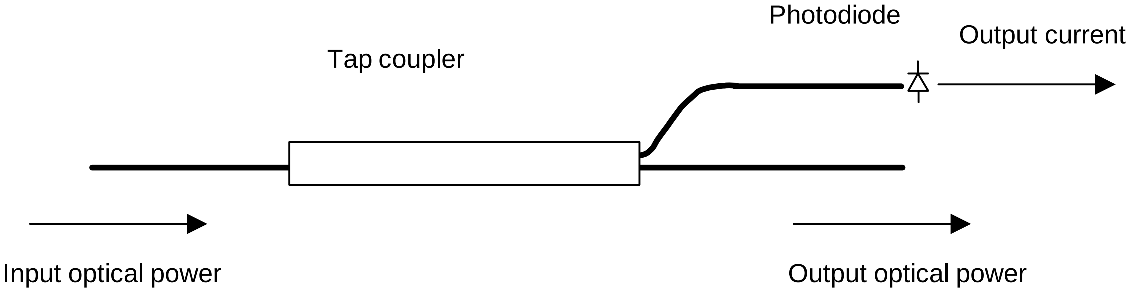
Technical Brief #5

Power Monitors

This note is one of a series of technical briefs developed from customer FAQs and intended to answer the majority of questions concerning the operation of Phoenix products. They are targeted at engineers to assist in incorporating Phoenix products into designs. Any detailed technical questions should be forwarded to Phoenix support.

What is a power monitor?

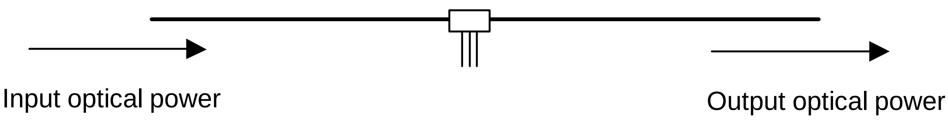
In many optical fiber networks it is critical to monitor the quality of the signal or the level of optical power in the fiber line. Conventionally this has been accomplished by tapping a small portion of signal (typically 1% to 5%) from the fiber using a fused coupler or similar to direct the signal to a photodetector, schematically shown below.



Conventional method for power monitoring, by 'tapping' power from the line to a photodiode detector using a fused coupler.

Evanescent field power monitor

Phoenix power monitors operate on a different principle to enhance performance and reduce size. Removing part of the cladding of an optical fiber gives access to the evanescent tail of the propagating wave. Replacing the cladding with an appropriate material creates coupling from the fiber mode(s) to radiation modes. The radiation modes can be detected by a photodiode and the level of power reaching the detector is proportional to the power in the fiber.



Evanescent field based power monitor detects signal directly from the fiber line.

Responsivity

The power monitor responsivity is specified as the current generated in an external circuit by the photodiode relative to optical power in the fiber at the power monitor input.

Typically, the responsivity of a pin photodiode at 1550nm is in the region of 1A/W. The table below gives the maximum responsivity achievable assuming that all of the power coupled from the fiber is captured by the detector with a responsivity of 1A/W.

Percentage power Coupled out	1%	2%	3%	5%	10%
Responsivity (mA/W)	10	20	30	52	111

This table represents the maximum possible responsivity achievable for the specified tap ratios.

Insertion loss

The insertion loss of the evanescent field fiber device depends on the following parameters:

- Depth of cladding removed
- Length of processed fiber
- Refractive index of the overlay material

There is a relationship between the insertion loss and responsivity; increasing insertion loss increases responsivity. The table below shows the maximum achievable responsivity for increasing insertion loss.

Insertion loss (dB)	0.1	0.2	0.3	0.4	0.5
Responsivity (mA/W)	23	47	71	96	122
Equivalent coupling ratio	2.3%	4.7%	7.1%	9.6%	12.2%

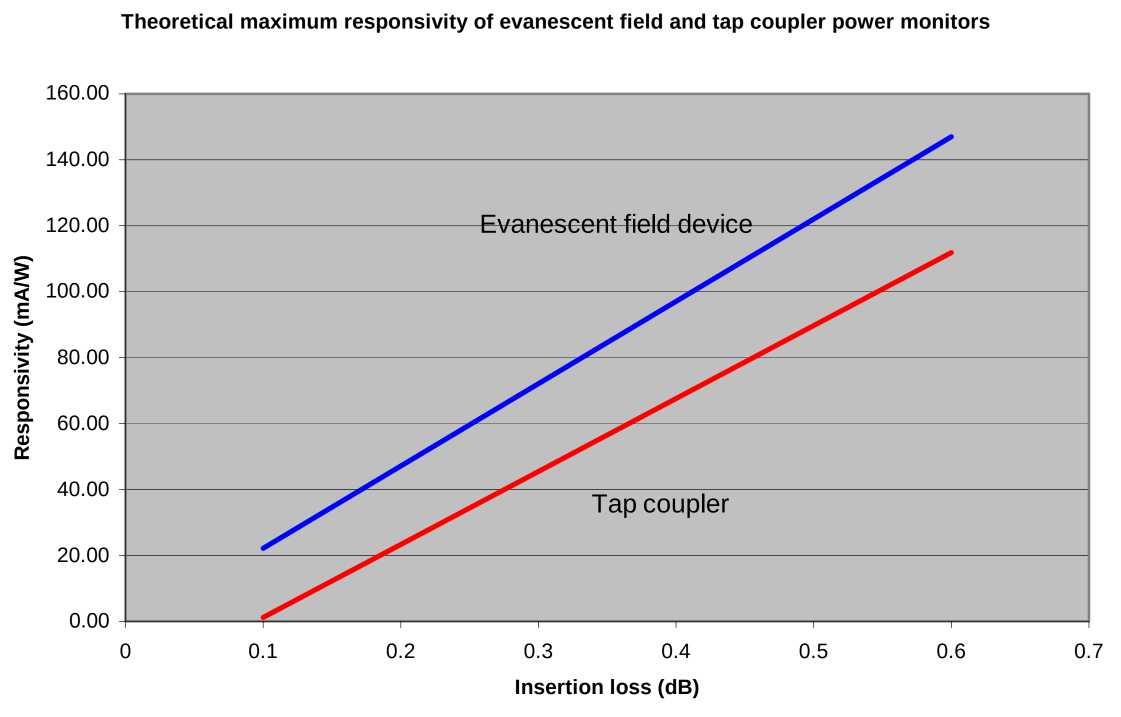
The assumption is that the insertion loss is due to coupling to radiation modes and all the radiated power is collected by the photodiode.

For the tap coupler-photodiode option the excess loss of the coupler should be considered and the table below shows the maximum achievable responsivity for a high quality tap coupler assuming no loss in the fiber lead and all power collected by the photodiode.

Coupling ratio	1%	2%	3%	5%	10%
Insertion loss (dB)	0.15	0.18	0.23	0.32	0.6
Responsivity (mA/W)	10	20	30	52	111

The figure below gives a comparison of the theoretically maximum achievable responsivity as a function of insertion loss for both type of device. Practical issues such as alignment to obtain maximum signal capture will reduce the responsivity achievable from either device type.

The evanescent field device gives a potentially higher responsivity for a specific insertion loss than the more conventional tap coupler option in a much smaller footprint, i.e. it is a single element component.



Polarization Dependent Responsivity (PDR)

The responsivity of the evanescent field power monitor is state of polarization (SOP) dependent, varying between maximum and minimum values as the input SOP is varied.

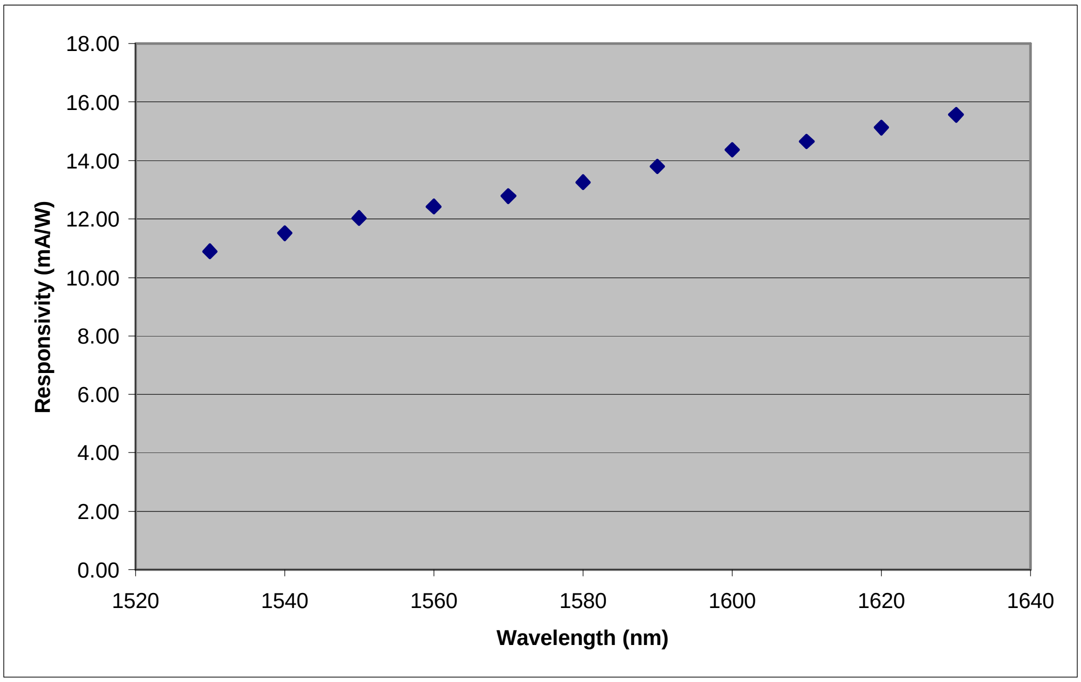
Polarization dependent responsivity (PDR) is defined as the ratio of the minimum to maximum responsivity and expressed in dB.

Polarization Dependent Loss (PDL)

There is a relationship between the PDL and PDR, but the PDL for the evanescent field devices is much lower than PDR typically below 0.05dB.

Wavelength Dependent Responsivity (WDR)

The evanescent field extends further into the cladding as wavelength increases, which gives evanescent field based fiber devices the characteristic of increased insertion loss with wavelength and for the power monitor increased responsivity as wavelength increases. The wavelength response is a combination of the evanescent field response and the photodiode wavelength response. A typical responsivity curve is shown below.



Maximum operational power

The dynamic range of the monitor is set by the pin photodiode dark current level and saturation power level. Saturation is typically 2mW power onto the detector. The saturation power level sets the maximum in-fiber power levels the monitors can accommodate. The table below shows the maximum fiber power levels that can be monitored for different tap ratio devices.

Coupling ratio	**1%**	**2%**	**3%**	**5%**	**10%**
Maximum power input (mW)	**200**	**100**	**67**	**40**	**20**
Maximum power input (dBm)	**23**	**20**	**18**	**16**	**13**

High power operation

The minimum achievable tap ratio from a fused coupler is limited and the excess loss associated with a coupler limits the maximum power range over which they can be effectively utilized in a power monitor application.

The level of power tapped from an evanescent field device is controlled by the level of cladding removed. This means that the power coupled to the detector can be kept below 2mW regardless of the level of power in the fiber. Removing less cladding reduces losses as a whole, therefore the evanescent field approach is ideal for high power requirements.

Fiber type

Evanescent field devices can be created on most silica based fiber types. Single mode and multimode fibers can be processed to make the power monitor. The fiber on which the device is fabricated can be matched to that utilized in the system.

Polarization maintaining fiber power monitor

A specific version of the power monitor is the polarization maintaining (PM) fiber option. For this device the PDR is no longer the critical parameter. The PM power monitor detects power from both linear polarization states of the fiber with different responsivity. However for a single polarization state on one axis the PDR is set by the quality of the fiber lead splice angle into the rest of the system.

All-fiber evanescent field power monitor benefits

This approach to an in-line fiber power monitor offers significant advantages to the design engineer:

- Improved loss characteristics to give lower insertion loss to achieve the required responsivity
- Single integrated, compact component.
- Optional high power operation
- Flexibility in choice of fibers to match system requirements
- Compact devices which can be easily integrated into small footprint multi-channel modules.
- Operation wavelength flexibility