Fiber Optics: How to Avoid Detector Overfill when Working with Fiber Optic Sources

This paper could just have easily been titled "estimating spot size at a distance", since we must calculate the diameter of the output beam of the fiber optic at the approximate distance from fiber tip to the surface of the active area of the detector.

We state approximate distance because we must assume that the tip of the fiber connector ferule, or the end face of the bare fiber, is flush to the output surface of the chuck used to mount the fiber, and that the cover glass of the photodiode is at the detector surface position. (Most diode manufacturers consider the distance between the cover glass and the actual photodiode surface to be proprietary.) It is the distance between the end of the ferule, or the end face of the bare fiber, and the cover glass of the photodiode that is used for calculating the output spot size of the fiber at the detector.

It is important to determine this spot size in order to know if the detector active area is being overfilled. Overfilling means that some light falls outside the edges of the diameter of the photodiode active area and, therefore, is not detected by the photodiode. This results in an inaccurate and lower than expected power measurement.

One method of correcting for overfill is to allow the output beam of the fiber to exit into free space and then use appropriate optics to reduce or expand the diameter of the beam and collimate it before it reaches the detector surface. In this case, you would assume the case of a divergent laser source and note the NA (numerical aperture) of the fiber.

For multi-mode fibers, choosing a lens with the same NA as the fiber, just as you would for free space coupling light into the fiber, will give you a collimated beam at the output of the fiber.

For single mode fibers, selection of the appropriate coupling optic for free space coupling is a bit more complicated. In this case we need to determine the required focal length of the lens. The equation used for this is given by

$$f = D(\pi\omega / 4\lambda)$$

where,

f = focal length of required coupling lens
D = collimated beam diameter of light source entering the coupling lens
ω = single mode fiber mode field diameter
λ = wavelength of light source

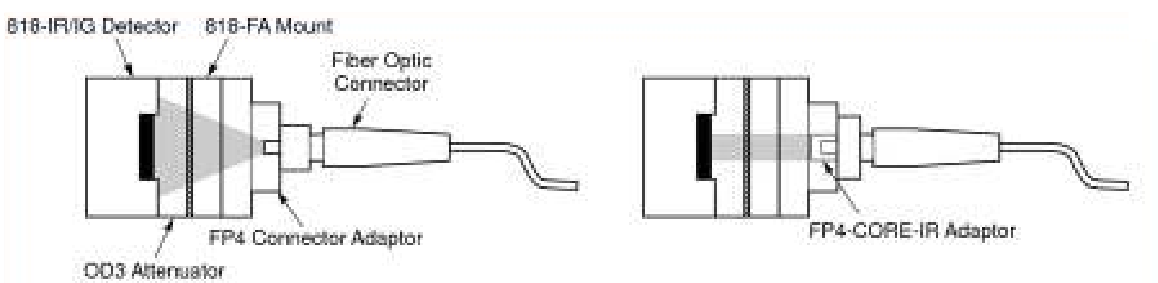
This lens can be used for collimating the output beam of the fiber.

Once the output of the fiber is collimated, it may still be necessary to enlarge or reduce the beam diameter. This will be dependant on the active area of the detector and its maximum acceptable power density. The resultant beam diameter should be no greater than the active diameter of the detector.

For those fiber outputs for which overfilling of the detector, or exceeding the maximum power density will not be a problem, Newport Corporation offers fiber adapters that are compatible with the 818- and 918D-series photodiodes. These adapters attach to the threaded front face of the detector and provide a convenient method for short distance free space coupling, but do not allow for the insertion of corrective optics.

For bare, non-connectorized, fibers whose diameters do not exceed 250 um, use the 818-FA2 spacer adapter and the FP3-FH1 bare fiber holder. The 818-FA2 threads onto the front face of the detector. The nose of the FP3-FH1 is then simply inserted into the front face of the 818-FA2 where it is held securely by spring loaded clamps. For distance calculations in the table below, it will be assumed that the end face of the fiber is flush with the flat face of the nose of the FP3-FH1.

For connectorized fibers, the 818-FA spacer adapter would be used instead of the 818-FA2. Connector adapters for FC, ST, SC, LC and SMA connectors are available. These would be inserted into the front face of the 818-FA spacer adapter. Three cores are also offered. These insert into the side of the connector adapter closest to the detector and are used to either lessen insertion loss when used with index matching fluid or collimate the output beam of the fiber. The FP4-CORE-IR has a collimating lens that can be used for the spectral range of 1000 nm to 1550 nm and helps to prevent overfill when used with the IR or IG models of the 818- and 918D-series detectors. The IR and IG models have active diameters of 3 mm, which is very small when dealing with a divergent output from a fiber. The FP4-CORE-VIS and FP4-CORE-NIR can be used, along with a small amount of index matching fluid, to lessen the insertion loss when connecting to the adapters. There are no collimation optics in these two cores. Note that the FP4-CORE series is not compatible with the FP3-SMA connector adapter.



Diverging beam overfills detector area

FP4-CORE-IR collimates beam onto small area detector, even with use of OD3 attenuator

For the distance calculations involving the connector adapters, it is assumed that the tip of the ferule is flush with the outer shoulder of the connector adapter.

As stated earlier, in order to determine the spot size at the detector active surface, we need to know the distance from the fiber tip to the active surface of the detector. Once we obtain that information, we can perform the following calculation to arrive at the approximate spot size.

$$D = 2*d*\tan\theta$$

where,

d = estimated distance from fiber tip to detector surface
D = approximate diameter of beam spot at detector surface

and θ can be determined using

$$NA = n*\sin\theta$$

Estimated distances from fiber tip to surface of the detector are given in the following tables.

818-series Photodiodes:

Detector Model	Required Adapters	Fiber Tip to Detector Surface Distance With Attenuator (mm)	Fiber Tip to Detector Surface Distance Without Attenuator (mm)
818-SL	FP4-FC and 818-FA	27.64	18.75
	FP4-SC and 818-FA	27.91	19.02
	FP4-ST and 818-FA	27.64	18.75
	FP4-LC and 818-FA	27.91	19.02
	FP3-SMA and 818-FA	22.35	13.46
	FP3-FH1 and 818-FA2	18.19	9.29
818-UV	FP4-FC and 818-FA	27.64	18.75
	FP4-SC and 818-FA	27.91	19.02
	FP4-ST and 818-FA	27.64	18.75
	FP3-SMA and 818-FA	27.91	19.02
	FP4-LC and 818-FA	22.35	13.46
	FP3-FH1 and 818-FA2	18.19	9.29
818-IR	FP4-FC and 818-FA	25.63	16.74
	FP4-SC and 818-FA	25.91	17.02
	FP4-ST and 818-FA	25.63	16.74
	FP4-LC and 818-FA	25.91	17.02
	FP3-SMA and 818-FA	20.34	11.46
	FP3-FH1 and 818-FA2	16.17	7.29
818-IG	FP4-FC and 818-FA	26.01	17.12
	FP4-SC and 818-FA	26.29	17.40
	FP4-ST and 818-FA	26.01	17.12
	FP4-LC and 818-FA	26.29	17.40
	FP3-SMA and 818-FA	20.73	11.84
	FP3-FH1 and 818-FA2	16.56	7.67

918D-series Photodiodes:

Detector Models	Adapters	Fiber Tip to Detector Surface Distance (mm)
918D- series (all models)	FP4-FC and 818-FA	24.49
	FP4-SC and 818-FA	24.77
	FP4-ST and 818-FA	24.49
	FP4-LC and 818-FA	24.77
	FP3-SMA and 818-FA	19.20
	FP3-FH1 and 818-FA2	15.04