



# Fast Photodiode Detectors

## FPD-IG-175, FPD-UV-3000, FPD-VIS-300

Temporal Sensors

User Manual

# Ophir Fast Photodiode Detector User's Manual

Thank you for purchasing your Fast Photodiode Detector from Ophir. This user's manual will help answer any questions you may have regarding the safe use and optimal operation of your Fast Photodiode Detector.

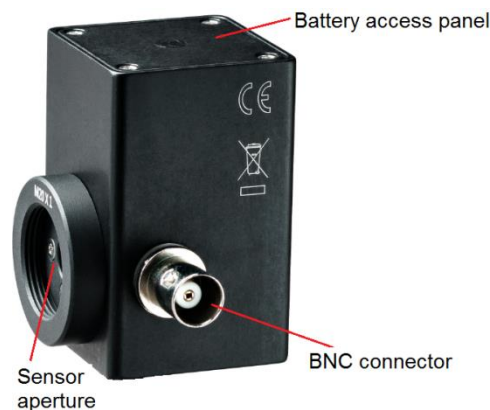
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## I. Fast Photodiode Detector Overview

Ophir's Fast Photodiode Detectors contain PIN photodiodes that utilize the photovoltaic effect to convert optical power into an electrical current for measurement. Internal circuitry provides a reverse bias voltage to improve the photodiode's response time. For optimal performance, the output should be connected to a 50Ω load resistance. Figure 1 below identifies the main elements of your Fast Photodiode Detector.

**Figure 1: Ophir Fast Photodiode Detector**



When terminated into the 50Ω input of an oscilloscope, the pulse width of a laser can be measured. When terminated into a spectrum analyzer, the frequency response of a laser can be measured.

## II. Operation of your Ophir Fast Photodiode Detector

- A. Caution: Eye safety precautions must be followed with any equipment used in the vicinity of laser beams. Laser beams may reflect from the surface of the detector or the optical mount and caution must be exercised.
- B. Mount the detector to an optical stand using the mounting holes on the bottom of the detector housing. Each detector is provided with an 8-32 threaded nylon standoff. If the detector is mounted to a metal post, it is recommended to insert the standoff between the detector and the post in order to minimize the potential for electrical noise pickup.
- C. Adjust the voltage scale of the oscilloscope to 100mV/division before connecting the detector. On models with >3V bias supply, the signal may be large enough to damage the oscilloscope if this is not done.
- D. Connect the detector to the oscilloscope using a 50Ω coaxial cable that is one meter or less in length.
- E. Use the 50Ω impedance input of the oscilloscope or other measurement instrument. If the oscilloscope does not have a 50Ω input, connect a 50Ω terminator between the coax cable and the oscilloscope's high impedance input.

**Note: Current will be drawn from the batteries whenever a load is present at the output. In order to avoid draining the batteries, the output connection should be disconnected whenever the product is not in use.**

- F. Verify that the laser power density is below the maximum recommended signal level and place the detector in the laser beam. However, it is not necessary for the detector to be located directly in the laser beam to measure properly. If the laser beam is too powerful and it saturates the detector, the beam can be scattered from a white surface and the detector can be placed at a distance from the beam to look at a small fraction of the beam intensity. The distance from the scattering surface and the detector can be varied to get a good but not saturated signal. If the intensity is still too high, or it is not convenient to measure scattered light, filters are available to lower the laser intensity. See the Accessories section below.

## III. Batteries

Batteries will typically operate for several years, but operation with CW or high rep rate lasers can drain the batteries much faster. Leaving the detector output connected to a load for long periods of time can also drain the batteries. It is recommended to disconnect the output whenever the detector will not be in use for long periods of time.

As the batteries become depleted, the bias voltage on the photodiode will decrease. This will increase the rise and falls times of the detector and also reduce its saturation level. The ability of the battery to supply current quickly will also be reduced which is manifested as saturation effects in the output signal.

The batteries can be accessed for checking their voltage and replacement by removing the top plate of the housing. If necessary, replace with type CR2430 lithium cells. Check the specifications below for the number of batteries required for each model. Install batteries with positive side down.

## IV. Accessories

The following types of accessories are available for use with Ophir Fast Photodiode Detectors:

1. Fiber optic cable connectors
2. Adapters for attachment to IS6 integrating spheres
3. ND filters for attenuating the laser signal level

<b>Fiber Adapters</b>	SC type	7Z08227
	ST type	7Z08226
	FC type	7Z08229
	SMA type	1G01236A
<b>ND Attenuators</b>	ND1 nom. X10 attenuator	7Z08200
	ND2 nom. X50 attenuator	7Z08201
<b>IS6 Integrating Sphere Adapter</b>	For FPD detectors	7Z08350

**SC fiber adapter**



**ST fiber adapter**



**FC fiber adapter**



**SMA fiber adapter**



**ND Attenuators**



**IS6 Integrating Sphere Adapter**



## V. Troubleshooting

### A. No signal is seen the first time the detector is used.

1. Be certain that the signal is not too high for the scale set on the oscilloscope.
2. Is the wavelength of the laser within the spectral range of the detector?
3. Is the coaxial signal cable terminated into a 50Ω connection?
4. Try moving the detector within the laser beam. The detector's small active area may make alignment somewhat difficult.
5. Is the light level (see sensitivity spec on the data sheet) incident on the detector sufficient to generate a measurable signal?

**B. A signal has been detected previously obtained, but is currently lost.**

1. Try steps listed under A.
2. Inspect the active area of the photodiode for any signs of damage.
3. Try a higher input termination on the oscilloscope, but remember to return to  $50\Omega$  if this does not work.
4. Test the power supply:
  - a. Units with internal batteries will typically operate for several years, but operation with CW or high rep rate lasers can drain the batteries much faster. **If a load is present at the output, current will be drawn from the batteries, so disconnect the BNC when not in use.** Remove top cover to replace the 3V lithium cells with Duracell Model DL2430, positive side down.
  - b. Units with an external power supply should at least receive the voltage that is printed on the plug.
5. You can terminate the detector in  $1M\Omega$  input of an oscilloscope to obtain a higher output voltage signal but this will decrease the detector's bandwidth by a factor of  $5 \times 10^5$ .

**C. Increasing the power incident on the detector does not result in a higher voltage signal on the oscilloscope:**

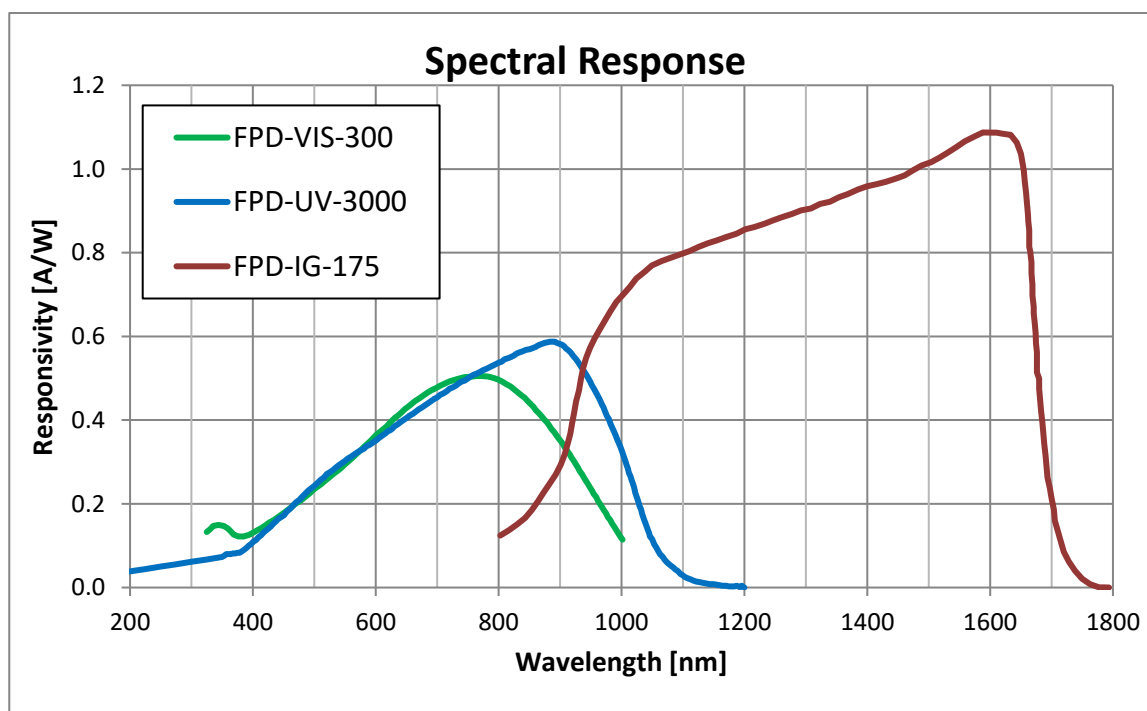
1. The detector is probably saturated. You should lower the power incident on the detector to a level below the saturation point.
2. Check that the photodiode bias voltage is correct. Check the power supply voltage is correct and connected or check the battery voltage.

**D. The measured pulse shape is not as expected. The rise and fall times are too long or the area around the peak is distorted and/or attenuated:**

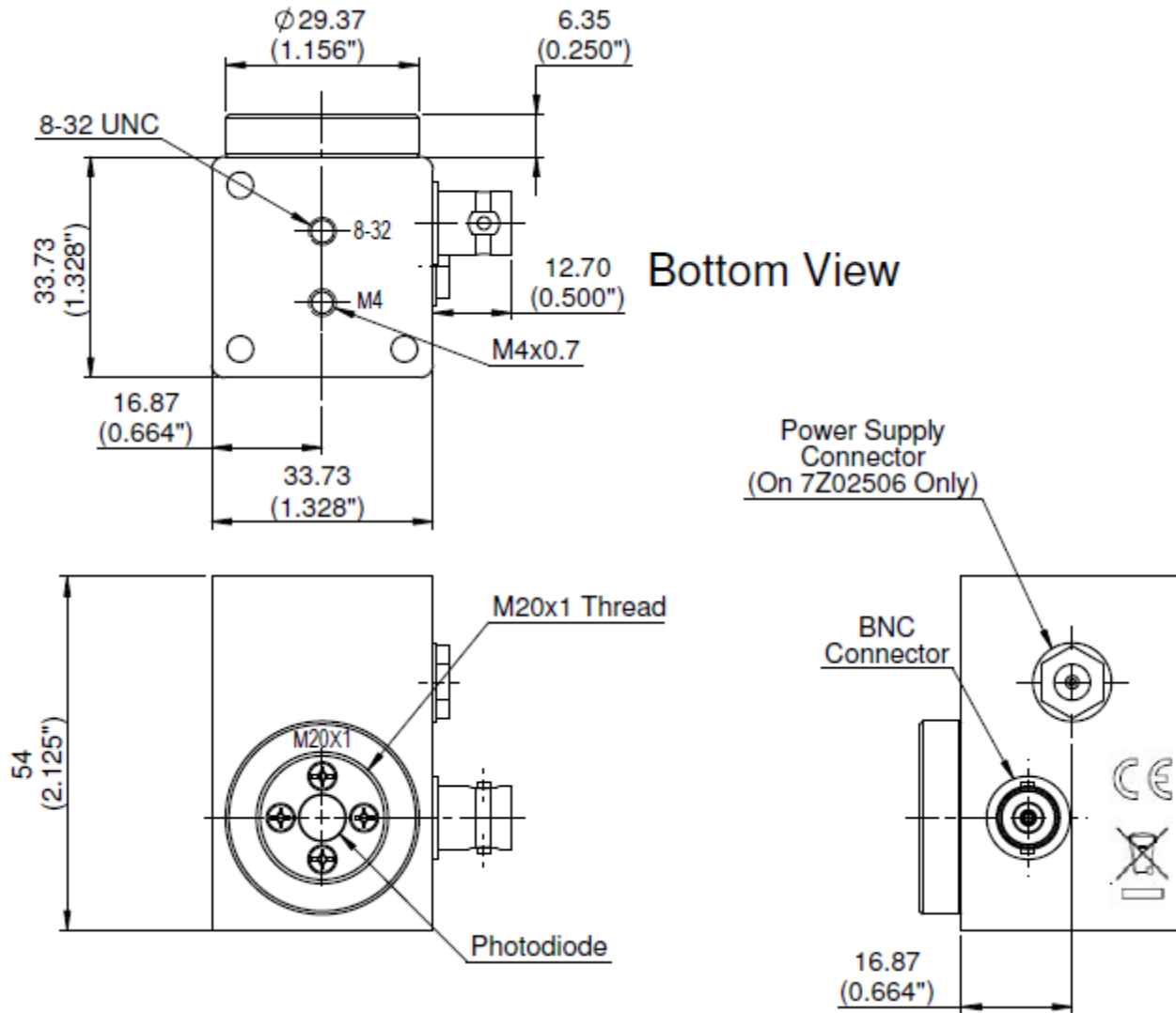
1. Check that the photodiode bias voltage is correct. Check the power supply voltage is correct and connected or check the battery voltage.

## VI. Specifications: Fast Photodiode Detectors

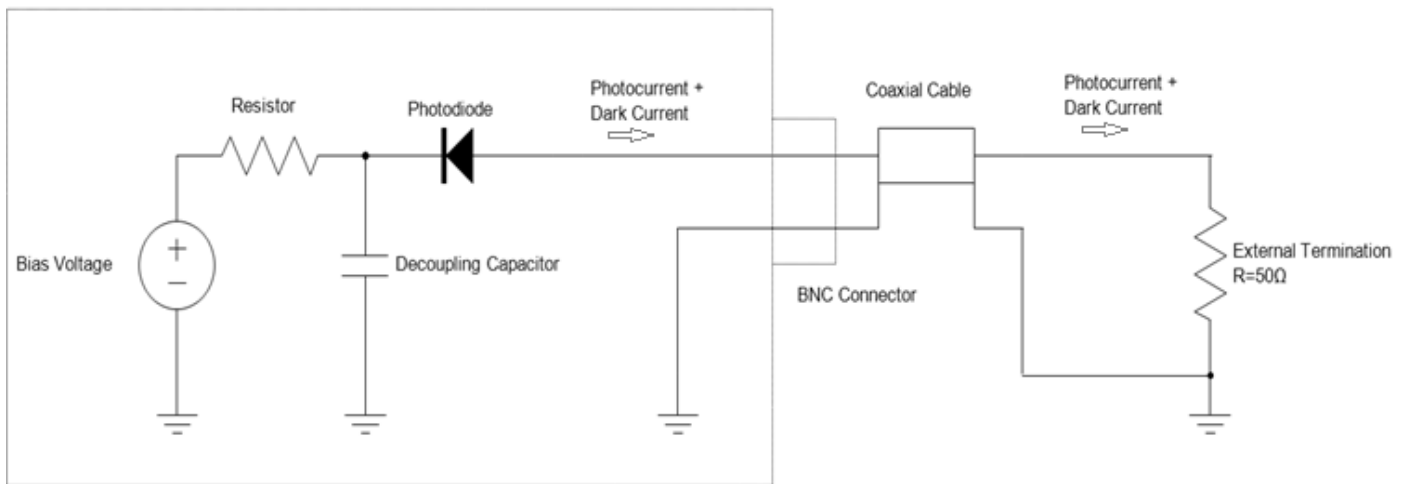
Model <sup>(a)</sup>	FPD-UV-3000	FPD-VIS-300	FPD-IG-175
Detector Type	UV-Si	Si	InGaAs
Rise Time/Fall Time nsec	3	<0.3	<0.175
Spectral Range nm (see graph below)	193-1100	320-1100	900-1700
Active Area Diameter mm	2.55	0.4	0.1
Detector Area mm <sup>2</sup>	5.11	0.13	0.0079
Wavelength of Peak Sensitivity nm	890	850	1600
Responsivity at Peak Wavelength A/W	0.58	0.5	1.1
Responsivity (Irradiance) at Peak Wavelength V/(W/cm <sup>2</sup> )	1.5	31 x 10 <sup>-3</sup>	4.3 x 10 <sup>-3</sup>
Bias Voltage VDC	24	9	6
Bias Voltage Source	External	Batteries	Batteries
Battery Type	NA	CR2430 x3	CR2430 x2
Bandwidth	>118 MHz	>1.2 GHz	>2 GHz
Dark Current nA	<10	<0.1	<2
Noise Equivalent Power <sup>(b)</sup> pW/√Hz	<0.10	<0.01	<0.03
Maximum Average Power Input <sup>(b), (c)</sup> mW	15	25	10
Mounting (Tapped Holes)	8-32 & M4	8-32 & M4	8-32 & M4
Output Connector	BNC	BNC	BNC
Accessory Threads	M20x1	M20x1	M20x1
Version			
Part Number	7Z02506	7Z02507	7Z02509
Notes: (a) All specs are with 50 Ω load			
Notes: (b) At wavelength of peak sensitivity			
Notes: (c) Maximum peak power is twice the average power for 10 nsec pulses			



## VII. Drawings: Fast Photodiode Detectors



## VIII. Schematic: Fast Photodiode Detectors



## IX. Glossary of Terms

**Bandwidth:** The range of frequencies from 0 Hz (DC) to the frequency at which the responsivity decreases by 3dB. Bandwidth and rise time can be approximately related by the equation:

Bandwidth  $\approx 0.35/\text{rise time}$  for a Gaussian pulse input.

**Bias Voltage:** The photodiode's junction capacitance can be modified by applying a reverse voltage. The bias voltage reduces the junction capacitance, which improves the photodiode's temporal response. The bias voltage also induces a dark current. When a photodiode is used with reverse bias, the shot noise of the dark current is usually the dominant contributor to the NEP.

**Dark Current ( $I_{dark}$ ):** When a photodiode is connected in a circuit and operated in reverse bias mode, a small DC current (typically nanoamps) will flow, even without the presence of an optical signal. Disconnecting the coaxial cable will prevent this current from flowing. If operated without a reverse bias (photovoltaic mode) the dark current will be comprised of thermally generated noise without any DC component. This thermal noise will typically be orders of magnitude lower than the shot noise of the dark current in the same device when it is reverse biased.

**Decoupling Capacitor:** A capacitor is connected in parallel with the bias voltage source. Its purpose is twofold: 1) It maintains the bias voltage when fast signal pulses would otherwise cause the battery voltage to droop (this would slow the response time of the photodiode) and 2) It also acts as a low-pass filter for external power supplies.



**Noise Equivalent Power (NEP):** NEP refers to the amount of optical input power that would generate an electric signal that is equal in magnitude to the electrical noise (in the dark). It is a function of the device responsivity and the dark current. Shot noise ( $I_{shot}$ ) is a source of noise generated by current; in the case of reversed biased diodes operating at high speeds and low signal levels, it is the dominant contributor to the total noise. NEP can be calculated from the shot noise and responsivity. For example, for the FPD-UV-3000 with a dark current of <10nA and responsivity of 0.58 A/W at 890 nm, the shot noise will be:

$$I_{shot} = \sqrt{2q I_{dark}} = \sqrt{2 \times 1.6 \times 10^{-19} As \times 10 \times 10^{-9} A} = 0.057 pA\sqrt{s} = 0.057 pA/\sqrt{Hz}$$

$$NEP_{\lambda} = \frac{I_{shot}}{R_{\lambda}} = \frac{0.057 pA/\sqrt{Hz}}{0.58 A/W} = 0.098 pW/\sqrt{Hz} \quad \text{at 890 nm}$$

$$q = \text{electron charge} = 1.6 \times 10^{-19} As$$

**Photodiode:** A semiconductor device that converts photons into an electrical current.

**Responsivity:** In amps per watt (A/W), responsivity is the current output of the photodiode per input power, and is determined by the diode structure. Responsivity varies with wavelength and diode material.

**Responsivity (Irradiance):** In V per W/cm<sup>2</sup> is the voltage output as a function of the light input irradiance. This is equal to the responsivity in units of A/W multiplied by the photodiode sensitive area and the effective impedance load seen by the photodiode.

**Rise Time & Fall Time:** Rise Time is the time required by a signal to change from a specified low value to a specified high value (typically 10% to 90%). Fall Time is the time taken for the amplitude of a pulse to decrease from the specified high value to the specified low value. In photodiodes, the junction capacitance is a major factor contributing to the rise time and fall times. Reverse biasing of the photodiode is a method used to decrease the junction capacitance and improve the rise and fall times.

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