Noise Equivalent Power (NEP)

Electronic circuits output noise as well as the desired signal; an example would be the hiss heard in a stereo when no music is playing. The noise spectrum has a relatively flat response, and the noise level changes with the square root of the frequency range; for example, if the frequency range doubles, the noise component increases by √2 (1.414). The optical input has to be large enough to overcome the noise component of the detector in order to have a measurable signal output. Noise equivalent power (NEP) is a specification that allows a customer to determine the noise component of a detector for their particular wavelength and measurement bandwidth. NEP is the minimum optical power required for an output signal-to-noise ratio (SNR) of 1. This means the signal level and the noise level are the same; an SNR of 10 or larger is recommended. NEP has units of W/√Hz or W, depending on the whether or not the measurement bandwidth is included.

NEP is calculated from measurement or photodiode parameters such as dark current (the current that flows through a reverse biased photodiode when light is not present). Typical values and noise sources are:

Non-amplified standard detector: 0.1pW/√Hz (dark current)
High speed detector: 30pW/√Hz (noise from internal 50Ω impedance matching resistor)
Amplified detector: 25pW/√Hz (amplifier noise)

EOT's data sheets provide NEP at a specific wavelength – this value is needed to determine NEP for other wavelengths. An example is shown below for the ET-2030:

Measurement Wavelength: 532nm
Measurement Bandwidth: 800MHz
Responsivity (R_λ) of ET-2030 at 532nm (from graph in data sheet): 0.27A/W
Responsivity (R_λ) of ET-2030 at 830nm (from table in data sheet): 0.47A/W
Datasheet NEP: 0.01pW/√Hz

$$\mathrm{NEP_{532nm}} = \mathrm{NEP_{datasheet}} \times \frac{\mathrm{R_{datasheet}}}{\mathrm{R_{532nm}}} = \frac{0.01\mathrm{pW}}{\sqrt{\mathrm{Hz}}} \times \frac{0.47\mathrm{A/W}}{0.27\mathrm{A/W}} = 0.02\mathrm{pW}/\sqrt{\mathrm{Hz}}$$

Including the bandwidth:

$$\mathrm{NEP_{532nm}} = \frac{0.02\mathrm{pW}}{\sqrt{\mathrm{Hz}}} \times \sqrt{(800 \times 10^6\mathrm{Hz})} = 566\mathrm{pW}$$

For an SNR of 10 the optical power would need to be 5.66nW (-52.5dBm). This value would be fine for a spectrum analyzer, but oscilloscopes typically require an output of 1mV or higher for a minimum value. In practice, this is too low of a value: 10mV to 20mV would be an acceptable

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minimum reading. Using the ET-2030 as an example, and working backward from the oscilloscope output of 1mV:

$$\text{Optical Input} = \frac{\text{Output Voltage}}{\text{Scope Termination}} \times \frac{1}{R_{532nm}} = \frac{0.001\text{V}}{50\Omega} \times \frac{\text{W}}{0.27\text{A}} = 74\text{uW}$$