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Demystifying D*
(And Other Radiometric Terms)

As new applications of IR technology are developed; more and more technical people with non photonics backgrounds are becoming involved with the technology. These "newcomers" maybe at a disadvantage when confronted with a data sheet for an IR component such as a detector and the terms used to describe performance. Hopefully the following will shed a little „light" (pun intended) on the subject.

Responsivity

The basic measure of the output sensitivity of an IR sensor is the responsivity. This is usually specified in volts or amps per watt (V/W, I/W). This means that for a given optical power input a voltage or a current will be produced which is measured at the device's terminals.

Responsivity should be referenced to the temperature or wavelength of the test source such as a black body (BB) temperature source or laser wavelength. This is important because a particular type detector can have a very large responsivity variation over its operating wavelength region. For example silicon photodiodes have very large responsivity at visible or near IR wavelengths but are insensitive at the longer mid and far IR wavelengths.

The responsivity is generally measured using an AC signal produced by modulating the test energy with a „chopper" in the measurement path. The measurement frequency (Hz.) or chopping speed is referenced when making the responsivity measurement as many detectors have a frequency dependent output.

Some devices are measured at a specified the „bias" voltage or current which must also be referenced. The test temperature must also be noted as many IR detectors must operate at other than ambient temperature or even at cryogenic temperatures so that the test temperature must also be specified.

The detectors that rely on photon effects generally have temperature dependent spectral response. When these are tested and measured with a broad bandwidth source such as the BB at a particular temperature the output is „corrected" for the non-uniform spectral responsivity. This corrected response is called the peak response or responsivity at Lambda Peak (λp). Again most vendors can supply data regarding the effect of temperature on wavelength and performance. Thermal IR detectors have outputs that are fairly independent of wavelength over the most commonly used IR wavelengths. (2 to 20 microns)

To further complicate the situation the responsivity can vary with the size of the element. Which should be specified as well as the temperature of the source, the chopping frequency, the ambient temperature, the temperature of the sensor and the bias voltage or current?

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Time Constant

Time constant (τ) is the response time of the sensor to an input signal and is measured in seconds. Most photon sensors have fairly fast time constants as they depend on direct electrical effects and are a function of material type, and temperature of measurement. The time constant of thermal detectors is dependent on the type of sensor. With DC type thermal detectors devices such as thermistors and thermopiles the thermal time constant (τt) is used to define the maximum speed of response or frequency for that particular DC sensor (shorter is better). With AC type thermal detectors (which have no DC response) such as pyroelectrics the τt represents the mini mum speed or frequency of response for that particular AC sensor (longer is better). With AC devices it is measured as the time it takes for the output signal from a step pulse to fall to 1/e of its maximum response. With DC devices it is measured by measuring the rise time to a pulse. (exclusive of preamp response)

Noise

A very difficult parameter to repeatedly measure is the electrical noise generated the sensor. This is due to the fact that the noise levels are usually quite low in magnitude and also greatly influenced by the environment. Especially the temperature, frequency, the bandwidth of the measurement, and the local environment (which produces microphonic, electrostatic and general background noise).

Noise is measured as a voltage or current at a particular frequency and electrical bandwidth and temperature. The square root of the measurement bandwidth is specified and used to normalize the noise signals measured. Electrical noise has a statistical variation and is measured as an RMS noise voltage at the square root of the measurement bandwidth.

NEP

The NEP or Noise Equivalent Power is the lowest detectable power with a signal to noise ratio of one. It is derived from a measurement of the RMS voltage responsivity and sensor noise. The units are Watts per square root of the noise measurement bandwidth (W/√Hz). The lower the NEP the better the sensor. Within the various types of detector smaller area detectors generally have better NEPs. Although it would be very nice to use the very lowest NEP device this device might be so small that the performance required is unobtainable or impractical.

D*

D* (pronounced D-Star) is often misunderstood and confusing. It is simply the normalized or specific detectivity. This term was developed to be able to better compare the overall performance of different types and sizes of detectors used in various applications.

D* or detectivity is calculated from the NEP:

$$D* = \frac{\sqrt{Ad}}{NEP}$$

Where Ad = detector area in cm^2.

The units are (cm√Hz) /W or "Jones") with a larger D* being more desirable. Again this parameter is dependent on the measurement conditions described above.

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