APPLICATION NOTE

MEASURING LOW POWERS WITH THE XLP12 THERMOPILE DETECTOR

This technical note is intended to those who want to understand how to achieve valid and accurate low power laser beam measurements with thermopiles, especially in the hundreds of microwatts scale. Gentec-EO's XLP12 is the detector of choice to make such measurements since it is the most sensitive thermopile of our power product line. To achieve good measurements, one has to take a few precautions in order to be able to minimize measurement uncertainty.

PRECAUTIONS WHEN USING THERMOPILES FOR LOW POWER MEASUREMENTS

Keep room temperature as constant as possible. This will help null the effects of thermal drift and thus reduce thermal noise and measurement uncertainty.

Avoid positioning thermopiles near fans, any sources of heat or air convection. Some thermopile detectors like our XLP12 are very sensitive devices and their output is destabilized by air currents that can either heat the disk or suck heat out of it.

Use the isolation tube provided with the XLP12. It helps eliminate power fluctuations created by possible air turbulence.

Avoid touching the casing of the detector or putting it in contact with a heat source. This can create an offset in the measurements.

(Optional) The XLP12F has an IR filter that removes unwanted infrared interferences and isolate the detector from heat and air currents.

Ambient thermal noise can be characterized by an acquisition (with laser OFF). This can help to make sure if the chosen environment is suitable for power measurements. To minimize signal fluctuations due to thermal fluctuations, one can use an enclosure such as a cardboard box to isolate the detector.

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APPLICATION NOTE

STEP-BY-STEP PROCEDURE FOR SUB-MILLIWATT MEASUREMENTS

The XLP12 is our most sensitive thermopile. The following steps are recommended in order to measure accurately in the low power range (≈100 µW). These steps are also valid for low power measurements with detectors of the UP family.

1. Make your measurements in a room or enclosure with constant temperature and no air currents. This is MANDATORY for very low power measurements.
2. Make sure that the expected power is at least 100 µW. This is the minimum measurable power with the XLP12 detector, considering an NEP of 0.5 uW.
3. With the laser OFF or the beam blocked, set up and visually align the center of the XLP12 with the optical axis of your laser source.
4. Connect the XLP12 to a monitor or PC.
5. Power up or unblock the laser.
6. With the laser ON, center the beam in the aperture of the detector.
7. Make sure the beam covers 10% to 80% of the aperture of the detector.
8. Power up the monitor or launch PC application.
9. Select the appropriate power scale and wavelength for your measurements.
10. Disable the anticipation (see the user manual of your monitor). If you are using a MAESTRO monitor or an INTEGRA version of the XLP12, activate also the "Moving Average" mode with the desired averaging period. Remember that a longer averaging period will give a better signal-to-noise ratio (SNR). These steps will slow the response of the detector and avoid triggering on noise.
11. Power OFF or block the laser beam.
12. Wait for the detector to reach thermal equilibrium.
13. Watch the measurements and for them to stabilize (they should be near zero). This can take a few minutes.
14. Use the Zero function to eliminate the offset coming from the environment.
15. You may have to go through the two previous steps a few time, until the detector reaches complete thermal equilibrium and the signal fluctuations are negligible.
16. Power up or unblock the laser and wait (several seconds) for the power reading to stabilize.
17. Make your power measurements.

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WANT TO KNOW MORE?

Noise Equivalent Power (NEP) & Signal-to-Noise Ratio (SNR)

For an optical power measurement, NEP is a measure of device sensitivity to a signal. It is defined as the power signal required to give the same electrical signal as the noise signal. NEP can be expressed in Watts. SNR is defined as the ratio of the measured power over the level of the electrical noise (NEP) specific to the measurement system. Ideally, an accurate measurement must have an SNR of at least 20. This factor is however dependant on the requirements of the application.

$$SNR = \frac{POWER\ (W)}{NEP\ (W)} \geq 20$$

For example, if the nominal NEP of a given detector is 20 µW, you need to measure a power of at least 400 µW to get a good SNR and thus a valid measurement. For some devices, we recommend a higher SNR. In the case of the XLP12, since it is highly sensitive and can trigger more easily on environmental noise, we recommend an SNR of 200, which corresponds to a minimum measurable power of 100 µW (NEP = 0.5 µW).

Anticipation & Moving Average (XLP12 and UP Detectors)

When using a thermopile for low power measurements (µW and mW levels), it is strongly recommended to turn off the anticipation on your monitor. Anticipation algorithms allow to get a faster response time by quickly analyzing the rise of the signal and anticipating the resulting measurement. As it greatly speeds up the measurement process, it also makes the system more sensitive and thus noisier. For low power measurements, keeping the noise at its lowest level is ideal. Anticipation should therefore always be turned off.

To further clean measurements from unwanted random noise, we recommend using the "Moving Average" measurement mode instead of the usual power mode. This mode is available on the MAESTRO monitor and with the INTEGRA detectors using the PC-Gentec-EO application. When selecting this mode, you can choose the period over which measurements will be averaged. This will mainly reduce the effect of random electrical noise and increase SNR proportionally to the square root of number of averaged values (n) and thus the square root of the averaging time (t).

$$(SNR)_{averaged} \sim \sqrt{n}(SNR)_{not\ averaged} \sim \sqrt{t}(SNR)_{not\ averaged}$$

By turning off anticipation and choosing the averaging mode with a relatively long averaging period, you can significantly reduce noise and get a better SNR.

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