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TECHNICAL NOTE

MEASURING LASER POWER WITH A THERMOPILE DETECTOR / THE BASICS!

MAESTRO POWER METER
AND XLP12 THERMAL PROBE

If you're involved with CW or Pulsed Lasers, doing research, system design, process control, final test, or field service, you are going to want to accurately measure your laser power. The more you know about the measurement process, the better the results. To this purpose I'd like to share the technical insights that I have learned over a 35 year span in the laser measurement field.

1. CHOOSING A THERMAL DETECTOR THAT MATCHES UP TO YOUR LASER

LASER POWER VS. DETECTOR POWER RANGE

The first thing to consider is the power of your laser (CW or Average if pulsed). What is the minimum and maximum power expected? For the low end, you'll need to select a detector whose minimum detectable power is about 5% of the lowest power you'll need to measure. This will insure you'll have a good signal-to-noise ratio (i.e. 20 to 1). On the high end, if you are measuring at power levels that are nearing the detector's limit, make sure that you are cooling the probe properly. This is especially important for our water-cooled power detectors.

LASER BEAM DIAMETER VS. DETECTOR DIAMETER

What is the area of your laser beam? Ideally, it should not exceed 80% of the detector's active area. For example, for a detector with an aperture of 19 mm, the input beam diameter should be 17 mm or less. This tip will help you avoid spatial non-uniformities that can be associated with the edges of the absorbing area. It will also make it easier to align the detector and help ensure that you are collecting all the power or energy in the beam.

MAXIMUM AVERAGE POWER DENSITY

It is also very important to consider the maximum average power density of your laser beam before choosing a thermal detector. First of all, to calculate this value (W/cm^2), you need to divide the power of your laser (W) by the area of your beam (cm^2). Then, since most lasers have Gaussian profiles and thus a power density that is not constant over the beam area, it is recommended to multiply the calculated value by a safety factor of 2. If you suspect that your beam contains hot spots (spots with an abnormally high power density) or if your profile is closer to a flat top, it is recommended to multiply your calculated value by a safety factor of 3.

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Once this is done, you can now compare the corrected value to the maximum power density threshold of the thermal detector you are considering. Be careful to choose the threshold that is closest to your laser parameters in terms of wavelength and pulse duration. A graphic of damage threshold vs. beam power can be found in the user manual of the detector. It is important to note that the threshold diminishes when the power is increased. Also, a graphic of beam power vs. beam diameter is provided in the user manual. This graph must be considered for beams with an area less than 10% of the detector's active area. Since the power of such a beam directly delivered on the center of the detector's active area will be dissipated less efficiently by the edges of this active area, it is important to take a look at this graphic and to make sure you are in the safe zone regarding laser power and beam diameter.

MAXIMUM PULSE ENERGY DENSITY

If you are trying to measure the average power of a pulsed laser, then you have to also look at the maximum energy density and compare it to the detector's specified limits. This tends to be a bit more complex than the previous steps. Maximum energy density depends on the laser wavelength, pulse width, repetition rate and spatial distribution of your laser as well as the detector's absorber type. For our typical broadband absorbing coating the numbers range from 0.3 J/cm^2 (@ 266nm) to 1.0 J/cm^2 (@ 1064 nm) for a 7 nsec pulse at 10 Hz. A good "rule of thumb", assuming a near Gaussian distribution, is to make sure the energy density is a factor of two below the specified Maximum Energy Density of the probe you select. Proceed cautiously!

2. THERMAL ENVIRONMENT: THINGS TO CONSIDER WHILE SETTING UP YOUR DETECTOR

The first thing to consider is that you're working with a thermal detector whose body (package) is usually an integral part of the heat sink. For our small, high sensitivity detector like the XLP12, it is very important to let it come to thermal equilibrium after being handled during set up. For larger (high thermal mass) high power probes, this need not be a consideration. The other thing to think about when measuring at low power levels, i.e. <100 mW, is to minimize the contribution of other sources of broadband radiation (heat), like power supplies, incandescent lamps, and/or the human body (if close to the detector). The light tube, provided with the XLP12, helps limit its field of view and minimize these effects.

If your laser wavelength is in the VIS to Near IR you may also consider using a detector that includes a quartz window like our XLPF12 (F is for Filter). The filter will block IR radiation coming from hot objects that are in the field of view, minimize the effects of air currents and make it easier to make a stable power measurement.

If you're making measurements in an environment that includes fairly intense radiant sources (high background) and/or has a lot of air movement, you may want to consider taking steps to isolate or insulate your detector from the environment. A simple enclosure of some type can help.

3. ALIGNING THE DETECTOR TO THE LASER PATH

THIS IS CRITICAL!

The detector should be carefully centered in the laser beam's path for a number of reasons:

a. Since the laser beam is centered on the detector during calibration, it is important that your measurement be the same. This will help ensure that you achieve the expected measurement uncertainty.

b. The region of the sensor that has the best spatial uniformity is the one that encloses 60% to 80% of the sensor area around the center.

c. This will also ensure that you are collecting the entire laser output.

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4. SIZE OF YOUR LASER BEAM VS. DETECTOR AREA

Ideally, you'd like the laser beam diameter to be about 60% to 80% of the detector area. There are a couple of reasons for this. First, this is the size of the beam we use when calibrating the detector, and second, the larger beam effectively averages out any spatial non-uniformity that might exist in the absorbing surface. If you are measuring a much smaller beam, say 10% or less of the detector area, then you'll want to consider selecting a smaller detector. You could also add a diverging lens to your optical set up, to spread the beam on the detector, but of course you'll have to account for the optical losses associated with it.

If you have to measure a focused beam, then make sure to re-consider the maximum power and/or energy density specifications. Try to make the measurement at a point just behind the focus, where the beam is divergent.

LET'S WALK THROUGH THE POWER MEASUREMENT STEPS:

1. With your laser OFF (or the beam blocked), set up and visually align your detector to the optical axis of your source
2. Connect your detector to the power monitor
3. Power up (or unblock) your laser
4. Using an alignment aide if necessary, carefully center the detector on the laser beam
5. Adjust the monitor to the correct power range
6. Don't forget to enter the wavelength of your laser, assuming you're using a digital meter. This will correct the power reading for the wavelength response of the detector.
7. Now block the laser beam again and allow the detector to reach thermal equilibrium, or the point at which the baseline power reading is close to zero and appears stable.
8. Use the Zero function (or button) to eliminate or offset any background noise. You may have to do this more than once.
9. Next, unblock the laser and allow about 4 seconds for the power reading to peak and stabilize.

We hope this technical information and setup instructions will prove useful!
Should you have more questions, please contact your local Gentec-EO representative.

In the coming months, we will explain how to select and use pyroelectric and photodiode based Joulemeters. Don't miss it!
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