TECHNICAL NOTE

MEASURING LASER PULSE ENERGY WITH A PYROELECTRIC DETECTOR / THE BASICS!

MAESTRO ENERGY METER AND QE50 PYROELECTRIC DETECTOR

If you're involved with pulsed lasers at any level in research, product development, final test, process control, field service or laser safety, it will be important for you to accurately measure the energy of your laser(s). To this purpose I would like to share the technical insights that I have learned over a 40 years span in the laser measurement field. In this technical note, you will learn about the parameters that you need to consider when selecting and using a pyroelectric detector, and about the typical steps for making good energy measurements.

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

LASER PULSE ENERGY VS. DETECTOR ENERGY RANGE

The first thing to consider is the energy range you need to measure. To cover the low end of your range, you will need to make sure the detector you choose has an NEE (Noise Equivalent Energy) 20 or 30 times below the minimum energy you want to measure. For example, if you need to measure 100 μJ, you will need to select a detector with an NEE of 5 μJ. This corresponds to a 20:1 signal-to-noise (SNR) ratio. On the high energy end of your range, you will have to consider two parameters. The first one is the maximum specified energy and the second one is the maximum energy density at the wavelength and pulse width you're working at. Energy density will be discussed in more details later in this document.

LASER BEAM DIAMETER VS. DETECTOR DIAMETER

In general, you need to select a detector whose active area is about twice that of your laser. This helps to ensure that the entire laser radiation is absorbed by the detector. It also helps averaging out any spatial non-uniformity that could affect the measurements and makes it easy to align the laser beam properly. Also, you always want to center the laser beam on the sensor. Since this is the way both the laser beam and the sensor are aligned during calibration, this method will give you the most accurate and repeatable measurements.

PULSE WIDTH AND REPETITION RATE

Before selecting a detector for your pulse energy measurements, you need to be sure that the pulse width of your laser is shorter than the specified maximum pulse width of the detector. This is to ensure that the voltage output is linear and directly proportional to the laser pulse energy. In addition, make sure that the laser repetition rate is less than or equal to the specified maximum repetition rate of the detector as well.

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MAXIMUM ENERGY DENSITY

The maximum energy density determines the point above which the absorber material of the detector can be damaged (i.e. ablated). Our typical maximum energy density specifications can vary dramatically depending on the type of absorber material: it can be as low as 50 mJ/cm² for our BL absorber or as high as 600 mJ/cm² for our MB absorber (these values are good for 7 ns pulses at 1064 nm). Be aware, however, *that the maximum energy density decreases as the pulse width gets shorter.*

> **CAUTION:** Never use the detector at the focal point of an optical system. Always place the detector before or after the focal spot, where the energy density is lower. We highly recommend that you use the "test target" we supply with each QE detector to make sure you are not exceeding the damage threshold of the absorber material.

The wavelength of the laser can also affect the maximum energy density. Typically, the shorter the wavelength the lower the damage threshold. Here is an example for our MB absorber: The maximum energy density is 0.6 J/cm² at 1064 nm and 0.5 J/cm² at 266 nm.

If maximum energy density is an issue for your measurements, you will have to consider using our QED attenuator. This accessory boosts maximum energy density to 16 J/cm² for a single pulse at 1064 nm and to 6 J/cm² at 10 Hz for the same wavelength.

MAXIMUM AVERAGE POWER

Why is average power a concern when selecting an energy detector? It is important to keep the average power below the maximum average power of the detector because it relates to the accuracy of the measurements.

Like all detectors, pyroelectric detectors have a "temperature coefficient" which is about 0.2%/°C. Temperature variations affect the voltage responsivity of a detector when in operation. For example, a 10°C temperature increase due to a high average power would result in a +2% change in the responsivity. Staying below the maximum average power specification ensures you that your measurements are within our uncertainty specifications.

USING A PYROELECTRIC ENERGY WITH AN OSCILLOSCOPE

When using a QE detector with our DB-15 to BNC adaptor connected to an oscilloscope, you need to consider the following:

a. Make sure the oscilloscope is set up for a 1 MΩ input (not 50 Ω)

b. Set the time base to about 1 msec (and adjust as needed)

c. Set the voltage scale to 100 mV division (and adjust as needed)

d. When you expose the detector to the pulsed laser, you will get an integrated voltage output that will rise from the baseline to a peak in about 500 μsec or less, you need to measure the voltage from the baseline to the peak (see the diagram in Fig. 1)

e. To determine the pulse energy, you need to divide the measured voltage by the voltage responsivity (V/J) of the detector

f. You will then have to apply a wavelength correction factor based on the spectral absorption curves or data supplied with the detector

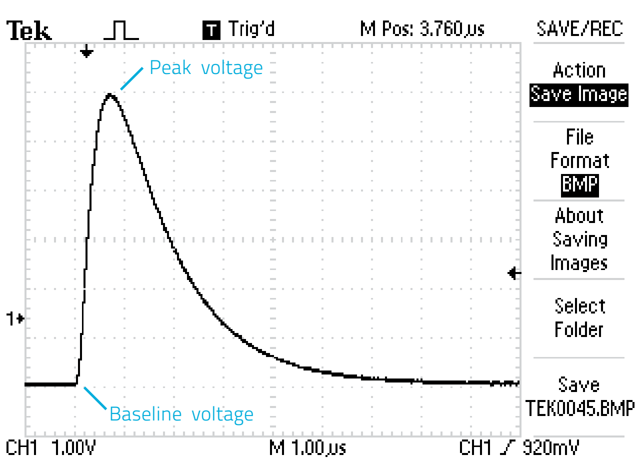

Fig. 1. Typical voltage output from a pyroelectric detector

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2. THINGS TO CONSIDER WHILE SETTING UP YOUR DETECTOR

MICROPHONIC RESPONSE OF THE DETECTOR

All pyroelectric detectors exhibit a piezoelectric response to a variety of sources. When mounting a detector on your optical bench, we recommend that you use the Delrin post that we supply with each detector. This provides isolation from mechanical vibrations that might be present in your lab and prevents the possibility of establishing a ground loop. The source of the vibrations could be a pump, a power supply, a fan, an optical chopper, and even a heavy truck rumbling by your facility. The piezo response, sometimes called microphonic noise, will appear as a random frequency voltage superimposed on the integrated voltage output of the detector. Try to isolate the detector as best you can from all sources of vibration.

ACOUSTIC RESPONSE OF THE DETECTOR

Another source of piezoelectric response can come from acoustic sources in your lab, such as sounds from a speaker, rumbling from a pump, or clapping of one's hands. The lower the energy level you are trying to measure, the more significant acoustic noise will be. The goal here is to once again isolate your detector from possible acoustic noise, or to simply remove the source.

THERMAL CONSIDERATIONS

Pyroelectric detectors, like all optical and thermal detectors, have a temperature coefficient as discussed earlier. Therefore, it is very important that once you have set the detector up in front of your laser, you allow a little time (5 to 10 minutes) for the detector to reach thermal equilibrium. Then, you can proceed with your pulse energy measurements.

OPTICAL CONSIDERATIONS

If you are using our detector with a beam splitter, plano or wedged, remember that there are two reflections, the front surface reflection and back surface reflection. For an accurate measurement, make sure that the detector only sees the front surface reflection. This will be a little more challenging for a near-IR or far-IR laser beam.

LET'S WALK THROUGH THE ENERGY 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 energy monitor (like our MAESTRO or M-LINK)
3. Power up (or unblock) your laser
4. Use the supplied test target to make sure the energy density is below the damage threshold of your detector
5. Using an alignment aid if necessary (like an IR card) and with the laser set to a safe energy level, carefully enter the detector on the laser beam
6. Adjust the monitor to the correct energy range (or set to AUTO RANGE)
7. Make sure the trigger level is low enough to trigger on the pulses but high enough so it does not trigger on the background noise (i.e. microphonic noise). The default trigger level in our monitors is 2.0%. When measuring in the low end of the detector, we recommend that you use the "external trigger" feature of the monitor
8. Set the wavelength of your laser in the monitor or PC-Gentec software. The absorbance of each detector has been measured accurately and is stored in the EEPROM of the detector
9. Allow a little time for the detector to reach thermal equilibrium (5 to 10 minutes)
10. You are now ready to make accurate pulse energy measurements with your QE pyroelectric detector

We hope this technical information and setup instructions will prove useful ! Should you have any questions, please contact your local Gentec-EO representative. Don Dooley (503) 697-1870 or ddooley@gentec-eo.com