ELTECdata # 109

Laser Detection with Lithium Tantalate Pyroelectric Detectors

ELTEC INSTRUMENTS, INC.

Pyroelectric detectors are widely used throughout the laser industry for several reasons:

1. Operation at all wavelengths. Being thermal detectors, photons are converted to heat to electrical output. From hard-UV to millimeter waves;
2. They operate at room temperature and do not need cryogenic cooling;
3. The crystal output itself requires no electrical biasing;
4. As thermal detectors, they can be calibrated from blackbodies and the transfer function applied to any monochromatic wavelength;
5. Depending on the choice of an optical filter, single detectors are available for about $50;
6. Pyroelectric detectors are particularly favored for use in the mid and far infrared because alternate detection schemes can be several orders of magnitude higher in price. The carbon dioxide laser at 10.6 micrometers is a good case in point;
7. Crystal size of 2.74 mm sq is common and those from .5 mm sq to 5 mm sq are readily available thereby giving a practical target size easily fitted into a small TO-5 or TO-99 transistor can. Crystals larger than 5mm sq are also readily available in larger size packages;
8. Fast response. Rise time of 2 nanoseconds is possible. Especially useful for power monitoring;
9. Optical radiation must be pulsed or modulated. Pyroelectric detectors need to see a thermal contrast;
10. They tolerate relatively high energy for extended periods — even years. This is the reason they are widely used for power monitoring in medical and dental applications.

Presently, single-crystal lithium tantalate is the preferred pyroelectric material for laser detection because it has a Curie point of 610°C and is non-hydroscopic, thus making it suitable for higher power inputs and use without an optical filter (when required).

Pyroelectric devices respond only to a change in temperature. Thus the detector must be used with a pulsed laser — or, if used with a continuous wave laser, with the light beam modulated or "chopped".

In a great many laser applications, the response of the crystal output is sufficient for the operation into an oscilloscope from a 50 Ohm termination. For lower incident-power inputs, pyroelectric detectors are available incorporating voltage follower or current mode hybrid amplifiers.

When used with high power lasers, beamsplitters are used to decrease incident energy to the detectors. When power reductions of less than an order of magnitude are required, a neutral density filter (gray filter) is often used between the laser and detector. Also, materials with poor transmission can be chosen for the detector filter. It must be noted, however, that care must be taken to select materials which can safely withstand consequential heating. Uncoated germanium is often effective because of the reflective losses due to its high index of refraction in the infrared.

Pyroelectric laser detectors are most commonly used for power monitoring. Also for pulse resolution to obtain an analog profile of the pulse shape through time. The profile can be integrated to obtain pulse energy, but as mentioned before, the basic circuit used for pulse resolution is simply to terminate the output in a resistor of low enough value to obtain the desired frequency response.

If the detector output is terminated in a capacitor, then the voltage of a charged capacitor obtained is proportional to the energy of the pulse (joules = $1/2CE^2$).

For pulse resolution or energy monitoring, a detector with a single sensing element is all that is required.

When pyroelectric detectors are used for beam alignment or to measure beam displacement, sensors incorporating multiple elements are desirable. Quad element detectors or 10-element linear arrays are readily obtainable.

Since pyroelectric detectors are responsive to light from all wavelengths, it is often necessary to block extraneous or unwanted light from the crystal. A variety of bandpass and band elimination optical filters are available either through ELTEC or optical coating firms. It is often advisable to verify that the optical filters do not "turn on" again at long wavelengths or to make provisions for elimination of unwanted bands. Sometimes remnants of the flashlamp or other driver can be blocked from the detector.

UV or Millimeter Wave Applications

Since pyroelectrics are thermal detectors, they are proving especially useful alternatives in laser applications involving ultraviolet light or extremely long wave (millimeter) communication applications.

Pure Detectors or Detectors with Integrated Electronics

For high power applications, the Model 420 detector (which contains only a pyroelectric crystal and no electronics) is recommended. For low power applications, detectors in the 441 Series (current mode) may be appropriate. Another alternative is the 406 Series (voltage mode) with lower value load resistors than standard. The Model 406 contains a sensing crystal and a source follower circuit (impedance buffer). The source follower circuit is very frequency dependent but the value of the load resistor can be chosen to give flat response to high frequencies. ELTEC is the world's leading manufacturer of high megohm, thick film chip resistors and special values are almost always immediately available from stock.

Arrays

Four-element quadrant arrays or 10-element linear arrays are available on special order. Request quotation on other configurations.

Power Limits

ELTEC's laser detector employs a face electrode crystal of lithium tantalate mounted directly to a high alumina substrate (which has a much higher thermal conductivity than most other ceramics and even higher than some metals). The crystal is bonded to the substrate with a material chosen for its high thermal conductivity to dissipate heat.

The power limit for any particular detector is a function of pulse power, duration and duty cycle.

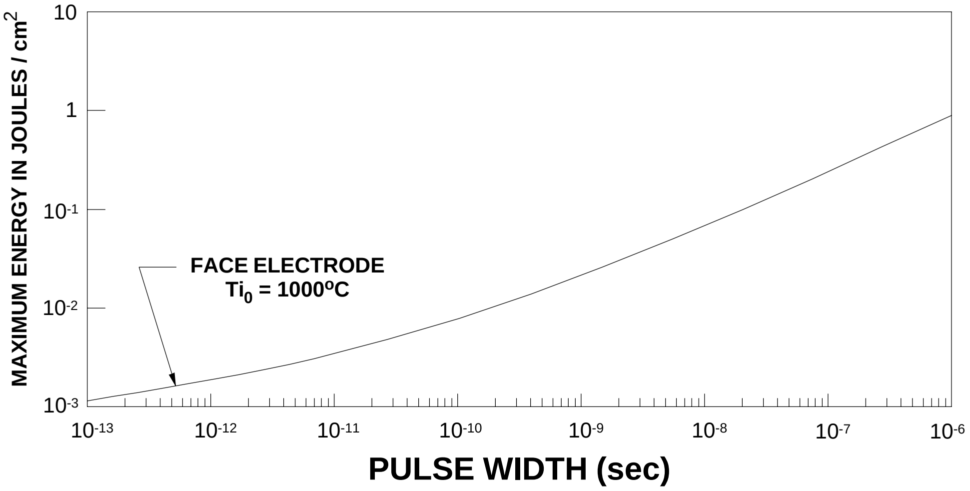
Roundy and Byer (Applied Physics Letters, Vol. 21, #10, 15 Nov. 1972, Pages 512-515) give 1.6 joule/sq cm as the maximum energy density for a 500°C rise in lithium tantalate. Since lithium tantalate has a Curie temperature of 610°C, the 500°C rise figure is well chosen. Relating that energy density to that of an ELTEC 420 crystal 7.50 sq mm gives 0.12 joule.

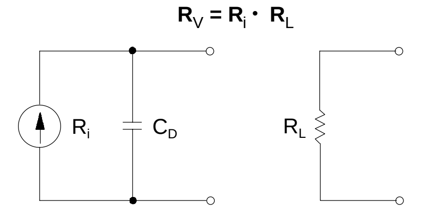
The other critical limiting parameter is the ability of the top face electrode to accept and transfer heat without vaporizing. Roundy and Byer give the maximum energy density for a thin electrode as 0.02 joule/sq cm for a 1,000°C temperature rise at a pulse width of 1 nanosecond. The 0.02 joule/sq cm is the energy per second while the effective peak energy is 2 x 10^7 Watts(peak). Refer to the chart below.

Laser Applications

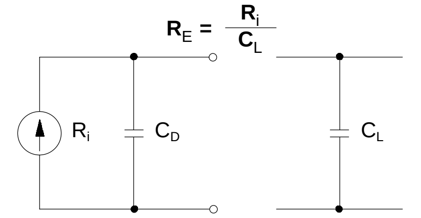
In high speed or fast pulse applications with a great deal of incident power, the detector can be operated without an impedance converter. If pulse resolution is required, the detector can be loaded down with a resistor — the value of which is determined by the speed of the event to be monitored. In this case, responsivity is R_V. The detector can also be used as an energy monitor by loading the output with a capacitor. In this case, responsivity is R_E.

MAXIMUM ENERGY DENSITY OF PYROELECTRIC DETECTORS VERSUS PULSE WIDTH





Circuit for pulse resolution in high power applications



Circuit for energy monitor of high power pulses

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