LASER DETECTION WITH LITHIUM TANTALATE PYROELECTRIC DETECTORS

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

1. They are thermal detectors (light is converted to heat and thence to a proportional electrical output) and response is largely independent of the particular laser wavelength;
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. Costs have dropped through recent years and single detectors are now available at less than $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 2.5 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;

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 a window (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 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 window. It must be noted, however, that care must be taken to select materials which can safely withstand consequential heating. Uncoated germanium is effective because of the reflective losses due to its high index of refraction in the infrared.

Pyroelectric laser detectors are most commonly used 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 windows are available either through ELTEC or optical coating firms. It is often advisable to verify that the windows do not "turn on" again at long wavelengths or to make provisions for elimination of unwanted bands.

UV or Millimeter Wave Applications

Since pyroelectrics are thermal detectors, they are proving especially useful 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, the Model 406 has proven useful in many applications. 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. No extra charge is made for selection of the load-resistor. ELTEC is the world's leading manufacturer of high megohm, thick film chip resistors and special values are almost always immediately available from stock.

Detectors incorporating operational amplifiers are also available where amplification is required.

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.

The specification in our data sheet gives the power limit as 5 W/sq cm.

However, with many, many units in the field, and years of service, we believe the power rating to be conservative. The following is relevant to the subject of power rating:

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 6.25 sq mm gives 0.1 joule—which is 20 times larger than our spec of 5 mJ.

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 10E7.

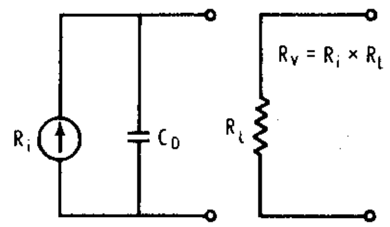
In short, the Model 420 laser detector "should" be able to take pulses from a laser to 100 watts (as long as the average energy density per second is within 0.02 joule per second).

To realize the potential of the pyroelectric material and the electrode, it takes manufacturing expertise, and in this regard, no other pyroelectric manufacturer in the world slices, polishes, deposits electrodes, dices and assembles as many lithium tantalate detectors a week as ELTEC. Our proprietary electrode is as thin as practicable while being applied with an evenness that comes only with volume production.

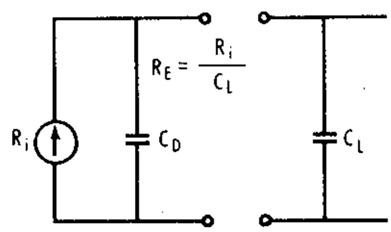
Laser Applications

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. The detector can also be used as an energy monitor by loading the output with a capacitor. In this case, responsivity is:

$$R_E = \frac{R_i}{C_L}$$



Circuit for pulse resolution in high power applications



Circuit for energy monitor of high power pulses