Centre for Imaging Research and Advanced Materials Characterization

Photo-Acoustical Nonlinearity

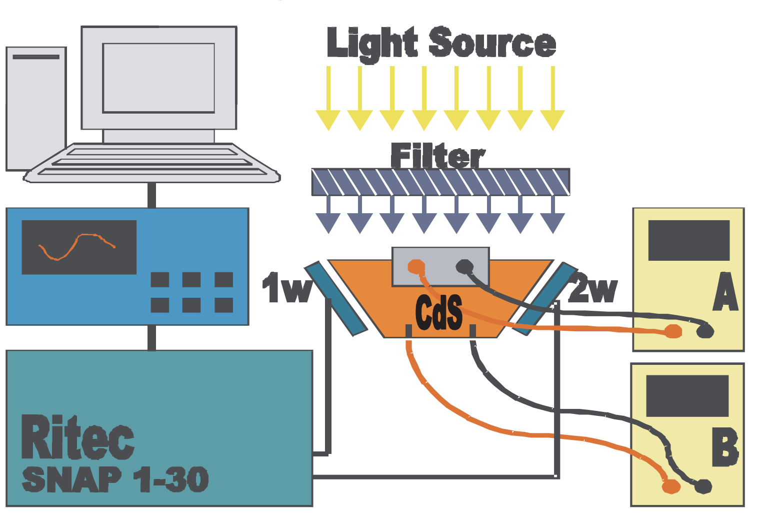
This is an experimental study of the higher harmonic generation due to nonlinear acousto-electronic interaction in a piezoelectric semiconductor. Specifically this experiment uses the Ritec SNAP 1-30 measurement system to explore the interaction characteristics in the frequency range up to 30 MHz in a Cadmium Sulfide crystal. The experimental results are interpreted and compared with theoretical calculations relevant to a small signal approximation.

Fundamental Theory

If an acoustic wave propagates in a piezoelectric material, the dislocation of the medium creates an electric field. Further, if this material is a semiconductor then the interaction between the oscillating electric field and the free electrons induces an electromagnetic wave. The acoustic and electromagnetic waves are then coupled together together as a “piezoelectrically active” wave which can be observed physically through the attenuation, dispersion and nonlinearity of the acoustic wave. These physical effects can be found to be dependent on both the frequency of the acoustic wave and the conductivity within the crystal.

Basic Experiment

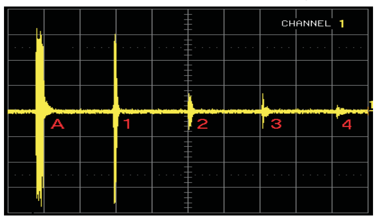
- The conductivity within the Cadmim Sulfide crystal is controlled through a variable intensity light source. If a monochromatic light source is desired, a filter may be placed above the crystal.
- The intensity of the light source and the conductivity within the crystal are monitored separately.
- Acoustic pulse waves are generated within the crystal using the Ritec SNAP advanced measurement system and are monitored with an oscilloscope.
- One transducer is placed on each end of the crystal with the frequency of the second transducer being a multiple of the first. This allows the higher harmonics to be measured along with the fundamental.



The Ritec SNAP 1-30 advanced measurement system sends and receives acoustic pulses to and from the transducers. The filtered light source stimulates the conductivity within the crystal which is monitored via resistivity with ohmmeter B. Ohmmeter A is connected to a photo-intensity meter and measures the intensity of the filtered light reaching the crystal.

Preliminary Results

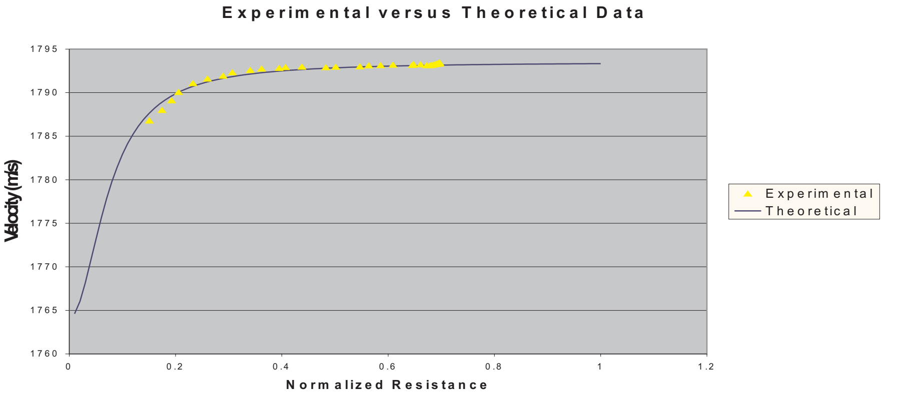
In initial experiments, the velocity change of a shear acoustic wave in a Cadmium Sulfide crystal was determined with respect to measured resistance. This was done by determining the “time of flight” between subsequent echoes from the back surface of the crystal for various conductivity levels.



Sample Oscilloscope Screen:

The initial pulse is labeled A and all subsequent echoes are numbered 1 through 4.

Once a correlation between flight time and resistance, or equivalently, conductivity was determined, the velocity versus resistance for this crysal could be compared to a theoretical curve. As can be seen by the graph below, the theoretical and experimental curves are in good agreement.



According to theory, with a decrease in conductivity within a piezoelectric semiconductor, one should observe an increase in the velocity of sound due to an overall stiffening of the crystal. Thus, a measure of higher resistance within a CdS crystal is accompanied by a higher acoustic wave velocity. This can be seen in both the theoretical and experimental curves above.

Future Development

Linear Experiments

- Velocity of 2*w*-waves as a function of conductivity.
- Dispersion mismatch versus conductivity.
- Attenuation coefficient as a function of conductivity and voltage for *w*- and 2*w*- waves.

Nonlinear Experiments

- Amplitude dependence of the second harmonic upon conductivity, voltage and distance.
- Dependence of amplitude upon these same variables for the third and fourth harmonic.

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