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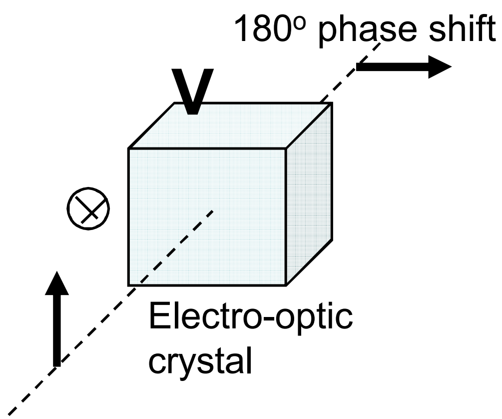

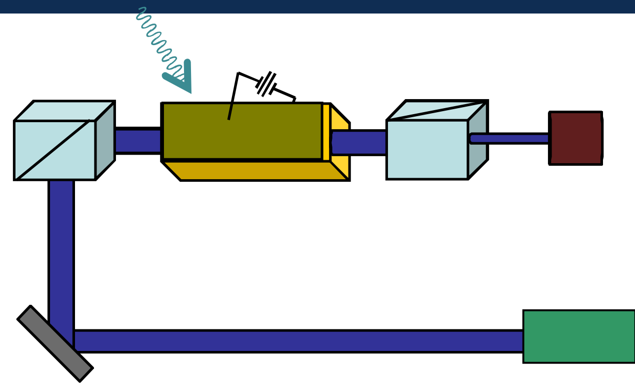

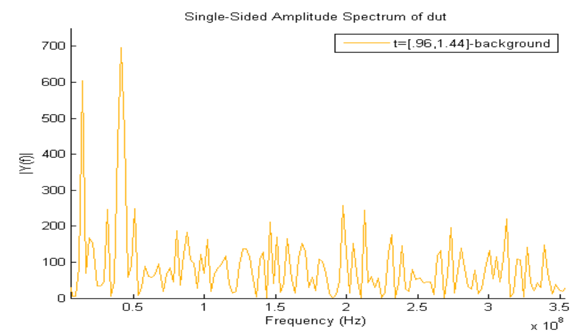

Electro Optic Detector for Tracking Ionizing Radiation Events

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Sandia National Laboratories

October 26, 2011

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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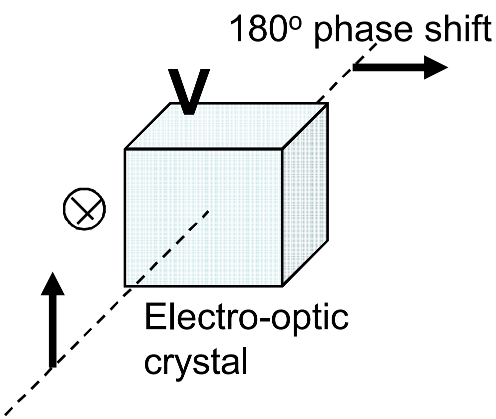
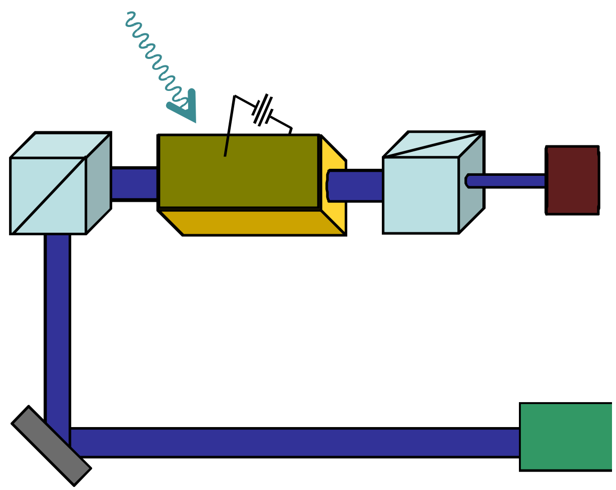
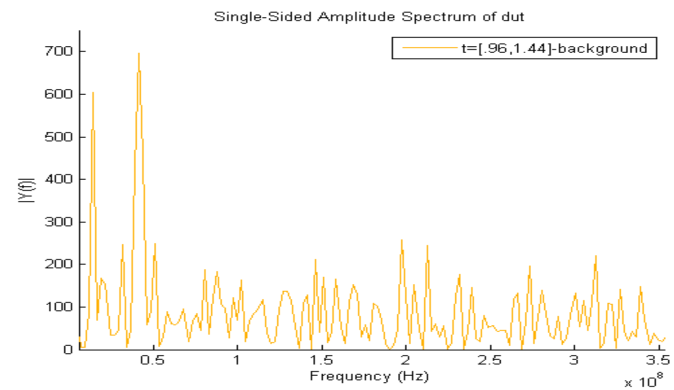
Outline

- Electro-optic detector description
- Experimental Setup
- FFT analysis
- Conclusion







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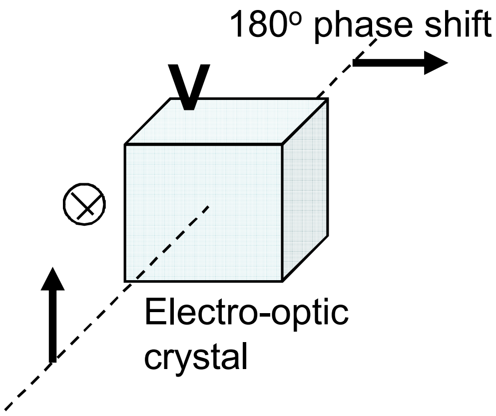
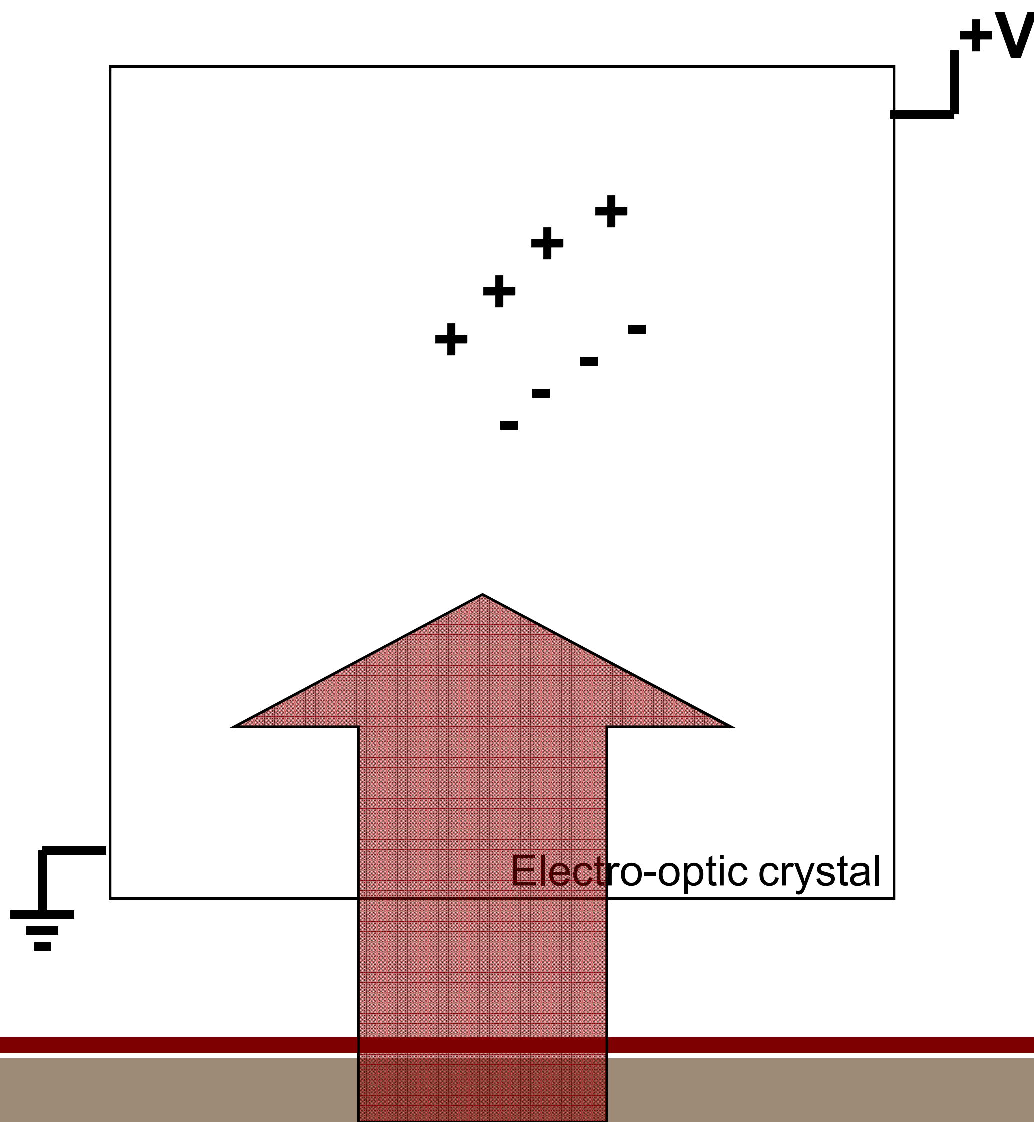


Electro-optic Detector



- Want to resolve *individual* ionizing radiation events
- Radiation (n,γ) interacts with the crystal creating electron-hole pairs
- Electrons drift due to an externally applied electric field
- Creates a locally varying electric field inside the crystal
- Due to the radiation interaction a locally varying index of refraction "track" can be probed with laser light
- Light can be analyzed through polarization spectroscopy imaging

Past Research

- Electro-optic imaging first demonstrated by illuminating small objects/masks with X-rays
  - Berzins, G and Graser, M. Appl. Phys Let. 34, 500 (1979)
- Used to detect thermal neutrons at a nuclear power plant.
  - K. Nelson, et.al. NIM A 620, 363 (2010).

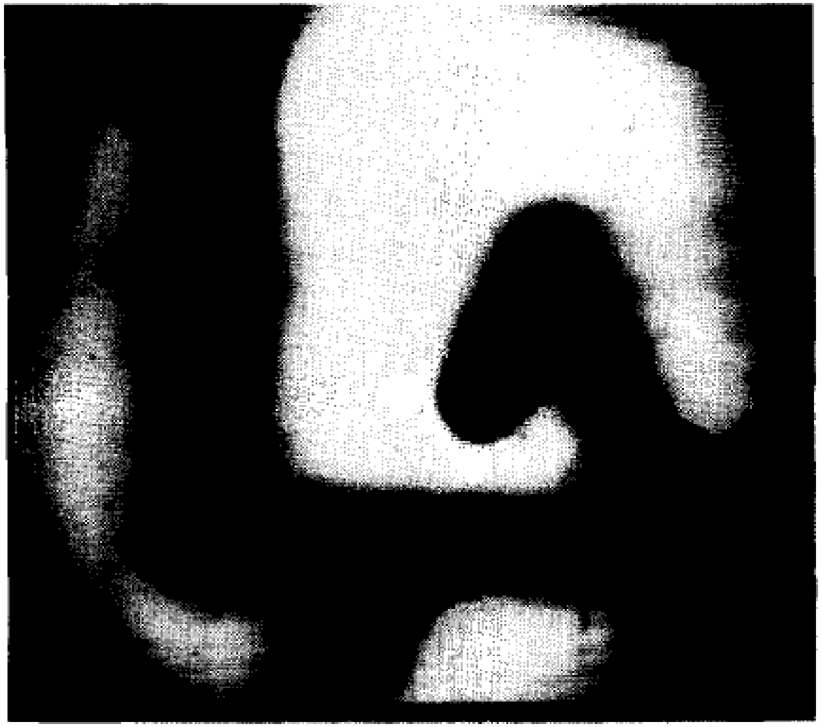
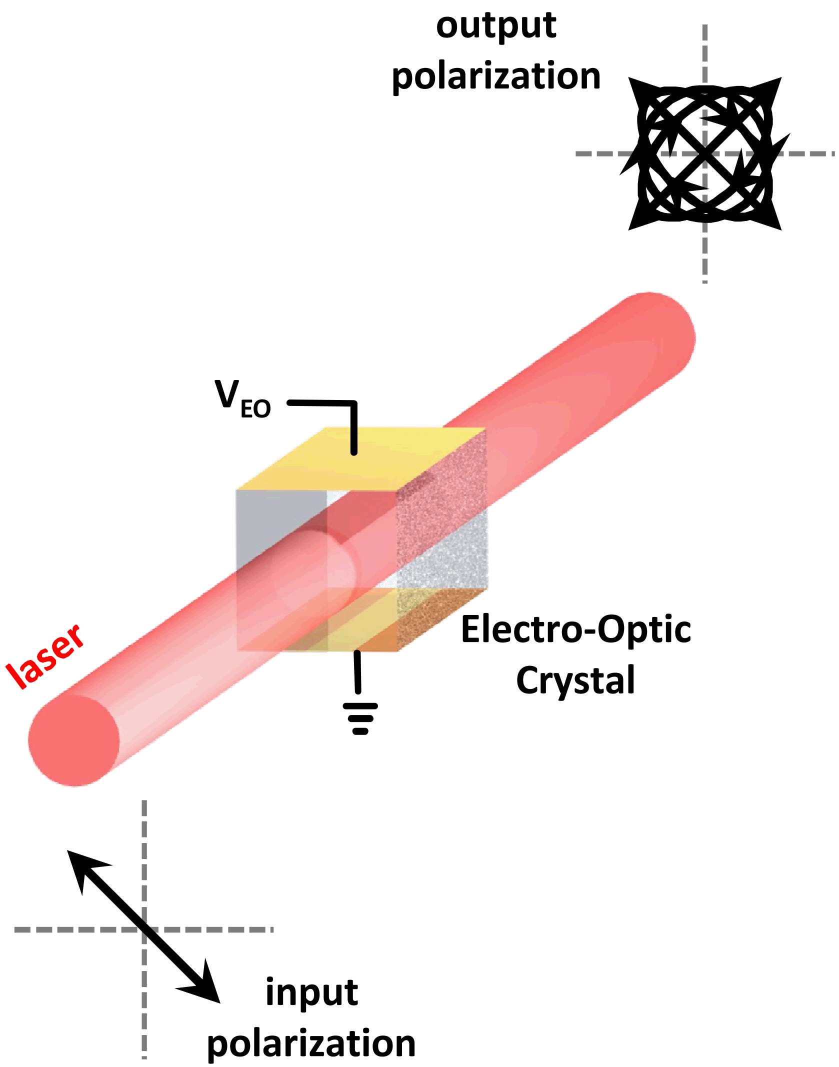


FIG. 3. TV-monitor photograph showing an x-ray shadowgraph of a 3-mm-thick lead mask. The black areas in the image correspond to open areas in the mask. The stem of the "L" in the logo was 1.6 mm wide.

Berzins, G and Graser, M. Appl. Phys Let. 34, 500 (1979)

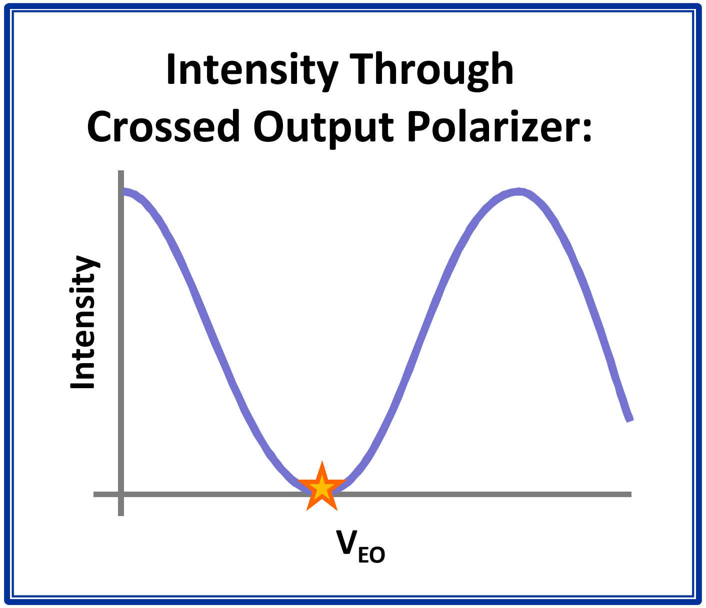
Electro-Optic Crystals

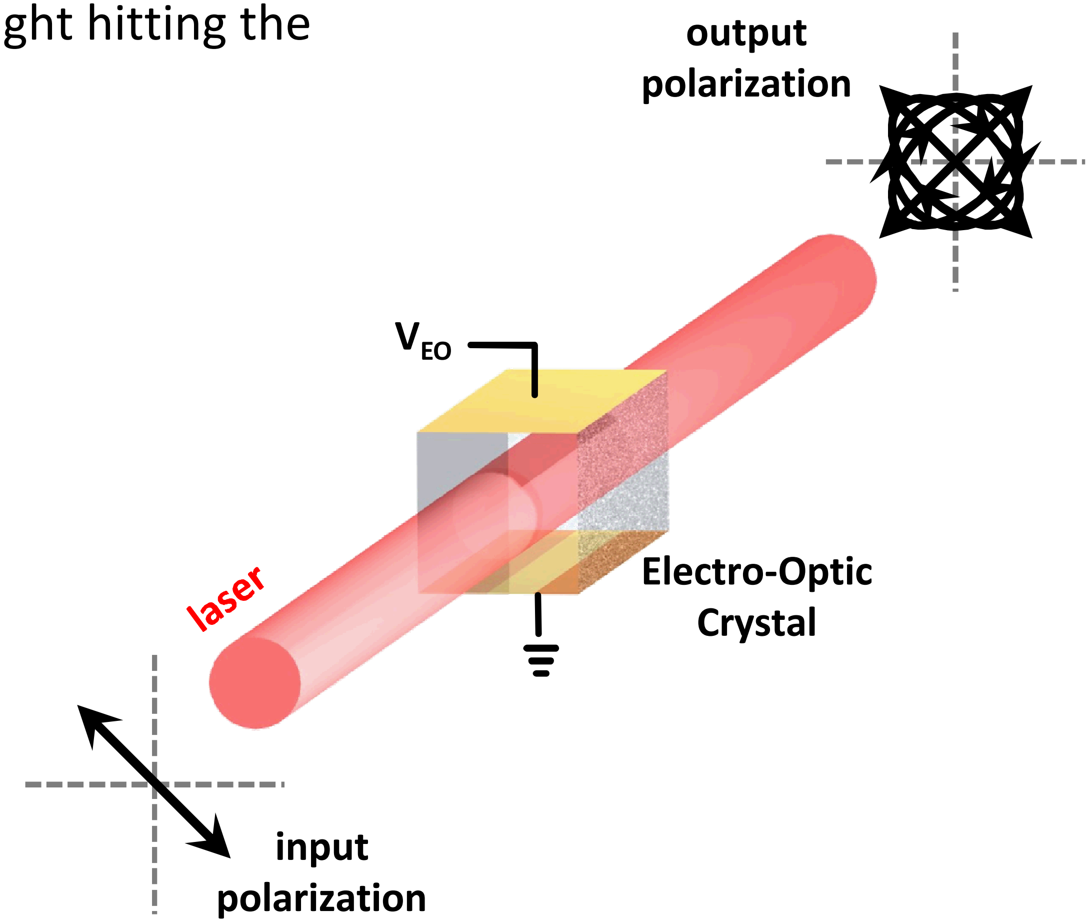


- Commercially available crystals include KDP, ADP, $LiNbO_3$, $LiTaO_3$
- Pockels effect- production of birefringence in a noncentrosymmetric crystal that is proportional to the applied electric field
- Applied electric field creates a change in index of refraction, Δn

Polarization Spectroscopy

- Crossed polarizers extinguishes the laser beam
- Any change in the birefringence of the electro-optical crystal results in more light hitting the detector





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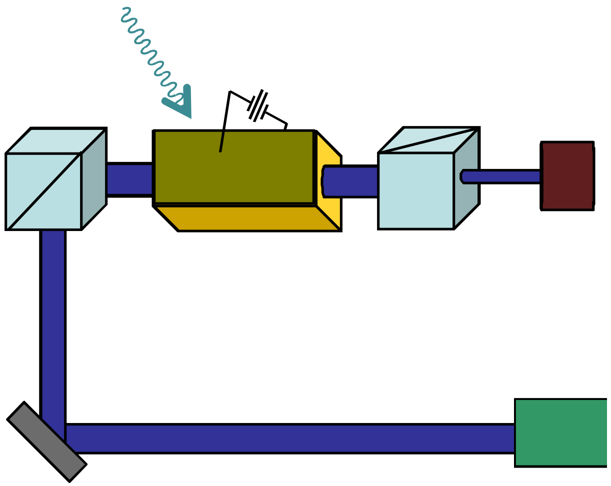
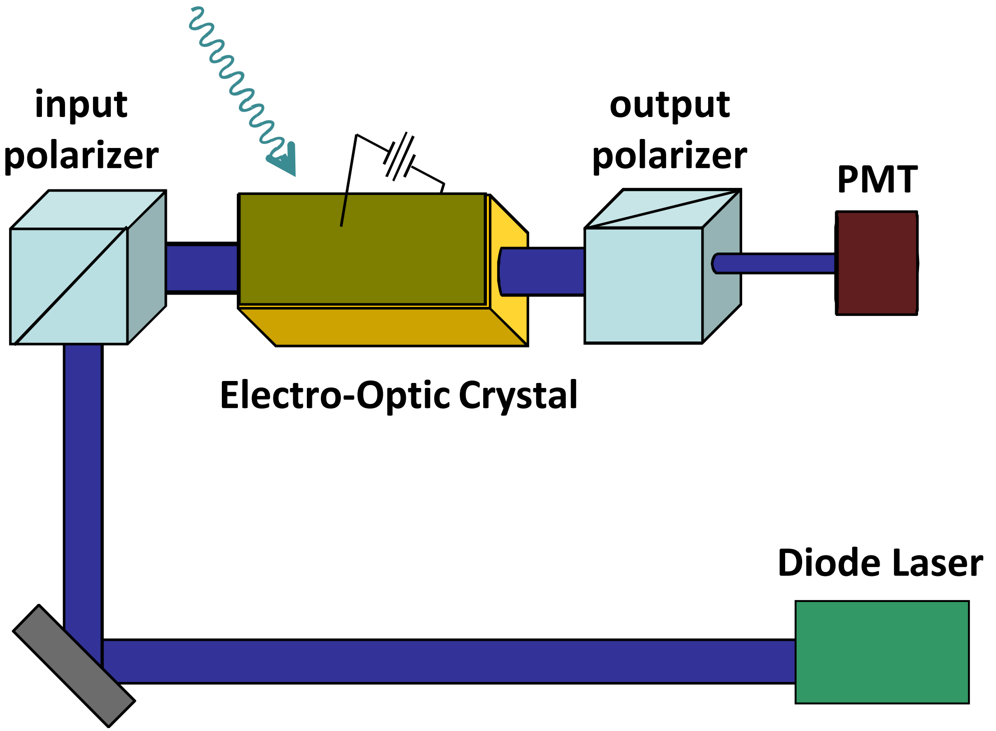
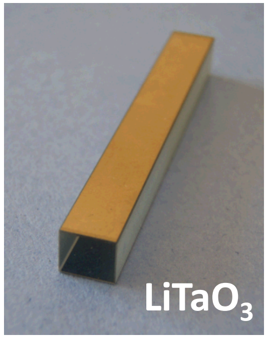


Experimental Setup

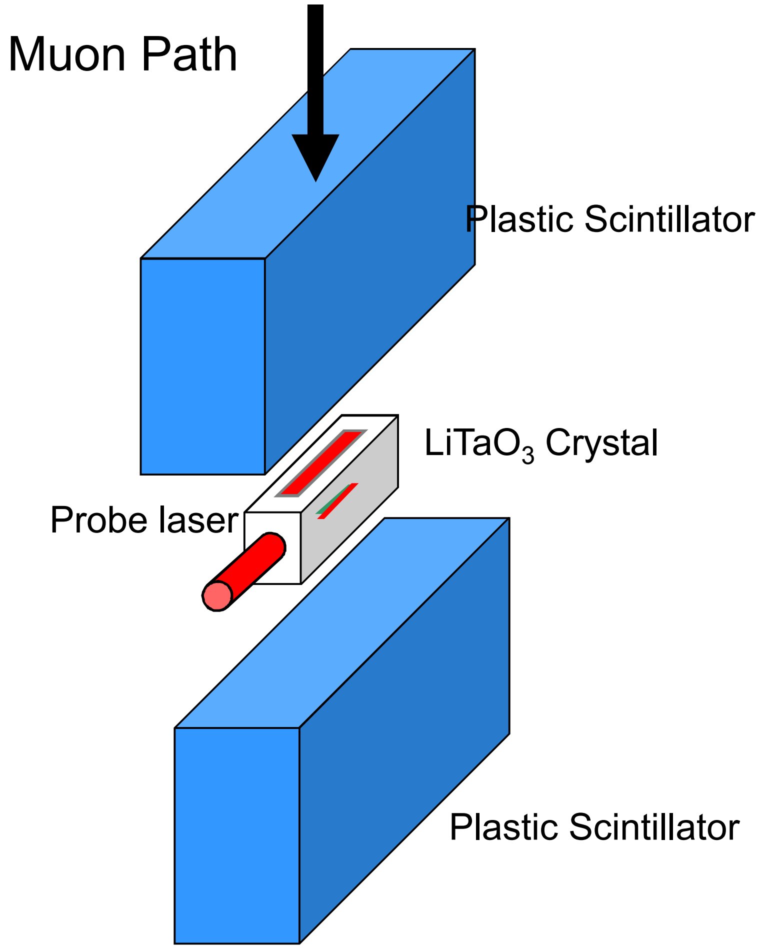


- Electro-optic crystal: $LiTaO_3$ with gold electrodes
- Laser: cw, 780 nm
- Detector: PMT w/AC amplifier
- Signal recorded on oscilloscope
- Uses polarization spectroscopy



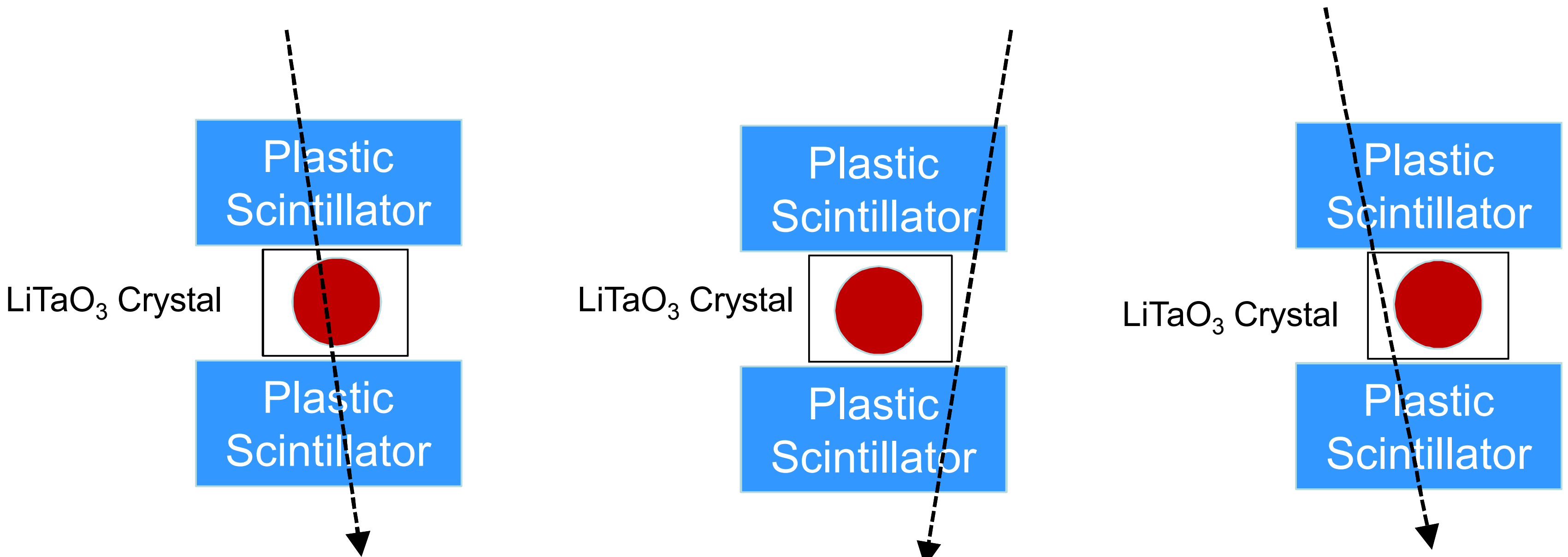
Experimental Parameters: Signal

- Signal
  - Time resolved/spatially integrated change in the index of refraction
  - 780 nm laser light, 10 mW
  - Hamamatsu PMT detector with AC amplifier, 500 V, O (ns) rise times
- Radiation interaction
  - 4 MeV/cm deposited within the $LiTaO_3$ crystal with 4 eV band gap
  - 150,000 electron-hole pairs created due to radiation interaction
  - linear electron-hole pair density of 30 /μm.



Experimental Parameters: Trigger

- Trigger
  - Trigger requires high light levels on both upper and lower scintillator
  - 0.2 mHz trigger rate
- 1/3 of all triggers produce a signal.



Muon travels through both scintillators and through the probe volume in the $LiTaO_3$ crystal

Muon travels through both scintillators but misses the $LiTaO_3$ crystal

Muon travels through both scintillators and through the $LiTaO_3$ crystal but misses the probe volume

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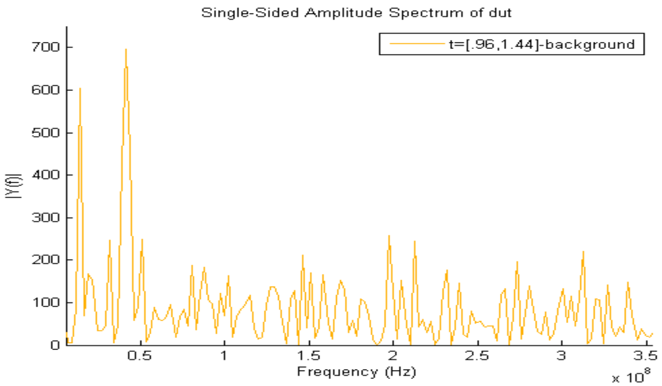
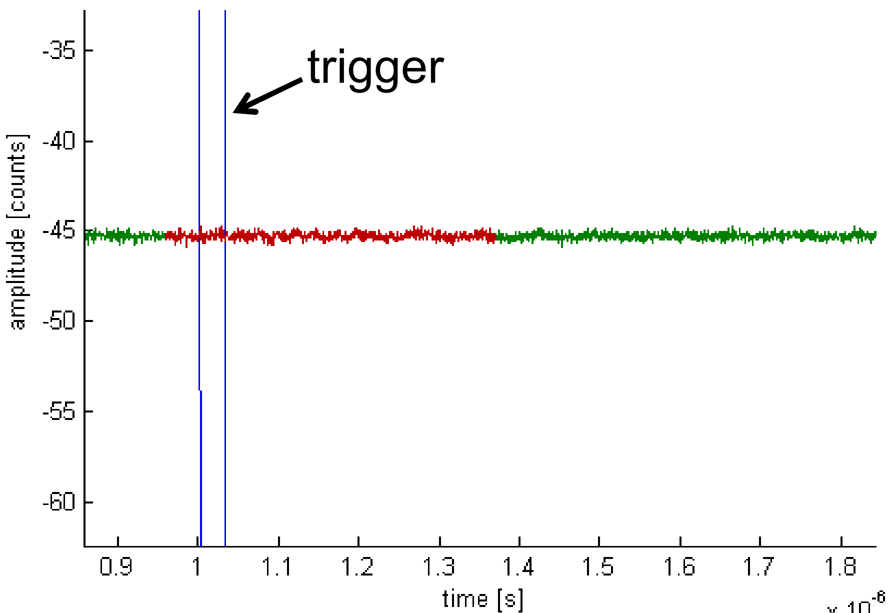
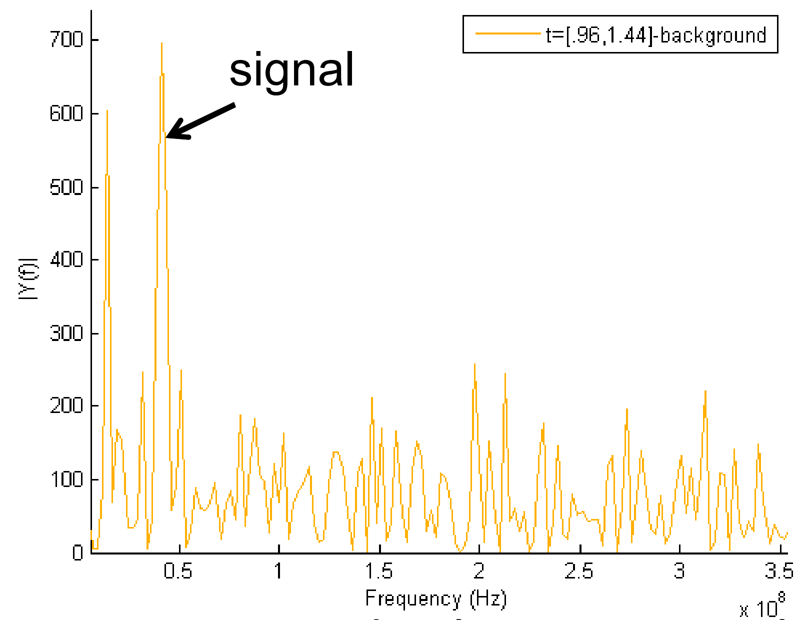


FFT Analysis: Averaged signal

Average of 47 triggers



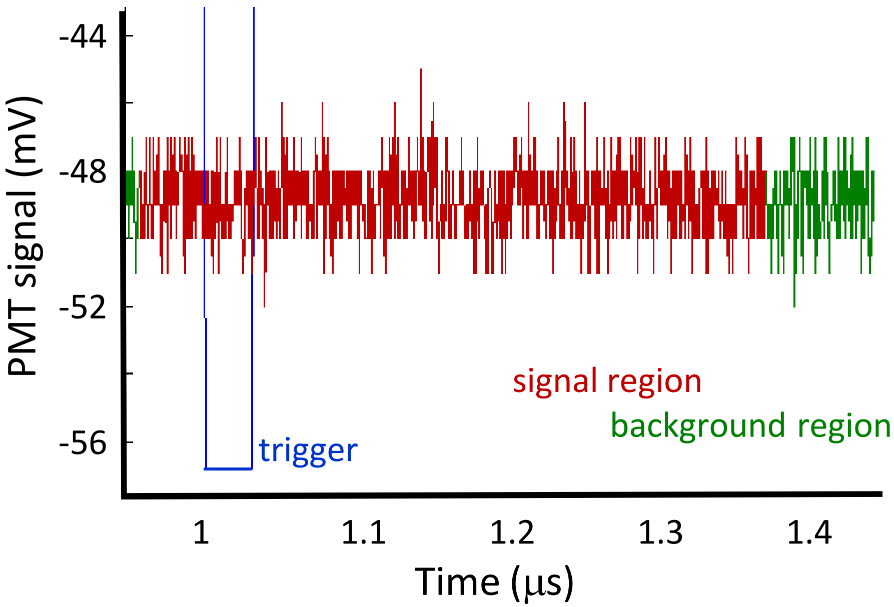
Average of 47 triggers



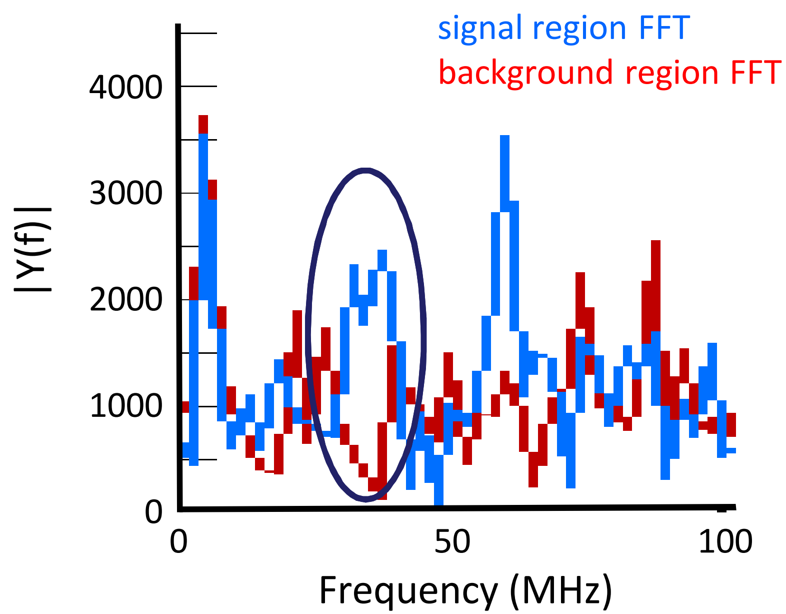
- Goal: Identify individual muon interactions inside the EO crystal
- Method: Compare an average 47 PMT traces
  - Average signal (red): + 0.4 μs from the trigger
  - Average background (green): Time before the trigger
- Perform an FFT on each part of the signal and background subtracted
  - Identify a region of interest at 39-45 MHz

FFT Analysis: Individual Muon Triggers

Single Trigger Raw Signal

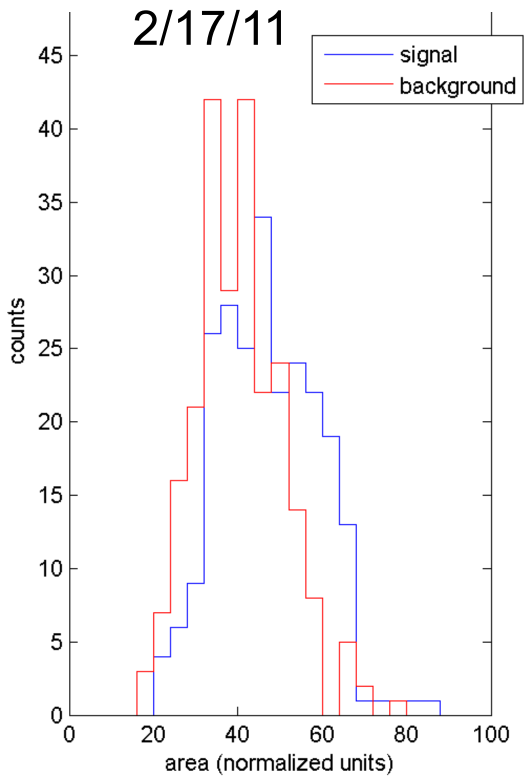


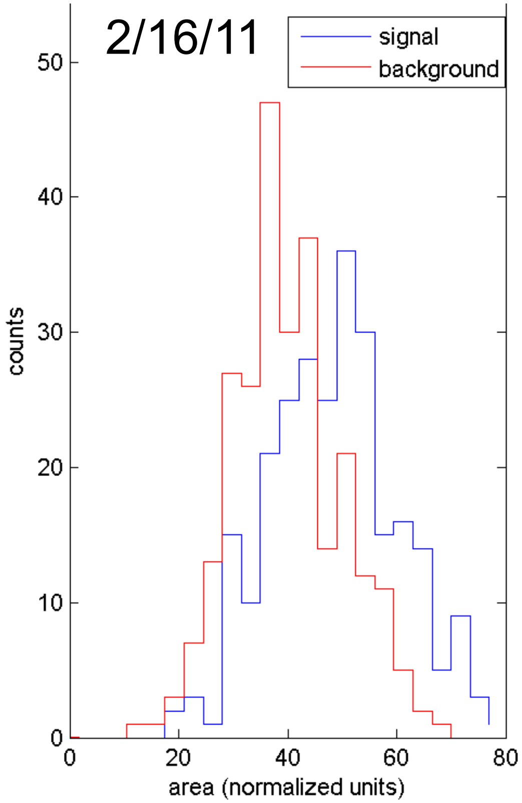
FFT of Single Trigger



- Integrate the FFT trace from 39 MHz to 45 MHz for both signal and background portions of the trace

Comparison signal to background





- Histogram of individual muon triggers showing different distributions for signal region compared to background.
- Each graph has ~250 triggers from one night of data collection at $V_{crystal}$= 2100 V

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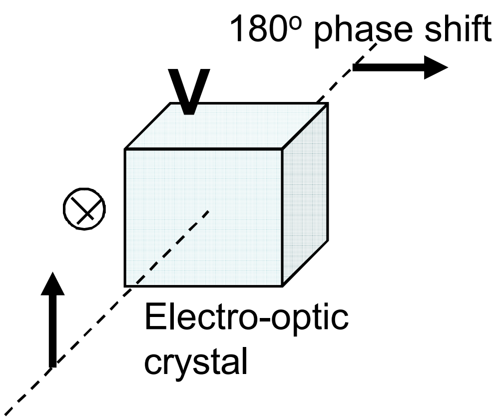

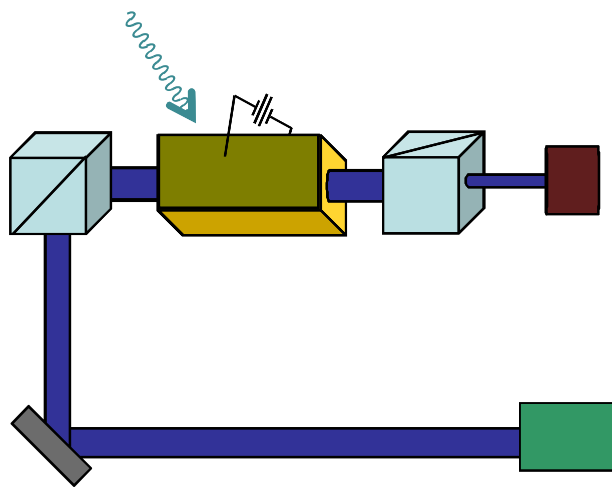

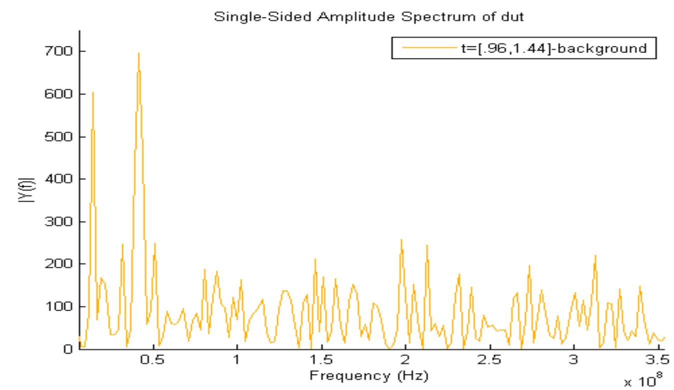

Conclusion

- Electro-optic detector has a change in index of refraction due to ionizing radiation's interaction with the crystal
- A polarization analysis experiment can be done in order to measure the interactions of minimal ionizing radiation with the crystal
- Using a FFT analysis individual muon events can be distinguished from background noise

- Research Team: Alexandra Hoops, Scott Bisson, Jeffery Fein, Lorraine Sadler, John Steele and Kevin Strecker
- This work is funded by the DOE/NNSA Office of Nonproliferation Research & Development, Special Nuclear Material Movement / Radiation Sensing Program-Thank you!