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Order and Charge Collection Correlations in Organic Materials for Neutron Detection

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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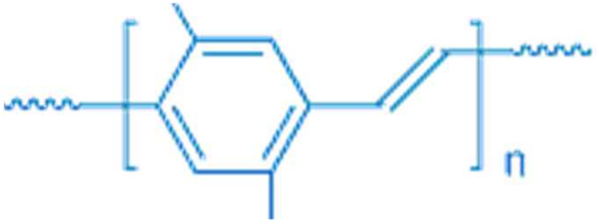
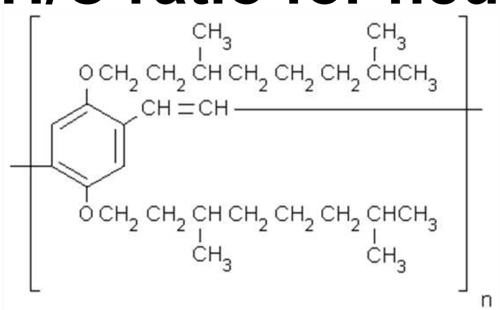
Overview

- Polymers for Radiation Detection
  - Advantages over current methods
  - Electrical/material property considerations
- Processing Effects
  - Order
  - Electrical



Polymer Radiation Detection - Why?

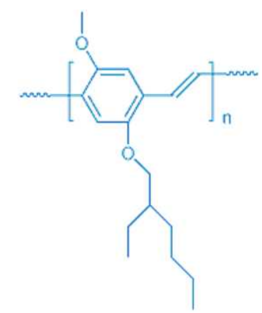
- **Direct detection of fast neutrons (2MeV), with no moderator**
- **Semiconducting radiation detectors allow direct detection with no photomultiplier, as required with scintillators**
- **Room temperature operation improves cost, size and convenience**
- **Low Z polymer provides natural gamma discrimination**
- **High H/C ratio for neutron sensitivity**



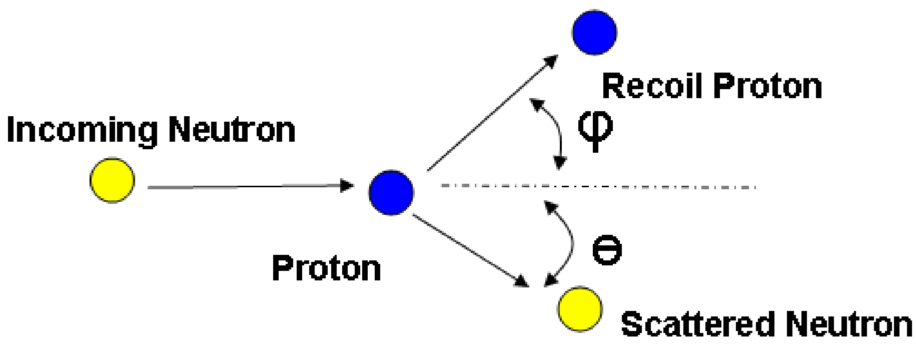
Chemical structure of D1PPV,

poly[2,5-bis(3′,7′-dimethyloctyloxy)-1,4-phenylenevinylene]

H/C ratio = 1.7



Polymer Radiation Sensors – How?



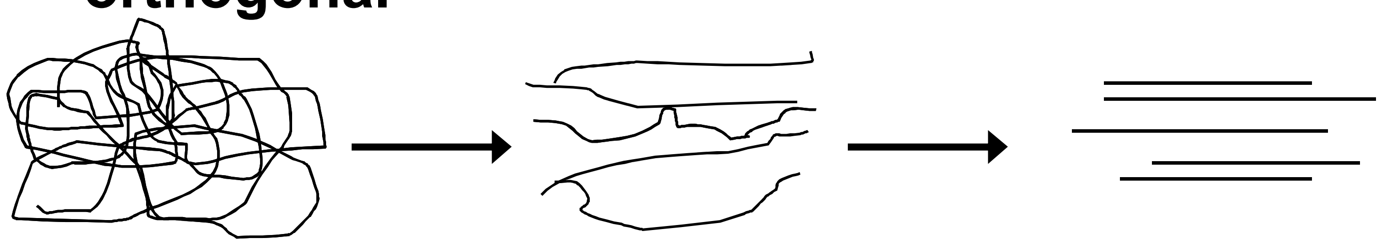
- Proton recoil reaction
- Proton is a mobile charged particle → detection

- We Need
  - High mobility
  - High resistivity
  - Thickness (high H density per unit area)
  - Low trapping

- Controlled by
  - Environment
  - Processing!!
  - Additives

Processing/ Orientation

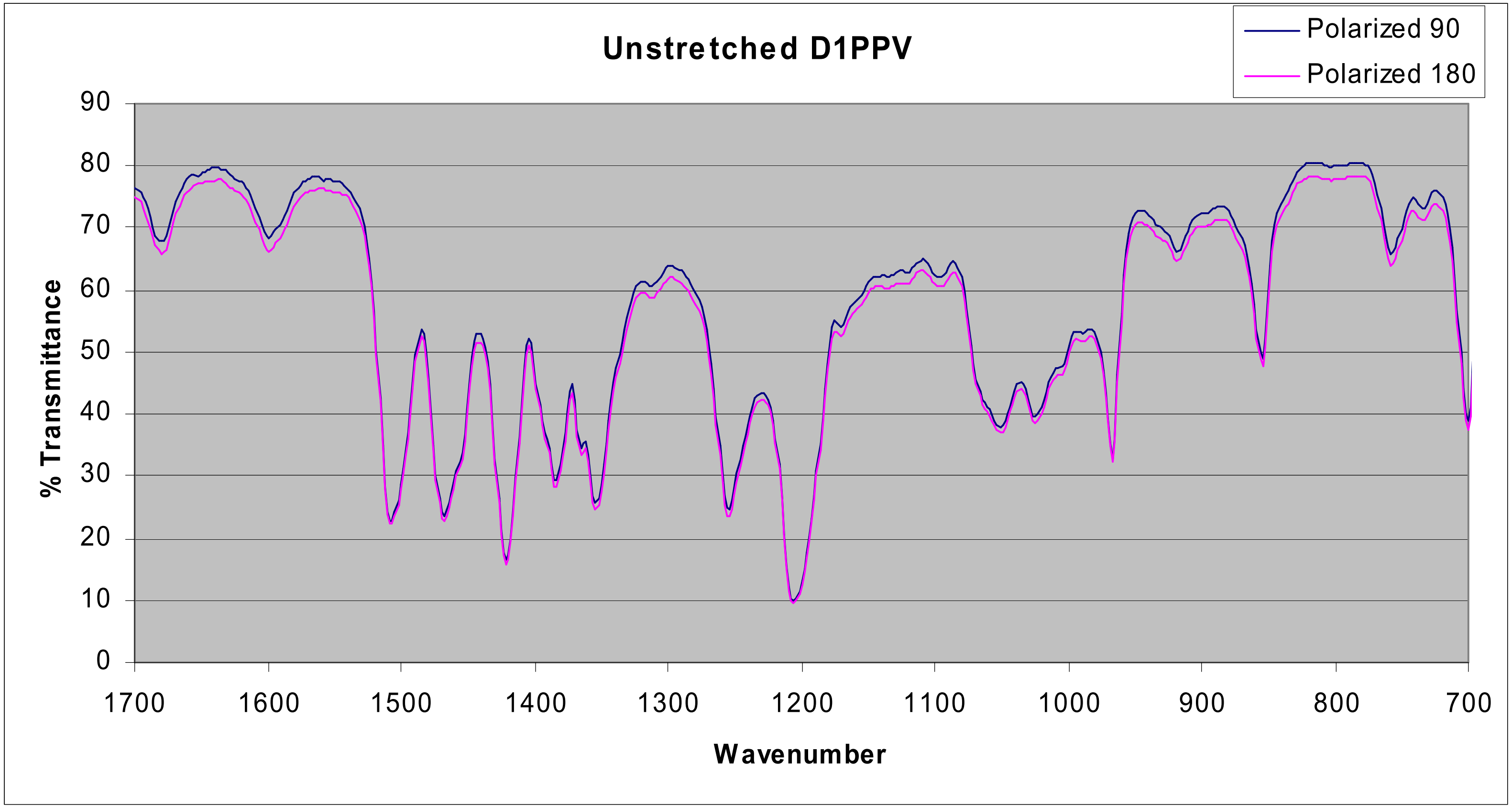
- Drop cast onto glass/electrodes
- Drop cast onto unoriented PTFE surface, remove and test
- Drop cast onto skived PTFE substrate, dry, remove and test
  - Skive direction
  - orthogonal
- Drop cast onto skived PTFE substrate, dry and stretch, then remove and test
  - Stretched direction
  - orthogonal



Polarized FTIR

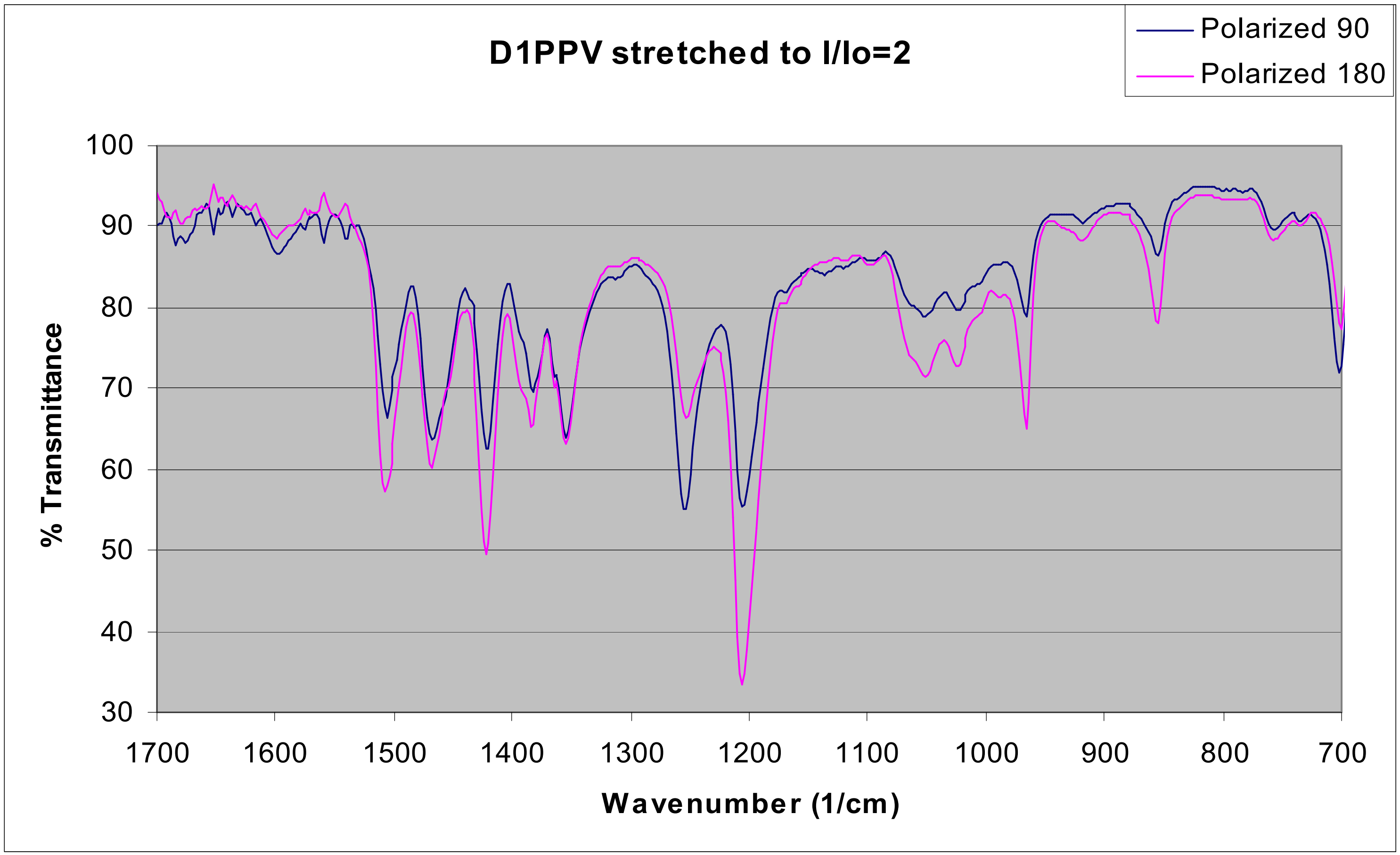
- Use two orthogonal angles of polarization
- Vibrational excitations respond differently based on angle relative to polarization angle
- Dichroic ratio is ratio of absorbance in one orientation relative to that in orthogonal orientation
- Dichroic ratio of 1 is perfectly amorphous and tends toward 0 or ∞ with increasing order
- Ratio is a figure of merit used to determine an order parameter, s
- Working to improve dichroic ratio and identify more peaks in spectra and excitation angles

As cast film



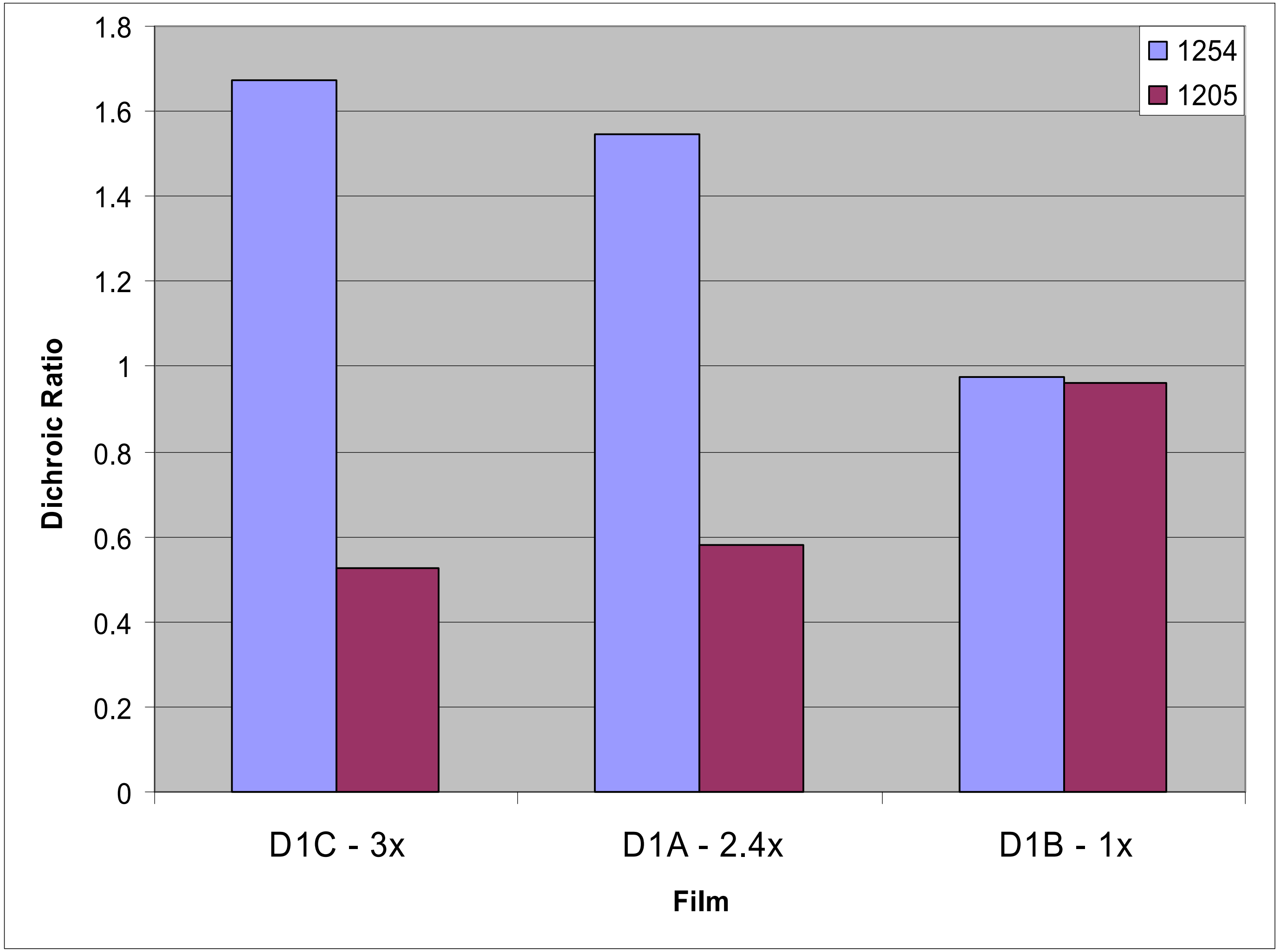
Unstretched sample shows negligible dichroism, .97 and .96 for peaks at 1254 and 1205 wavenumber

FTIR Results



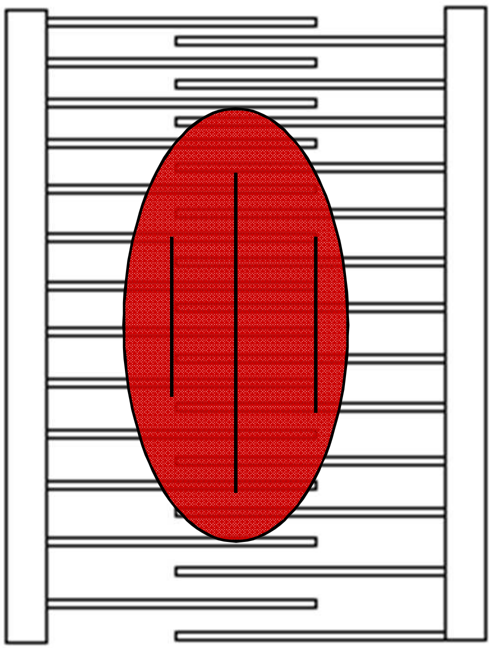
Stretched sample shows significant dichroism, ratios of 1.54 and .58 for peaks at 1254 and 1205 cm^{-1}

IR Dichroism



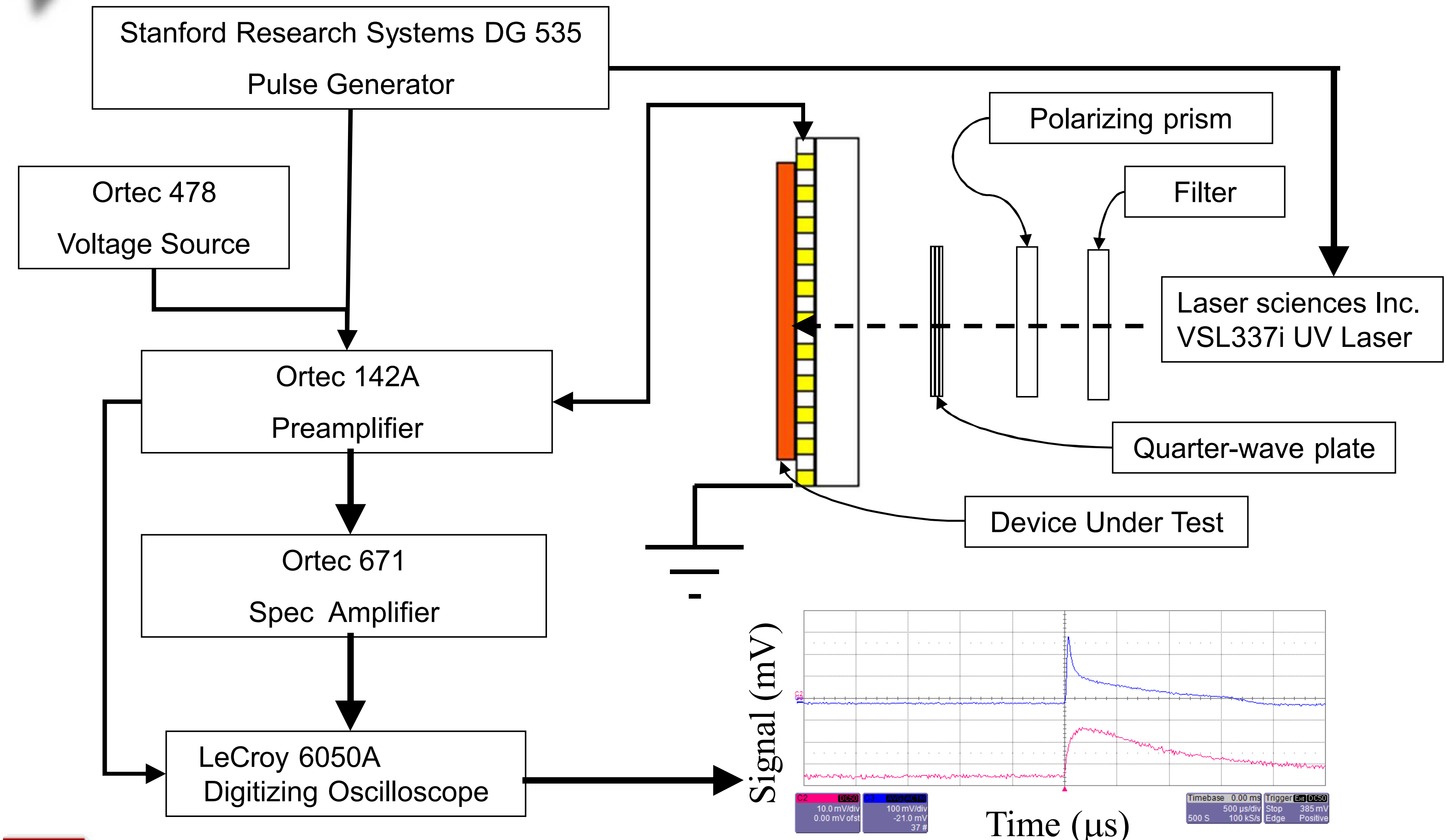
Electrical Testing

- Interdigitated electrodes (IDEs)
- Spacing of 8 μm to 64 μm
- Bias between electrodes
- Can orient film for bias to be parallel or perpendicular to the orientation direction
- Can also directly apply solution with no orientation

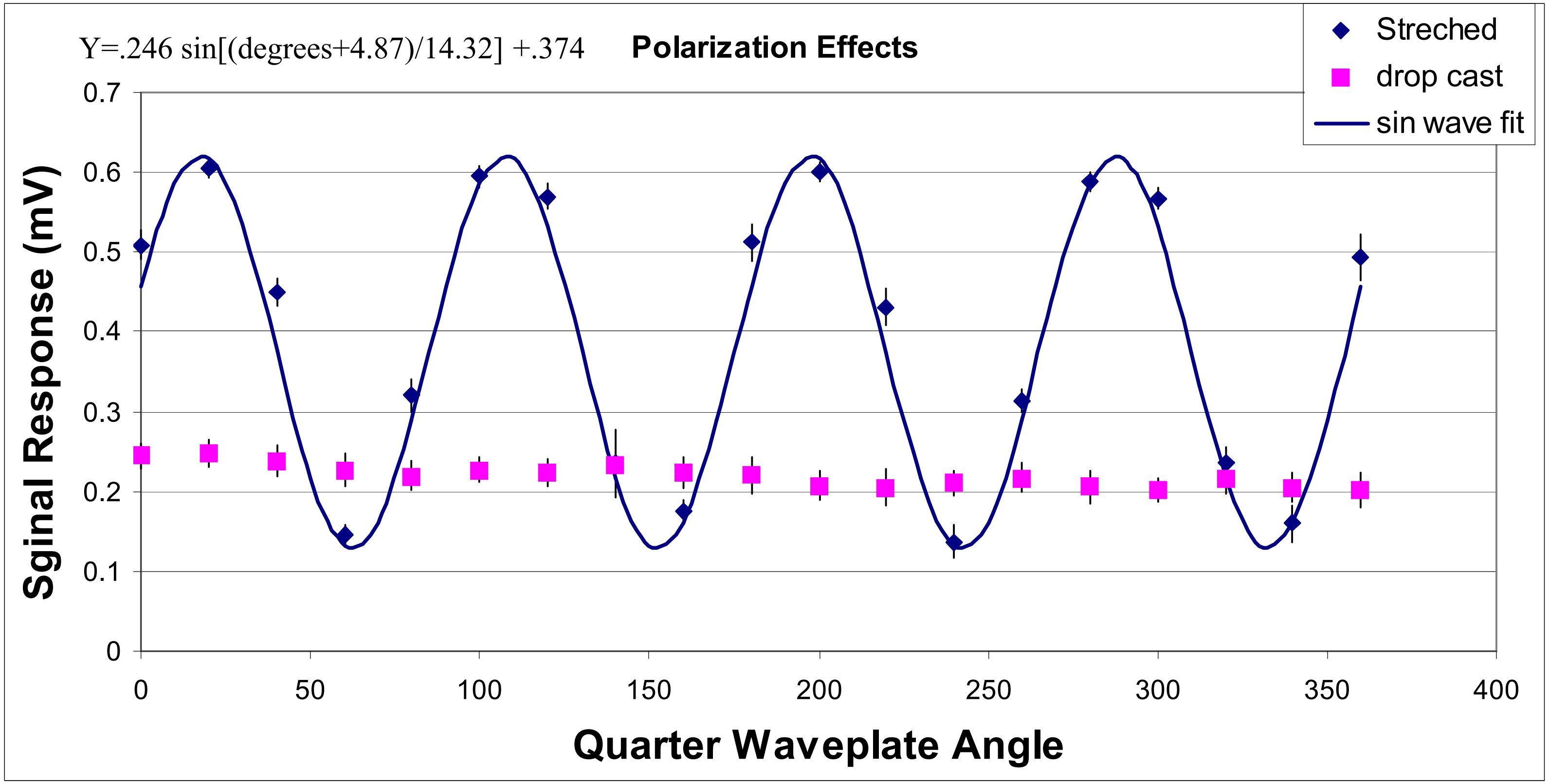


Parallel Orientation

Pulsed Photoconductivity setup

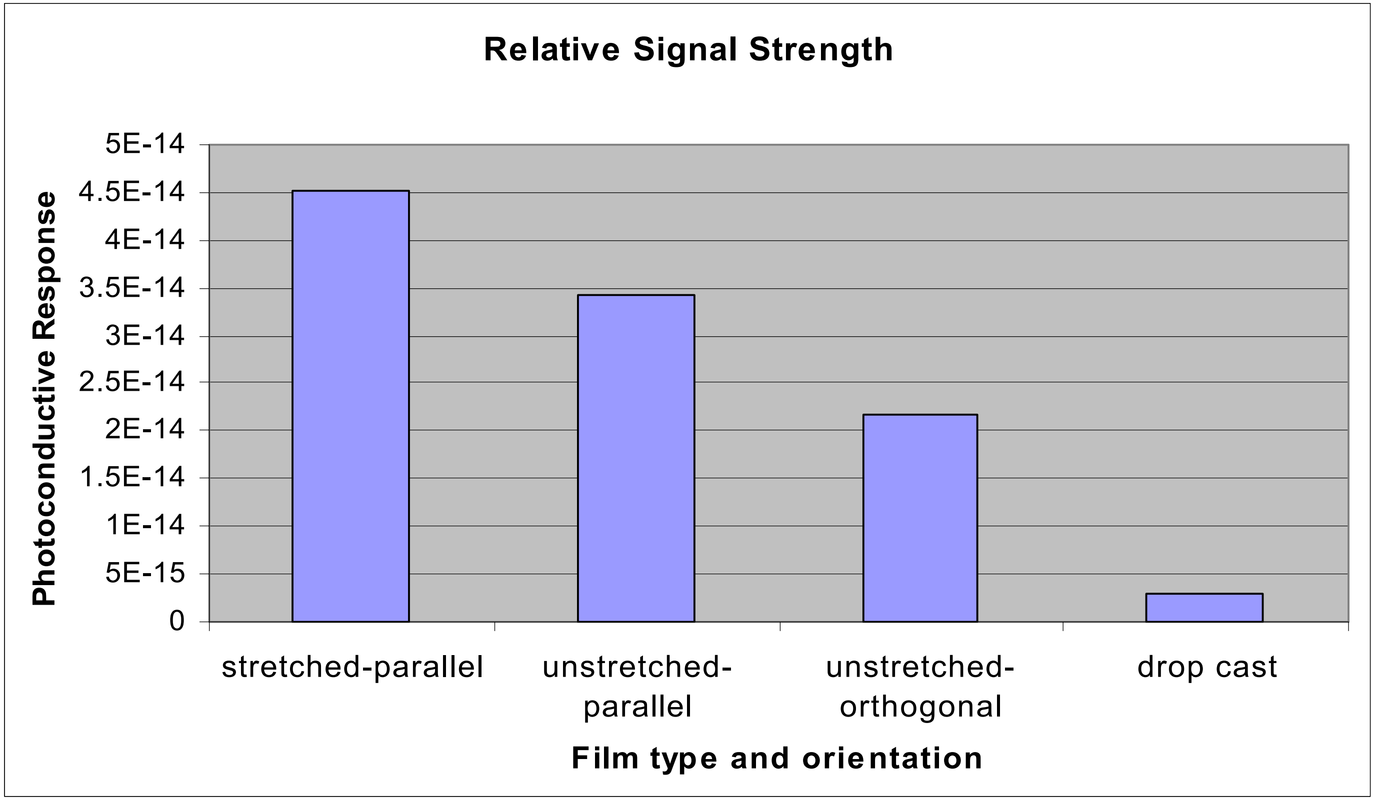


Polarization Response



- **Effect of stretching on polarization response**
- **590 nm stimulus with polarizing filter**
- **Values shown are for comparison only, not absolute**
- **Response fits well to a sin wave**

Photoconductive Response



- Pulsed laser stimulus, 590nm
- Interdigital gold electrodes on glass
- Same spacing used for all tests – 64um

Conclusions

- Stretch alignment of polymers can improve order in a film
- Order changes affect electrical response
- Much more improvement should be possible, particularly combined with other variables of additives, plasticizers, and secondary dopants
- Improved knowledge of structure/property relations will greatly improve device performance
- Preliminary data looks promising for a semiconducting polymer neutron detector

Future Work

- Improve processing for higher mobility
- Testing over larger parameter space for
  - orientation parameter (dichroic ratio)
  - electrical properties
  - photoresponse
- Repeatability testing
- Test other variables
  - plasticizers
  - stretch rate
  - secondary solvent
  - anneal
- Test with nanoparticle additives
- Optimization of variables for neutron detection

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