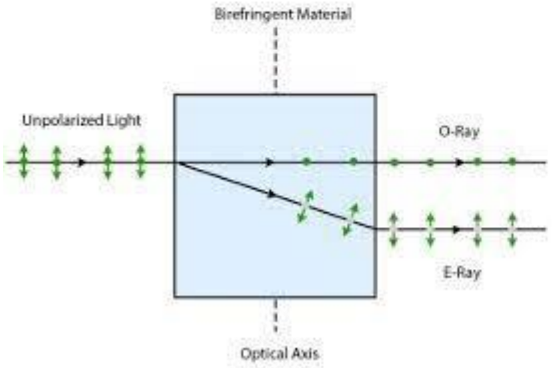
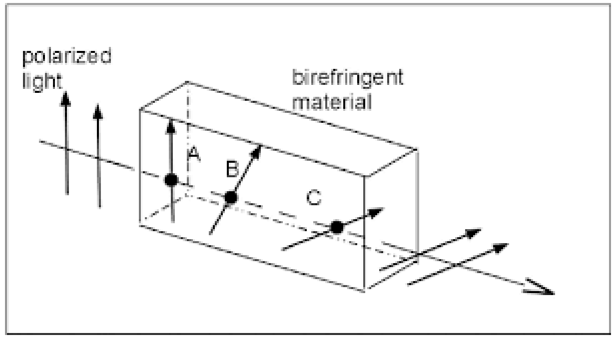
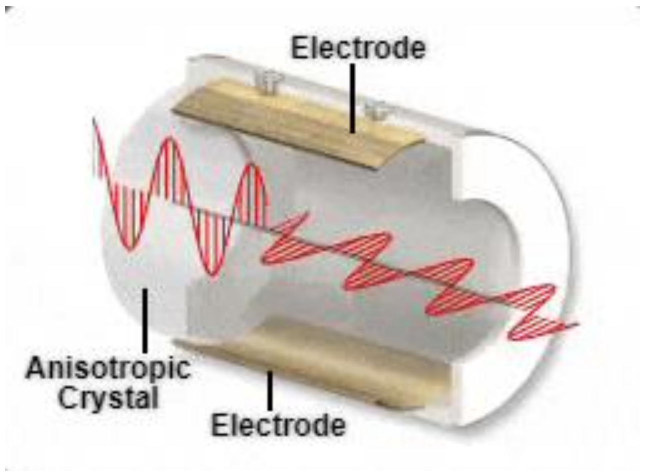
Pockels effect

- An anisotropic crystal such as CZT will have different refractive indices based on crystal lattice orientation. This phenomenon is also called “birefringence”.
- Pockels effect is an electro-optical effect of *varying the directionally dependent refractive index* in response to an applied E-field.
  - E-Field “modulates” the refractive indices in the crystal
- Most application use Pockels effect to change the state of light.
  - Optical shutter, attenuator, ultrafast lasers
- We use the resultant light to investigate the E-field profile of the material

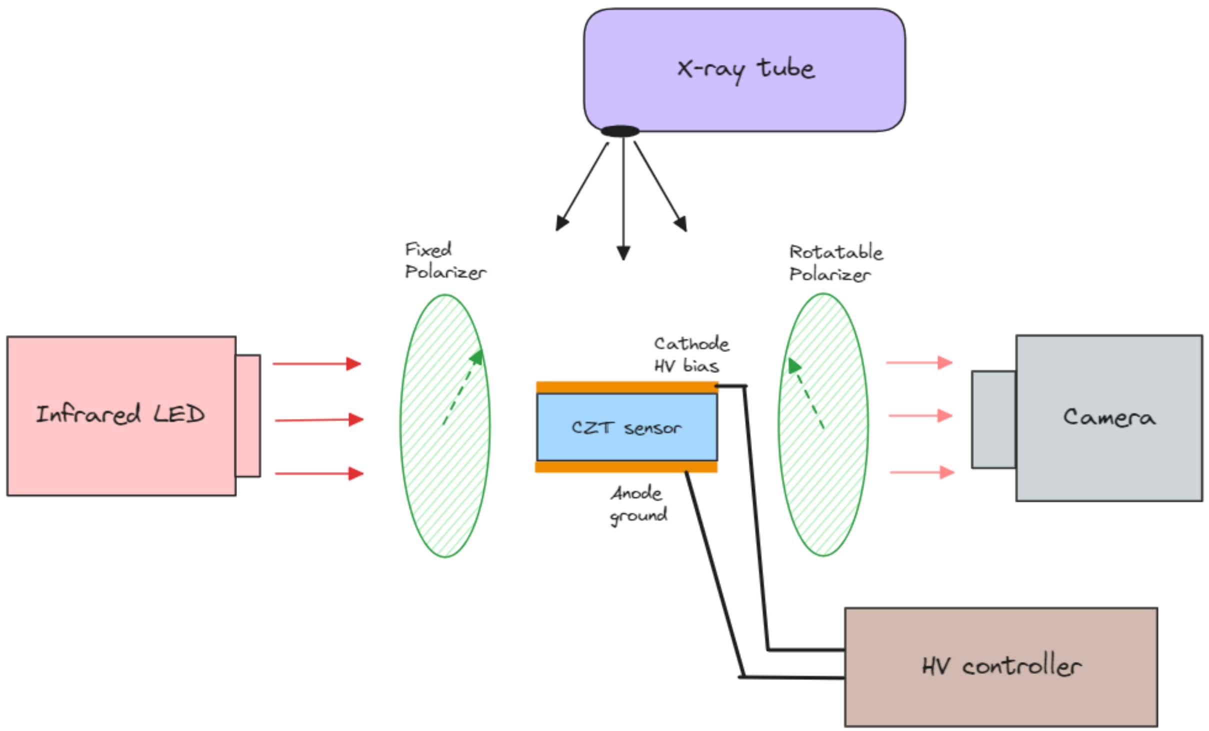




Animation of Pockels cell



Pockels apparatus



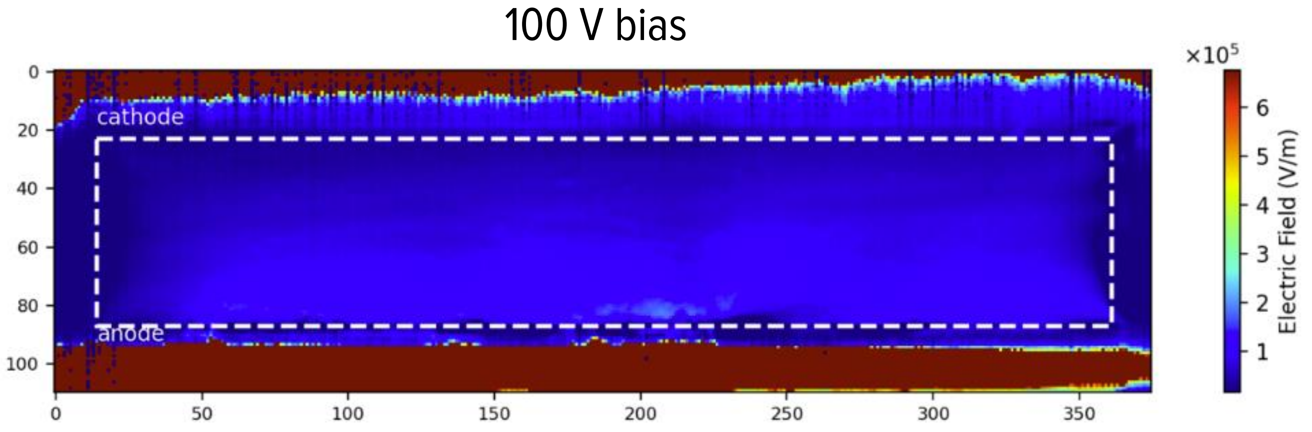
- First polarizer is fixed at 45 degrees
- Second polarizer (aka "analyzer") has two orientations:
  - Parallel (45 degrees) for calibration
  - Crossed (135 degrees) for bias measurements
- $\boldsymbol{T} = \frac{I_{\perp,bias} - I_{\perp,0V}}{I_{||,0V} - I_{||,bkg}} = sin^2(\alpha \boldsymbol{E})$

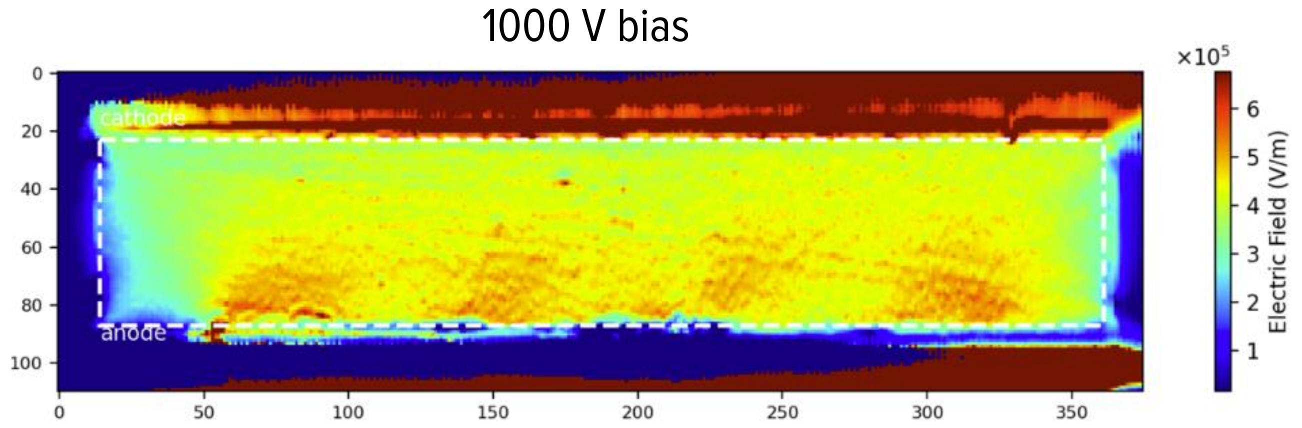
$$\left(\alpha = \frac{\sqrt{3}\,\pi\, n_0{}^3\, r\, d}{2\lambda_0}\right)$$

- $\boldsymbol{E} = \frac{1}{\alpha}\sqrt{(\arcsin(T))}$
- Both $\boldsymbol{T}(x, y)$ and $\boldsymbol{E}(x, y)$ are 2D maps
- When there's no electric bias (0V), $T \approx 0$

Calculation of E-field map

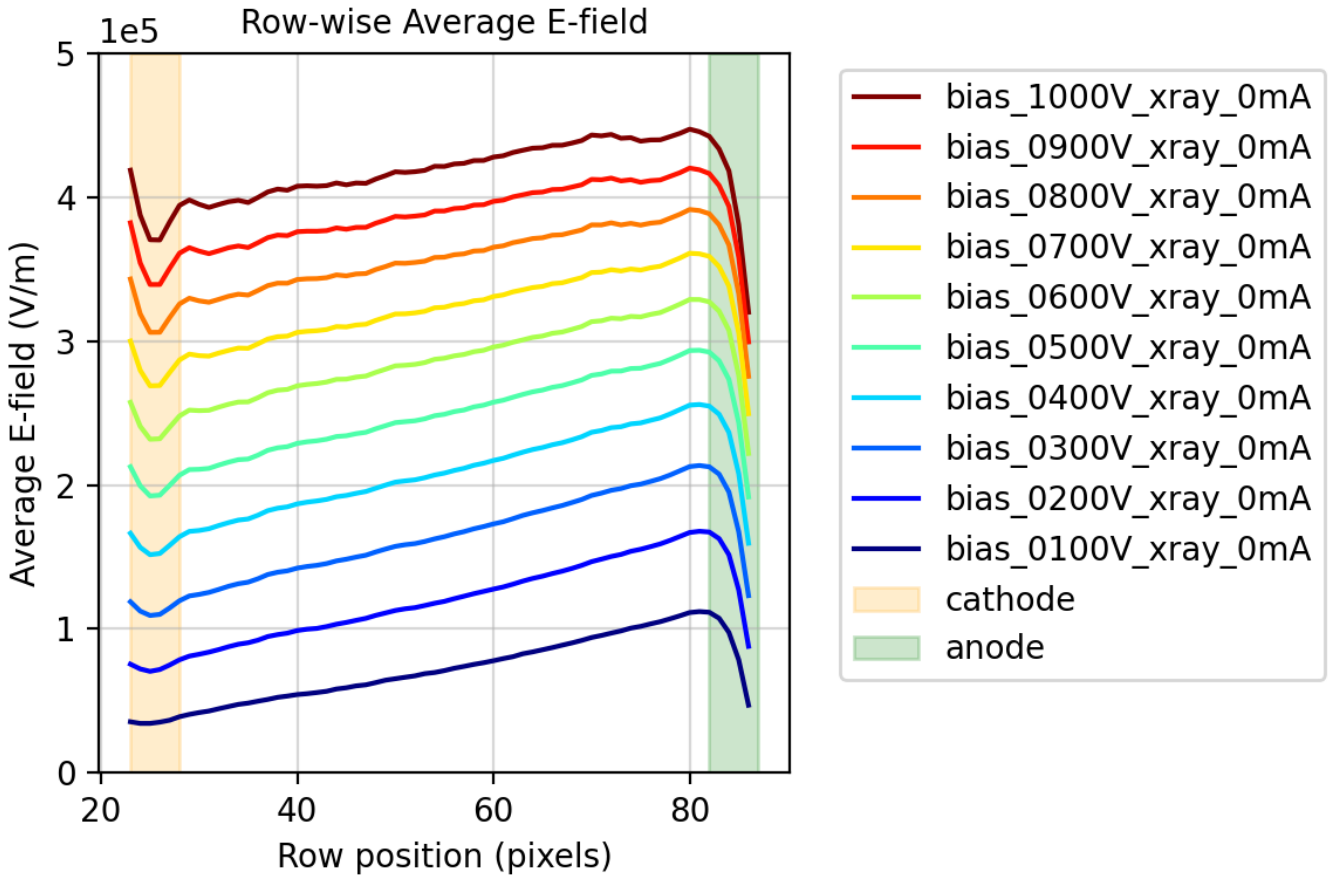
- $\boldsymbol{T}(x, y) = \frac{I_{\perp,bias} - I_{\perp,0V}}{I_{||,0V} - I_{||,bkg}} = sin^2(\alpha \boldsymbol{E}(x, y))$
- Capture 3 calibration images
  - Light on, analyzer at parallel, $I_{||,0V}$
  - Light on, analyzer at crossed, $I_{\perp,0V}$
  - Light off, analyzer at parallel, $I_{||,bkg}$
- Pockels effect is induced for any electric bias, start to see transmission of light
- E-field map is calculated by inverting the equation above





E-field profile per applied voltage

- The total E-field within CZT increases with bias
- The slope of each curve tells us the space charge density inside



How to calculate space charge density

Gauss's Law

$$\oint_S \vec{E} \cdot \overrightarrow{dA} = \frac{Q_{enclosed}}{\epsilon_0} = \frac{\rho \cdot V}{\epsilon_0}$$

Assume an infinite slab of uniform charge density, the internal electric field is

$$E(x) = \frac{\rho}{\epsilon_0}\left(\frac{d}{2} - x\right)$$

$$E_{total}(x) = E(x) + E_{bias}$$