Kerr Effect

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The Electro-optic Kerr Effect

- It is a quadratic optical effect, where the application of an Electric field across a sample leads to a change in its refractive index proportional to the square of the magnitude of the Electric field.

  $$\Delta n = \lambda K E^2$$

  K: Kerr constant

- In this experiment, the sample used is a PLZT element. The mechanism of this effect is birefringence. In the presence of an applied voltage, the sample becomes birefringent. When monochromatic light is incident on the sample, this leads to the creation of “ordinary” rays and “extraordinary” rays (parallel and perpendicular polarization) inside the sample.
- To verify the Kerr effect, the phase difference between these two rays, which is proportional to the induced refractive index change, will be correlated with the square of the applied voltage.

Equations

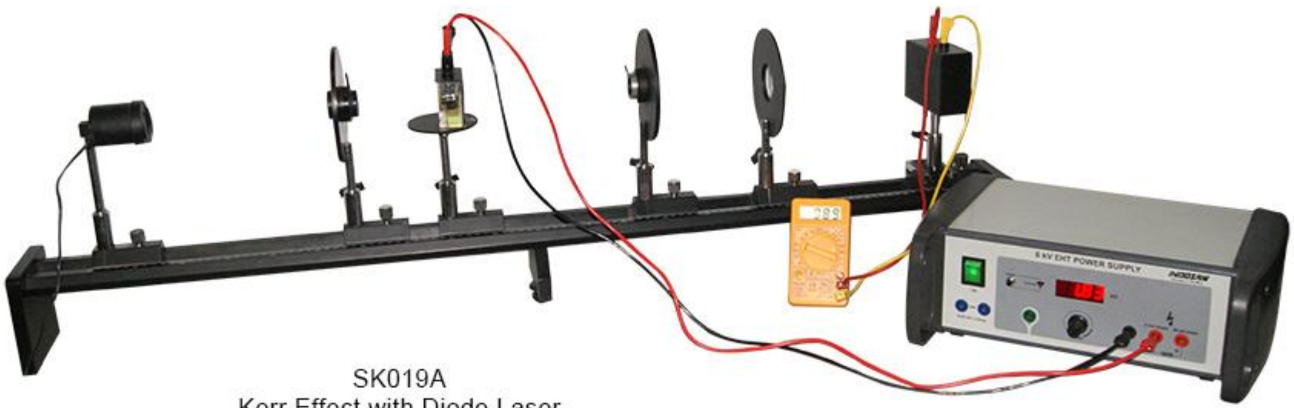
Path Difference $= l\delta n$

where l is the actual path length and δn is the refractive index change.

$$\Delta = \frac{2\pi}{\lambda} l \delta n \qquad \Delta = 2\pi K l E^2 \qquad E = \frac{U}{d} \qquad I = I_0 \sin^2\left(\frac{\Delta}{2}\right)$$

$$\Rightarrow U^2 = \frac{d^2}{2\pi K l}\Delta$$

Setup



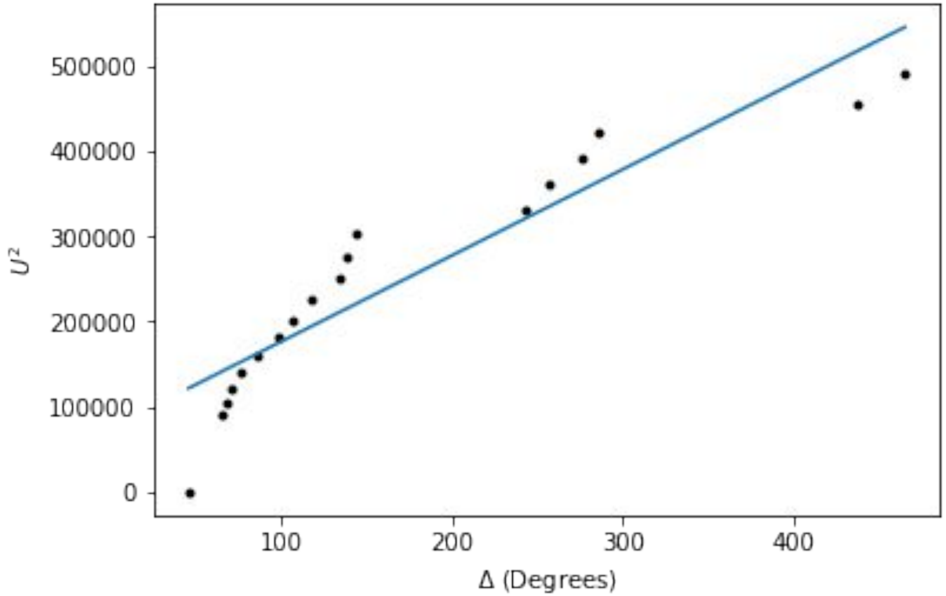
SK019A
Kerr Effect with Diode Laser

Procedure

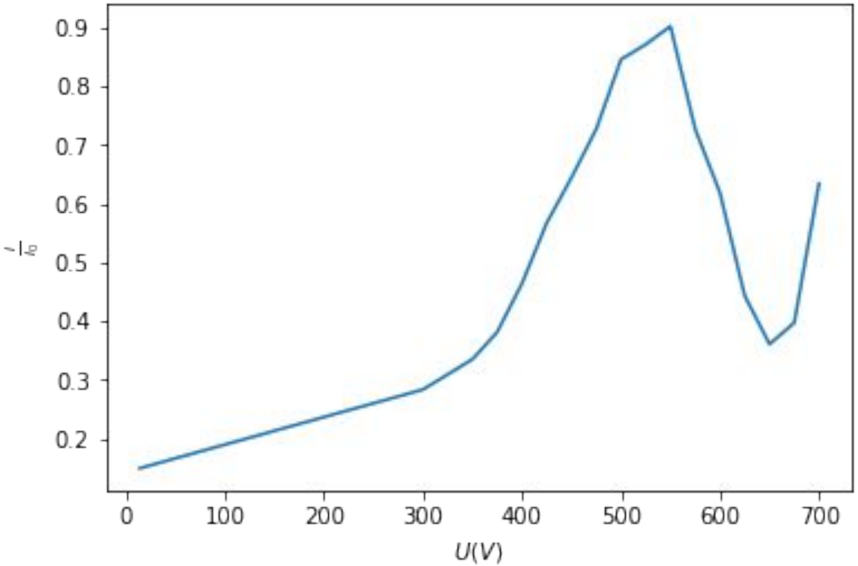
- First the maximum intensity I_0 is measured at minimum applied voltage, and this sets the relative angle between the polarizer and analyzer for the rest of the experiment.
- Then intensity I is measured for values of voltage between 300V and 700V in steps of 25 V.

$$\Delta = 2\sin^{-1}\left(\sqrt{\frac{I}{I_0}}\right)$$

Data, Fits



500000
400000
300000
200000
100000
0
U^2
100
200
300
400
Δ (Degrees)



0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
100
200
300
400
500
600
700
$U(V)$

Calculations

$$\text{Slope of } U^2 \text{ vs } \Delta$$

$$\approx 1007.9V^2 \text{ per degree}$$

$$= 57,748V^2 \text{ per radian}$$

$$\text{Slope} = \frac{d^2}{2\pi Kl} \Rightarrow K = 3.6 \times 10^{-9} m\, rad/V^2$$

[substituting d = 1.4mm and l = 1.5mm]

Error Analysis

$$\frac{dK}{K} = 2\frac{dU}{U} + \frac{1}{2}\frac{dI}{I}$$

$$dU = 1V,\ dI = 0.001V$$

$$\text{For } U = 500V,\ I = 0.164V$$

$$\text{Substituting, } \frac{dK}{K} \approx 0.007 \Rightarrow \text{Percentage error } = 0.7\%$$

$$dK = 2.54 \times 10^{-11}$$

$$\Rightarrow K = (3.6 \times 10^{-9} \pm 2.54 \times 10^{-11}) m\, rad/V^2$$

Discussion

- Although the supply used has a large least count of 1V, the large range in which we measure U (300-700V) leads to a very low percentage error in the determination of K.
- The Kerr effect has potential applications in the design of photo-sensors, nanophotonic devices and all-optical switching, and is hence a widely used tool in experimental optics.

Thank You

Reference:

Python code used for plots(Jupyter notebook) -
https://drive.google.com/open?id=1ISG2e2UiEEv-S-6HHtE4RWWfUbAxrh51