

Measurement of Acoustic Radiation Pattern in an Acousto-Optic Modulator

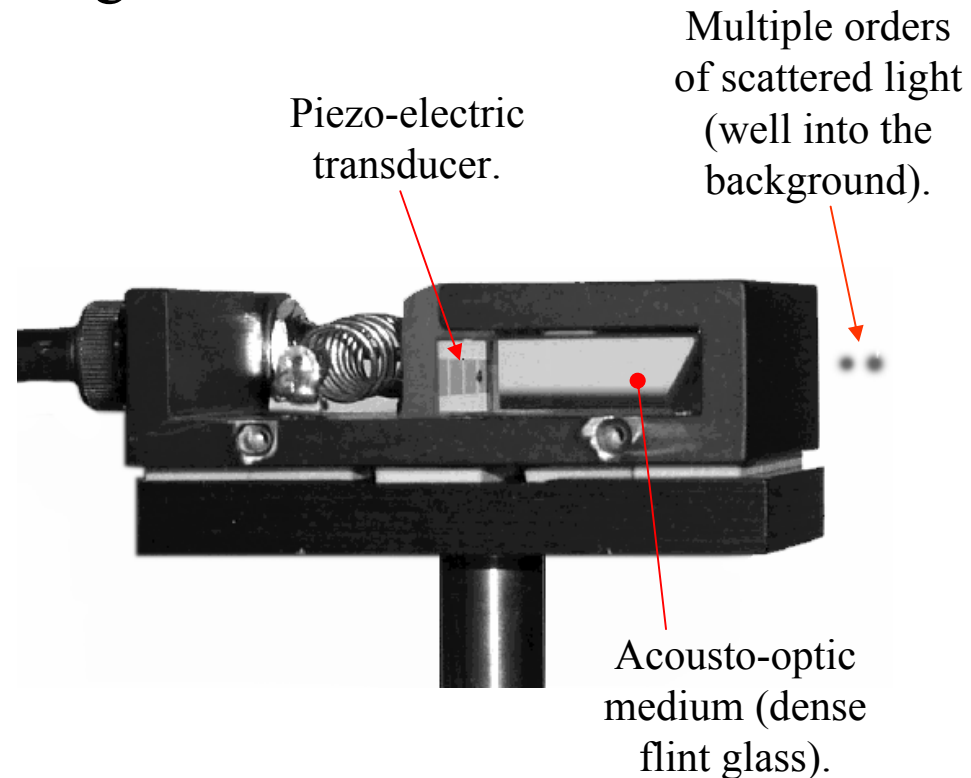
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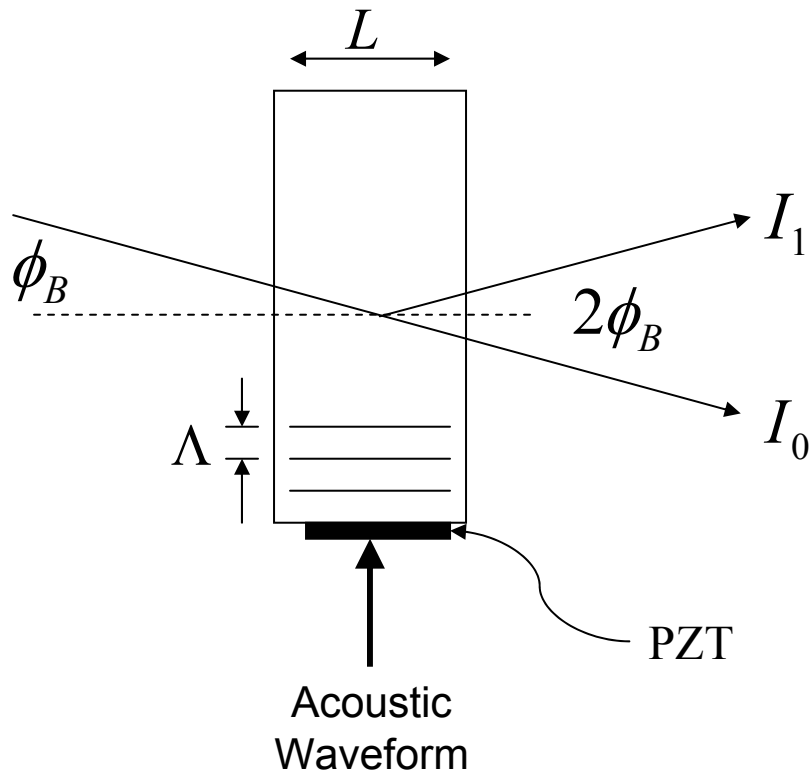
- This experiment is one of a series performed to illustrate applications of acousto-optics in the undergraduate laboratory.
- The experiment presents a method of determining the acoustic radiation pattern of an acousto-optic modulator by measuring diffracted light intensities.

The Acousto-Optic Modulator (AOM)

- The AOM consists of a piece of crystal or glass to which a piezoelectric transducer is bonded.
- When a voltage waveform is applied to the transducer, many diffracted orders of light are generated.
- Applications
 - Frequency shifting of laser light.
 - AM/FM light modulation and laser communication.
 - Optical scanning.



The Acousto-Optic Modulator



L = width of sound column.

Λ = wavelength of sound.

I_0 = zeroth order diffraction intensity.

I_1 = first order diffraction intensity.

$\phi_B = \sin^{-1}\left(\frac{\lambda}{2\Lambda}\right)$ = the Bragg angle.

Wave Vector Diagrams

- Conservation of Momentum

$$\hat{h}\mathbf{k}_{+1} = \hat{h}\mathbf{k}_0 + \hat{h}\mathbf{K}$$

$$\mathbf{k}_{+1} = \mathbf{k}_0 + \mathbf{K}$$

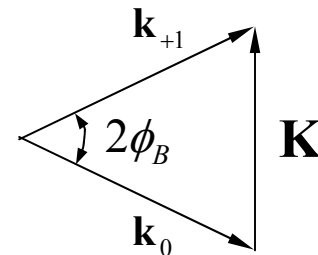
where

\mathbf{k}_{+1} = wave vector of scattered light.

\mathbf{k}_0 = wave vector of incident light.

\mathbf{K} = wave vector of sound.

$\hat{h} = h/(2\pi)$, h = Planck's constant



- Conservation of Energy

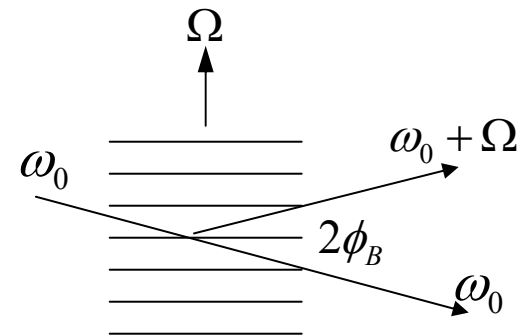
$$\omega_{+1} = \omega_0 + \Omega$$

where

ω_{+1} = wave vector of scattered light.

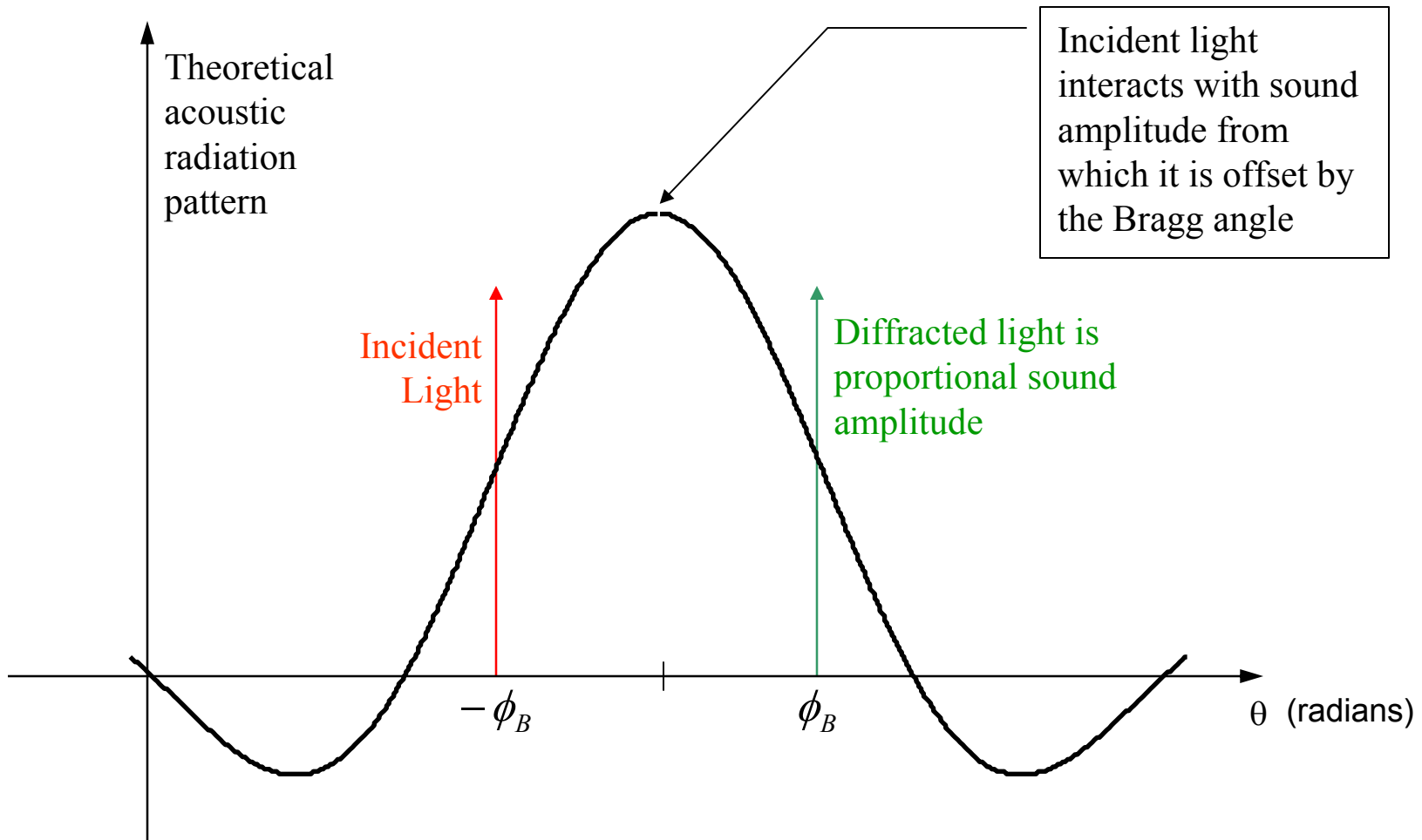
ω_0 = wave vector of incident light.

Ω = wave vector of sound.

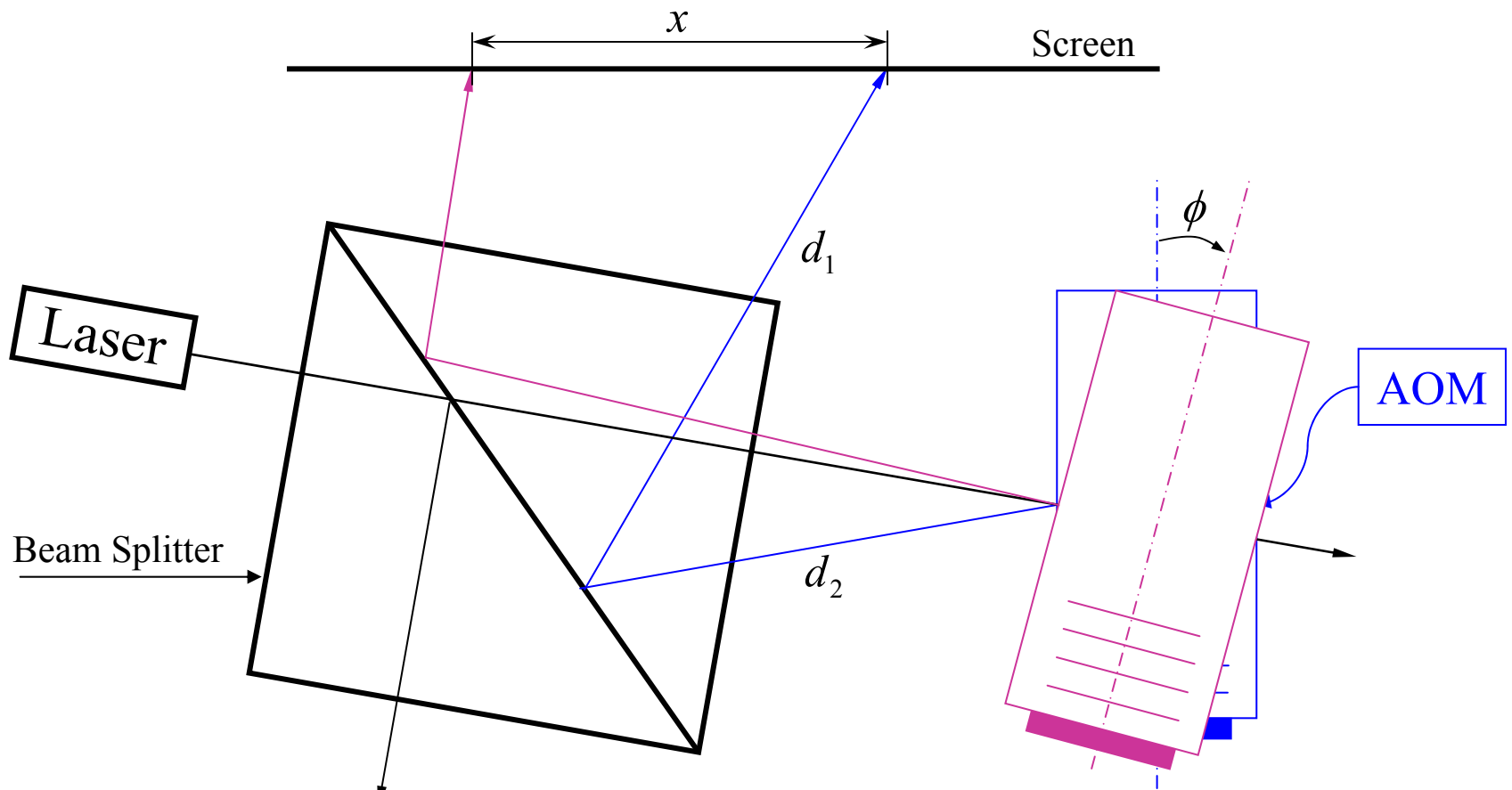


Measuring the Acoustic Radiation Pattern

- If we vary the incident angle and track the diffracted light intensity, we can measure the acoustic radiation pattern.

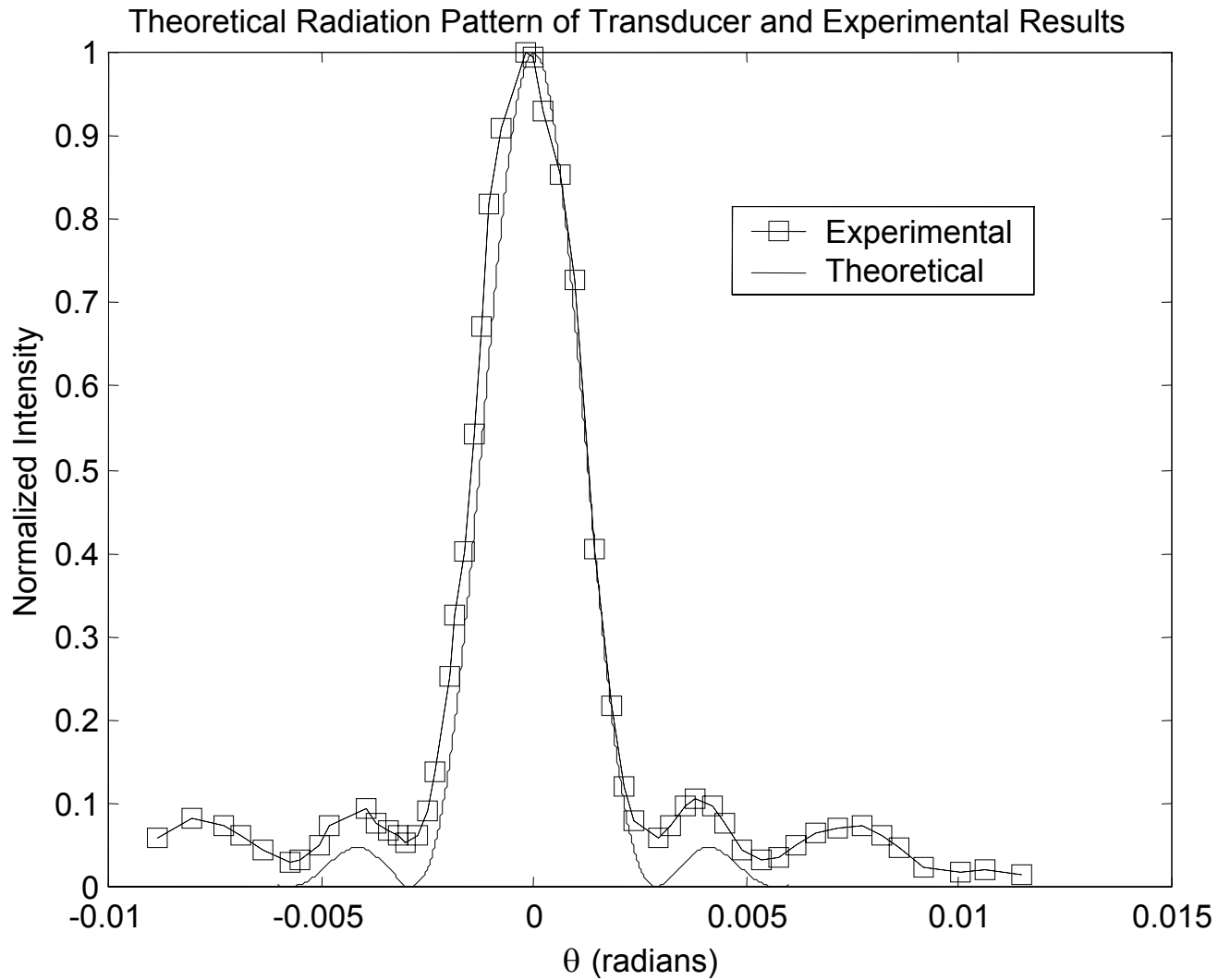


Experimental Configuration



$$\phi = \frac{1}{2} \sin^{-1} \left(\frac{x}{d_1 + d_2} \right)$$

Results



Plane-wave Interaction Theory

Plane-wave interactions in the AOM are described by a set of infinitely linked differential equations [Korpel and Poon, *J. Opt. Soc. Am.*, 70, 817-820, 1980.]:

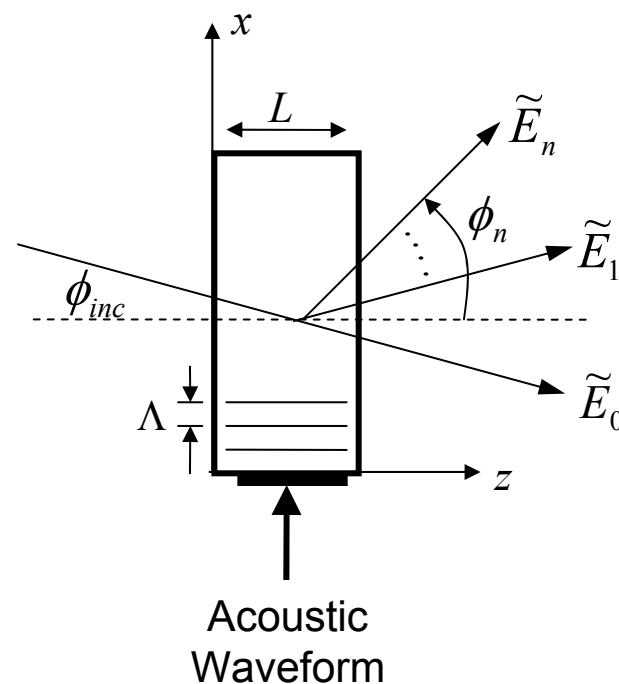
$$\frac{d\tilde{E}_n}{d\xi} = -j\frac{\alpha}{2} \exp\left\{\frac{-jQ\xi}{2} \left[\frac{\phi_{inc}}{\phi_B} + (2n-1)\right]\right\} \tilde{E}_{n-1} \\ - j\frac{\alpha}{2} \exp\left\{\frac{jQ\xi}{2} \left[\frac{\phi_{inc}}{\phi_B} + (2n+1)\right]\right\} \tilde{E}_{n+1}$$

\tilde{E}_n = Plane wave of n^{th} order light.

α = Peak - phase delay of AO medium
(proportional to sound amplitude).

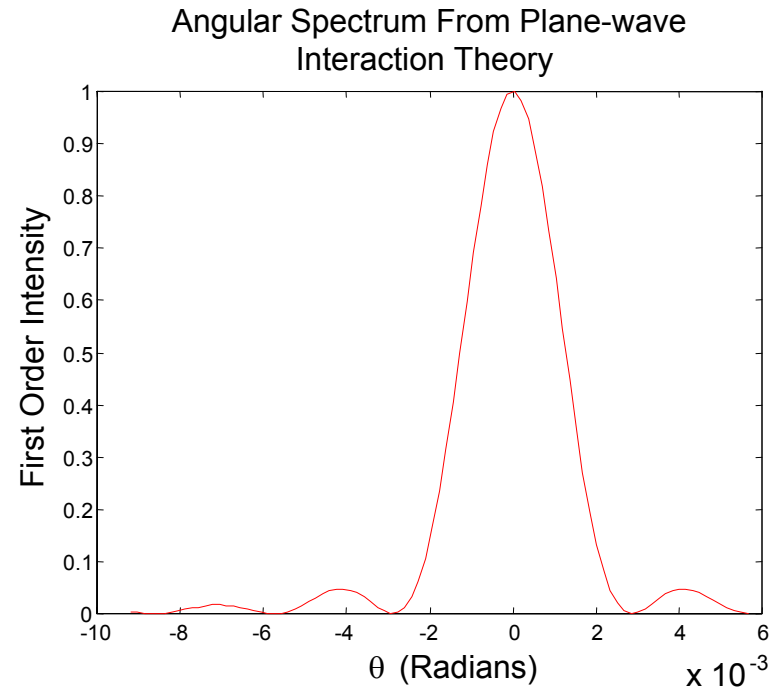
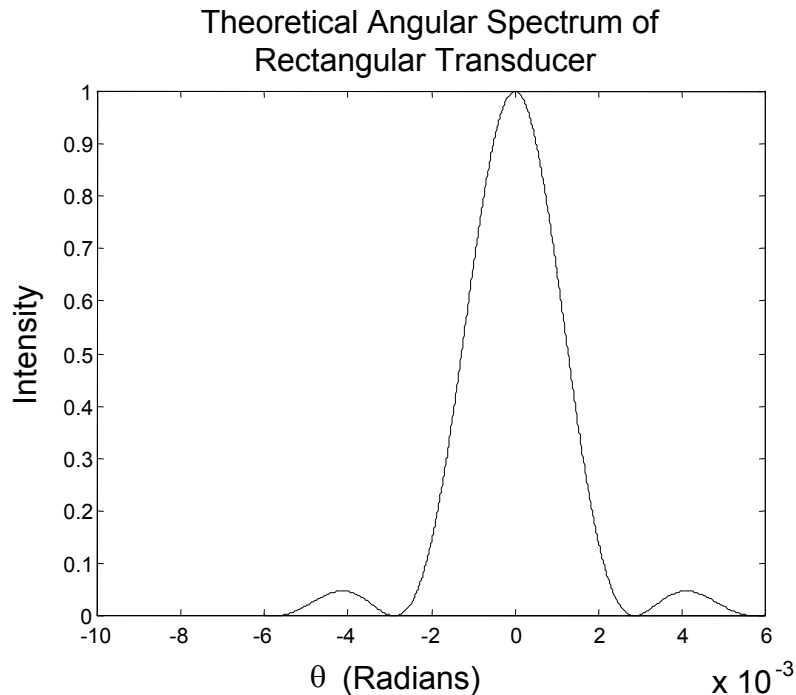
Q = Klein - Cook parameter.

$\xi = z / L =$ Normalized position within AO cell.



Plane-wave Interaction Theory

- Plane-wave theory is used to validate experimental results.
- The Runge-Kutta numerical method to solve differential equations was implemented in Matlab.
- The results are indistinguishable from the theoretical radiation pattern used above.



- Acknowledgments

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- This work was conducted in the Optical Image Processing Laboratory at Virginia Tech. Lab director is Dr. Ting-Chung Poon.

- References

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