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 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

\[ L = \text{width of sound column.} \]
\[ \Lambda = \text{wavelength of sound.} \]
\[ I_0 = \text{zeroth order diffraction intensity.} \]
\[ I_1 = \text{first order diffraction intensity.} \]
\[ \phi_B = \sin^{-1}\left(\frac{\lambda}{2\Lambda}\right) = \text{the Bragg angle.} \]
**Wave Vector Diagrams**

- **Conservation of Momentum**
  \[
  \hat{h}k_{+1} = \hat{h}k_0 + \hat{h}K
  \]
  \[
  k_{+1} = k_0 + K
  \]
  where
  \- \(k_{+1}\) = wave vector of scattered light.
  \- \(k_0\) = wave vector of incident light.
  \- \(K\) = wave vector of sound.
  \- \(\hat{h} = h/(2\pi)\), \(h\) = Planck's constant

- **Conservation of Energy**
  \[
  \omega_{+1} = \omega_0 + \Omega
  \]
  where
  \- \(\omega_{+1}\) = wave vector of scattered light.
  \- \(\omega_0\) = wave vector of incident light.
  \- \(\Omega\) = 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.

Incident light interacts with sound amplitude from which it is offset by the Bragg angle.
\[
\phi = \frac{1}{2} \sin^{-1} \left( \frac{x}{d_1 + d_2} \right)
\]
Results

Theoretical Radiation Pattern of Transducer and Experimental Results

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

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

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

\( \alpha \) = 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.
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• References