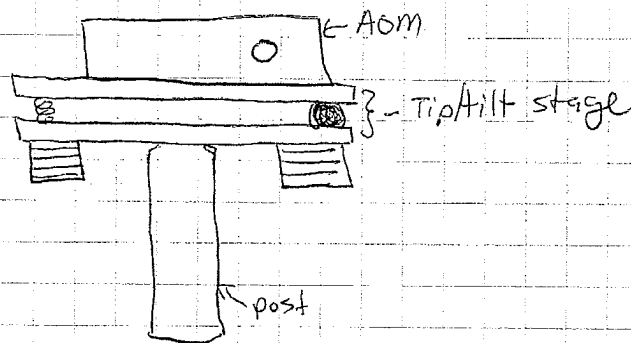


## Notes on Acousto-Optics Lab

- Because of mismatched electronics and amplifiers we barely got this lab to work, but we did not have any control on parameters other than frequency.
- We did not have an amplifier so we used the max output of the synthesizer and changed the frequency output even though the frequencies were far outside the bandwidth of the device. We were able to get a very dim 1st order spot. The students' data and graph are on the next page. They used the 60 MHz synthesizer (HP ##### I believe)
- On page 88 I provide a list of common Acousto-optic materials.
- On page 89 I provide information on AOMs you could buy. The department has an AOM. If I get it to work before I leave, I will add more. ~~information~~ (see pg 91)
- The AOM should lie horizontally on a tip-tilt stage in order to ~~make~~ match the acoustic wave overlap with the optical wave.



- One experiment would be to use the AOM as a switch or a spectrum analyzer.

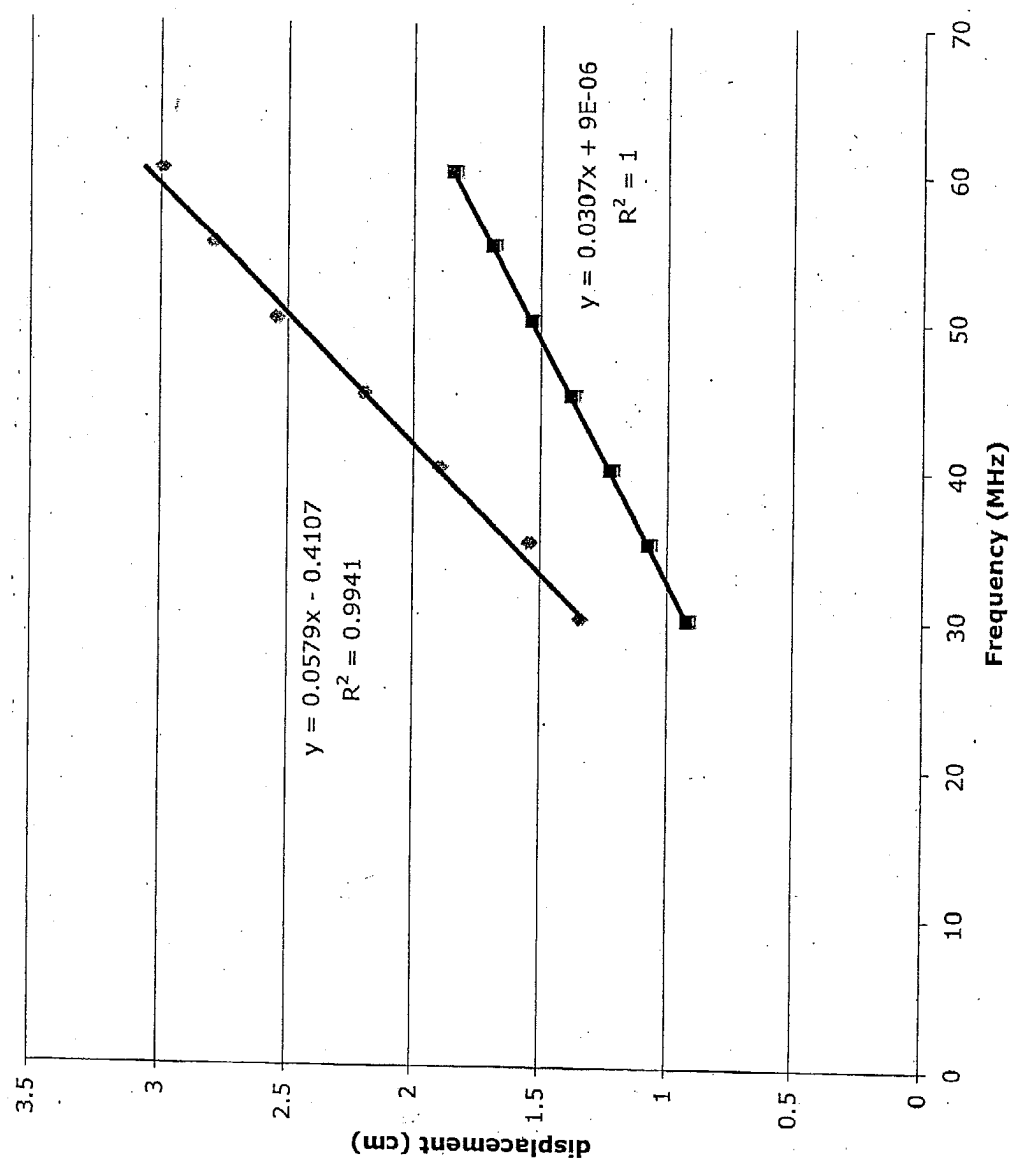
Distance from modulator to central point: 2.7051 m

speed of sound = 5570 m/s <sup>← how do you know that</sup> <sup>← chose to put screen for</sup>

We are using the small angle approximation to assume that displacement  $\propto \sin(\frac{\phi_0}{2})$  <sup>← away to get to split</sup>

| Frequency (MHz) | Distance between dots (GREG) | Distance between dots (cm) | displacement from straight through | wavelength here (m)          |
|-----------------|------------------------------|----------------------------|------------------------------------|------------------------------|
| 60              | 30                           | 6                          | 3                                  | 0.000000633                  |
| 55              | 28                           | 5.6                        | 2.8                                |                              |
|                 |                              |                            |                                    | modulator-beam stop distance |
| 50              | 25.5                         | 5.1                        | 2.55 (m)                           |                              |
| 45              | 22                           | 4.4                        | 2.2                                | 2.7051                       |
| 40              | 19                           | 3.8                        | 1.9                                | v sound in m                 |
| 35              | 15.5                         | 3.1                        | 1.55                               | 5570                         |
| 30              | 13.5                         | 2.7                        | 1.35                               |                              |

| Theoretical Frequency (MHz) | Frequency (Hz) | displacement (m) | displacement (cm) |
|-----------------------------|----------------|------------------|-------------------|
| 60                          | 60000000       | 0.018445081      | 1.844508095       |
| 55                          | 55000000       | 0.016908007      | 1.690800657       |
| 50                          | 50000000       | 0.015370928      | 1.537092809       |
| 45                          | 45000000       | 0.013833846      | 1.383384589       |
| 40                          | 40000000       | 0.01229676       | 1.229676034       |
| 35                          | 35000000       | 0.010759672      | 1.075967181       |
| 30                          | 30000000       | 0.009222581      | 0.922258068       |



- ◆ Experimental
- Theoretical
- Linear (Experimental)
- Linear (Theoretical)

The slope is off because the students assumed the crystal in the AOM was the same as in the pre-lab assignment. Based on the actual slope you could figure out the velocity of sound in the material and possibly determine the material the AOM crystal is made of.

**Table 12-1** A List of Some Materials Commonly Used in the Diffraction of Light by Sound and Some of Their Relevant Properties.  $\rho$  is the Density,  $v_s$  the Velocity of Sound,  $n$  the Index of Refraction,  $p$  the Photoelastic Constant as Defined by Equation (12.3-9), and  $M_{\omega}$  is the Relative Diffraction Constant Defined Above. (After Reference [4].)

| Material                                                   | $\rho$<br>(mg/m <sup>3</sup> ) | $v_s$<br>(km/s) | $n$  | $p$  | $M_{\omega}$ |
|------------------------------------------------------------|--------------------------------|-----------------|------|------|--------------|
| Water                                                      | 1.0                            | 1.5             | 1.33 | 0.31 | 1.0          |
| Extra-dense flint glass                                    | 6.3                            | 3.1             | 1.92 | 0.25 | 0.12         |
| Fused quartz (SiO <sub>2</sub> )                           | 2.2                            | 5.97            | 1.46 | 0.20 | 0.006        |
| Polystyrene                                                | 1.06                           | 2.35            | 1.59 | 0.31 | 0.8          |
| KRS-5                                                      | 7.4                            | 2.11            | 2.60 | 0.21 | 1.6          |
| Lithium niobate (LiNbO <sub>3</sub> )                      | 4.7                            | 7.40            | 2.25 | 0.15 | 0.012        |
| Lithium fluoride (LiF)                                     | 2.6                            | 6.00            | 1.39 | 0.13 | 0.001        |
| Rutile (TiO <sub>2</sub> )                                 | 4.26                           | 10.30           | 2.60 | 0.05 | 0.001        |
| Sapphire (Al <sub>2</sub> O <sub>3</sub> )                 | 4.0                            | 11.00           | 1.76 | 0.17 | 0.001        |
| Lead molybdate (PbMoO <sub>4</sub> )                       | 6.95                           | 3.75            | 2.30 | 0.28 | 0.22         |
| Alpha iodic acid (HIO <sub>3</sub> )                       | 4.63                           | 2.44            | 1.90 | 0.41 | 0.5          |
| Tellurium dioxide (TeO <sub>2</sub> )<br>(Slow shear wave) | 5.99                           | 0.617           | 2.35 | 0.09 | 5.0          |

**Table 12-2** A List of Materials Commonly Used in Acoustooptic Interactions and Some of Their Relevant Properties.  $M = n^3 p^2 / \rho v_s^3$  is the Figure of Merit, Defined by (12.3-20) and is Given in MKS Units. (After Reference [6].)

| Material                                 | $\lambda$ ( $\mu$ m) | $n$   | $\rho$ (g/cm <sup>3</sup> ) | Acoustic wave<br>polarization<br>and direction | $v_s$ (10 <sup>3</sup> cm/s) | Optical wave<br>polarization<br>and direction* | $M = n^3 p^2 / \rho v_s^3$ |
|------------------------------------------|----------------------|-------|-----------------------------|------------------------------------------------|------------------------------|------------------------------------------------|----------------------------|
| Fused quartz                             | 0.63                 | 1.46  | 2.2                         | long.                                          | 5.95                         | $\perp$                                        | $1.51 \times 10^{-15}$     |
| Fused quartz                             | 0.63                 |       |                             | trans.                                         | 3.76                         | $\parallel$ or $\perp$                         | 0.467                      |
| GaP                                      | 0.63                 | 3.31  | 4.13                        | long. in [110]                                 | 6.32                         | $\parallel$                                    | 44.6                       |
| GaP                                      | 0.63                 |       |                             | trans. in [100]                                | 4.13                         | $\parallel$ or $\perp$ in [010]                | 24.1                       |
| GaAs                                     | 1.15                 | 3.37  | 5.34                        | long. in [110]                                 | 5.15                         | $\parallel$                                    | 104                        |
| GaAs                                     | 1.15                 |       |                             | trans. in [100]                                | 3.32                         | $\parallel$ or $\perp$ in [010]                | 46.3                       |
| TiO <sub>2</sub>                         | 0.63                 | 2.58  | 4.6                         | long. in [11-20]                               | 7.86                         | $\perp$ in [001]                               | 3.93                       |
| LiNbO <sub>3</sub>                       | 0.63                 | 2.20  | 4.7                         | long. in [11-20]                               | 6.57                         |                                                | 6.99                       |
| YAG                                      | 0.63                 | 1.83  | 4.2                         | long. in [100]                                 | 8.53                         | $\parallel$                                    | 0.012                      |
| YAG                                      | 0.63                 |       |                             | long. in [110]                                 | 8.60                         | $\perp$                                        | 0.073                      |
| YIG                                      | 1.15                 | 2.22  | 5.17                        | long. in [100]                                 | 7.21                         | $\perp$                                        | 0.33                       |
| LiTaO <sub>3</sub>                       | 0.63                 | 2.18  | 7.45                        | long. in [001]                                 | 6.19                         | $\parallel$                                    | 1.37                       |
| As <sub>2</sub> S <sub>3</sub>           | 0.63                 | 2.61  | 3.20                        | long.                                          | 2.6                          | $\perp$                                        | 433                        |
| As <sub>2</sub> S <sub>3</sub>           | 1.15                 | 2.46  |                             | long.                                          |                              | $\parallel$                                    | 347                        |
| SF-4                                     | 0.63                 | 1.616 | 3.59                        | long.                                          | 3.63                         | $\perp$                                        | 4.51                       |
| $\beta$ -ZnS                             | 0.63                 | 2.35  | 4.10                        | long. in [110]                                 | 5.51                         | $\parallel$ in [001]                           | 3.41                       |
| $\beta$ -ZnS                             | 0.63                 |       |                             | trans. in [110]                                | 2.165                        | $\parallel$ or $\perp$ in [001]                | 0.57                       |
| $\alpha$ -Al <sub>2</sub> O <sub>3</sub> | 0.63                 | 1.76  | 4.0                         | long. in [001]                                 | 11.15                        | $\parallel$ in [11-20]                         | 0.34                       |
| CdS                                      | 0.63                 | 2.44  | 4.82                        | long. in [11-20]                               | 4.17                         | $\parallel$                                    | 12.1                       |
| ADP                                      | 0.63                 | 1.58  | 1.803                       | long. in [100]                                 | 6.15                         | $\parallel$ in [010]                           | 2.78                       |
| ADP                                      | 0.63                 |       |                             | trans. in [100]                                | 1.83                         | $\parallel$ or $\perp$ in [001]                | 6.43                       |
| KDP                                      | 0.63                 | 1.51  | 2.34                        | long. in [100]                                 | 5.50                         | $\parallel$ in [010]                           | 1.91                       |
| KDP                                      | 0.63                 |       |                             | trans. in [100]                                |                              | $\parallel$ or $\perp$ in [001]                | 3.83                       |
| H <sub>2</sub> O                         | 0.63                 | 1.33  | 1.0                         | long.                                          | 1.5                          |                                                | 160                        |
| Te                                       | 10.6                 | 4.8   | 6.24                        | long. in [11-20]                               | 2.2                          | $\parallel$ in [0001]                          | 4400                       |
| PbMoO <sub>4</sub> [14]                  | 0.63                 | 2.4   |                             | long. $\parallel$ c-axis                       | 3.75                         | $\parallel$ or $\perp$                         | 73                         |

\*The optical-beam direction actually differs from that indicated by the magnitude of the Bragg angle. The polarization is defined as parallel or perpendicular to the scattering plane formed by the acoustic and optical  $k$  vectors.

## Acousto-Optic Modulators

| Model #   | Part #      | Wavelength<br>(nm) | Material              | Center<br>Freq | RF<br>Power<br>(watts) | Min Rise<br>Time<br>(ns) | Mod<br>Max BW<br>(MHz) | Active Acoustic<br>Aperture<br>(l x h) | Package  | Connector<br>Type |
|-----------|-------------|--------------------|-----------------------|----------------|------------------------|--------------------------|------------------------|----------------------------------------|----------|-------------------|
| 3200-1220 | 97-02513-01 | 257                | Crystalline<br>Quartz | 200            | 1.0                    | 10                       | 50                     | 0.5 x 0.25                             | Style 2B | SMB               |
| 3200-1210 | 97-02377-01 | 325-365            | Crystalline<br>Quartz | 200            | 2.5                    | 10                       | 50                     | 0.5 x 0.25                             | Style 2B | SMB               |
| 3220-120  | 97-02439-01 | 413                | Crystalline<br>Quartz | 220            | 2.5                    | 19                       | 60                     | 0.5 x 0.25                             | Style 2B | SMB               |
| 3110-121  | 97-01638-01 | 442-488            | TeO <sub>2</sub>      | 110            | 0.5                    | 18                       | 28                     | 2.5 x 0.60                             | Style 2  | SMB               |
| 3200-120  | 99-48146-10 | 442-488            | TeO <sub>2</sub>      | 200            | 0.7                    | 10                       | 50                     | 2.5 x 0.45                             | Style 2  | SMB               |
| 3200-130  | 99-20022-01 | 442-488            | TeO <sub>2</sub>      | 200            | 0.7                    | 10                       | 50                     | 2.5 x 0.40                             | Style 3  | SMA               |
| 3200-141  | 99-48146-13 | 442-488            | TeO <sub>2</sub>      | 200            | 0.7                    | 10                       | 50                     | 2.5 x 0.45                             | Style 4  | SMA               |
| 3224-120  | 97-20010-01 | 442-488            | TeO <sub>2</sub>      | 224            | 0.7                    | 10                       | 50                     | 2.5 x 0.45                             | Style 2  | SMB               |
| 3225-120  | 97-20122-01 | 442-488            | TeO <sub>2</sub>      | 224            | 0.9                    | 15                       | 50                     | 2.5 x 0.60                             | Style 2  | SMB               |
| 3350-120  | 97-02089-01 | 488-532            | TeO <sub>2</sub>      | 350            | 1.0                    | 6                        | 88                     | 2.0 x 0.10                             | Style 2  | SMB               |
| 3080-110  | 99-48201-10 | 442-633            | TeO <sub>2</sub>      | 80             | 0.5                    | 25                       | 20                     | 2.5 x 1.00                             | Style 1  | SMB               |
| 3080-120  | 99-48201-11 | 442-633            | TeO <sub>2</sub>      | 80             | 0.5                    | 25                       | 20                     | 2.5 x 1.00                             | Style 2  | SMB               |
| 3080-125  | 97-01598-01 | 442-633            | TeO <sub>2</sub>      | 80             | 1.0                    | 25                       | 20                     | 2.5 x 2.00                             | Style 2  | SMB               |
| 3080-151  | 99-01000-01 | 442-633            | TeO <sub>2</sub>      | 80             | 1.0                    | 25                       | 20                     | 2.0 x 2.00                             | Style 5  | BNC               |
| 3110-110  | 99-48012-10 | 442-633            | TeO <sub>2</sub>      | 110            | 0.7                    | 18                       | 28                     | 2.5 x 0.60                             | Style 1  | SMB               |
| 3110-120  | 99-20068-01 | 442-633            | TeO <sub>2</sub>      | 110            | 0.7                    | 18                       | 28                     | 2.5 x 0.60                             | Style 2  | SMB               |
| 3110-140  | 97-00811-01 | 442-633            | TeO <sub>2</sub>      | 110            | 0.7                    | 18                       | 28                     | 2.5 x 0.60                             | Style 4  | SMA               |
| 3200-115  | 97-01621-01 | 515-633            | TeO <sub>2</sub>      | 200            | 1.5                    | 10                       | 50                     | 2.5 x 0.40                             | Style 1  | SMB               |
| 3200-121  | 99-48146-11 | 515-633            | TeO <sub>2</sub>      | 200            | 1.0                    | 10                       | 50                     | 2.5 x 0.32                             | Style 2  | SMB               |
| 3200-144  | 97-01407-02 | 515-633            | TeO <sub>2</sub>      | 200            | 1.0                    | 10                       | 50                     | 2.5 x 0.32                             | Style 4  | SMA               |
| 3080-122  | 97-01280-01 | 780-850            | TeO <sub>2</sub>      | 80             | 1.0                    | 25                       | 20                     | 2.5 x 1.00                             | Style 2  | SMB               |
| 3200-124  | 97-01544-01 | 780-850            | TeO <sub>2</sub>      | 200            | 2.0                    | 10                       | 50                     | 2.5 x 0.32                             | Style 2  | SMB               |
| 3080-197  | 97-02848-01 | 1047-1060          | TeO <sub>2</sub>      | 80             | 1.5                    | 25                       | 20                     | 2.5 x 1.00                             | Style 2  | SMB               |
| 3110-197  | 97-01672-11 | 1047-1060          | TeO <sub>2</sub>      | 110            | 2.5                    | 18                       | 28                     | 2.5 x 1.25                             | Style 2  | SMB               |
| 3180-110  | 97-02159-03 | 1047-1060          | TeO <sub>2</sub>      | 180            | 2.5                    | 11                       | 45                     | 2.5 x 0.10                             | Style 1  | SMB               |
| 3200-1113 | 97-02029-05 | 1047-1060          | TeO <sub>2</sub>      | 200            | 2.5                    | 10                       | 50                     | 2.5 x 0.10                             | Style 1  | SMB               |
| 3165-1    | 97-01287-02 | 1300-1550          | TeO <sub>2</sub>      | 165            | 4.0                    | 12                       | 41                     | 2.5 x 0.60                             | Style 1  | SMB               |