

# The Lightwave Model 142 CW Visible Ring Laser, Beam Splitter, Model ATM- 80A1 Acousto-Optic Modulator, and Fiber Optic Cable Coupler Optics Project

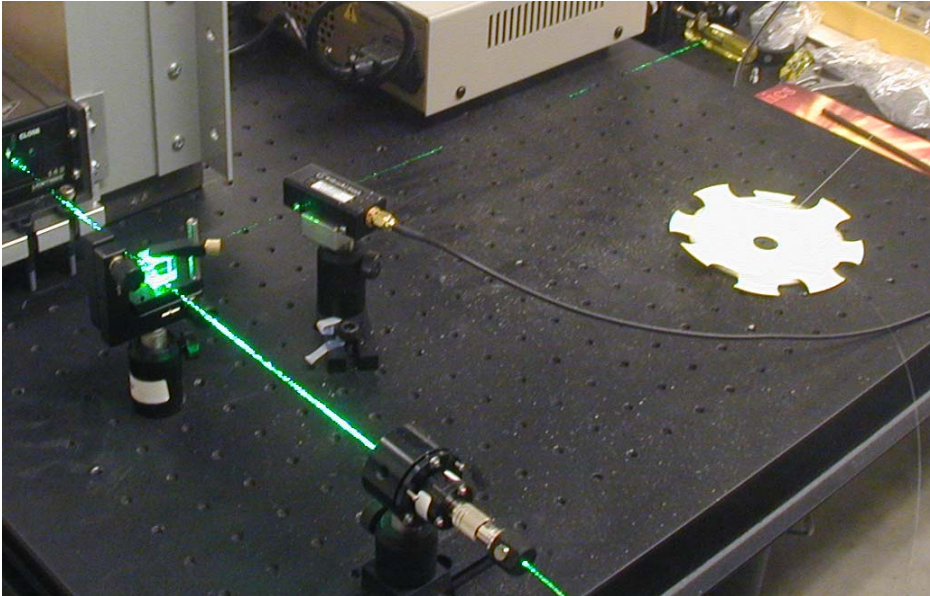
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## Abstract

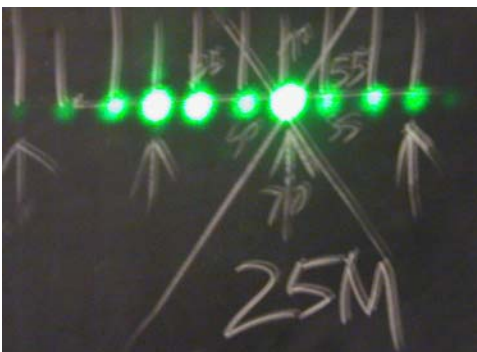
A Lightwave Electronics Model 142 continuous wave visible (green) laser output was aligned to a beam splitter. The output of the beam splitter was coupled to a fiber optic cable and a Model ATM-80A1 acousto-optic modulator. The system is shown in Figure 1.

**Figure 1 Ring Laser, Beam Splitter, Fiber Optic Cable Coupler, and Acousto-optic Modulator**

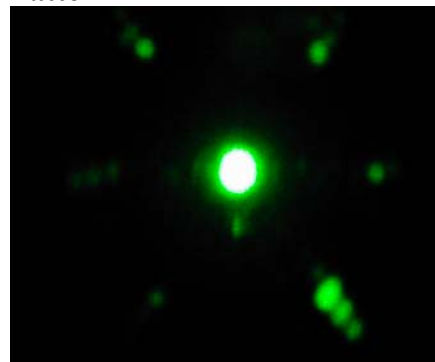


The acousto-optic modulator consisted of a piezo-electric crystal that coupled an 80 MHz RF electro-magnetic wave from a transmitter to a Tellurium Dioxide ( $\text{TeO}_2$ ) crystal. An acoustic standing wave was developed within the  $\text{TeO}_2$  crystal that set up a Bragg diffraction grating. A waveform function generator controlled the transmitter and the output was monitored using an oscilloscope. Two different modes of operation were observed, linear combinations of spots and a hexagonal combination of spots as shown in Figures 2 and 3 respectively.

**Figure 2 Linear Diffraction Pattern**



**Figure 3 Hexagonal Diffraction Pattern**

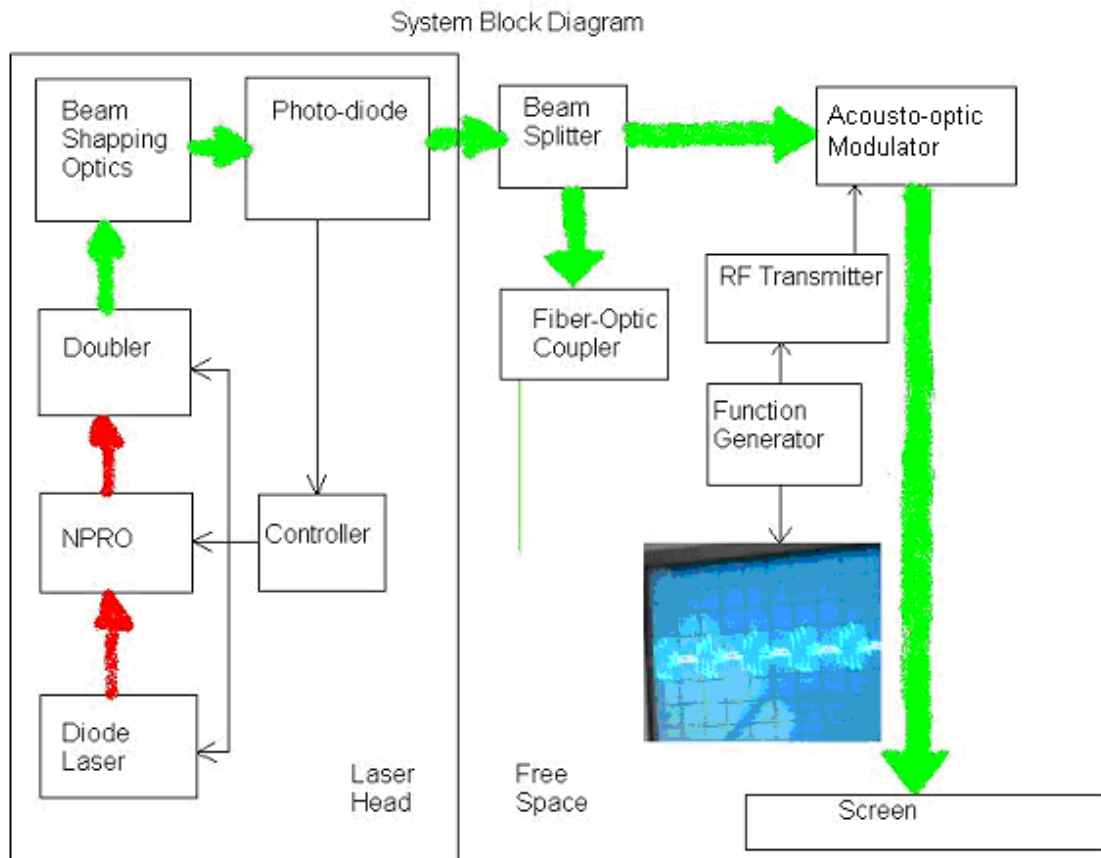


Amplitude, or spot intensity, modulation was accomplished due to Bragg diffraction losses of the incident laser beam from the modulator. The experimental results for spot separation correlated with the acousto-optic modulator instruction manual equations and the diffraction grating equation. The fiber optic cable was coupled to the beam splitter as an exercise in termination.

### Introduction

A Lightwave Electronics Model 142 CW visible (green) laser with a 100:1 horizontal polarization [1] was aligned with a beam splitter and the output of the beam splitter was coupled to a fiber optic cable and a Model ATM-80A1 Acousto-Optic Modulator as shown in Figure 1 and the block diagram in Figure 4.

**Figure 4 Laser System Block Diagram**

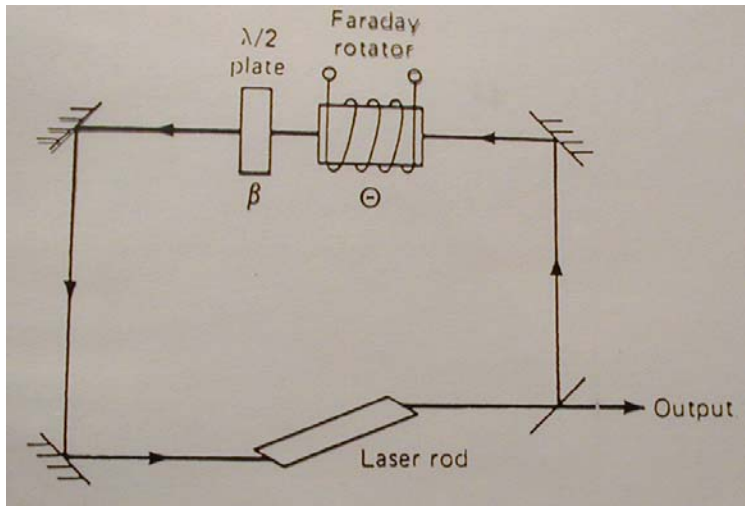


Amplitude, or spot intensity, modulation used Bragg diffraction within the acousto-optic modulator of the incident laser beam. This project was a detailed study of how the acousto-optic modulator worked and a practicum on how to build an optical network.

## Ring Laser

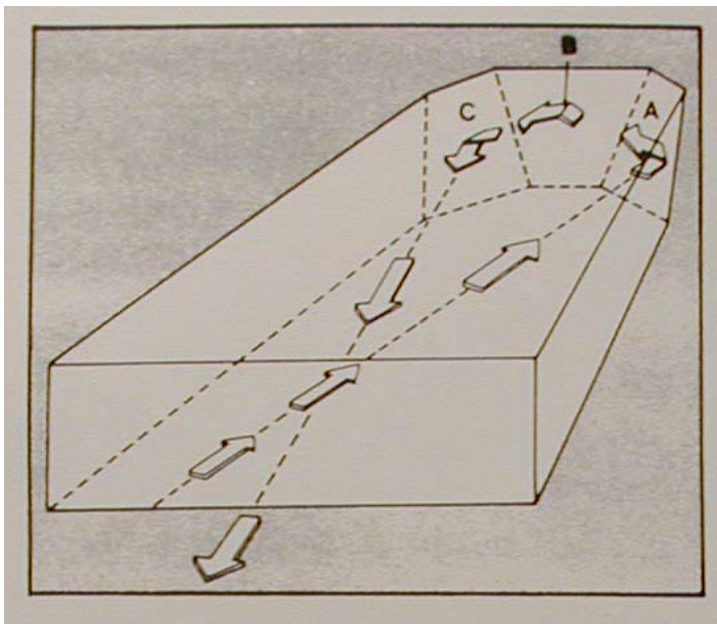
Early versions of ring lasers [2] were configured as shown in Figure 5.

**Figure 5 Early Ring Lasers**



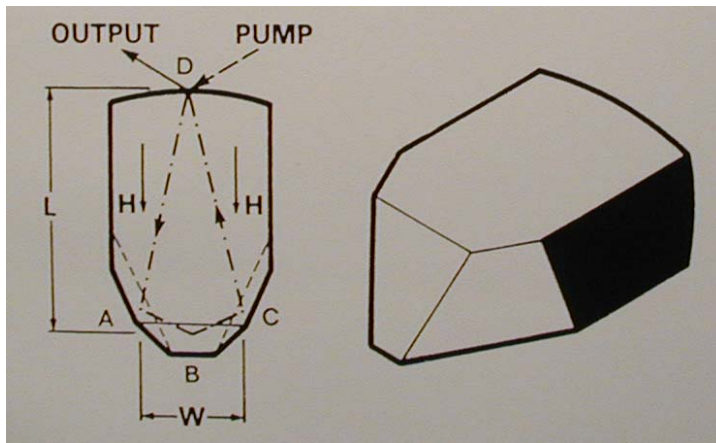
The quarter wave-plate and the Faraday rotator gave the laser a steady output signal and prevented counter-rotating waves that produced standing wave patterns that could cause spatial hole burning, an undesirable effect leading to damage in the laser medium. The Lightwave Electronics Model 146 prevented counter rotating waves by reflecting the wave in a single direction through the monolithic crystal [1, 3] as shown in Figure 6.

**Figure 6 Non Planer Ring Oscillator monolithic Nd: YAG crystal**



Laser light from a diode laser was incident upon the lens of a Non-Planer Ring Oscillator monolithic Nd: YAG crystal at the Brewster angle to prevent any reflections. The monolithic crystal was shaped with mirrors to reflect the beam 180 degrees, while stimulating emission as the beam traveled, and back out of the monolithic crystal at the Brewster angle as shown in Figure 7.

**Figure 7 Monolithic Crystal**



The output beam of the monolithic crystal had a 1064 nm wavelength until it was sent through beam shaping optics and a frequency doubler that produced a continuous green monochromatic output wavelength of 532 nm. The wavelength was controlled by a microprocessor with a photodiode providing feedback to keep it at 1064 nm. Additionally, operation temperature was controlled using a diode thermo-electric cooler. The laser specifications [4] were: 100 mW of output power with a narrow linewidth (less than 10 kHz / 1 ms), and low noise (10 Hz to 2 MHz +/- 0.2%). The Model 142 diode-pumped ring laser was a class IIIB laser as defined by the Federal Register 21 CFR 1040.10 Laser Safety Standard.

### **Beam Splitter**

The beam splitter was the first element encountered by the Model 142 YAG ring laser. The beam splitter was a cubic crystal that transmitted 50% of the incident beam and reflected the other 50% of the incident beam in a direction related to the alignment of the beam splitter. In this system the reflected angle was 90 degrees from the incident angle. The transmitted beam went straight through the beam splitter and was incident on a fiber optic cable coupler. The transmitted beam direction was independent of the beam splitter orientation angle to the incident beam. The reflected beam was incident on the Model ATM-80A1 acousto-optic modulator.

### **Fiber Optic Cable Coupler**

The fiber optic cable coupler consisted of a lens that focused the incident beam onto the end of the fiber and a mechanism that held the fiber in place. Coupling the incident beam to the fiber required precise alignment to get light out of the end of the cable. This part of the project was an exercise in alignment since the other end of the cable was not

terminated. We were only able to get a small amount of light to come out the end of the cable.

### **Acousto-Optic Modulator**

The acousto-optic modulator consisted of two components, a Model ME-801T Light Modulator Signal Processor (LMSP), and a Model ATM-80A1 Acousto-Optic Modulator (AOM) [5]. The AOM had a Lithium Niobate piezo-electric transducer crystal attached to a Tellurium Dioxide (TeO<sub>2</sub>) crystal that coupled an 80 MHz RF electro-magnetic wave from the LMSP [6]. When an RF frequency acoustic wave propagates inside an optically transparent medium, a periodic change in the refractive index occurs due to the compressions and rarefactions of the sound wave [5]. This periodic change sets up a Bragg diffraction grating within the crystal. The diffraction spacing is equal to the acoustic wavelength.

Wavelength of the acoustic wave:

$$\lambda_{\text{Acoustic}} = V_{\text{TeO}_2} / \text{RF}$$

Speed of sound in TeO<sub>2</sub>:

$$V_{\text{TeO}_2} = 4260 \text{ m/s}$$

Radio Frequency:

$$\text{RF} = 80 \text{ MHz}$$

Resulting in an acoustic wavelength of

$$\lambda_{\text{Acoustic}} = 53.25 \text{ } \mu\text{m}.$$

The laser wavelength was 532 nm.

From the geometry of the setup we measured the distance from the AOM to the screen to be 30 ft 8 inches or 934.7 cm. We measured the spot separation to be 3.75 inches or 9.53 cm. From these measurements we calculated the separation angle;

$$\tan(\theta_{\text{Separation}}) = 9.53 \text{ cm} / 934.7 \text{ cm}$$

$$\theta_{\text{Separation}} = \arctan(9.53 / 934.7) = .0102 \text{ rad}$$

Using the transmission grating equation [7]

$$\lambda_{\text{Acoustic}} * \sin(\theta_m) = m * \lambda_{\text{laser}}$$

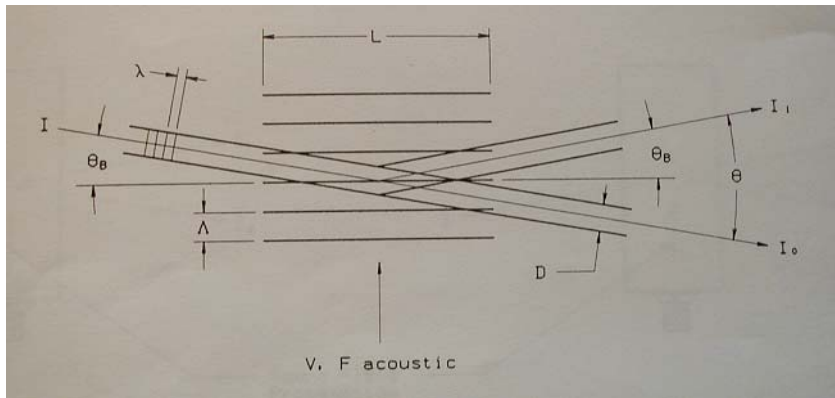
In this equation  $m$  is an integer denoting order and  $m = 1$  was the distance to the first spot to the right of the fundamental spot and  $m = -2$  was the distance to the second spot to the left of the fundamental spot.

Diffraction angle:

$$\theta_m = \arcsin[(m * \lambda_{\text{laser}}) / \lambda_{\text{acoustic}}]_{|m|=1} = .0099 \text{ rad}$$

According to the specifications in the AOM instruction manual and Figure 8

**Figure 8 Bragg and Separation Angle**



the theoretical Bragg angle equaled

$$\theta_{\text{Bragg}} = \lambda_{\text{laser}} / (2 * \lambda_{\text{acoustic}}) = 532 \text{ nm} / (2 * 53.25 \text{ } \mu\text{m}) = .0049 \text{ rad.}$$

The theoretical spot separation angle is twice the Bragg angle therefore,

$$\theta_{\text{Separation}} = 2 * \theta_{\text{Bragg}} = .0099 \text{ rad.}$$

The experimental results for spot separation correlated with the AOM instruction manual theoretical equations and the diffraction grating equation.

An oscilloscope was used only to monitor the waveform of a function generator that controlled the LMSP. We input a square-wave, sine-wave, and a saw-tooth waveform but they only affected spot size or intensity. The input voltage had no effect on modulation until the input voltage was 2 volts. At 2 volts the spot intensity would begin to increase until the input voltage was 5 volts. The intensity seemed to remain the same from 5 volts to 10 volts (the max output voltage of the function generator). Two different modes of operation were observed, a linear combination of spots and a hexagonal combination of spots as shown in Figures 3 and 4 respectively. The linear combinations were observed at several angles and the radial pattern occurred at a unique aperture fringe angle.

Some possible causes of the radial pattern may be due to some unique zone of higher order nonlinear modes due to the acoustic wave collapsing and or forming, causing reflections or complicated zones of refraction within the TeO<sub>2</sub> crystal.

### **Conclusion**

Two different modes of operation were observed, a linear combination of spots and a hexagonal combination of spots as shown in Figures 3 and 4 respectively. Amplitude or spot intensity modulation of the incident beam was accomplished due to Bragg diffraction losses. Modulation was accomplished by diffracting the incident ray at the 80 MHz modulation frequency, and varying the spot intensity in time. Additionally the higher order (diffracted) spots switched from zero to some peak intensity as a percentage of the incident intensity and provided a high extinction ratio and could be used for digital switching. The experimental results for spot separation correlated with the AOM instruction manual theoretical equations and the diffraction grating equation.

The fiber optic cable was coiled with a radius of 6 cm and had about 50 turns. The fiber was coupled to the transmitted beam of the beam splitter as an exercise in termination. The loss in intensity of the fiber was so high that the alignment of the coupler to the incident laser beam had to be very precise to get any light to the end of the fiber.

## References

1. Berube, M., "Lightwave Request Form", Attachment, February 21, 2003.
2. Koechner, W., "Solid-State Laser Engineering, Fourth Extensively Revised and Updated Edition" Springer Series in Optical Sciences, 1996.
3. Berube, M., "Lightwave Request Form", E-mail, February 21, 2003.
4. Lightwave Electronics, "Series 142 User's Manual, Diode-pumped Single-frequency CW Green Laser", July 19, 2001.
5. IntraAction Corp., "Model ATM-80A1 Acousto-Optic Modulator, Instruction Manual", March 28, 2002.
6. IntraAction Corp., "Model ATM-801T Light Modulator Signal Processor, Instruction Manual", March 26, 2002.
7. Hecht, E., "Optics, Fourth Edition" Addison Wesley, 2002.

## Attachments

1. Berube, M., "Lightwave Request Form", E-mail, February 21, 2003.
2. Berube, M., "Lightwave Request Form", Attachment, February 21, 2003.