Laboratory work: Acousto-optics

March, 2015

1 Introduction

Acousto-optics is the physics that studies the interactions between acoustic (sound) waves, of mechanic origin, and light waves.
This phenomenon can be described as follows: an acoustic wave, produced by a piezoelectric transducer, travelling in an solid or liquid medium, generates periodic constraints in this medium (compression - dilatation). These will generate a variation of the refractive index (photoelastic effect) with a space and time periodicity. The acoustic wave can be assumed to be stationary as its speed is much lower than that of light wave.
The refractive index grating constituted by the acousto-optic interaction will therefore have an influence on certain parameters (intensity, frequency, direction...) of the light wave travelling through the medium.

In 1922, Léon Brillouin was the first to predict this kind of interaction. In 1932, Lucas and Biquard in France, and Debeye and Sears in the USA, experimentally verified the light diffraction by ultrasonic waves. At that time, the acousto-optics was only used to measure the acoustic constants and coefficients. Since the apparition of the Laser (1960), which is a coherent and powerful light source, many applications have been developed as the acousto-optical deflector and modulation.

The aim of this lab work is the visualisation of this physical phenomenon and to give an overview of its applications.
The student will start by characterising the acousto-optic medium, than he will put in evidence and study two applications of the acousto-optical deflection and modulation. A lab report is expected at the end of the manipulations with an introduction resuming the aims of the manipulations, the results, the conclusions and remarks.

2 Laser: safety information

Since its invention in 1960, the laser has constantly been developed and new applications are found. Therefore, the number of accidents due to lasers also increased. In most of the accidents, eye damage are reported. The dangerousness of the laser are divided in different classes.
→ Class 1: lasers are not dangerous for the eye in any observation conditions
→ Class 2: lasers are safe under normal conditions. They emits in the visible, the blink reflex of the eye will prevent damage
→ Class 3R: lasers are usually up to 5 mW and involve a small risk of eye damage within the time of the blink reflex. Staring into such a beam for several seconds is likely to cause damage to a spot on the retina
→ Class 3B can cause immediate eye damage upon exposure
→ Class 4 lasers can burn skin, and even scattered light can cause eye and/or skin damage. Many industrial and scientific lasers are in this class
The users have to be careful: a class 1 laser can be dangerous if wrongly used. Thus, be careful and if required:

- Wear the protection goggles
- Make sure that the door is closed and the laser warning light is switched on
- The person switching on the pump diode, make sure everybody in the room has the protection goggles on
- Knock at the door and wait for response before entering the room with the setup
- People in the laser room, respond with clear indications, if somebody is knocking.
- Everybody entering the room remove any jewellery, watches etc.
- Take care to block the light every time you want to use a tool on the setup. This is the most common laser accident: reflecting the laser with a tool in the eyes of a colleague!

For more information refer to a laser safety training/course.

3 Study of the acousto-optic medium

3.1 Optical transmission

If the laser is not vertically polarised, use the half wave plate. The plate has to be perpendicular to the base of the AO crystal.

The AO cell and the detector have to be fixed on the optical table.
In the following, the cell will be rotated and the detector will have to move vertically. The fixations of these two elements have to be chosen properly.

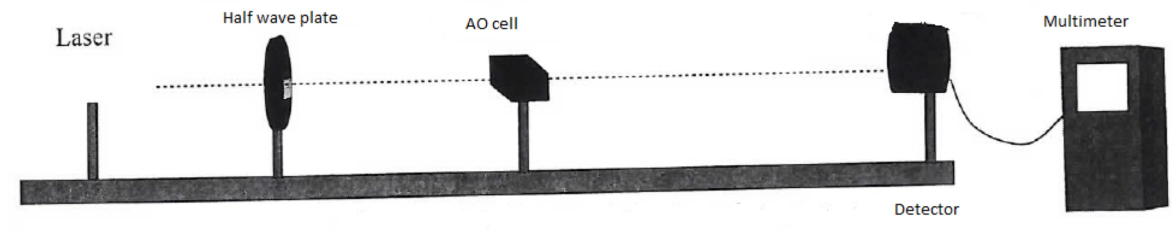

Figure 1: Setup to be build

The voltage shown by the voltmeter is directly proportional to the intensity collected by the photodiode. Intensity and voltage will be used interchangeably in the following.

Questions

- After measuring the intensity with and without the AO cell, determine the transmission factor T of the deflection modulator.
- Calculate the theoretical reflection R by using the refractive index of the material.
- Comment.

3.2 The slit separation of the acoustic grating

Give an approximation of the slit separation of the acoustic grating when the frequency of the acoustic wave is the central frequency F_c.

3.3 Access time

Calculate the time necessary for the acoustic wave (perpendicular to the optical table) to travel through the whole optical beam.

3.4 Bragg angle and deviation angle

3.4.1 Calculation

The frequency is assumed to be always equal to F_c.
Questions

- Calculate the theoretical Bragg angle in the air and in the medium.
- Deduce the value of the deviation angle in the air.
- The frequency goes from 90 to 130 MHz, calculate the displacement of the spot of order 1 on the screen situated at 4m of the deflector.

3.4.2 Measurements

Modify the previous setup. Remove the detector and place a screen at 4 m of the deflector. Apply a frequency of 110 MHz and a voltage of 10 V to the Bragg cell.

Setting of the Bragg angle
The deflector has to be positioned at normal incidence right after the laser (or the half wave plate). Different diffraction orders appear. Set the deflector at the Bragg incidence, for which only the first order diffraction exists. The diffraction efficiency has to be higher than 85% according to the technical details of the constructor.

Questions

- Measure the distance between the order 0 and 1.
- Deduce the deviation angle.
- Determine the Bragg angle by calculation.
- Find the speed of the acoustic wave in the material.
- Comment.

4 Study of the deflexion

4.1 Deviation of the wave

Use the same setup as before. A screen is positioned at 4 m of the deflector.

Questions
The voltage has to be varied from 0 to 10 V by steps of 1 V.

- Measure the distance between the order 0 and 1 (take the centre of the spot).
- Deduce the real frequency F of the acoustic grating.
- Conclusion.

4.2 Deflection by frequency modulation

The preceding study showed the role of the acoustic frequency on the direction of the deflected wave. In the following part, which aims at drawing a line, the frequency is modulated by a function generator.
Use the setup 1 and connect the output of the function generator on the entrance of the frequency modulator of the AO power supply.
Set the offset of the generator such that the acoustic wave is adjusted on its central frequency.

Questions

- Calculate the width of the acoustic frequency (ΔF) necessary for the order 1 to have a width of 2 cm with the screen at 4 m.
- Deduce the modulation amplitude of the voltage to apply at the modulation entrance of the frequency of the AO power supply.
- Apply your calculated results and measure the effective length of a line.
- What happens if you modify the modulation frequency?
- Considering your manipulations, give some applications of this setup.