

Pre-Lab 11

You are in a lab room and you find the following equipment in a cabinet:

- A He-Ne Laser
- 3 Polarizing Beamsplitting Cubes (PBC's)
- 3 Linear polarizers
- 3 half-wave plates
- 3 quarter-wave plates

You need to determine some method that will...

- Divide the single laser beam into 3 laser beams
- Each of the 3 laser beams has the same laser power and the same linear polarization (as would be measured by the "Polarama 2.1" program).
- You should try to minimize the loss of laser light

Make a sketch of an experimental set up that will accomplish these goals. Also indicate how you would select the angle for any polarizer or wave plate.

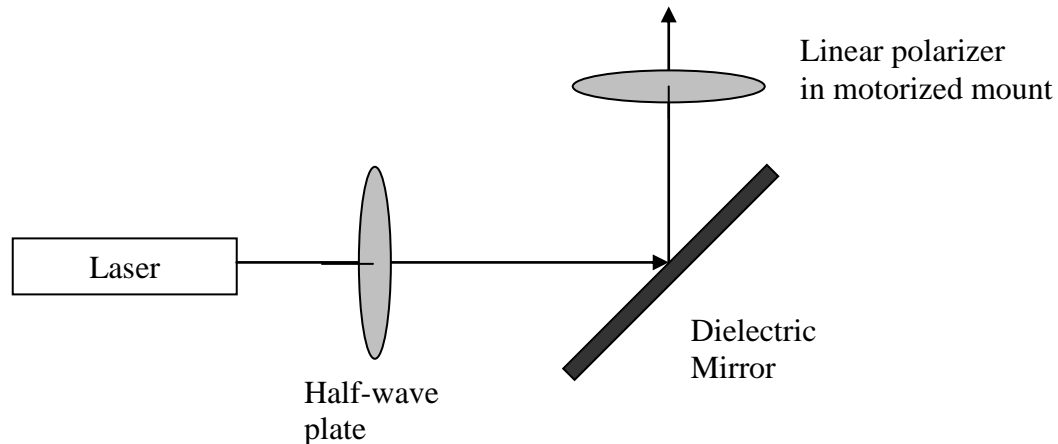
Why did you choose each piece of equipment?

Lab 11 Polarization 3: Revenge of the photons

Section 1

In this section you will examine the polarization of the light after a reflection from a dielectric mirror.

Set up the following using the mounted half-wave plate and linear polarizer from last week:



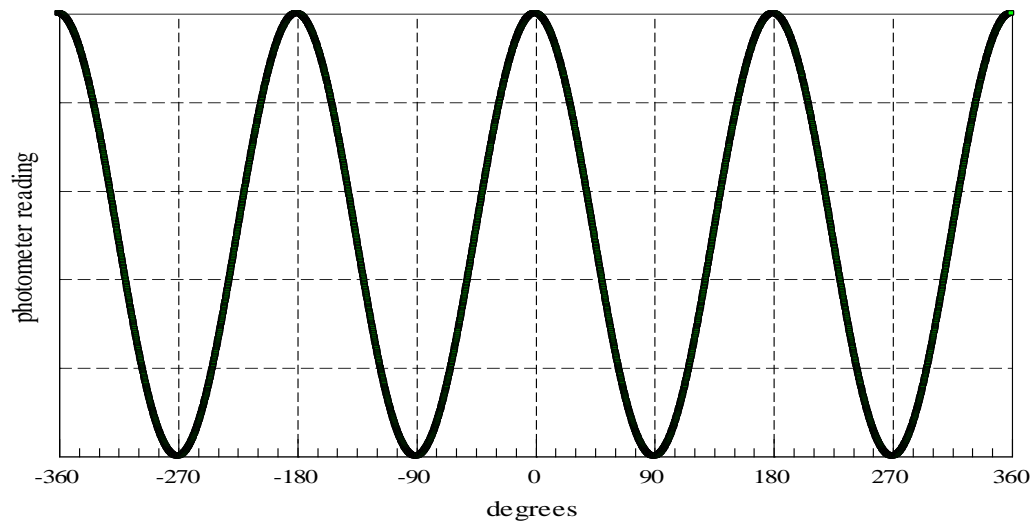
Orient the motorized mount so that the label on the mount faces the propagation direction of the laser beam. Orient the half-wave plate's mount so that the numbers face the propagation direction of the laser beam.

Open the LabView program called "Polarama 2.1".

Enter the average phase you found in lab 9 section 2 into the box (in the LabView program) called "phase offset".

You will need to refer back to lab 9 for your initial half wave plate measurements. If you do not have lab 9 with you for reference, you will have to complete the measurements with the half wave plate and without the mirror before proceeding.

Suppose the half-wave plate was turned to 0° (using the definition of lab 9 section 4). The sketch below shows the photometer reading vs. angle directly out of the laser. Predict on the same sketch what you expect to see measuring the polarization after the light reflects from the mirror. Explain your reasoning.



Predict values for the following for the polarization after the reflection. Explain your reasoning.

Amplitude	DC Offset	Phase angle

SHOW YOUR PREDICTIONS TO YOUR INSTRUCTOR

Using the LabView program (“Polarama 2.1”), produce a graph of photometer reading vs. angle.

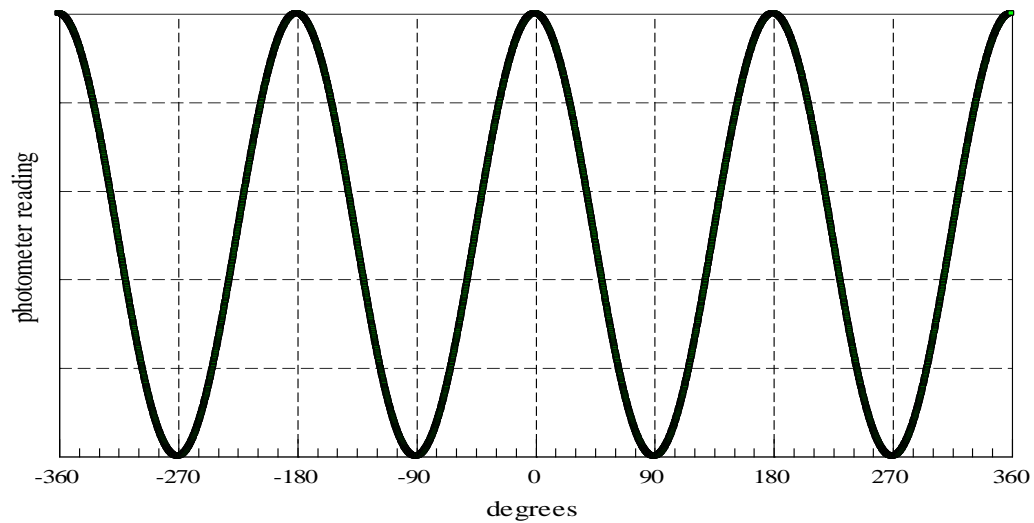
Amplitude	DC Offset	Phase angle	Eccentricity	Tilt angle

Resolve any and all differences with your prediction.

What is the mathematical difference (i.e., subtraction) between the DC offset and the amplitude?

A student states that this should be zero for any linearly polarized light. Do you agree or disagree? Explain!

Suppose the half-wave plate was turned to 45° (using the definition of lab 9 section 4). The sketch below shows the photometer reading vs. angle directly out of the laser. Predict on the same sketch what you expect to see measuring the polarization after the light reflects from the mirror. Explain your reasoning.



Predict values for the following for the polarization after the reflection. Explain your reasoning.

Amplitude	DC Offset	Phase angle

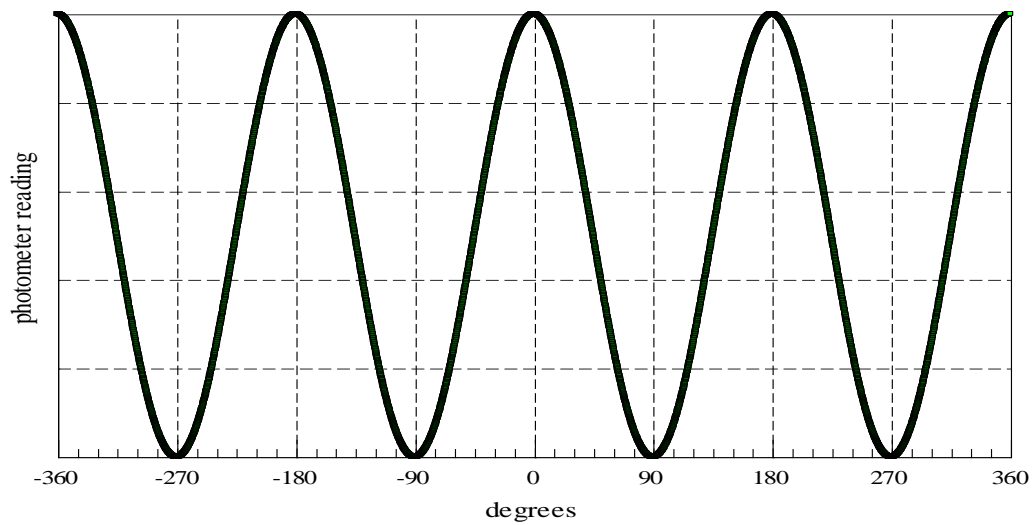
SHOW YOUR PREDICTIONS TO YOUR INSTRUCTOR

Using the LabView program (“Polarama 2.1”), produce a graph of photometer reading vs. angle.

Amplitude	DC Offset	Phase angle	Eccentricity	Tilt angle

Resolve any and all differences with your prediction.

Suppose the half-wave plate was turned to 22.5° (using the definition of lab 9 section 4), the sketch below shows the photometer reading vs. angle directly out of the laser. Predict on the same sketch what you expect to see measuring the polarization after the light reflects from the mirror. Explain your reasoning.



Predict values for the following for the polarization after the reflection. Explain your reasoning.

Amplitude	DC Offset	Phase angle

SHOW YOUR PREDICTIONS TO YOUR INSTRUCTOR

Using the LabView program (“Polarama 2.1”), produce a graph of photometer reading vs. angle.

Amplitude	DC Offset	Phase angle	Eccentricity	Tilt angle

Did your prediction match the measured results?

Previously, in Lab 9 you were told that: *“You can consider eccentricity as a measure of the degree of the light’s linear polarization. 1 indicates perfectly, linear polarization. 0 indicates almost no variation in the intensity of the light reaching the detector as the polarizer is turned.”*

For the three different half-wave plate rotations (0° , 45° , 22.5°), was there any significant change in the eccentricity of the reflected light’s polarization?

In which case or cases (half-wave plate at 0° , 45° , 22.5°) does the linear polarizer at the optimal angle seem less effective in regard to perfectly eliminating the reflected light?

When the eccentricity is reduced after a reflection, which of the following explanations seems most plausible to your group:

- The decrease in eccentricity is due to the reflection changing the relative positive percentages of vertically and horizontally linearly polarized light.
- The decrease in eccentricity is due to the light becoming more “unpolarized” after the reflection.
- The decrease in eccentricity is due to the light becoming elliptically polarized. That is, the electric field and magnetic field change in magnitude and rotate about the light’s propagation direction tracing out an ellipse.

Explain the reasons for your group’s selection.

SHOW YOUR ANSWERS TO YOUR INSTRUCTOR BEFORE PROCEEDING.

Section 2

The purpose of this section is to examine the hypothesis that the decreased eccentricity is simply due to different proportions of horizontal and vertically linearly polarized light.

If the eccentricity is one, how many different directions does the electric field point for a beam of light?

Suppose we define the z-direction as the propagation direction of the laser beam, the y-direction as vertically upward off the laser table, and the x-direction is the cross-product of y and z directions (it is perpendicular to both).

With these definitions, in which direction (or directions) does the electric field point for a beam of light with vertical linear polarization?

With these definitions, in which direction (or directions) does the electric field point for a beam of light with horizontal linear polarization?

We can represent these electric fields as a plane wave (at least for our purposes here). A plane wave traveling in the z-direction may be expressed as...

$$\vec{E} = \vec{E}_0 \cos(\omega t - kz) \text{ where } \vec{E}_0 \text{ is a constant vector.}$$

Let $\vec{E}_1 = E_{01} \hat{y} \cos(\omega t - kz)$ represent one form of linearly polarized light and

$\vec{E}_2 = E_{02} \hat{x} \cos(\omega t - kz)$ represents another form of linearly polarized light.

Now suppose we had a beam of light with an electric field given by the sum of the two linear polarizations above: $\vec{E} = (E_{01} \hat{y} + E_{02} \hat{x}) \cos(\omega t - kz)$. Imagine you were at $z=0$, what would the direction of the electric field be for values of $\omega t = 0, \pi/2$, and π .

How many different directions does this electric field point in?

When the electric field for light is $\vec{E} = (E_{01} \hat{y} + E_{02} \hat{x}) \cos(\omega t - kz)$, is this linearly polarized light? Explain.

Now suppose we had a beam of light with an electric field in which the electric field along the \hat{x} direction has a $\pi/6$ phase shift with respect to the electric field in the \hat{y} direction. Now the electric field for the beam of light is given by

$\vec{E} = E_{01} \cos(\omega t - kz) \vec{y} + E_{02} \cos\left(\omega t - kz + \frac{\pi}{6}\right) \hat{x}$. Imagine you were at $z=0$, what would the direction of the electric field be for values of $\omega t = 0, \pi/2$, and π .

How many different directions does this electric field point in? Explain.

Now refer to your data from Lab 9. In particular, the exercises where you might have used these particular rotations of the half-wave plate.

If you looked at the polarization of the light just after the half-wave plate, is it ever NOT linearly polarized? Explain and use your data wherever appropriate.

In Lab 11 section 1, was the light always linearly polarized? Explain using your data wherever appropriate.

Could an eccentricity of approximately 0.9 be due to different positive contributions of vertical and horizontal light given your answers above (with phase difference of zero)? Explain.

SHOW YOUR ANSWERS TO YOUR INSTRUCTOR BEFORE PROCEEDING.

When we deal with polarized light interacting with surfaces (i.e., reflections), we have to consider two orthogonal orientations of the electric field vector with respect to the surface. The normal vector (which passes perpendicularly through the area of the reflector) and the light's propagation direction define a plane. The component of the electric field vector that lies in this plane is called p-polarization. The component of the electric field vector that is perpendicular to this plane is called s-polarization. S-polarization experiences no phase shift upon reflection. While p-polarization experiences a phase shift of π radians (inverts the wave).

Beyond this difficulty of different electric field orientations experiencing different phase shifts, some mirrors (like dielectric mirrors) do not only reflect at the surface. Some of the light is reflected beneath the mirrors surface. This can lead to one component of polarization (s and p) lagging the other.

Here are some rules of thumb when dealing with reflections from dielectric mirrors and polarizations

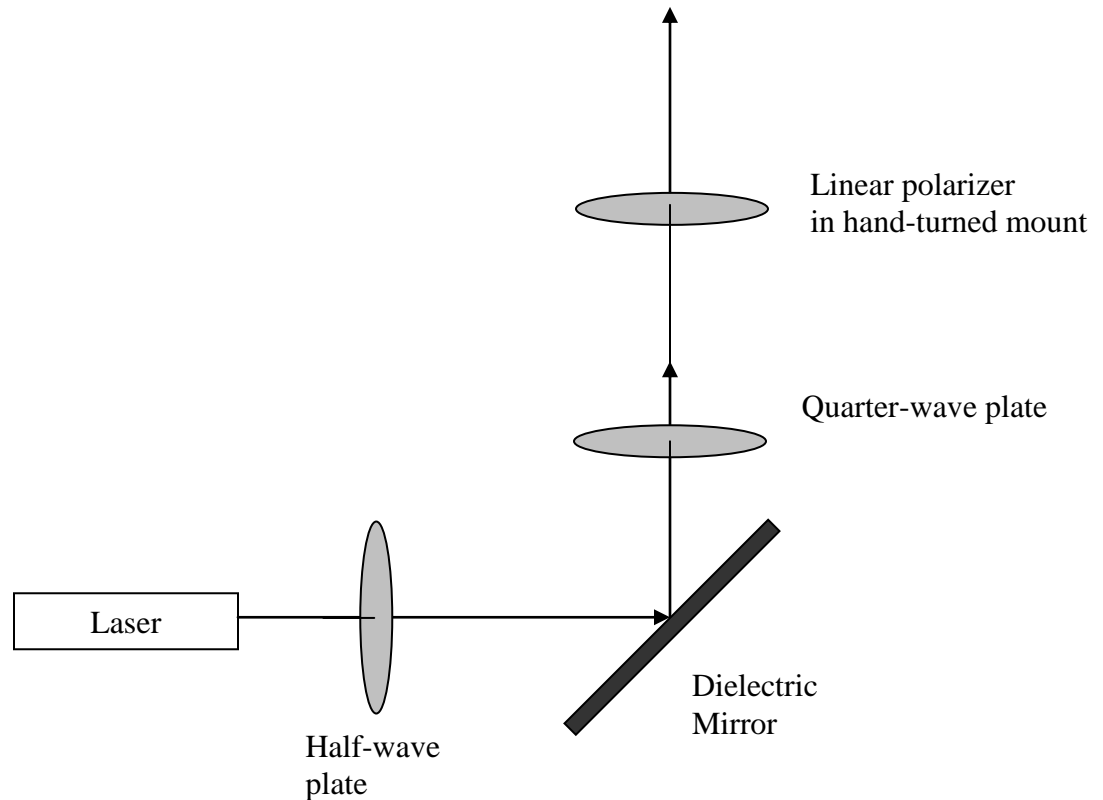
- A retro-reflection (the light reflected back upon itself) will not have a significant change in its polarization compared to the incident beam's polarization.
- The best way to maintain polarization of a laser beam is to keep the beam at a constant height off the table and use either purely vertical or horizontal linear polarization.

Section 3

This section examines whether a reflected beam can become more "unpolarized" or more elliptical (i.e., less eccentric).

Suppose we examined light using the program, "Polarama 2.1". If the eccentricity was 0.80 and we assumed that this meant that the light was 80% linearly polarized, could we make the light linearly polarized if we used a quarter-wave plate?

Set up the following situation...



Turn the half-wave plate to 22.5° . Then turning both the quarter-wave plate and linear polarizer, try to minimize the light that passes through the linear polarizer. Can you make the light passing through the quarter-wave plate linearly polarized? Explain.

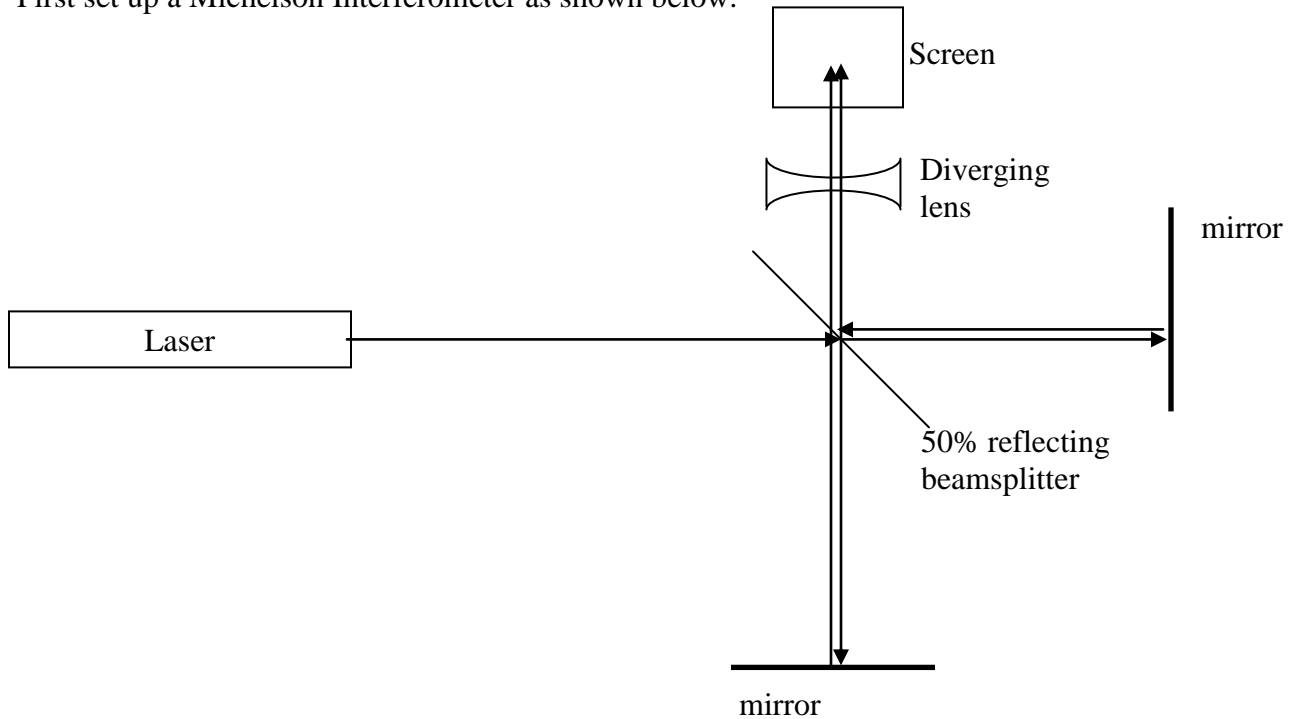
Contrast this with the results of the light bulb experiment in Lab 10 Section 3 and those of the $\frac{1}{4}$ wave plate.

Reconsider the question on top of page 7. Which of the explanations do you think is most plausible? Explain using your data wherever appropriate.

What does this tell you about maintaining polarization after reflection?

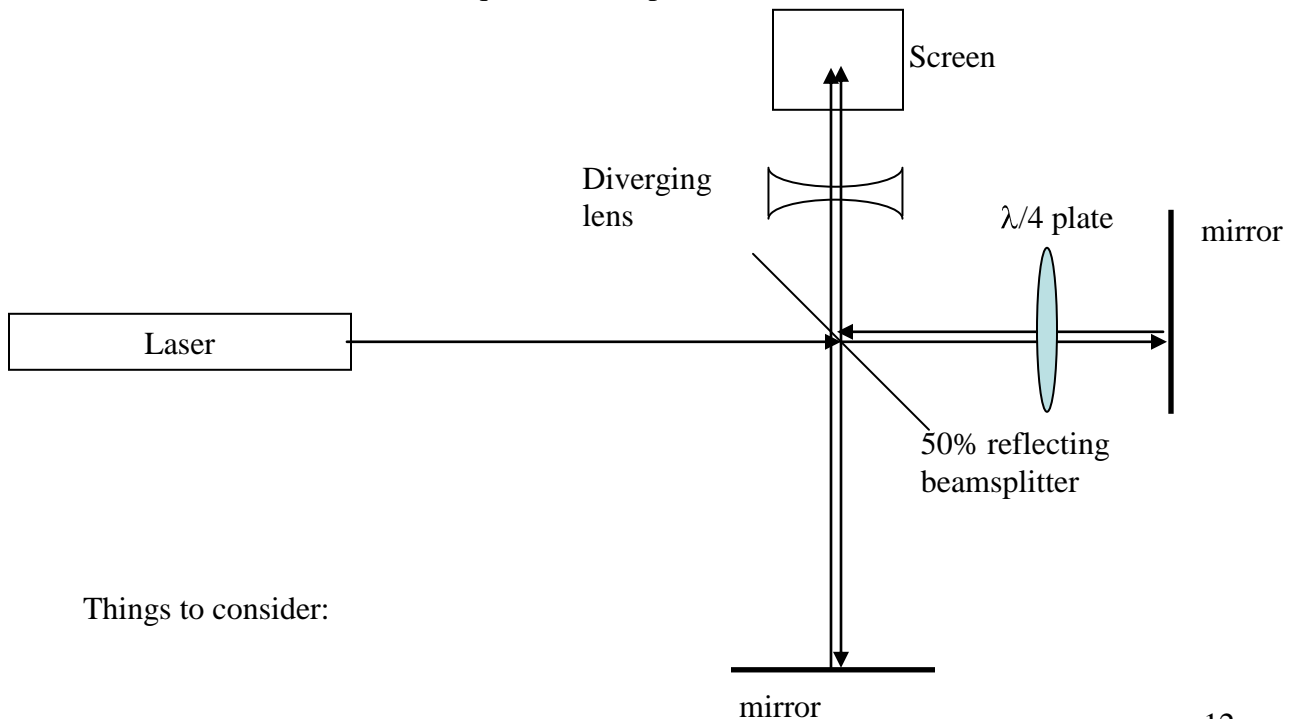
Task

First set up a Michelson Interferometer as shown below.



The two beams heading to the screen MUST co-propagate (lie on top of each other). If you set up the interferometer properly you should see light and dark bands of light on the screen due to the interference of light.

Now predict what we would observe if we placed a quarter-wave plate in the interferometer and rotated the quarter-wave plate (see the sketch shown below).



Things to consider:

How many times does the laser beam pass through the $\frac{1}{4}$ wave plate and what impact might this have?

How is the light's polarization just after the $\frac{1}{4}$ wave plate compare with the light's polarization just after reflection.

SHOW YOUR PREDICTION TO YOUR INSTRUCTOR BEFORE PROCEEDING.

Put a quarter-wave plate into your Michelson Interferometer and rotate it observing the fringes on the screen. Resolve any differences between the experiment and your prediction.