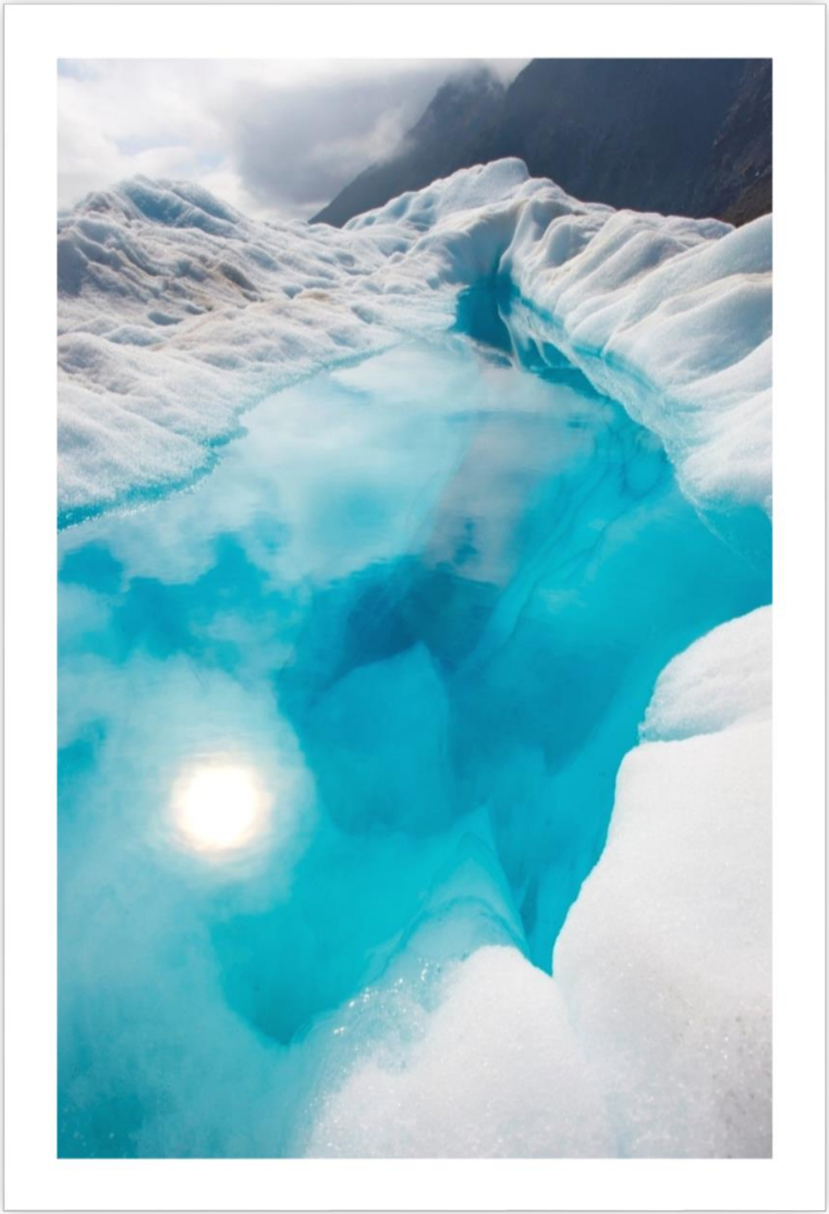

Polarization Imaging

SENSORS AND DIGITALIZATION EXPERIMENT NO 1

DANIEL GONZÁLEZ ADELL
NAYEE MUDDIN KHAN DOUSAI

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Objective

The goal of this experiment is to understand how a simple camera can be transformed into a polarization state measurement system. This experiment introduces two different systems:

- A simplified polarization imaging set-up that consists of a manually rotating polarizer placed in front of the sensor
- A contrast polarization measurement system that uses a Twisted Nematic Liquid Crystal

Introduction

The experiment polarization Imaging is mainly focused to observe the difference of images with respect to polarizers and their angles. The polarization imaging techniques wolff's method and Least Mean Square Method is also mentioned and calculated with polarizer orientation of 0, 45 and 90 by using Matlab. Acroptix rotator was used to observe the contrast measurement of the image. The observed results are tabulated in matlab and labelled with different images.

Equipment

For the proper arrangement of the experiments, we will consider:

- PC Computer
- Frame Grabber – IEEE 1394
- Camera – Allied Vision Technologies GUPPY
- Lens
- Video Cable
- Acroptix switchable polarization rotator 0-90 º (Twisted Nematic Liquid Crystal)
- Acroptix USB LC Driver
- Two Linear Polarizers
- Four mounting posts and four post holders
- Lighting Device
- Polarized Ring

Software

- AVT Vimba Viewer
- Acroptix USB LC Software
- Matlab

Installation

For this experiment, we are using Allied Vision Technologies GUPPY camera to capture the images. All the equipment's mentioned above are arranged in a proper setup as labelled in figure 1 like Connection of Camera, PC, Polarized ring, Lightening device, Two linear polarizers and acroptix switchable polarizer. This experiment is mainly divided into simplified and contrast polarization imaging.

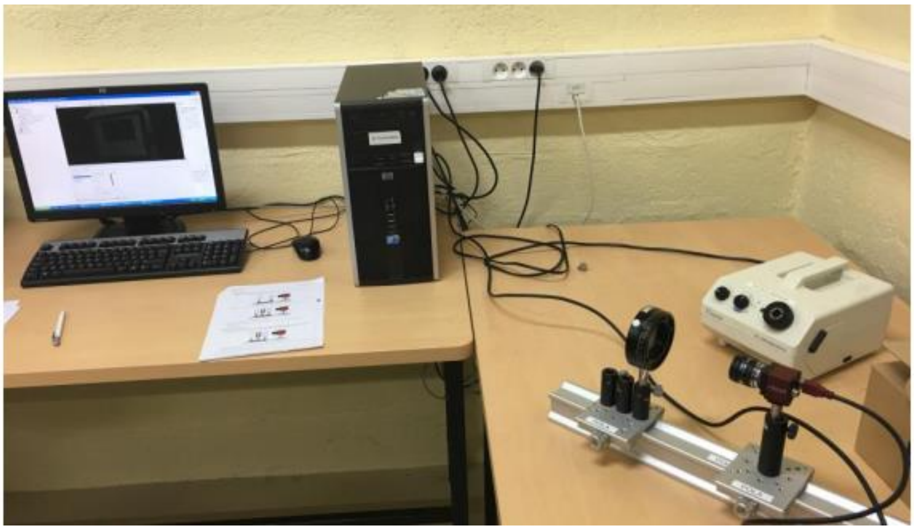


Figure 1. Working setup

Simplified Polarization Imaging

In simplified polarization imaging, only one polarizer and guppy camera is used to capture the images as labelled in figure 2.

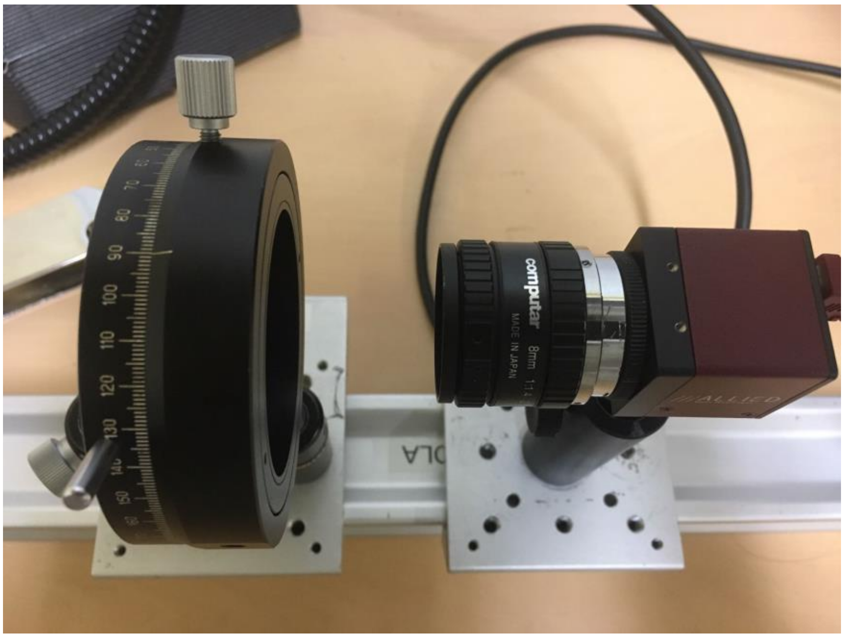
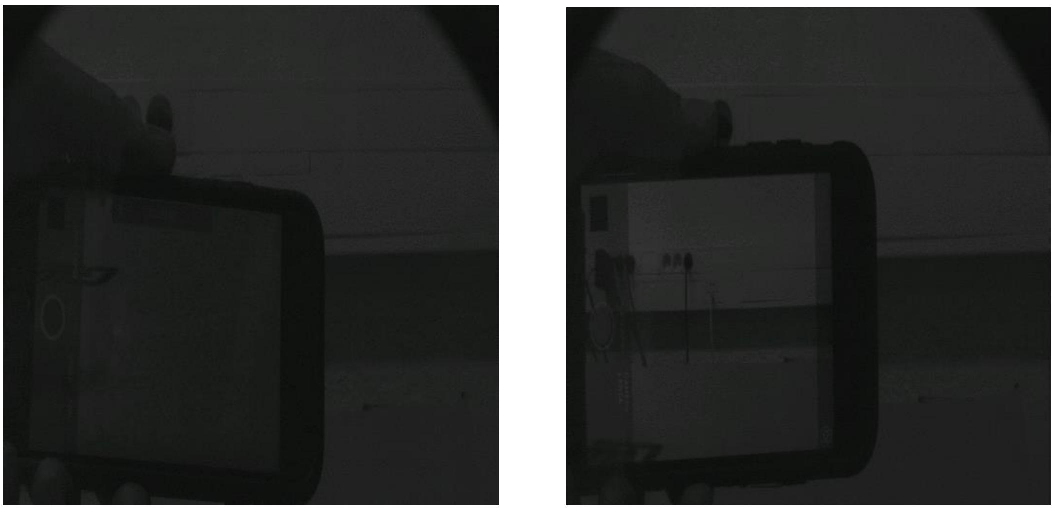


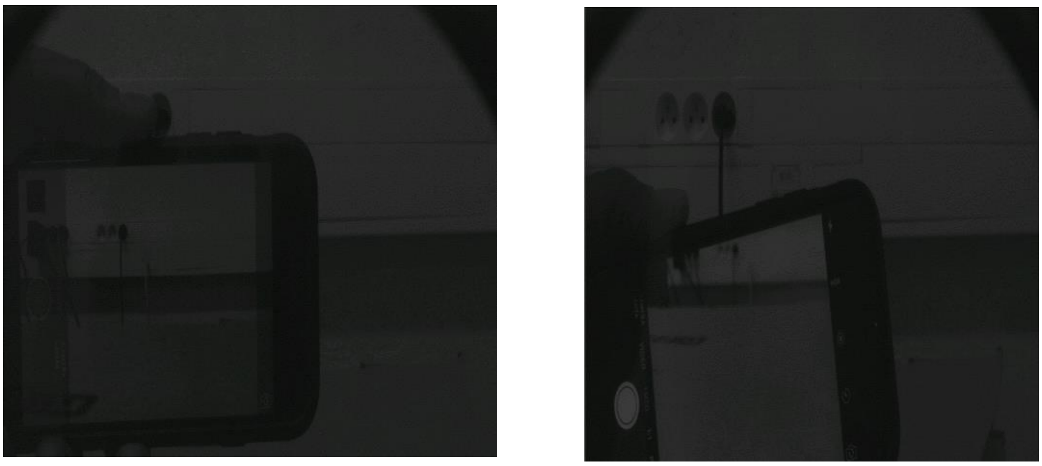
Figure 2. Guppy Camera and Polarizer

After mounting the camera and one linear polarizer we started to take images of the environment at different angles by rotating the polarizer. The angles are: 0º, 45 º, 65 º, 85 º, 100 º, 120 º, 200 º, 260 º and 330 º.

Polarizer at 0 º and 45 º



Polarizer at 85 º and 200 º



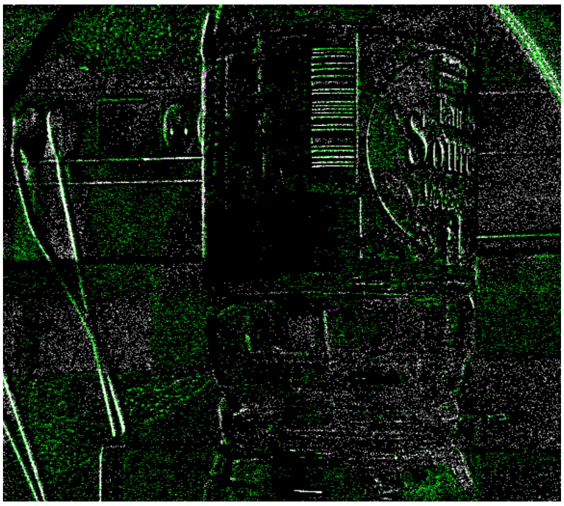
Polarizer at 260 º and 330 º

Figure 3. Polarizer set with different angles

Wolff’s Method

Polarization parameters are computed as below in Matlab:

```
I = Ip0 + Ip90;
num = (I-2*photo45);
den = (I-2*photo90);
fracphi = num ./ den;
rho =   sqrt(  (double(num.^2)) + (double(den.^2))) /double(I);
```



Angle of Polarization Degree of Polarization

Figure 4. Angle and degree of polarization using wolff’s method

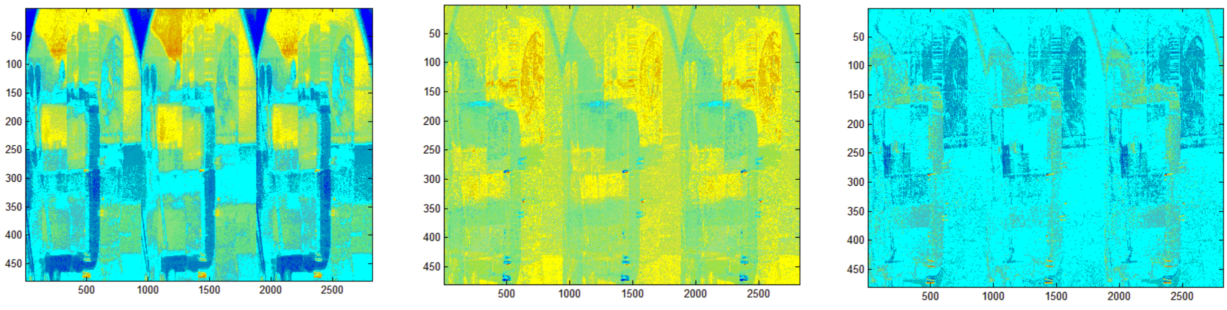
Least Mean Square Method

For computing the LMS Method, we take many pictures by rotating the polarizer at many different angles like 0º, 45º, 85º, 90º, 100º, 120º, 200º and 260º. Now we will calculate the least mean square method by calculating the parameters of the stokes vector S0, S1 and S2 by using Matlab. The code follows as:

```
Im0=double(imread('0.png'));
Im45=double(imread('45.png'));
Im85=double(imread('85.png'));
Im90=double(imread('90.png'));
Im100=double(imread('100.png'));
Im120=double(imread('120.png'));
Im200=double(imread('200.png'));
Im260=double(imread('260.png'));
[n1 n2]=size(Im0);
A= 0.5 * [ 1 cos(0) sin(0);
 1 cos(2*45) sin(2*45);
 1 cos(2*85) sin(2*85);
 1 cos(2*90) sin(2*90);
 1 cos(2*100) sin(2*100);
 1 cos(2*120) sin(2*120);
 1 cos(2*200) sin(2*200);
 1 cos(2*260) sin(2*260)];
for i=1:n1
 for j = 1:n2
 P = [Im0(i,j); Im45(i,j);
 Im85(i,j); Im90(i,j);
 Im100(i,j); Im120(i,j);
 Im200(i,j); Im260(i,j);];
 s_temp = (A' * A)^(-1)*A'*P;
 S0(i,j) = s_temp(1);
 S1(i,j) = s_temp(2);
 S2(i,j) = s_temp(3);
 end
```

```
end
figure;imagesc(S0);
figure;imagesc(S1);
figure;imagesc(S2);
```

The results for S0, S1 and S2 are as follows:



S0 S1 S2

Figure 5. Illustration of LMS Method

Contrast Polarization Measurement

In contrast polarization, we use two polarizers to change the direction and to remove the specular reflections. At first, we tested by keeping the first polarizer as constant and changing the second polarizer (newly added) in three step ways of 0º, 45º and 90º. The images are shown in below figure.

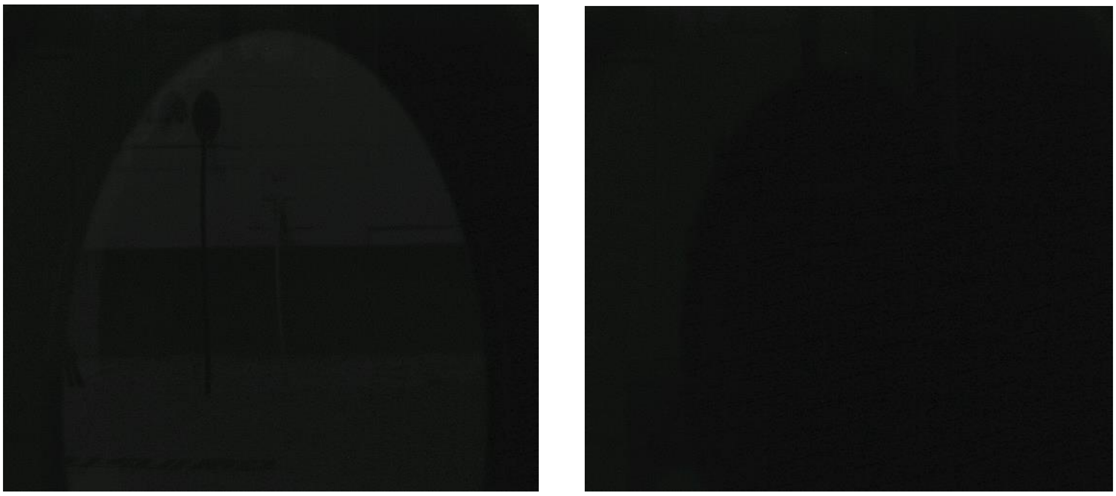


Figure 6. Two polarizers with (00 º - 00 º), (45 º - 00 º) and (90 º - 00 º)

From the above figure, we can observe that, the first polarizer is constant and we change the angle of new polarizer from 0 to 90 degree. There will be change of decrease intensity as we change the angle of polarizer. When the polarizer reaches to 90º, there will be a complete dark image.

Now we will keep our newly added polarizer to 0 and change the old polarizer from 0º to 90º in three step ways of 30º, 50º and 90º. The images are shown below.

Figure 7. Two polarizers with (00 º - 30 º), (00 º - 50 º) and (00 º - 70 º)

The Malus law state the following:

$$I = I_0 \cos^2 \theta_I$$

Where I_0represents the initial intensity. If two polarizers are placed one after the other, the mutual angle between their polarizing axes gives the value of θ_I. By this formula, it is expected that the light intensity through two polarizers would decrease.

For the next step, we will insert acroptix switchable polarization rotator between two polarizers as labelled in below figure. Make sure acroptix USB LC driver is connected to the computer. This rotator is considered as third polarizer where we can change the value of voltage through LC software. The intensity of the image changes when we increase the voltage by acroptix software as the angle of polarizer is changed. At first we keep 0 mV, we will observe the image is completely dark and the image intensity increases as we increase the voltage to 2.3 mV. The images are labelled below.

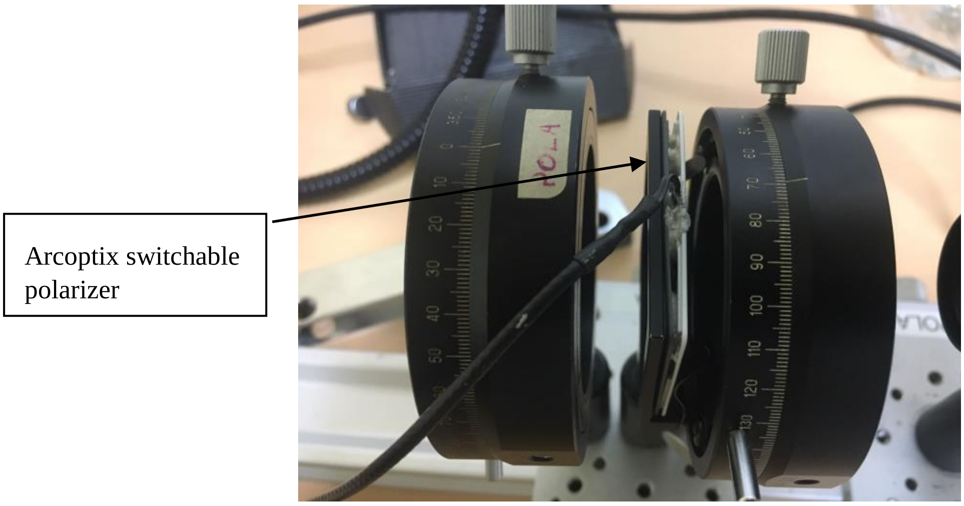


Figure 8. Acroptix Switchable polarizer with two polarizers

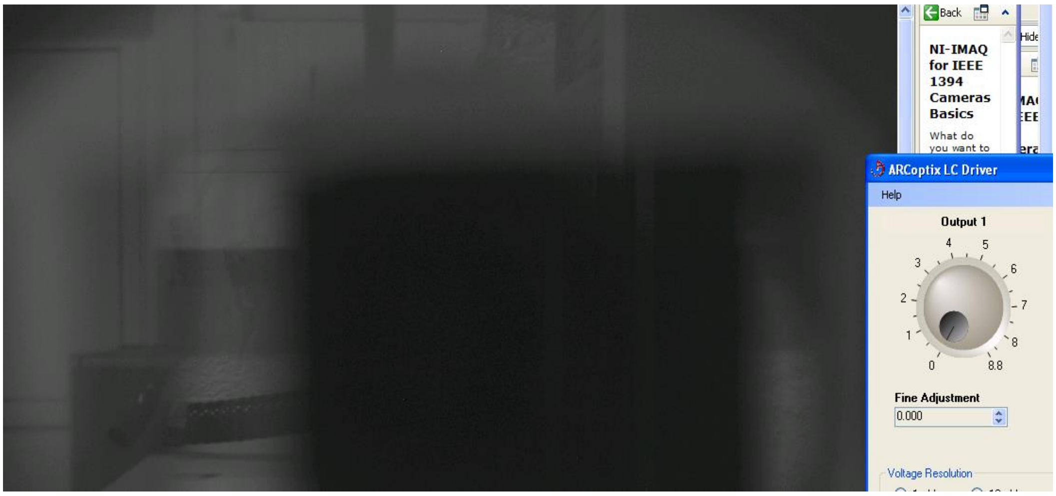


Figure 9. Rotator with 0 mV

Figure 10. Rotator with 2.8 mV

At the end, we will try with polarized light source called as diffuse specular reflection. This procedure is used to minimize the specular reflections from the images. This can be done by adding a polarized ring lightning source in front of the arcoptix polarizer as shown in the below figure.

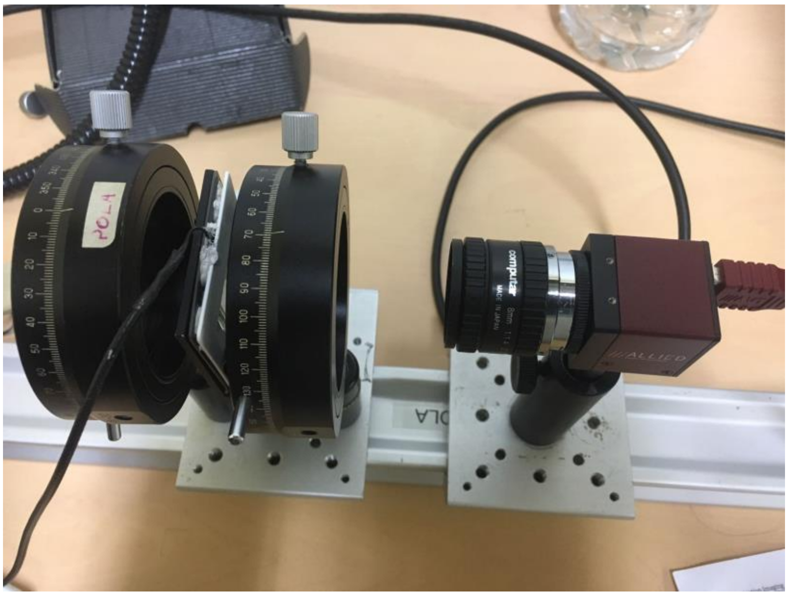


Figure 11. Lighting ring source polarizer

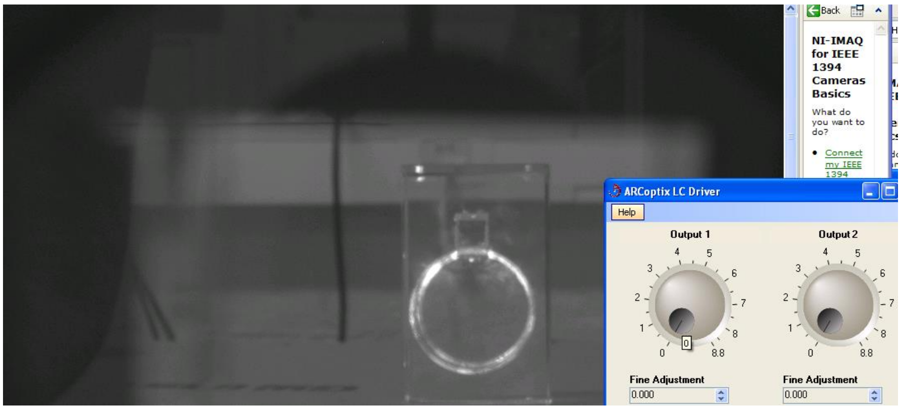


Figure 12. Polarizer in parallel

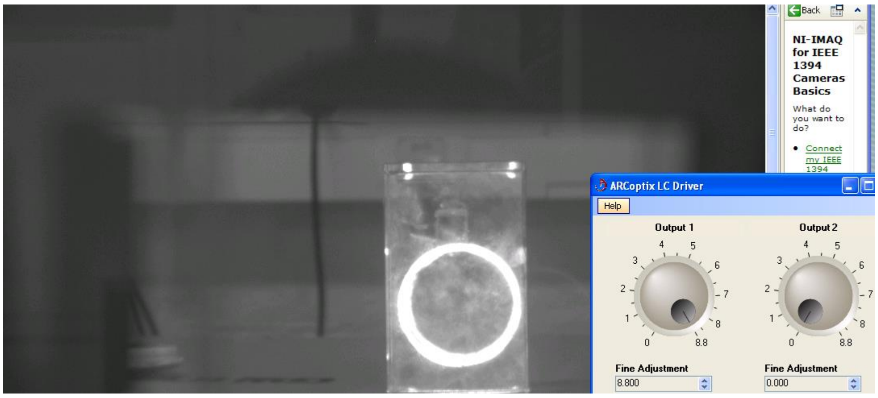


Figure 13. Polarizer in perpendicular

From the above pictures, it is observed that when the polarizers are parallel there will be reflections of light i.e.., specular reflections so we will make the polarizer to perpendicular which makes the better picture by defusing the reflections and increasing the intensity.

Conclusion

We have conducted various experiments with various polarizers like linear, acroptix and ring light source. The results are observed in Matlab and labelled with different pictures. The two methods simplified and contrast polarization are described precisely. For simplified we have used one polarizer and the results are observed in Matlab for both wolff’s method and least mean square method.

For contrast polarization measurement using Arcoptix rotator, we set the voltage resolution at one milli voltage and adjusted the voltage from software to see the changes of light intensity. All the results are tabulated with respective pictures.