PH4201: Adv. Optics Lab Report

Observation of Pancharatnam-Berry Phase in Polarized Light

Debayan Sarkar

Roll No: 22MS002

Sabarno Saha

Roll No: 22MS037

Diptanuj Sarkar

Roll No: 22MS038

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1. Aim

In this experiment, we will use the Michelson Interferometer to demonstrate the Pancharatnam-Berry phase in polarized light.

2. Materials required

1. Collimated Laser Source(wavelength: 650 nm)
2. Two Quarter-Wave Plates and one linear polariser
3. Two mirrors
4. Beam Splitter
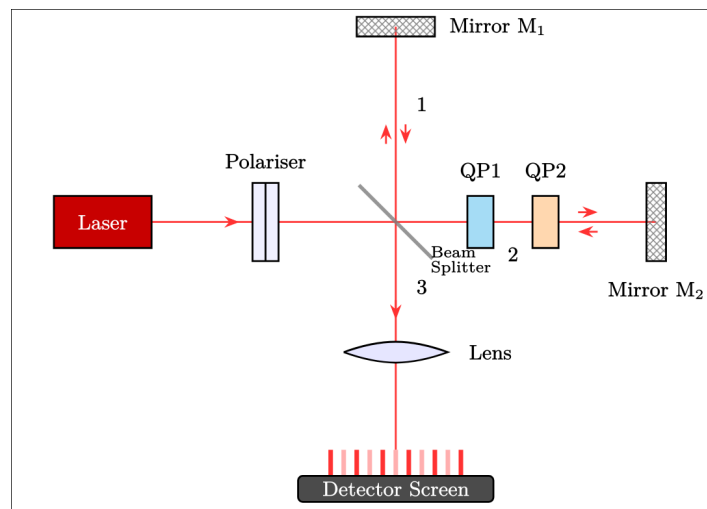5. Biconvex Lenses

3. Theory

Figure 1: Experiment Setup for a Michelson Interferometer, to observe the Pancharatnam-Berry phase in polarized light.
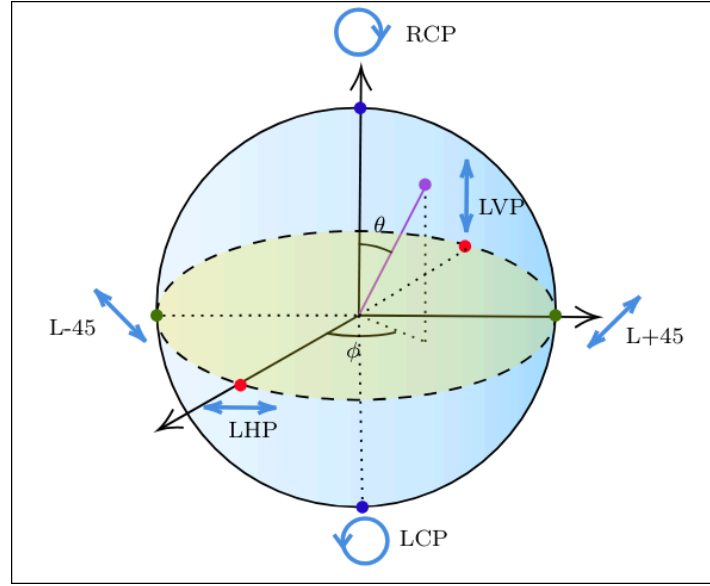
Figure 2: Poincaré sphere representation of the polarization states of light.
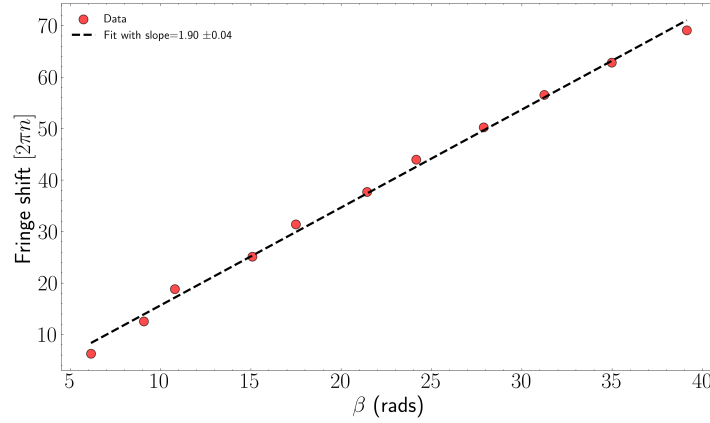
4. Results and Analysis

Figure 3: Fringe shift vs β for Data Set 1. The slope of the fit is 0.50 ± 0.02, which is in good agreement with the theoretical prediction of 0.5.

Figure 4: Fringe shift vs β for Data Set 2. The slope of the fit is 0.49 ± 0.02, which is in good agreement with the theoretical prediction of 0.5.

Figure 5: Fringe shift vs β for Data Set 3. The slope of the fit is 0.51 ± 0.02, which is in good agreement with the theoretical prediction of 0.5.
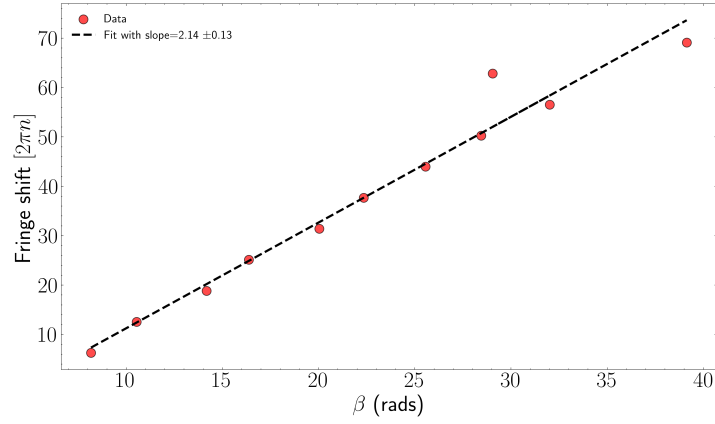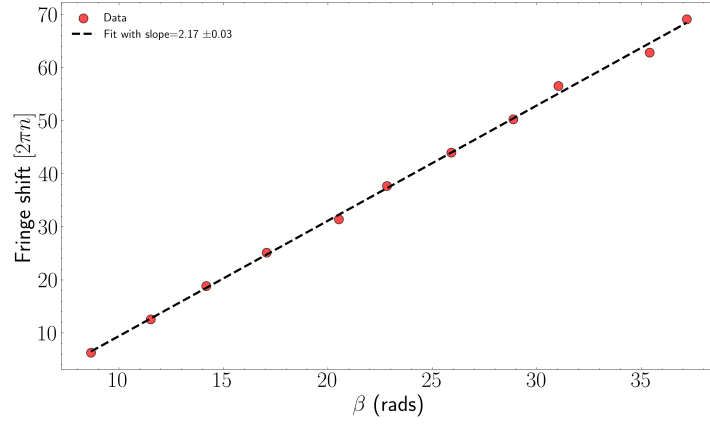

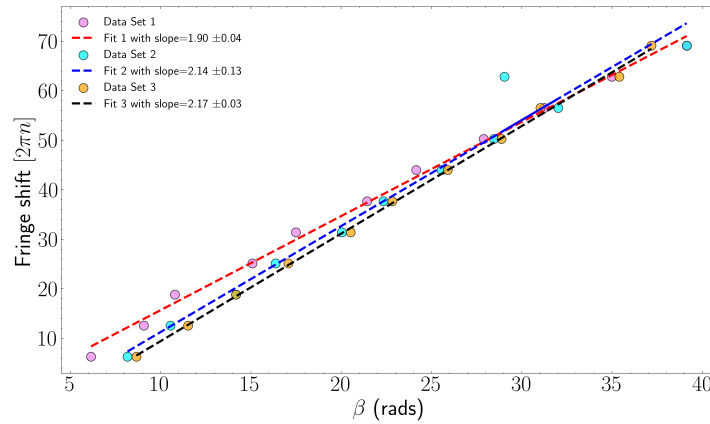**Figure 6:** Fringe shift vs β for all three data sets. The slopes of the fits are 0.50 ± 0.02, 0.49 ± 0.02, and 0.51 ± 0.02 for Data Sets 1, 2, and 3 respectively, all of which are in good agreement with the theoretical prediction of 0.5.

5. Discussion

5.1. Sources of error

Since refractivity of air is on the order of 10^{-6}, the experiment is a delicate one and is susceptible to a number of random and systematic errors that will be discussed below:

1. **Adiabatic heating**: Introduction of air into the pressure chamber causes adiabatic heating of the air inside. As a result, the temperature inside the chamber is slightly higher than the ambient temperature. Since refractivity is inversely proportional to temperature, this causes a systematic underestimation of the refractive index of air.

2. **Environmental changes in the composition of air**: The composition of the air in the room is subject to changes, as experimenters breathing near the setup can increase the concentration of carbon dioxide and water vapor locally. Since all these components have different specific refractivities, error is introduced in the calculated value of the refractive index.

3. **Geometric errors**: The alignment of the interferometer is a source of error, which can cause the fringes to be non-parallel. In the case of circular fringes, misalignment can cause the center of the rings to shift, or concentric rings to distort.

4. **Fringe counting error**: The dominant source of error in the experiment is, as mentioned before, the uncertainty in fringe shift counting. This can be mitigated or atleast estimated more conservatively if we have access to an electronic system to determine contrast on the interference pattern.

5. **Secondary reflections**: Observation of faint secondary fringes due to reflections from the surfaces of the beamsplitters and lenses can cause contrast reduction.

6. **Sphygmomanometer error**: The pressure gauge relies on a two way valve system to measure the pressure difference. As a result, the pressure fluctuates at lower pressures, causing uncertainty in the pressure measurement.

5.2. Inability to observe complementarity

In carrying out the last aim of the experiment, it was noticed that the phase inversion expected on the center of the ring fringes on each detector was not reliably visible. While no single reason could be isolated, here are some possible reasons for this:

1. **Plate beamsplitters are not ideal**: Since we are using a laser diode, the light is atleast slightly polarized. This, combined with the non-ideal nature of the beamsplitters make the phase shift on air-dielectric reflection a function of polarization, angle of incidence, and coating quality. This partial phase shift induced will result in the fringes not being exactly complementary.

2. The usage of two lenses also increases the effect of jitters on the interference pattern. This can destabilize the patterns and make the phase inversion difficult to resolve.

3. Asymmetric splitting at the second beamsplitter can cause a differential phase visibility on the two detector screens. Combined with the comparitively low resolution of the human eye and the low contrast, the makes the center spot difficult to resolve.

4. Speckle effects due to spatial coherence of the diode laser may also reduce resolvability of the center rings.

6. Conclusion

The refractive index of air was determined to be 1.000248 ± 0.000006. This is in good agreement with the accepted value of 1.000293. Spherical fringes were obtained, but a demonstration of the complementary nature of the center spot was not reliably shown.

7. Supplementary Data

Set 1 Data

β(in deg.)	β(in rad)	fringe shift
184	3.211405824	0
352	6.143558967	1
520	9.07571211	2
618	10.78613478	3
864	15.07964474	4
1002	17.4881991	5
1228	21.43264321	6
1384	24.15535685	7
1598	27.89036145	8
1790	31.24139361	9
2004	34.97639821	10
2242	39.13028183	11
2410	42.06243497	12
2640	46.07669225	13
2780	48.52015321	14
3022	52.74385	15

Set 2 Data

β (in deg.)	β (in rad.)	fringe shift
314	5.480333851	0
468	8.168140899	1
604	10.54178868	2
812	14.17207353	3
938	16.37118838	4
1148	20.03637981	5
1280	22.34021443	6
1464	25.55162025	7
1630	28.44886681	8
1834	32.00933848	9
1664	29.04227875	10
2242	39.13028183	11
2412	42.09734156	12
2628	45.86725274	13
2744	47.89183467	14
2906	50.71926806	15

Set 3 Data

β (in deg.)	β (in rad.)	fringe shift

296	5.166174586	0
496	8.65683309	1
660	11.51917306	2
812	14.17207353	3
978	17.06932008	4
1176	20.525072	5
1308	22.82890662	6
1484	25.9006861	7
1654	28.86774583	8
1778	31.0319541	9
2028	35.39527723	10
2130	37.17551307	11
2248	39.23500158	12
2418	42.20206131	13
2564	44.75024202	14
2698	47.08898322	15