Construct, Conduct & Comprehend Physics Experiments

LEOK-3-19 Building a Mach-Zehnder Interferometer and Analogizing Quantum Erasing

- *Complete set*
- *Cost effective solution*
- *Detailed instructional manual*
- *Easy alignment*

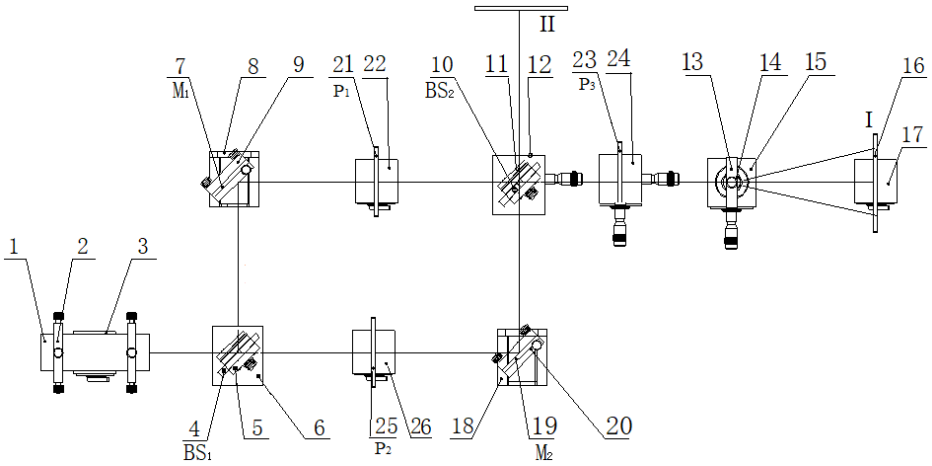

Figure 19-1 Schematic of experiment setup

1: He-Ne Laser L (LLL-2)
2: Laser Holder (SZ-42)
3: Magnetic Base (SZ-04)
4: Beam Splitter (5:5, BS_1)
5: Plate Holder (SZ-12)
6: Magnetic Base (SZ-04)
7: Flat Mirror M_1
8: Magnetic Base (SZ-04)
9: Two-axis Holder (SZ-07)
10: Beam Splitter (5:5, BS_2)
11: Plate Holder (SZ-12)
12: Magnetic Base (SZ-04)
13: Lens Holder (SZ-08)
14: Beam Expender (f'=4.5 mm)
15: Magnetic Base (SZ-04)
16: White Screen (SZ-13)
17: Magnetic Base (SZ-04)
18: Magnetic Base (SZ-04)
19: Flat Mirror M_2
20: Two-axis Holder (SZ-07)
21: Polarizer P_1 with Holder (SZ-51)
22: Magnetic Base (SZ-04)
23: Polarizer P_3 with Holder (SZ-51)
24: Magnetic Base (SZ-04)
25: Polarizer P_2 with Holder (SZ-51)
26: Magnetic Base (SZ-04)

Theory

The principle and configuration of a Mach-Zehnder interferometer (MZI) has been described in previous experiment and does not repeat here. This experiment is to analogize the working principle of a quantum eraser. As shown in Figure 19-1, three polarizers are used in the setup. After properly setting up the optical path, experimental phenomena can be observed in either path behind the second beam splitter.

Without polarizer P_3, rotate polarizer P_2 continuously (do not touch P_1), the visibility of the interference pattern will be changed periodically, i.e. when P_1 and P_2 are parallel, clear interference pattern can be observed, and when P_1 and P_2 are crossed at 90°, interference pattern disappears. This phenomenon has been explained through classical electrodynamics. From the point view of quantum-mechanics, if the light source of the MZI emits photons with known polarization direction (horizontal or vertical), when the two polarizers are 90° crossed, we can know the photons (as particles) pass through which arm of the interferometer when they arrive at the screen, this means we obtain the path information of the particles. Since an interference pattern is created by the wave property of light, from quantum mechanics, wave property and particle property cannot be observed simultaneously, therefore, no interference pattern can be observed when the two polarizers are 90° crossed. This experiment implies that photons have the property of wave-particle duality.

By inserting the third polarizer P_3 between the second beam splitter and the screen, when the polarization direction of P_3 is at 45° to both the polarizers P_1 and P_2, all of the photons passing through P_3 and arriving at the screen will have the same polarization directions, which means we cannot know which photon passing through which arm of the MZI, i.e. no path information is known or the path information is erased. Therefore, the interference pattern appears again on the screen.

Experiment Procedures

1. Refer to Figure 19-1, align all the components at same height on an optical table. At this moment, the beam expander and the three polarizers should not be placed in the light path.
2. Adjust the output of the He-Ne laser to make it parallel to the surface of the optical table;
3. Adjust beam splitter BS_1 at an angle of 45° with respect to the beam axis, and adjust its tilt so that the two beams (transmission and reflection) are parallel to the table;
4. Adjust mirrors M_1 and M_2 until the light beams reflected by them parallel to the table surface and strike at the same position on BS_2;
5. Insert the beam expander, interference pattern should be observed on the screen (if not, repeat the above steps); depending on the situation of the intersection angle of the two interference beams, the pattern shape could be rings, partial rings or straight lines.
6. Finely adjust the tilt angle of M_2, obtain optimal interference pattern;
7. Insert two polarizers (P_1 and P_2) respectively in the two arms of the MZI optical path. Let the direction of P_1 polarization at approximate 45° intersection with the laser polarization. Rotate P_2 continuously, the interference pattern periodically disappears and appears every 180° of rotation.
8. At the time of interference pattern disappears, i.e. P_1 and P_2 are 90° crossed, insert the third polarizer P_3 in between the beam splitter BS_2 and the white screen. Rotate P_3 continuously, the interference pattern periodically disappears and appears every 90° of rotation.

Note:

1. Since the He-Ne laser source is polarized, may rotate the laser tube to adjust the polarization direction of the input beam to enabling the light intensities in the two arms as closer as possible.
2. For correctly using the beam splitter, please set the front surface of the beam splitter to face to the incident light and let the light reflected from the front surface.