Novel Double Slit Experiments: Right-hand Rule and Left-hand Rule —Interference Patterns Curved, Expanded and Inclined Simultaneously

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Keywords: double slit experiment, interference pattern, quantum mechanics, optics

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Novel Double Slit Experiments: Right-hand Rule and Left-hand Rule
---Interference Patterns Curved, Expanded and Inclined Simultaneously

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Abstract:
Young’s double slit experiments express the mystery of quantum mechanics. To explore the
mystery, varieties of the double slit experiments were performed. In this article, we show the novel
double slit experiments in which the following three phenomena emerged simultaneously:

(1) the interference patterns incline towards the axis that perpendicular to the axis the diaphragm
rotating around; (2) the interference patterns curved; (3) the distances between the fringes of the
interference patterns expanded. To determine the direction the pattern curved towards, we propose the
right-hand rule for the clockwise rotating diaphragm and the left-hand rule for the counterclockwise
rotating diaphragms. Those experiments show more mysteries of the double slit and provide
comprehensive data for developing/testing a theoretical model.

Declaration: this work has no potential interesting conflict

Keywords: double slit experiment, interference pattern, quantum mechanics, optics

1. Introduction
Young’s double slit experiment was first performed in 1801 [1,2], which, 100 years later, led to
wave-particle duality. Feynman called the double slit experiment ”a phenomenon which is impossible
[…] to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it
contains the only mystery [of quantum mechanics].” [3]. Moreover, the nature of photons truly puzzled
Einstein. He wrote to M. Besso: “All these 50 years of conscious brooding have brought me no nearer
to the answer to the question: What are light quanta?” [4].

In the standard double slit experiments, the characteristics of the interference patterns are
described by three factors, wave length, the spacing between two slits and distance between the double
slit and screen, as described by equation, \( y_{\text{const}} = \frac{m \lambda}{d} L \). Note that (1) there is only one factor related
to the parameter of the diaphragm of the double slit, i.e., the spacing \( d \); (2) the fringes of the interference pattern distribute along a straight line; (3) the equation was derived for a special situation that the light beam is perpendicular to the plane of the diaphragm of the double slit.

We raised a question whether the orientations of the diaphragm affect the characteristics of the interference pattern? To answer this question, several experiments have been performed [5] [6] [7] [8].

The double slit experiments show that the characteristics of the interference patterns vary with different orientations of the diaphragm of double slit. Namely, when the diaphragm rotates around Y-axis which is defined to be perpendicular to the double slit, the interference pattern curved; while the diaphragm rotates around Z-axis which is defined to be parallel with the double slit, the distances between the fringes expand.

The cross-double slit experiments show that, beside the above two phenomena, portion of the interference patterns incline towards the axis that is perpendicular to the axis the diaphragm rotating around.

We raise a question whether the interference patterns of the double slit experiments incline?

In this article, we show that, by rotating the diaphragm of the double slit around one axis, all of three phenomena are observed in the same interference pattern simultaneously: (1) the interference patterns incline towards the axis that perpendicular to the axis the diaphragm rotating around; (2) the interference patterns curved; (3) the distances between the fringes of the interference patterns expanded.

To determine the curved direction of the interference patterns, we propose Left-hand Rule and Right-hand Rule.

2. **Apparatus**

The experiments utilize a laser source, the diaphragms of the double slit, a protractor and a screen/detector. To study, we setup the diaphragm of the double slit in two original orientations:

1. **First original orientation**: X-axis is along the normal vector of the plane of the diaphragm, setup Y-axis is vertical and in the plane of the diaphragm and passing through the spot the laser beam passing through (Figure 1); the angle between the double slit and Y-axis is 45° clockwise.
(2) **Second original orientation**: the angle between the double slit and Y-axis is 45° counterclockwise (Figure 2).

![Figure 1 Diaphragm of First Orientation and Original Interference Pattern-1](image1.png)

![Figure 2 Diaphragm of Second Orientation and Original Interference Pattern-2](image2.png)

### 3. Experiments

#### 3.1. Experiments with First Original Orientation

With the setup of First original orientation,

![Figure 1](image3.png)

we perform experiments in two steps.

**First step**: rotating the diaphragm 60° and 75° respectively around Y-axis counterclockwise (Figure 3).

![Figure 3](image4.png)

**Observation** (Figure 3b and 3c): the larger the rotation angle of the diaphragm, the larger the expansion of the distance between the fringes, the smaller the curvature, and the closer to the horizontal axis. The interference pattern curved upwards.

**Second step**: rotating the diaphragm 60° and 75° respectively around Y-axis clockwise.
Figure 4 Rotating diaphragm around Y-axis clockwise: (b) $60^\circ$; (c) $75^\circ$

**Observation** (Figure 4b and 4c): the larger the rotation angle of the diaphragm, the larger the expansion of the distance between the fringes, the smaller the curvature, and the closer to the horizontal axis. The interference pattern curved downwards.

### 3.2. Experiments with Second Original Orientation

With the setup of Second original orientation,

![Figure 2](image)

Figure 2

we do experiments in two steps.

**First step:** rotating the diaphragm $60^\circ$ and $75^\circ$ respectively around Y-axis counterclockwise (Figure 5).

Figure 5 Rotating diaphragm around Y-axis counterclockwise: (b) $60^\circ$; (c) $75^\circ$

**Observation** (Figure 5b and 5c): the larger the rotation angle of the diaphragm, the larger the expansion of the distances between the fringes, the smaller the curvatures, and the closer to the horizontal axis. The interference pattern curved downwards.

**Second step:** rotating the diaphragm $60^\circ$ and $75^\circ$ respectively around Y-axis clockwise.
Observation (Figure 6b and 6c): the larger the rotation angle of the diaphragm, the larger the expansion of the distances between the fringes, the smaller the curvature, and the closer to the horizontal axis. The interference pattern curved upwards.

4. Left-Hand Rule and Right-Hand Rule to Determine Directions Patterns Curved towards

We have shown that, due to the rotations of the diaphragm, either clockwise or counterclockwise, the patterns/interference patterns curved [5] [6] [7] [8]. To determine the direction the patterns curved towards, we propose Left-hand Rule and Right-hand Rule.

4.1. Left-hand Rule and Right-hand Rule

The experiments above show complex forms showing how the interference patterns curved towards. To determine the direction of the interference patterns curved towards, we propose the Left-hand Rule and Right-hand Rule.

Left-hand Rule: For the curved pattern created by diaphragm rotating counterclockwise. To determine the direction of the patterns curved towards, point the left thumb to the source, the index finger is aligned with the direction of the original pattern, and the middle finger will point in the direction of the patterns curved towards, which is attributed to the counterclockwise rotation of the diaphragm.

Right-hand rule: For the curved pattern created by diaphragm rotating clockwise.
To determine the direction of the patterns curved towards, point the right thumb in the direction of the source, the index finger is aligned with the direction of the original pattern, and the middle finger will point in the direction of the patterns curved towards, which is attributed to the clockwise rotation of the diaphragm.

![Figure 8 Right-hand Rule](image)

4.2. Testing Left-hand Rule and Right-hand Rule

The experiments above obey Left-hand Rule and Right-hand Rule. Now let us test other curved pattern/interference patterns reported before [6] [7] [8].

**Single slit experiments.** Rotating the diaphragm of the single slit around Y-axis.

![Figure 9](image)  ![Figure 10](image)

Figure 9 shows its original vertical pattern of the single slit experiments. Then rotating the diaphragm clockwise, the created patterns are curved towards the left as shown in Figure 10, which obeys Right-hand Rule. Then rotating the diaphragm counterclockwise around Y-axis, the created patterns are curved towards the right as shown in Figure 11, which obeys Left-hand Rule.

**Double slit experiment.** Rotating the diaphragm of the double slit around Y-axis.

![Figure 12](image)  ![Figure 13](image)  ![Figure 14](image)
Figure 12 shows its original vertical interference pattern of the double slit experiments. Then rotating the diaphragm clockwise, the created patterns are curved towards the left as shown in Figure 13, which obeys Right-hand Rule. Then rotating the diaphragm counterclockwise around Y-axis, the created interference patterns are curved towards the right as shown in Figure 14, which obeys Left-hand Rule.

5. Possible Application

The novel phenomena of the double slit experiments may be applicable in industry, such as in the grating-based x-ray imaging/tomography [9]. The grating is the multi-slits.

6. Summary

By rotating the diaphragm of the double slit around one axis, we observe three phenomena simultaneously, namely, the interference patterns curved, expanded and inclined simultaneously (see attached video).

To determine the direction of the curved interference patterns, we propose Left-hand Rule and Right-hand Rule. The experiments in this article and in previous articles obey the rules. However, the underlying physics of the Rules is unclear.

Note:

Please see the next page for the link to the attached video which shows the evolution of the interference pattern of the novel double slit experiments presented in this paper. The video shows how the characteristics of the interference patterns vary when the diaphragm is rotating. We start from the original orientation of the diaphragm, namely, the laser beam is perpendicular to the plane of the diaphragm and the angle between the double slit and the vertical direction is 45 degrees. The original interference pattern is shown.

Then rotating the diaphragm around the vertical direction counterclockwise. The interference patterns change gradually in three aspects continuously:

First aspect, the whole pattern is inclined towards the horizontal axis.
Second aspect, the distances between fringes are expanded.
Third aspect, the patterns curve upwards.

Then go back to the original orientation and rotate the diaphragm clockwise. The interference patterns still vary in three aspects: First and Second aspects are the same. Third aspect, the patterns curve, but to opposite direction, i.e., downward.

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Appendix: Attached Video of evolution of the characteristics of the interference patterns of the double slit experiments.

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Supplementary Files

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- 020210719patternevolution.mp4