

Non-Uniform Diffraction Pattern of 2D-Cross-Grating—Rotating Grating Around Three Axes (4)

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Research Article

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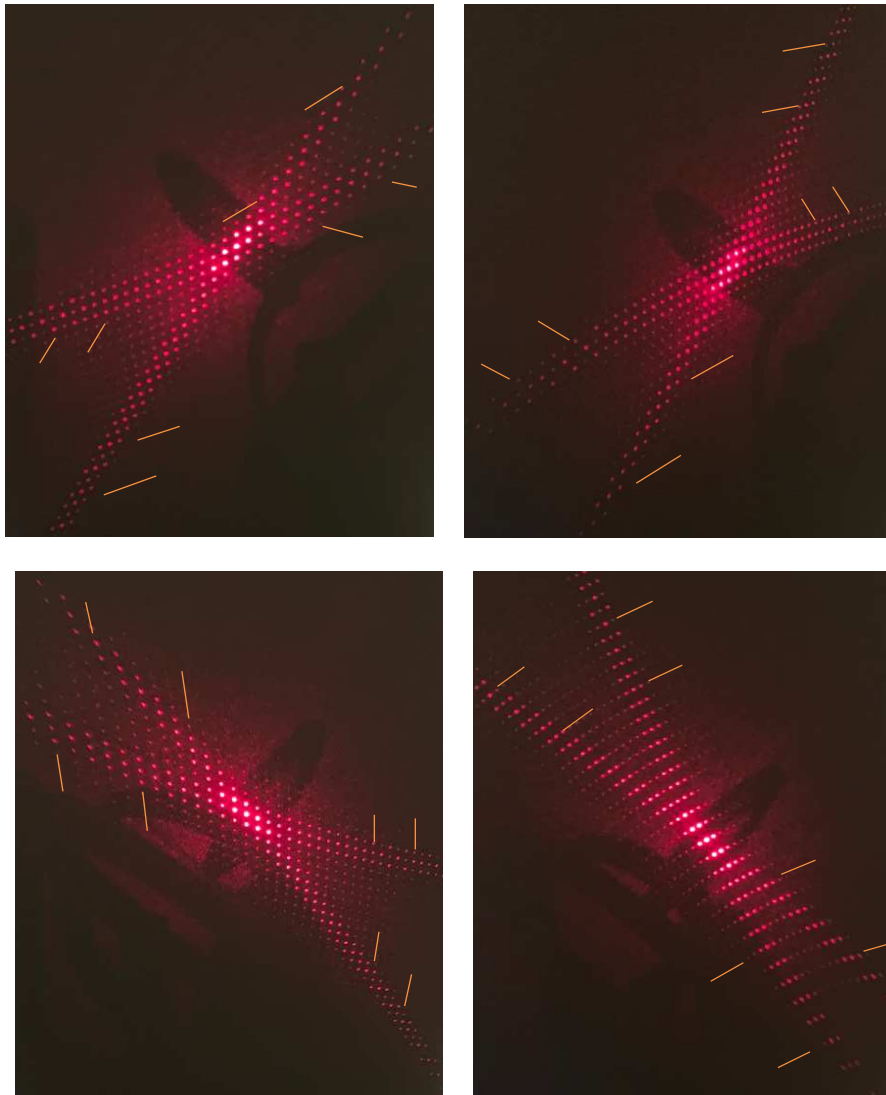
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Non-Uniform Diffraction Pattern of 2D-Cross-Grating ---Rotating Grating Around Three Axes (4)

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Abstract The orientation-dependence of the diffraction patterns of the 1D-grating experiments have been systematically studied by utilizing the 3-axis-rotation apparatus. It is shown that the spacings between adjacent diffraction orders are non-uniform. Namely, from “one end” of the pattern to “other end”, the spacings between adjacent diffraction orders gradually increase. In this article, we systematically study the orientation-dependence of the diffraction patterns of the 2D-cross-grating. The experiments show that the diffraction patterns are non-uniform as that of the 1D-grating experiments.



This extraordinary phenomenon challenges the existing theoretical description of the grating experiments. The above observed phenomena provide the comprehensive phenomena to theoretical

study of the grating experiments. We suggest that the complete mathematical model should contain three rotation angles as parameters and should be able to describe the phenomena of the non-uniform-spacing, curved, expanded, inclined and mirror-symmetric diffraction patterns consistently.

Keywords: grating experiment, cross-grating experiments, diffraction pattern, normal incident light beam, oblique incident light beam, orientation-dependence, non-uniform diffraction pattern, curved diffraction pattern, expanded diffraction pattern, inclined diffraction pattern, mirror-symmetric pattern

Declaration: This article has no potential conflicts of interesting

1. Introduction

The orientation-dependence, for certain orientations, of the interference patterns of the 1D-double slit and 2D-cross-double slit experiments have been studied experimentally [1-4]. The universal phenomena of the curved, expanded and inclined patterns were observed.

Recently, we have introduced the 3-axis-rotation apparatus [5], by which, the orientation-dependence of the diffraction patterns of the 1D-grating experiments have been studied [5-7]. The simultaneously non-uniform spacing, curved, expanded, inclined and mirror-symmetric diffraction patterns (hereafter denoted as “pattern”) emerged in the 1D-grating experiments. Indeed, the new phenomena show that the characteristics of the patterns depend on the orientations of the grating.

In this article, we study the orientation-dependence of the patterns of the 2D-cross-grating by utilizing the 3-axis-rotation apparatus. The 2D-cross-grating is rotated around three axes sequentially and respectively. The study of the patterns is achieved intuitively. We observed the phenomena that, the spacings between adjacent diffraction orders are *non-uniform*.

The phenomena challenge both the standard theory of the grating for the normal incident light beam and the theories of the grating for the oblique incident light beam [8-11].

The novel phenomena of the continuously non-uniform spacing, curved, expanded, inclined, and mirror-symmetric patterns provide the comprehensive phenomena to theoretically study the grating experiments. We suggest that a complete mathematical model should contains three rotation angles as parameters and should be able to describe all phenomena of the orientation-dependence of the patterns consistently.

2. Three-Axis-Rotation Apparatus and Associated Coordinate System

The 3-axis-rotation apparatus has been proposed (Figure 01) [5]. Figure 01 shows the experimental setup and the coordinate. The horizontal slits S1 and the vertical slits S2 create the vertical pattern and

horizontal pattern respectively, referred as branch-patterns. In the previous articles [7], the 1D-grating has been rotated around 3 axes.

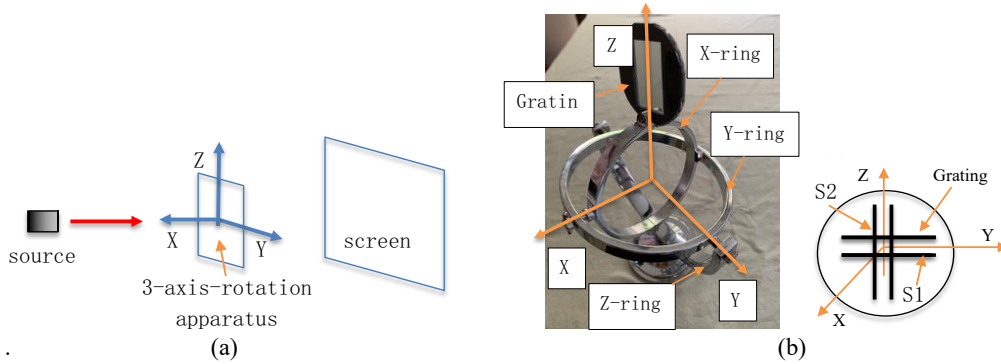


Figure 01. Experimental setup (a); the 3-axis-rotation apparatus and 2D-cross grating (b):

the 2D-cross-grating can be rotated around X-axis, Y-axis and Z-axis

In this article, we perform four experiments by rotating the 2D-cross-grating around 3 axes.

Namely, rotating the 2D-cross-grating clockwise (CW) and counterclockwise (CCW) around X axis, CW and CCW around Y axis, and CW and CCW around Z axis respectively and sequentially.

Direction of Rotation: to define the direction of the CW and CCW rotation, we introduce the right-hand rule that states that the thumb of the right hand is pointed in the direction of the axis, the CCW rotation is given by the curl of the fingers (Figure 02).

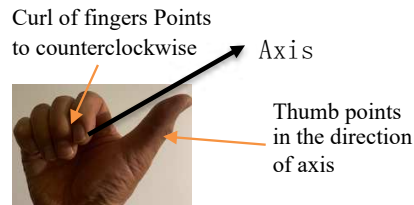
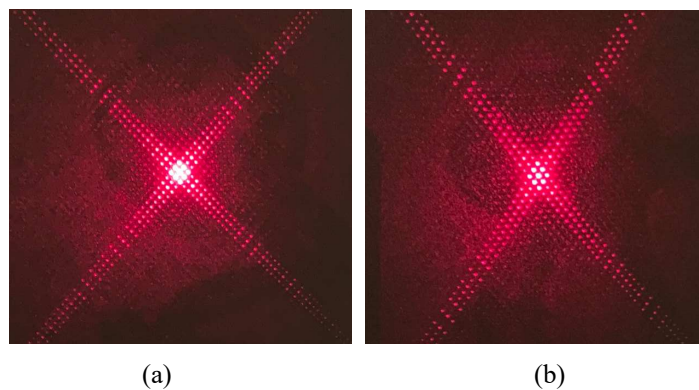


Figure 02. Right-hand rule for determining direction of rotation

CW vs. CCW rotation of the 2D-cross-grating: when rotating CW and CCW the 2D-cross-grating around the X-axis by the same angle, the diffraction pattern due to the CW rotation is the same as that due to the CCW rotation. Thus, we perform the experiments only with the CCW rotation around the X-axis. Experiments start with rotating CCW the 2D-cross-grating around X axis by 45° (Figure 03a).



(a)

(b)

Figure 03. Patterns; (a) 2D-cross-grating rotating CCW around X axis by 45° ; (B) 2D-cross-grating rotating CCW around X axis by 45° and, then rotating CW around Y axis by 45°

Figure 03a shows that the first rotation (around the X axis) of the apparatus causes the pattern rotating, and the characteristics of the pattern have no change. Figure 03b shows that the second rotation (CW around the Y axis) causes that each branch-pattern expanded, curved, and inclined towards the vertical axis.

In Experiment-1 to -4, we use the specific discrete angles for rotating around each axis, one can rotate the 2D-cross-grating either with any discrete angles or continuously rotating the 2D-cross-grating around any axis.

3. Experiments: Rotating 1D-grating Around 3 Axes

3.1. Rotating 2D-Cross-Grating CCW Around X Axis by 45° , CW Around Y Axis by 45° , Then Rotating CW and CCW Around Z axis

From the orientation of the 2D-cross-grating (Figure 03b), performing the following two Experiments, respectively: rotating the 2D-cross-grating CW and CCW around Z axis respectively.

Experiment-1: Rotating the grating: CCW X (45°) + CW Y (45°) + CW Z (70°)

Rotating the grating CCW around X axis by 45° , CW around Y axis by 45° and, then, CW around Z axis by 70° (Figure 1).

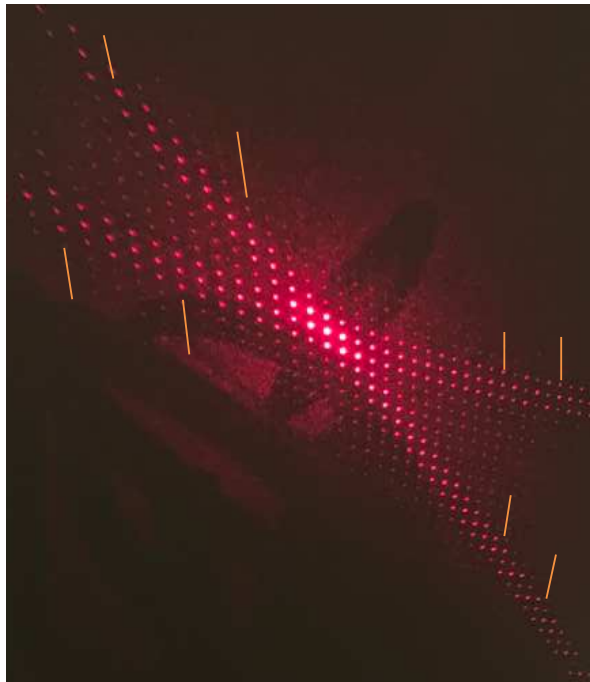


Figure 1. Patterns: rotating 2D-cross-grating CCW around X axis by 45° , then CW around Y axis by 45° , and CW around Z axis by 70°

Figure 1 shows the pattern of the 2D-cross-grating after rotating around 3 axes.

Observation: The comparison of Figure 03b and Figure 1 shows that the third rotation (around the Z axis) causes that each branch of the patterns expanded more, curved more, and inclined more towards the horizontal axis. The pattern as a whole rotates CCW.

The most significant novel phenomenon of Experiment-1 is that each branch of the pattern is expanded non-uniformly. More specifically, the expansion of the spacing between the adjacent diffraction orders of each branch of the pattern increase gradually from the bottom-portion to the top portion of the pattern. To show the expansion, we use the short-orange-lines that shows the distances between 5 diffraction orders on each branch of the pattern.

Experiment-2: Rotating the grating: CCW X (45°) + CW Y (45°) + CCW Z (70°)

Rotating the grating CCW around X axis by 45° , CW around Y axis by 45° and, then, CCW around Z axis by 70° (Figure 2).



Figure 2. Patterns: rotating grating CCW around X by 45° , CW around Y axis by 45° and CCW around Z axis by 70°

Observation: The comparison of Figure 03b and Figure 2 shows that the third rotation (around the Z axis) causes that each branch of the patterns expanded more, curved more, and inclined more towards the horizontal axis. The pattern as a whole rotates CW.

Experiment-2 shows the novel phenomena that each branch of the pattern is expanded non-uniformly. More specifically, the expansion of the spacing between the adjacent diffraction orders of each branch of the pattern increase gradually from the bottom-portion to the top-portion of the pattern. The short orange lines show the distances between 5 diffraction orders on each branch of the pattern.

3.2. Rotating 2D-Cross-Grating CCW Around X Axis by 45° , CCW Around Y Axis by 45° , Then Rotating CW and CCW Around Z axis

Next, let us rotate the grating CCW around X axis by 45° and CCW around Y axis by 40° (Figure 04b). Figure 04a shows the pattern after the first rotation (around the X axis) of the apparatus. Figure 04b shows that the second rotation (CCW around the Y axis) causes that each branch of the patterns expanded, curved, and inclined towards the vertical axis.

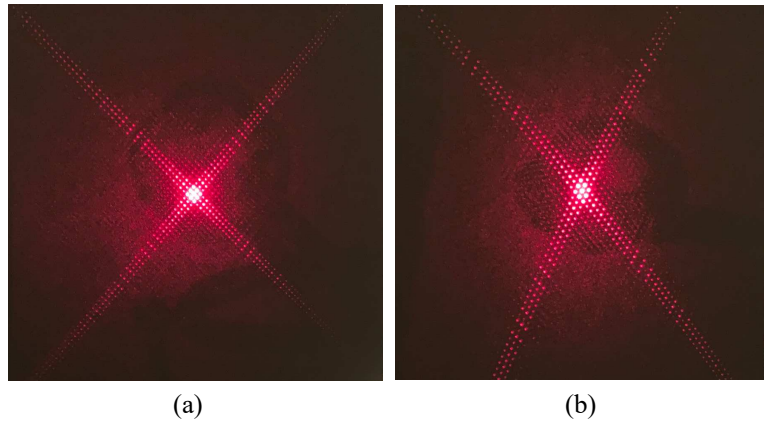


Figure 04. Patterns; (a) 2D-cross-grating rotating CCW around X axis by 45° ; (b) 2D-cross-grating rotating CCW around X axis by 45° and, then rotating CCW around Y axis by 40°

From the orientation of the 2D-cross-grating (Figure 04b), performing the following two Experiments, respectively: rotating the 2D-cross-grating CW and CCW around Z axis respectively.

Experiment-3: Rotating the grating: CCW X (45°) + CCW Y (40°) + CW Z (70°)

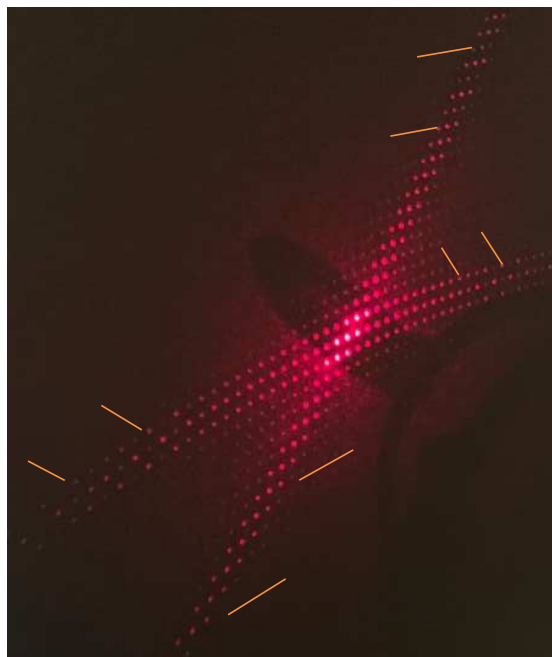


Figure 3. Patterns: rotating grating CCW 45° around X by 45° , CCW around Y axis by 40° and CW around Z axis 70°

Observation: The comparison of Figure 04b and Figure 3 shows that the third rotation (around the Z axis) causes that each branch of the patterns expanded more, curved more, and inclined more towards the horizontal axis. The pattern as a whole rotates CW.

Experiment-3 shows that the pattern is expanded non-uniformly (shown by the short orange lines on each branch of the pattern). Namely, the expansions of the spacings between the adjacent diffraction orders increase gradually from the top-portion to the bottom portion of each branch of the pattern.

Experiment-4: Rotating the grating: CCW X (45°) + CCW Y (40°) + CCW Z (75°)

Rotating the grating CCW around X axis by 45° , CCW around Y axis by 40° and, then, CCW around Z axis by 70° (Figure 4).

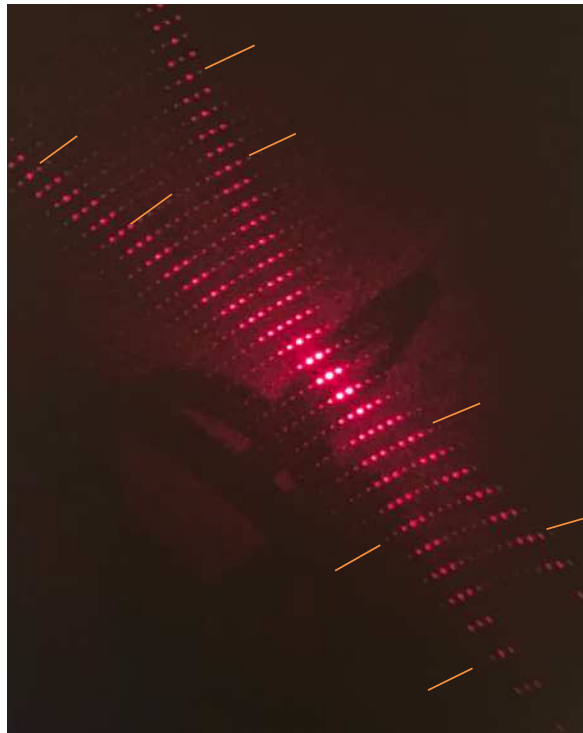


Figure 4. Patterns: rotating CCW grating around X by 45° , CCW around Y axis by 40° and CCW around Z axis by 75°

Observation: The comparison of Figure 04b and Figure 4 shows that the third rotation (around the Z axis) causes that each branch of the patterns expanded more, curved more, and inclined more towards the horizontal axis. The pattern as a whole rotates CW.

Experiment-4 shows that the pattern is expanded non-uniformly. Namely, the expansions of the spacing between the adjacent diffraction orders increase gradually from the top-portion to the bottom-portion of the pattern.

4. Discussion

The preliminary experiments of this article show, the first time:

(1) the non-uniform spacings between adjacent diffraction orders of the pattern of the 2D-cross-grating. More specifically, the spacings are gradually increase either from the top-portion to the bottom-portion of the pattern, or from the bottom-portion to the top-portion of the pattern.

(2) the phenomena of the non-uniform spacings exist regularly.

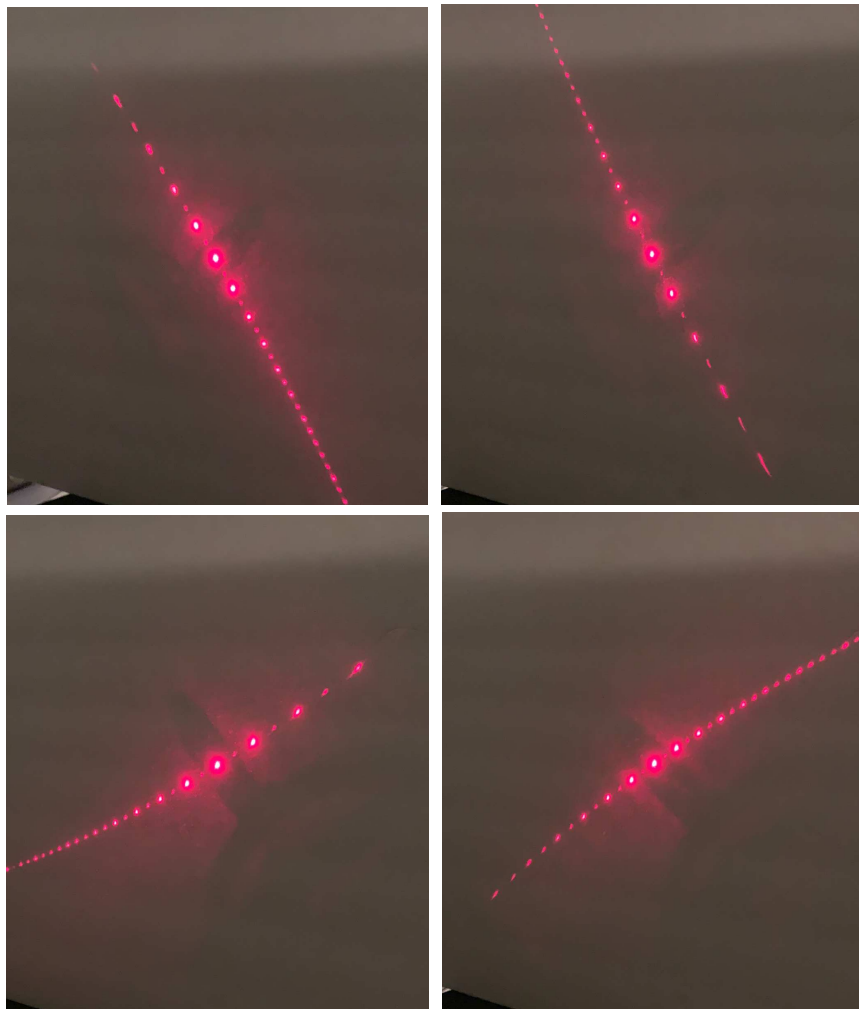
The phenomena challenge both the standard theory of the 1D-grating for the normal incident light beam and the theories of 1D-grating for the oblique incident light beam. For example, see [8-11] and references within.

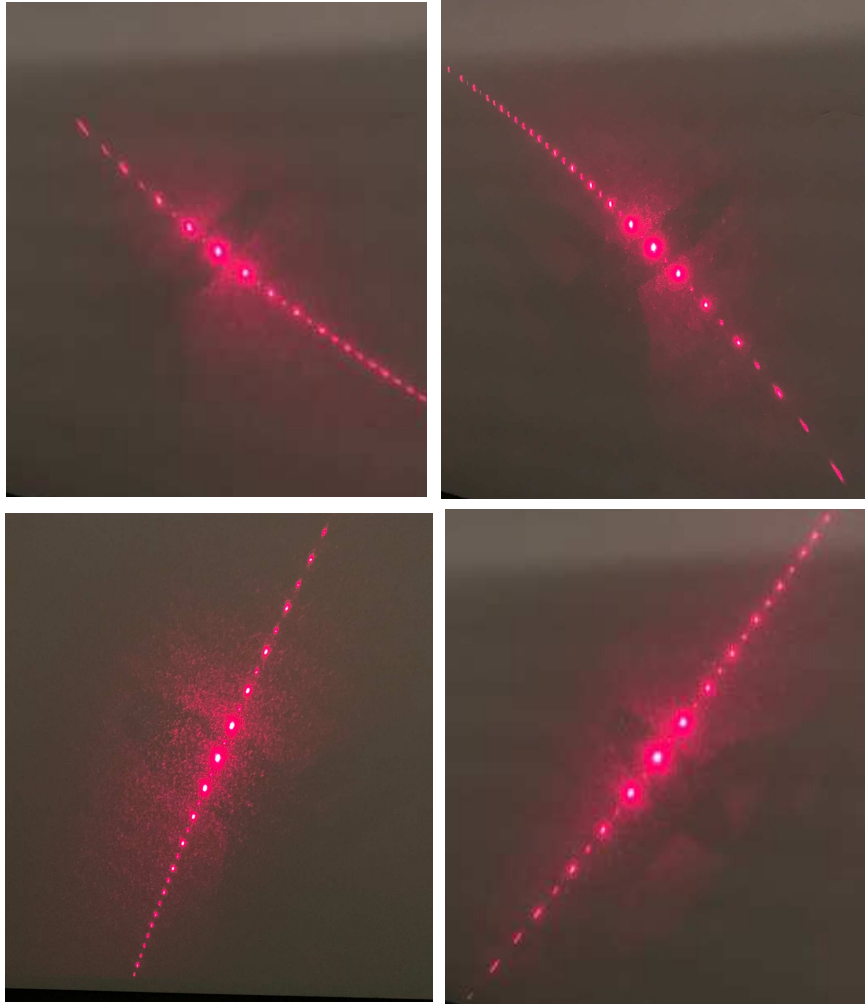
5. Recent Developments of Research on Double Slit and Grating Experiments

5.1. Recent Developments of 1-D-Grating Experiments

*) **non-uniform spacing between adjacent diffraction orders of the pattern of the 1D-grating [7]**

The comparison of the non-uniform spacings of the patterns of the 1D-grating (below) and of the 2D-cross-grating (Figure 1-4) shows that the spacing-increasing rate of the 1D-grating is larger than that of the 2D-cross-grating.





5.2. Recent Developments of Double Slit Experiments: Violate Wave Interpretations

Feynman stated that Young's double slit experiment was the mystery of the quantum mechanics. It is interesting to show how the study of the mystery of the double slit experiments has been progressed recently.

*) **Pattern of the standard double slit experiments:**



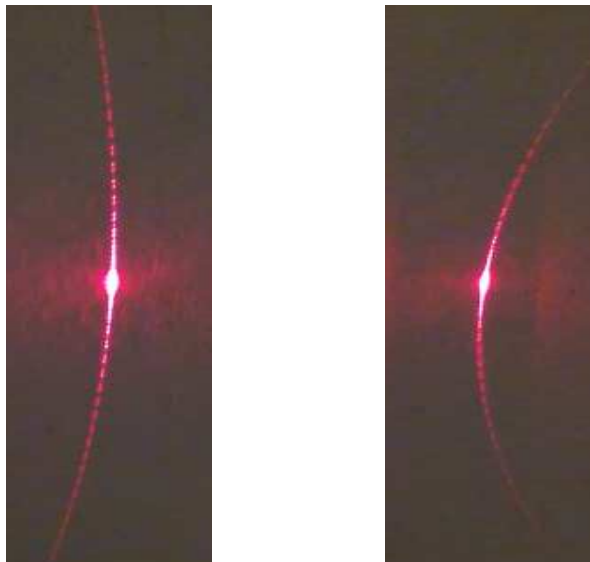
*) **Patterns of the cross-double slit experiments [12-14]:**



***) Expanded patterns of the same diaphragm of the double slit [1]:**



***) Curved patterns of the same diaphragm of the double slit [2] [15]:**



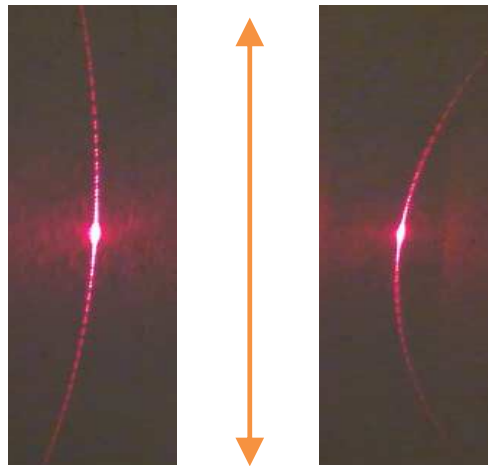
***) Curved and Expanded patterns of the same diaphragm of the cross-double slit [2]:**



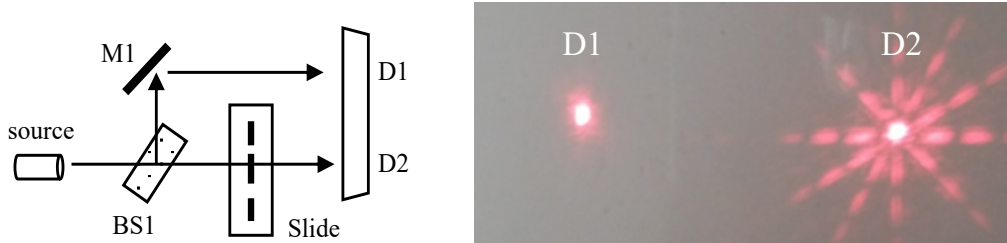
***) Curved, expanded and inclined patterns of same diaphragm of the tilted double slit [16,17]:**



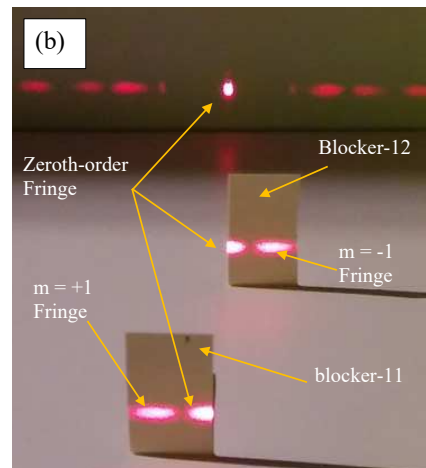
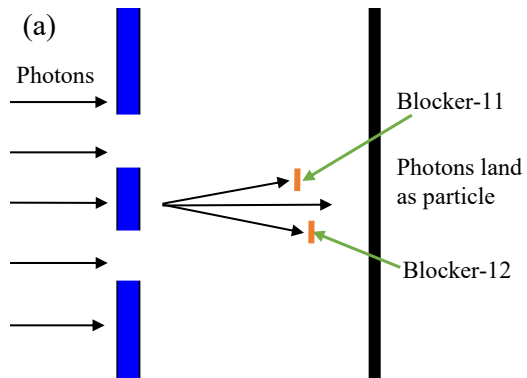
***) Mirror-symmetry Patterns of the same diaphragm of the double slit [6]:**

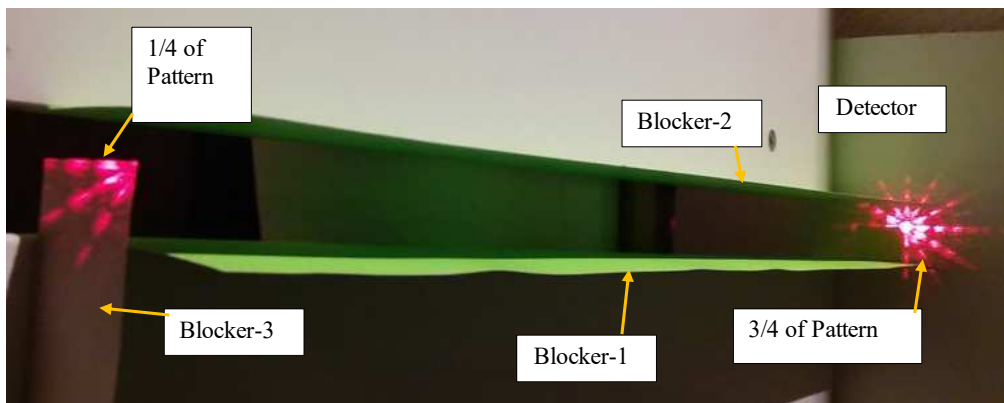
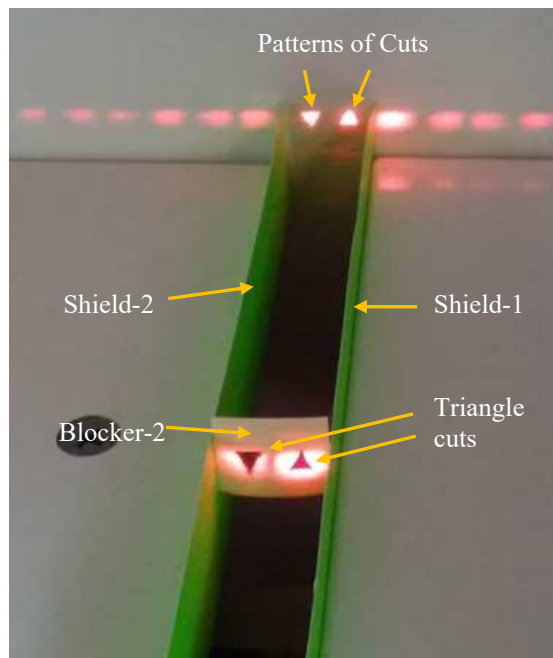
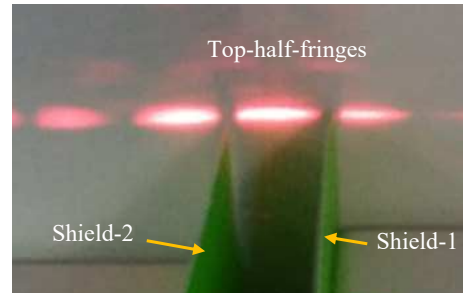
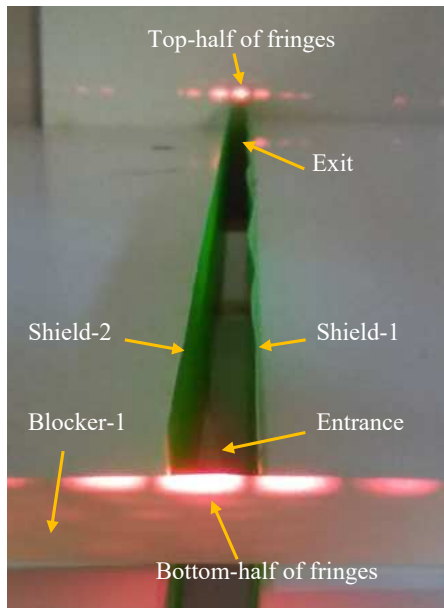


***) before passing through double slit, light beam behaves as particles, photons [18]**

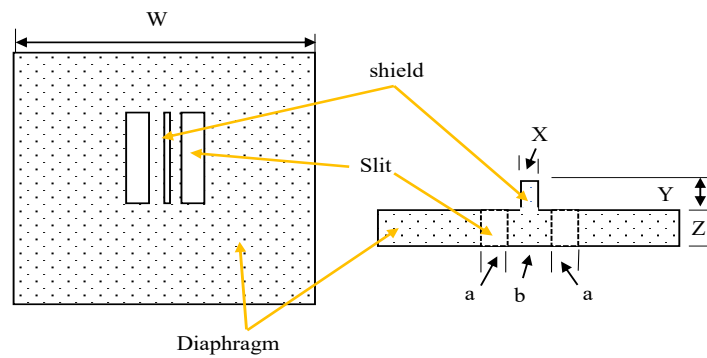
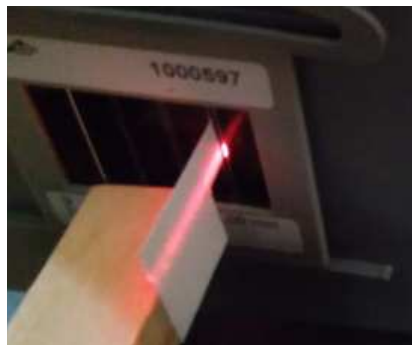
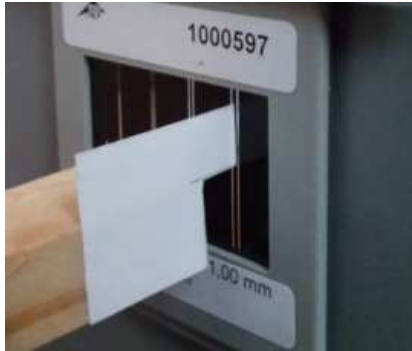
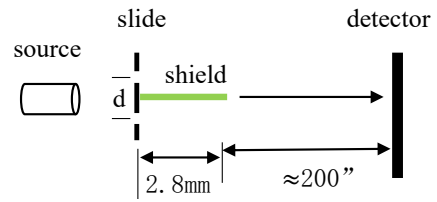
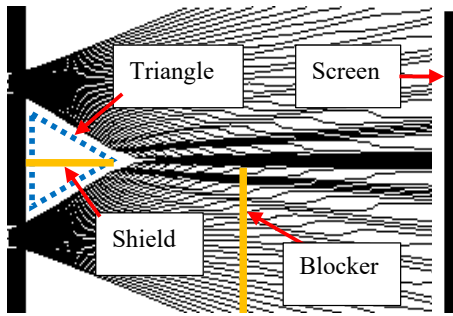


***) before landing on the screen, light beam behaves as particles, photons**



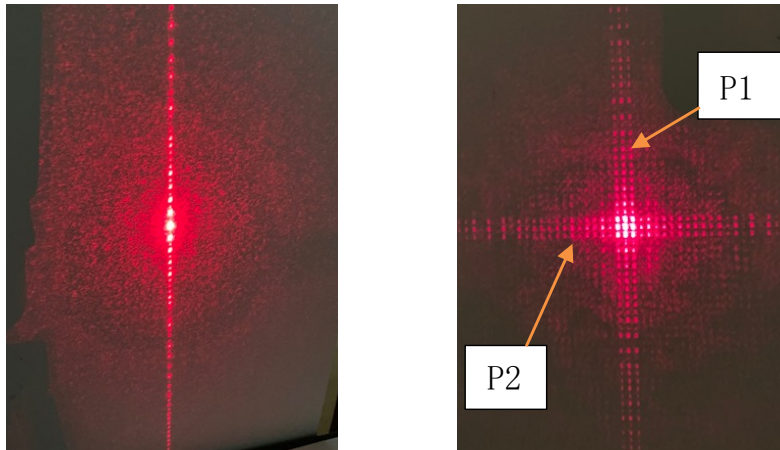


5.3. Violating Trajectory Theory: Shield contacting Diaphragm of double slit [19]



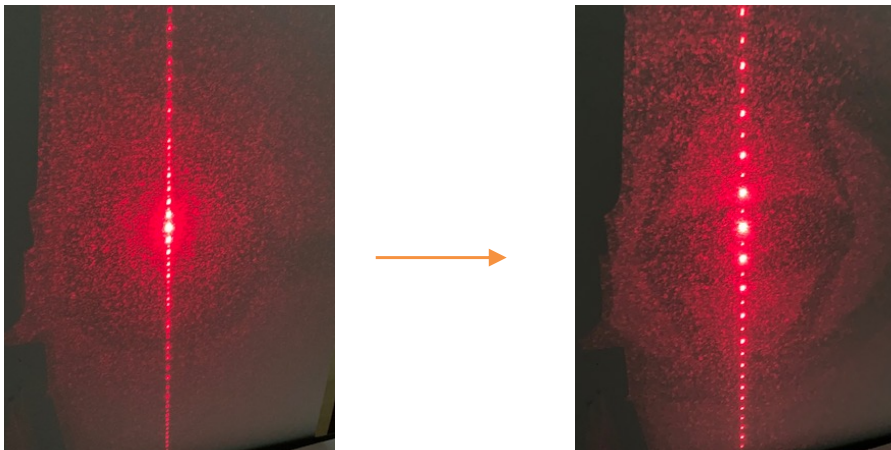
5.4. Recent Developments of 1D-Grating and 2D-Cross-Grating Experiments

*) Standard patterns of 1D-grating and 2D-Cross-Grating

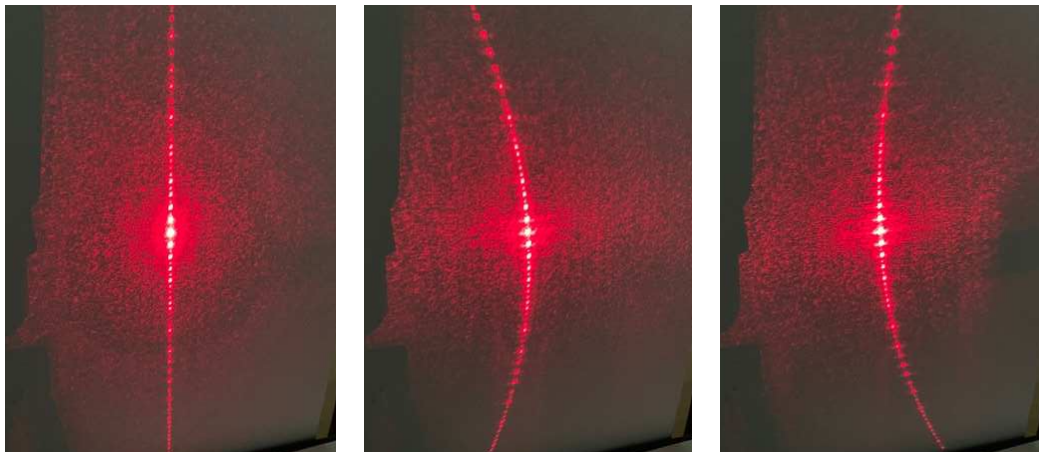


(B1) Recent Developments of 1D-Grating Experiments

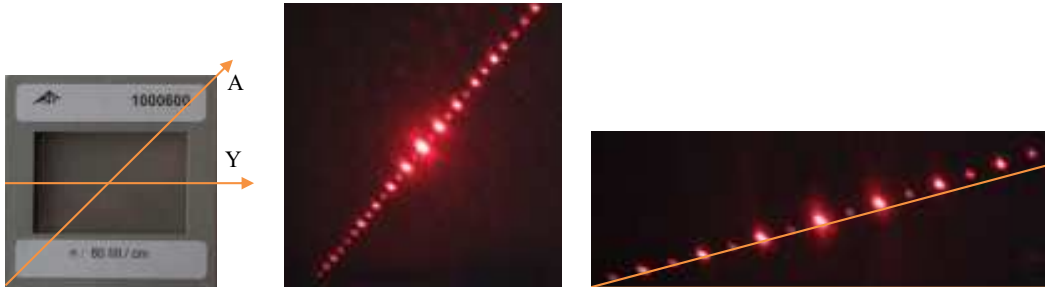
***) Expanded diffraction patterns of the same 1D-grating [17] [5]:**



***) Curved patterns of the same 1D-grating [5][4]:**

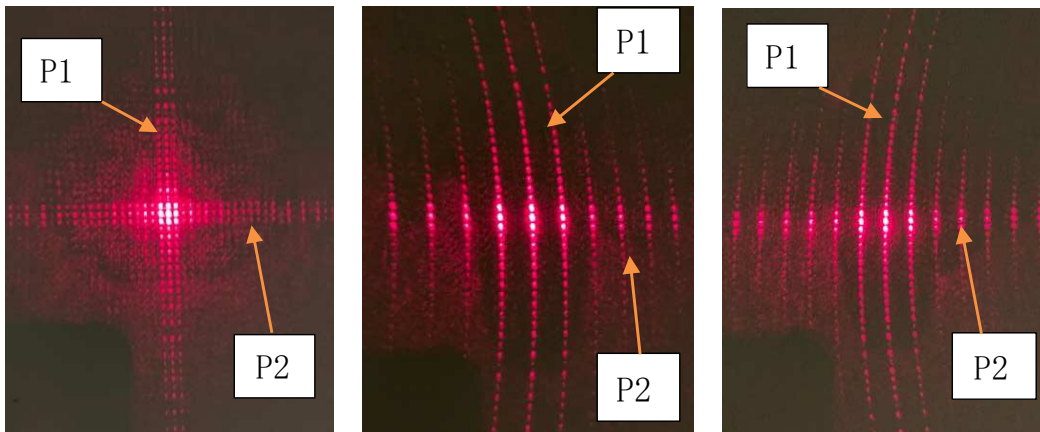


***) Curved, expanded and inclined patterns of the same tilted 1D-grating [17] [5]**

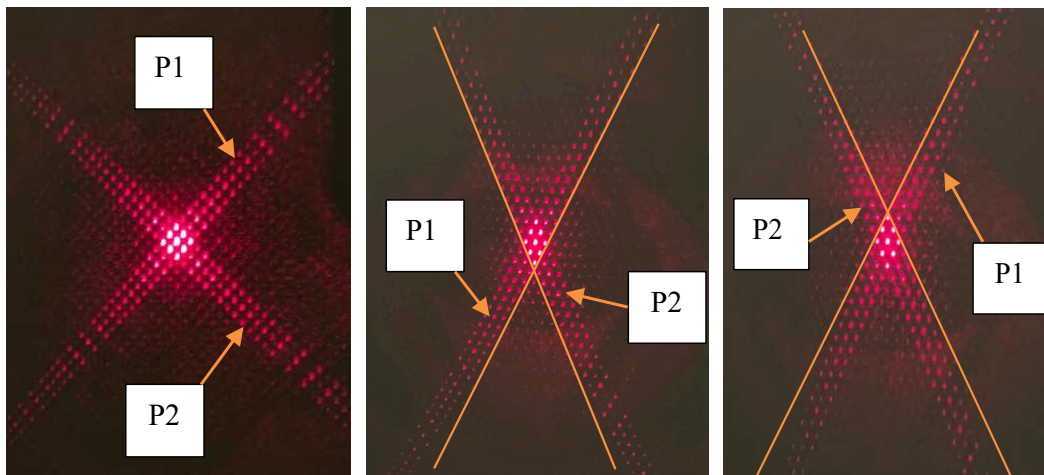


(B2) Recent Developments of 2D-Cross-Grating Experiments

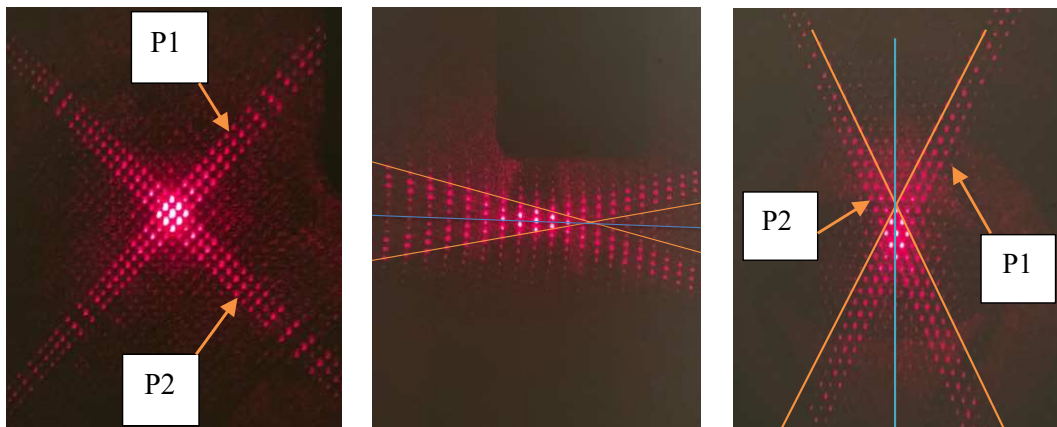
***) Curved and expanded patterns of the same 2D-cross-grating [20] [6]:**



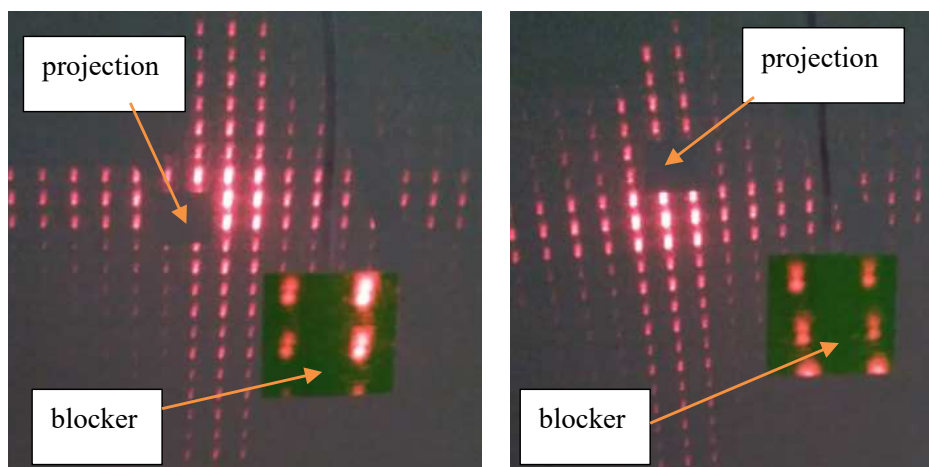
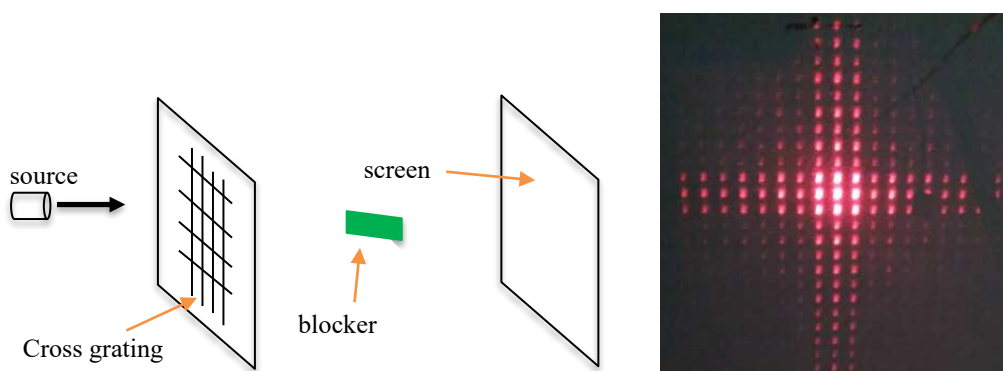
***) Curved, expanded and inclined patterns of the same tilted 2D-cross-grating [6]**



***) Mirror-symmetric patterns of the same tilted 2D-cross-grating [6]:**



*) Light beam behaving as particles before striking on screen: Grating experiments [6]



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