Wave-particle Duality of Macroscopic Particles

MingShan Ye

Nanchang City, China

E-mail: yemingshan2006@163.com

Abstract: Different schools have different explanations for the wave-particle duality of microscopic particles. Hidden variable interpretation, pilot wave interpretation, stochastic processes interpretation and so on all think that the generation of wave-particle duality has deeper reasons. According to these interpretations, macroscopic objects can also exhibit significant wave-particle duality. The authors performed a "round-hole diffraction experiment of powder particles": some powder particles of the same mass and shape are freely dropped to a plane one by one through a circular hole. At first, the powder particles are distributed disorderly on the plate in the box. With the increase of the number of falling powder particles, a diffraction pattern composed of several concentric rings is gradually presented. This implies that wave-particle duality is not unique to microscopic particles, and it is also exhibited by macroscopic objects. The experimental results help to reveal the nature of wave-particle duality.

Keywords: Powder particle, Diffraction, Probability wave , Wave-particle duality

1 Introduction

Wave-particle duality is the physical basis of quantum mechanics. The essence of wave-particle duality can have various interpretations. Among them, hidden variable, pilot wave, stochastic processes, and other such interpretations indicate that wave-particle duality has deeper underlying causes. According to these interpretations, it can be inferred that macroscopic objects can also present obvious wave-particle duality as long as they satisfy certain conditions. If macroscopic wave-particle duality can be determined through experiments, it could be understood, which would help in accurately understanding quantum mechanics in depth. This will promote the development of quantum mechanics. Therefore, the study of macroscopic wave-particle duality has attracted significant attention. For example, in recent years, wave-particle duality of oil droplets moving on a liquid surface has been studied extensively [2]–[8].

This paper provides a more intuitive macroscopic wave-particle duality: some powder particles with the same mass and shape fall freely to a plane one by one through a circular hole, and form a diffraction pattern composed of several concentric rings. The experiment is simple and the results are intuitive and reliable.

2 Materials and methods

A box with a width of approximately 250 mm and a height of approximately 400 mm was fabricated. The side of the box was made of transparent glass for easy observation of its insides.

The top of the box had a circular hole of approximately 10-mm diameter. A small piece of hard plastic sheet (or metal sheet) of approximately 0.2-mm thickness was used to cover the circular hole; it was fastened with tape. A needle was then used to drill a small hole with a diameter of approximately 0.15 mm at the center of the plastic sheet (or metal sheet). A flat panel inside the box behaved as a receiving powder particle, the position of which can be adjusted. (Fig.1).

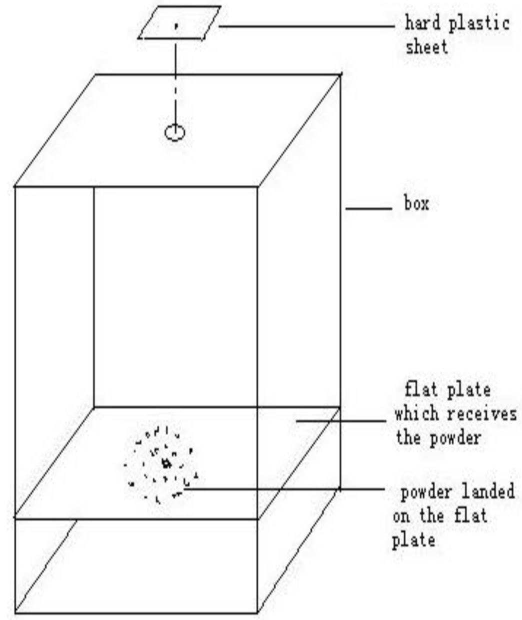


Figure 1. Schematic of experiment device

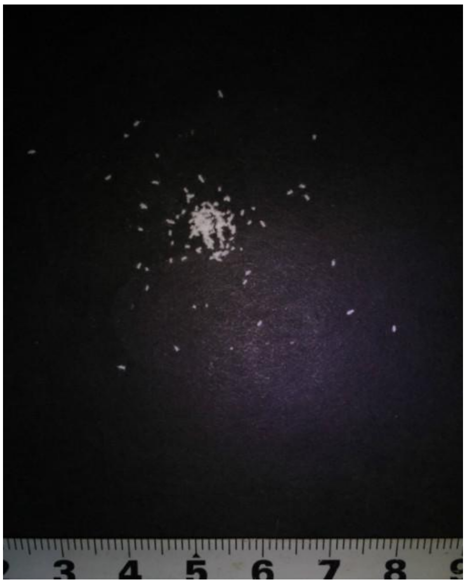
A small amount of talc powder was poured on the plastic sheet. Then, a small bamboo pole with a diameter approximately 1 mm is used to scrape the talc powder into the holes in the center of the plastic sheet along the same direction. This is done so that the powder can be extruded from the holes, and they fall on the receiving plate in the box. In this manner, the small holes act as a "molding," causing each falling powder to extrude into particles of uniform volume and shape. In the experimental operation, try to make the initial momentum of each powder particle the same.

3 Results and Discussions

The experimental observations showed that the powder particles was initially distributed out of order on the flat plate in the box. However, as the amount of dropped powder particles increased, it started forming a pattern constituted of several concentric rings pattern. If the distance between the plate in the box and the top of the box is changed before the experiment, the size of the concentric ring in the diffraction pattern also changes. Moreover, with the change in the above-mentioned distance, the center of the diffraction pattern changes. It could be a solid circular spot (Figs. 2a and 2c) or a hollow ring (Figs. 2b and 2d), indicating that the particles have the characteristics of probability waves when they fall.

a

b



C

d

Fig. 2 Pattern formed when powder fell onto the flat plate

Because the speed of the falling powder is not constant, it is difficult to quantitatively study the experiment results. On one hand, there is no fixed momentum value for the continuous change of velocity during the falling process of the powder particles; on the other hand, when we calculate the probability-wave wavelength of the powder particles according to the circular-hole diffraction pattern of the powder particles, we find that the radius of concentric rings is different, the corresponding wavelength is different, and the larger the radius of the concentric rings, the longer is the wavelength of the probability wave. The exact reason why such a result can be obtained is still unknown. It is only speculated that the accelerated falling of the powder particles under the action of gravity has some influence on it. At present, we can only give a qualitative explanation for this experimental result: the random action of air leads to additional Brownian motion when the powder particles fall, which can form probability waves. Therefore, the powder particles have wave-particle duality.

4 Conclusions and recommendations

The diffraction experiment results of the powder particles show that wave-particle duality is not a phenomenon unique to the microscopic world, and macroscopic objects can also exhibit significant wave-particle duality under certain conditions. This experimental result is of great significance for us to reveal the essence of wave-particle duality, and it also brings forward a new research topic for classical statistical physics.

In order to quantitatively study the experimental result, it is necessary to avoid the influence of gravity. Therefore, it is suggested to use high frequency ultrasound pulse instead of powder particles to do single hole (or single slit) diffraction experiment and double hole (or double slit) interference experiment. When ultrasonic wave propagates in the air, it has strong linearity and can be neglected by the influence of gravity. It is required that the frequency of ultrasonic wave be more than 1 MHz, the ultrasonic beam be focused in a straight line, the diameter is less than 1 mm, and there is no loss in the process of propagation. The ultrasonic generator, the baffle plate and the receiving screen are fixed in a box, and ultrasonic pulses are shot to the receiving screen one by one through a single hole (or two holes) on the baffle plate. It is expected that the impact points of the ultrasonic pulse on the receiving screen will be distributed disorderly at first, and with the increase of the number of the impact points, regular diffraction patterns (or interference patterns) will gradually appear. In different experiments, the frequency and amplitude of ultrasound, temperature, humidity and pressure of air in the box can be adjusted, and the experimental results are compared. Through qualitative and quantitative research on the experimental results, it is hopeful to find out the cause of the probability wave, and to find out the relationship between the probability wave wavelength and the "momentum" of the ultrasonic pulse. In addition, ultrasound itself is a kind of mechanical wave. If the ultrasonic pulse has the properties of probability wave, So is there a relationship between the wavelength of the mechanical wave of the ultrasonic pulse and the wavelength of the probability wave? This problem is also expected to be solved through experimental research.

Reference：

[1] M. Jammer, *The Philosophy of Quantum Mechanics* (The John Wiley & Inc., New York, 1974).

[2] Y. Couder, E. Fort, A. Boudaoud, and S. Protière, Nature 437(7056):208 ·October 2005.

[3].A. Eddi, E.Fort, F.Moisy and Y. Couder, Phys. Rev. Lett. 102,240401 (2009).

[4] E.Fort, A.Eddi, A.Boudaoud, J.Moukhtar,and Y.Couder,PNAS,107,41(2010).

[5] Y.Couder,A.Boudaoud,S.Protière & E.Fort,epn(europhysicsnews).(2010).

[6]D.M. Harris, J.W.M .Bush, J. Fluid Mech.(2014),vol .739,pp.444-464.

[7]J.W.M. Bush, Physics Today 68, 8 (August 2015).

[8]G. Pucci,.D.M .Harris, L.M. Faria, J.W.M .Bush, J. Fluid Mech. (2018), vol. 835, pp. 1136–1156.