

Compact Disc and Electron Diffraction

Monalizza Hervina Latununuwe[#], Andreas Setiawan, Suryasatriya Trihandaru

Physics Department, Science and Mathematics Faculty, Universitas Kristen Satya Wacana

Jl. Diponegoro No. 52-60, Salatiga 50711, Indonesia

[#]monalizza89@gmail.com

Abstract - A simple tool for explaining the electron diffraction pattern has been created. The tool consists of a pile of a few pieces of compact disc (CD) that has never been used and thrown away the outer layer and then it is irradiated with a laser beam. The experiment results show that the spot diffraction patterns look like the electron diffraction. The numbers of spots depend on the number of the stacks of CD.

Index Terms - Compact disc (CD), laser, electron diffraction

1. Introduction

Compact disc (CD) has been used as an experimental tool diffraction and interference of light. Dorado, et al. have researched the difference between CD duplication and replication based on Fraunhofer diffraction [1]. Cope has also successfully demonstrated the physical properties of the CD that in the part of the CD there is a section called "pit (hole)" and "land (flat part)" which can serve as a diffraction grating [2]. Moreover, Planinsic, et al. used CD to measure and calculate the spectra of the rainbow [3]. Ouseph has also demonstrated the occurrence of a rainbow by using CD [4]. Furthermore, Marques, et al. have investigated the process of interference and diffraction pattern by using a CD and the results were used for optical experiments in laboratory [5].

The diffraction pattern of the crystal is theoretically similar to the laser diffraction pattern of the optical gratings which is commonly used in the teaching of physics. In the learning process at schools as well as at universities, it is very hard to do the X-ray diffraction experiment because its equipment is very expensive to be afforded by schools and universities in developing countries. Demonstrating the crystal diffraction in the physics learning process can be done by using laser beam instead of X-ray. It also needs a replacement material that can be used as an optical grating. Compact disc (CD) is one of the materials that can be used as an optical grating.

Based on the results of the studies mentioned above, which is one of the physical properties of the CD serving as a diffraction grating, it was found in this study a new way of determining the same diffraction pattern by electron diffraction or X-rays diffraction pattern using several pieces of CD. It has successfully created a simple apparatus consisting of only arrangement or a pile of pieces of compact discs (CDs) and only using the laser beam instead of X-rays. The use of this equipment produces a diffraction pattern similar to the pattern of electron diffraction. Besides, this equipment can explain the crystal diffraction pattern with Debye-Scherrer method.

2. Experimental

Firstly, the CD was cleaned by peeling off the outer layer. Furthermore, the CD was cut into small pieces in the

circle form with the same size; thickness 0.1 cm and diameter 2.5 cm as shown in Fig. 1. The pieces were neatly stacked in a cylindrical stainless steel tube in which the tube was placed horizontally with the arrangement illustrated in Fig. 2. When the tube containing fragments of CDs was being irradiated with He-Ne laser beam ($\lambda = 633 \text{ nm}$) (Research Electro Optics), a diffraction pattern appeared on a screen placed in front of the tube so that the pattern can be recorded using a digital camera. The distances of the He-Ne laser beam and the pile of CDs as well as the pile of CDs and the screen were 23 cm and 4.85 cm, respectively.



Fig. 1 Pieces of CDs

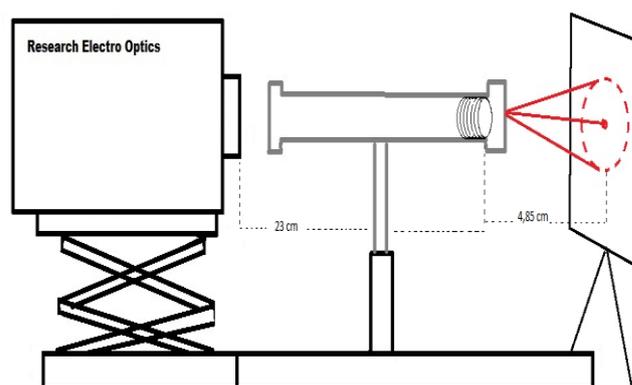


Fig. 2 Schematic of experimental equipment

3. Results and Discussion

If two pieces of CDs are stacked together and irradiated with the laser beam, then the diffraction pattern is formed as shown in Fig. 3. It is a vertical thin line observed on the screen. Furthermore, by making the pile of seven pieces of CDs and irradiating it with the laser beam, the shape of the diffraction pattern as given in Fig. 4. There is a

bright, wide spot in the center and some bright dots surrounding it. Moreover, the shape of the diffraction pattern of fifteen pieces of CDs can be seen in Fig. 5. There is a ring with the diameter of 4.2 cm. Compared to Fig. 4 the ring becomes clearer in Fig. 5.

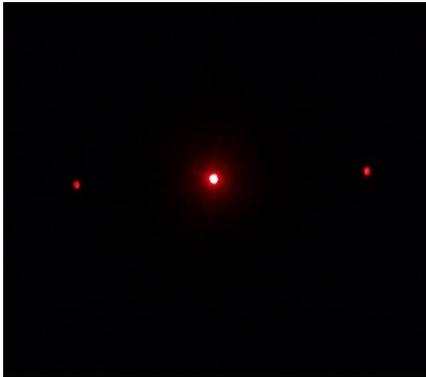


Fig. 3 Diffraction pattern of two pieces of CDs

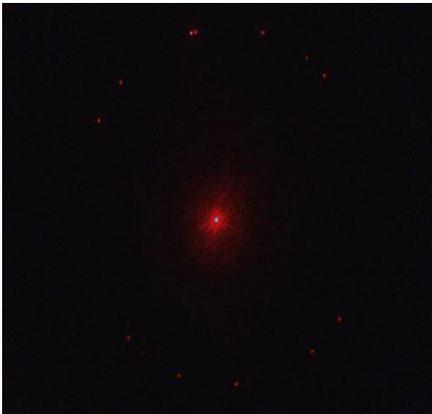


Fig. 4 Diffraction pattern of seven pieces of CDs

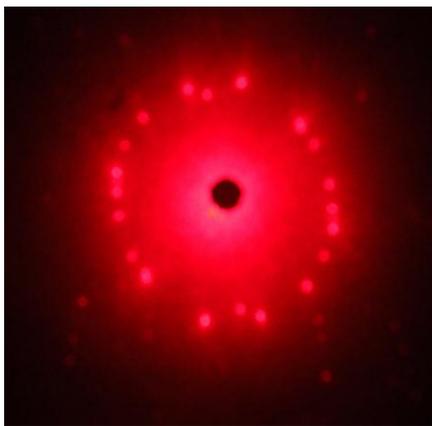


Fig. 5 Diffraction pattern of fifteen pieces of CDs. The diameter of the ring was 4.2 cm.

Based on Figs. 4 and 5, the electron diffraction pattern began to form with increasing the number of pieces of CDs. The more stacks of CD pieces, the better the electron diffraction pattern is. These results show that the spot and ring diffraction pattern looks like the electron diffraction.

According to the Bragg diffraction, an electron beam or X-rays passing through a single crystal will produce spot

diffraction patterns [6]. The diffracted light interacts with only one crystal domain, and it can only be oriented in one direction. As such, only singular bright spots are observed. Each spot on the diffraction pattern is corresponding to different set of crystal planes in the same crystal. The spots are discrete and correspond to the points in reciprocal lattice [7]. Moreover, if the diffraction pattern is taken from the area of a big number of discrete segments with the same structure in random orientations then diffraction spots are then arranged in concentric rings and it is a diffraction pattern of polycrystalline materials [7]. The diffraction pattern will therefore look like a superposition of single crystal spot patterns: a series of concentric rings resulting from many spots very close together at various rotations around the center beam spot. In other words, if a sufficient number of crystal domains are present, the multitude of bright spots forms a ring. The diffraction rings one can also determine the type of crystal structure and the "lattice parameter".

In this study, the crystalline powder is analogized with pieces of CDs that are put together randomly in the tube. The bright spot diffraction pattern of two and seven pieces of CD (Figs. 3 and 4) can be analogized as diffraction of single crystal lattices. If the laser beam interacts with two and seven pieces of CDs, it can be oriented in one direction and this interaction produces the bright discrete spots. On the other hand, fifteen pieces of CDs put together can be analogized as polycrystalline materials whose diffraction pattern looks like a diffraction pattern of polycrystalline materials. It means fifteen pieces of CDs is a sufficient number of CDs domain that produce bright spots to form a ring pattern. In this condition, each piece of CD domains will have a different orientation with regard to the incident light which laser beam passing through a multiple pieces of CD domain equivalent to that produced by this beam passing through series of pieces of CDs with various orientations.

To determine the lattice plane spacing, it is used the Bragg law as follows:

$$2d \sin \theta = n\lambda. \quad (1)$$

where n is the diffraction order, λ is the wavelength, d is the lattice plane spacing, θ is the Bragg angle relative to the primary beam,

with the radius

$$R = L \cdot \tan 2\theta \quad (2)$$

where L is distance between the sample and the screen.

According to the data of the experiment (see Figs. 2 and 6), the lattice plane spacing of CD (d) is calculated using Eq. (1) is similar to its theoretical track distance that is d of 1600 nm .

By using fifteen pieces of CDs, the diffraction pattern forms a ring around the black spot as given in Fig. 5. The appearance of the ring shows that the material (fifteen pieces of CDs) has similar character with crystal powder by using the Debye-Scherrer method within three-dimensional space that has three degrees of freedom (x , y , and z axes). However, in this experiment, the pieces of CDs only have

one degree of freedom which is in y -axis. Therefore, the relevant structure factor is only related with one numbers hkl , in this case is k .

The pieces of CDs are analogized as the *simple cubic* (SC) with the shaded area y -axis field as shown in Fig. 6, while Fig. 7 shows the theoretical of Debye-Scherrer method of the structure of crystal powder.

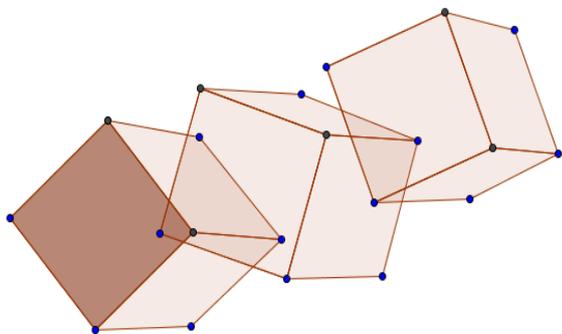


Fig. 6 Analogy of the pieces of CDs on the experiment showing the pieces of CDs only has one degree of freedom that is y -axis.

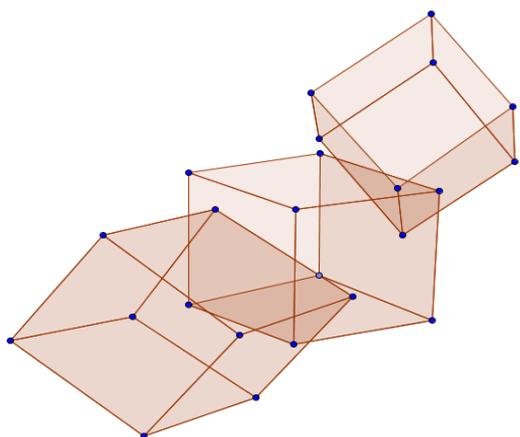


Fig. 7 Analogy of the crystal powder in the Debye-Scherrer method showing the crystal powder has three degree of freedom (x, y, z).

Based on Fig. 6, the pieces of CDs only has one degree of freedom as explained before which is y -axis and on Fig.7 the crystal powder in the Debye-Scherrer method has three degrees of freedom.

This research is being continued to determine the diffraction pattern by using Debye-Scherrer method which must be calculated with its *structure factor* (F) using Eq. (3).

$$F = fe^{i2\pi k \frac{y}{L}} \quad (3)$$

By assuming one cell (one piece of CD) only has single atom placed at $y=0$ then the value of the structure factor is

$$F = fe^{i2\pi k \cdot 0} = f \quad (4)$$

for all value of k .

4. Conclusion

It has successfully created a simple tool of CD to explain the formation process of the electron diffraction pattern or X-ray diffraction. This equipment can be made easily for the purposes of learning physics in high school or university so that it is not always required sophisticated and expensive equipment to perform such experiment and explain the diffraction pattern of the crystal. Using this equipment, it can be explained diffraction pattern of single crystal and polycrystalline materials. This tool also can be used to calculate the track distance of CD.

By using more pieces of CDs, this simple tool also shows the phenomenon of the crystal powder method.

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