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EXPERIMENTAL CONFIRMATION OF THE VALIDITY OF THE DE-BROGLIE'S HYPOTHESIS

Rakhmatullayeva Feruzakhon Ulugbek kizi,
Valikhujayev O.U.
Fergana state university

ABSTRACT

This article focuses on the importance and experience of physical process, which is the main important part of physics. The topic of experimental confirmation of the validity of de Broglie's hypothesis has been covered, and it should be noted that it is most important to take into account the simultaneous manifestation of two different properties of the wave in atomic physics.

Key words: *interference, diffraction, polarization, dispersion, reflaction and retraction, wave and particle property, photon, velosity, energy, light pressure, photoelectric effect, momentum, wavelength.*

АННОТАЦИЯ

В этой статье основное внимание уделяется важности и опыту физических процессов, которые являются основной важной частью физики. Тема экспериментального подтверждения справедливости гипотезы де Бройля освещена, и следует отметить, что наиболее важно учитывать одновременное проявление двух различных свойств волны в атомной физике.

Ключевые слова: *интерференция, дифракция, поляризация, дисперсия, отражение и втягивание, свойства волны и частицы, фотон, скорость, энергия, световое давление, фотоэффект, импульс, длина волны.*

INTRODUCTION

From the course of atom physics and optics we know that photon has a wave-particle duality properties:

*Phenomenas such as interference, diffraction, polarization, dispersion, reflaction and retraction of light are explained by the wave property of light.

*Phenomenas such as light pressure and photoelectric effect are explained by the partical property of light.

All these phenomenas were learned by as in different branches of physics, but in 1924 french physician Lui de Broglie in his doctoral dissertation work sayed the next:

"If photon as a particle has wave and particle properties in same time, why other elementar particles (such as electron, proton and etc.) cannot have these both properties in same time."

We know that

E =h ν and E = m c^2

according to wave property according to particle property

$$E = h\nu = h\frac{c}{\lambda};\ E = mc^2 = mc \cdot c = P \cdot c$$

If we equate energies of microobject according to both properties we have next:

$$h\frac{c}{\lambda} = P \cdot c \Rightarrow \lambda = \frac{h}{P}$$

from the last we can conclude that any microobject which have momentum (or which is in motion) will have wave property with the de Broglie’s wavelength.

$$\lambda_{d.B} = \frac{h}{mV} \qquad (1)$$

Formula of calculating the de Broglie’s wavelength of microobject, where m is the mass of object at rest, V is the velocity of object (V<< c).

$$\lambda_{d.B} = \frac{h}{\dfrac{m_0 V}{\sqrt{1 - \dfrac{V^2}{c^2}}}}$$

Formula of calculating the de Broglie’s wavelength of microobject, where m is the mass of object at rest, V is the velocity of object (V< c) and this formula is working in relativistic approximation.

QUESTION № 1:

Find the de Broglie’s wavelength of yourself when you are walking with speed 5 km/h.

SOLUTION № 1: we will work with formula (1) because of V<< c

$$\lambda_{d.B} = \frac{h}{m_{el}V_{el}} = \frac{6.62\cdot10^{-34}\,J\cdot s}{88kg\cdot\frac{5}{3.6}\frac{m}{s}} = 5\cdot10^{-36}m$$

From result we can see that the de Broglie’s wavelength of me is much less than subatomic scales. So that’s why we cannot see the wave properties of me, that is such phenomenas as interferention, diffraction or polarization.

QUESTION № 2:

Find the de Broglie’s wavelength of electron which is passing the electric field with accelerating voltage equal to 150V.

SOLUTION № 2:

From the course of elector and magnetism we know that accelerating voltage around 10^2 V does not accelerate the electron up to c. That’s why in solution of this problem we will use the formula (1)

$$\lambda_{d.B} = \frac{h}{P} = \frac{h}{\sqrt{2m_0E_k}}$$

Where $\sqrt{2m_0E_k} = \sqrt{2m_0\frac{m_0V^2}{2}} = \sqrt{m_0{}^2V^2} = m_0V = P$

In another case we know that work of electric field is equal to the difference of kinetic energy

$$A_{E.F} = \boldsymbol{\Delta} E_{kin}$$

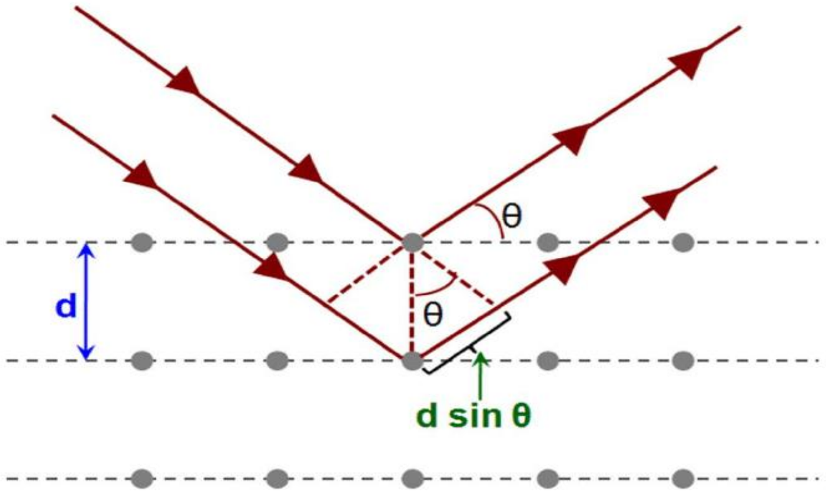
q = $(\varphi_1 - \varphi_2) = E_{kin} - E_{kin}{}^{(0)}$, where q=$|e|$ and $\varphi_1 - \varphi_2 = U_{acc}$. So finally

$$\lambda_{d.B} = \frac{h}{\sqrt{2m_0|e|U_{acc}}} = \frac{6.62\cdot10^{-34}\,J\cdot s}{\sqrt{2\cdot9.1\cdot10^{-31}kg\cdot1.6\cdot10^{-19}C\cdot100V}} \approx 1\cdot10^{-10}m$$

From the result we can see that the de Broglie’s wavelength of electron is around the subatomic scales. Which means that electron as a wave can be interference or diffracted with other electrons with same property.

These theoretical ideas were finally proved in 1927 by American scientist Clinton Joseph Devisson and Lester Helbert Jermer. In last question we have solved and found the wavelength of electron which was accelerated in electric field with voltage 150V and we know that wavelength around ΔA ($1\cdot10^{-10}m$) is same with X-ray illumination. So to see the wave properties of electron we must pass electrons through the stracture with dimension around $1\mathring{A}$ and we know that as a sample we can use any crystal structure of solid Davisson and Jermer investigated the reflection of electron beam from the surface of monocrystall of Nickel:

First of all let’s analyze the reflection of X-ray illumination from the surface of monocrystall:



d- distance between neighbour atoms or the constant of crystal lattice;

φ- angle of shift.

From the condition of INTERFERENSION MAXIMUM PHENOMENA, these waves reinforce each other if

$$\Delta = 2n\frac{\lambda}{2}$$

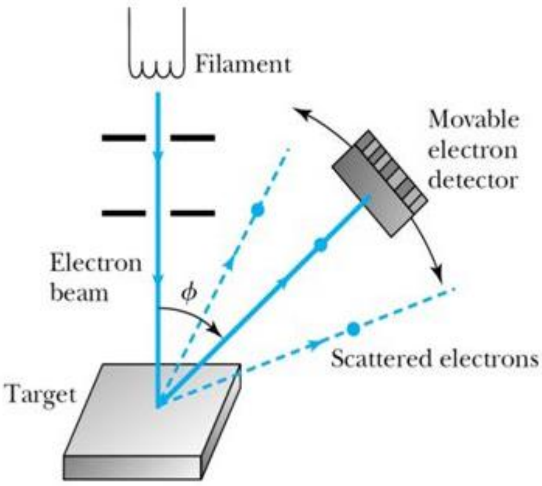
Where Δ –difference of path of X-ray, n- natural numbers (whole and positive numbers), λ- wavelength of X-ray illumination. From picture we can see that

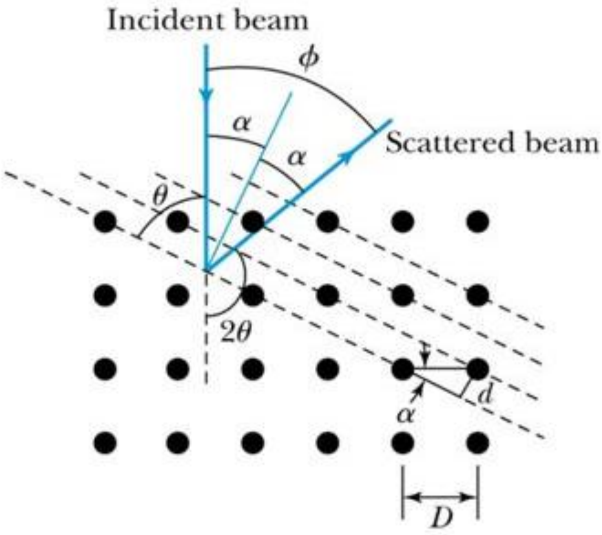
$$\Delta = 2 \cdot (d \cdot \sin\varphi)$$

So finally we have that $2\mathrm{d}\sin\varphi = n\,\lambda$

Wolf-Bregg's condition for reflaction of beam of X-rays in event INTERFERENSION MAXIMUM.

Devisson and Jermer applied Wolf-Bregg's condition to the beam of electrons in event of reflaction and interferension of electrons:





From experiment we can see that beam of electron getting to NICKEL CRYSTAL and the energy of electrons can be controlled by accelerated voltage. If electrons have a wave property then in condition of Wolf-Bregg they will reflected from periodical structure, where d is the distace between frontal surface of NICKEL CRYSTAL. Let's write the condition of Wolf-Bregg:

$$2\mathrm{d}\sin\varphi = n\,\lambda \qquad (1)$$

and from Lui de Broglie hypothesis we have calculated the wavelength of electrons which were accelerated by U_{acc} (see question 2).

$$\lambda = \frac{h}{\sqrt{2 \cdot e \cdot U}} \qquad (2)$$

So in next we have that

$$2 \mathrm{dsin}\, \varphi = \frac{n\, h}{\sqrt{2 \cdot e} \cdot \sqrt{U}}$$

Then

$$\sqrt{U} = \frac{n\, h}{\sqrt{2 \cdot e} \cdot 2dsin\, \varphi} \qquad (3)$$

Let’s return to experiment of Devisson and Jermer. The beginning and the end of laboratory are connected to the INSTALLATION BODY,that’s why we can consider that the circuit is closed. In this circuit the diraction of current is opposite to the motion of electrons. If electrons satisfy the Wolf-Bregg’s condition they will reflected from frontal surfaces of NICKEL CRYSTAL and go to the collector. In this case galvonometr’s indication will be different from zero. If electron do not sotisfy Wolf-Bregg’s condition will go through NICKEL CRYSTAL and will not be reflected from frontal surfaces. That’s why the galvonometr’s indication will show zero.

Formula (3) is the condition of Wolf-Bregg for reflaction of electrons, where n is equal to 1,2,3,... . Let’s be the

$$\frac{n\, h}{\sqrt{2 \cdot e} \cdot 2dsin\, \varphi} = const = L\,,$$

Then we have $\sqrt{U} = n \cdot L$ or $\sqrt{U_1} = L\,;\ \sqrt{U_2} = 2L\,;\ \sqrt{U_3} = 3L$ and etc.

We must assume that in this values of acceleration voltage electrons beam are reflected from the frontal surface of NICKEL CRYSTAL and get to collector and to other hand in different values of c as $\sqrt{U_1}$, $\sqrt{U_2}$ and $\sqrt{U_3}$ the current in circuit will have different maximums.

<u>CONCLUSION:</u> If for electron beam the condition $\sqrt{U} = n \cdot L$ is working, then the electron beam reflect from NICKEL CRYSTAL and get to the collector where we can see that thecurrent in circuit by galvonometr; if for electron beam condition $\sqrt{U} = n \cdot L$ is working or $\sqrt{U} \neq n \cdot L$, the electron beam path through through the NICKEL CRYSTAL and the indication of galvonometr will be equal to zero.

In both cases of conclusion we have proved that an electron in motion has a wave property. For this experimental work Devisson and Jermer had been awarded to Noble Prize.

Problem № 1: Find the wavelength of proton and electron with kinetic energy 1keV.

Answer: $\lambda_{d.B}{}^{(el)}=39\ pm$; $\lambda_{d.B}{}^{(pr)}=0.91\ pm$

Problem № 2: in experiment of Devisson and Jermer narrow beam of electrons fall at a glancing angle equal to 30° to the surface of ALUMINIUM CRYSTAL with the distance between frontal surfaces is equal to 0.2 nm. When the value of accelerated voltage is equal to U_0 and the next maximum of current is observed in acceleration voltage equal to 2.25 U_0. Find the voltage U_0.

*Problem № 3:*In Tomson-Tortokovski's experiment the flow of electrons drop to the polycrystal with kinetic energy 10keV. If the distance between polycrystal and screen equals to 10 cm and the radius of the interferension ring in screen with numeration 3 is equal to 1.6 cm find the distance between frontal surfaces of atoms.

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