# On the experimental choice between the ether wave hypothesis and quantum hypothesis of the light I . Röntgen radiation

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## 1 Description of the problem

There is widespread opinion that if the electron is accelarated then it radiates the electromagnetic waves isotropicaly i.e. for any distance from the emission center the energy density of the waves does not depend on the direction with regard to this center. I have shown in another my paper that this opinion is nothing more than a hypothesis. It is some extrapolation of the experience which comes from the space-time superposition of the radiation by many electrons on the elementary process of radiation by the single electron.

The quantum hypothesis of the light gives us some other understanding of this elementary radiation process. This hypothesis tells us that the electromagnetic radiation of the single electron spreads out not in accordance with the low of the proportionality to the square of the distance to the emission center but is concentrated on some finite volume independently from this distance. It spreads out not in all possible directions from the emission center but only in some direction which can be defined as the direction of the mass center associated with the volume where the radiation energy is concentrated.

The difference between the ether wave hypothesis and the quantum hypothesis of light with regard to the elementary process can be formulated in a most evident way with the help of a concept of the electromagnetic momenta. Let $E$ and $H$ be electric and magnetic field vectors respectively and $S$ be the wave vector. Then the density of the electromagnetic momenta is defined as the following value $g = \frac{1}{c^2}S = \frac{1}{4\pi c}[E, H]$ where $c$ is the speed of light. The integral $\int gdv$ which is taken around the sphere with the center where the radiating electron is and with the surface which contains the whole radiation gives us the value of the total electromagnetic momenta.

In accordance with the ether hypothesis this total momenta is zero for the case of the single electron as well. We get the same result for the total force which acts on this electron because of this radiation. Namely, it is as follows: $\frac{d}{dt}\int gdv = 0$. So, following this hypothesis we get that the radiating electron can be accelarated only if it collides with other matter particles. The total momenta of colliding particles should be constant $(m_1 v_1 + m_2 v_2 = const)$ and the transformation of the mechanic energy into the electromagnetic energy and vice versa is then impossible.

The other result concerning this problem can be obtained if to following the quantum hypothesis. In accordance with this hypothesis the total momenta of the out-going wave from the accelarated electron is non zero. Namely, it is equal to the ratio $\frac{hn}{c}$ where $h$ is the Planck constant and $n$ is the frequency. The direction of this momenta is defined by the center of mass movement of this radiation quant. Due to this definition the force which acts on the electron because of it's radiation is also non zero. During the emission the electron and the out-going radiation undergo the recoil influence from each other. Namely, the force of the recoil which acts on the electron from the side of the radiation is equal to the force which acts on the radiation from the side of electron. Let $m_1 v_1$ and $m_2 v_2$ be the mechanic momenta of two particles before the collision and $m_1 v_1'$ and $m_2 v_2'$ be the momenta after collision. Let $\frac{hn}{c}$ where $c$ is the speed of the mass center of the wave packet be the momenta of the radiated electromagnetic wave. Then due to the total momenta conservation law we have the equation

$$m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2' + \frac{hn}{c}$$

If the elementary process goes from left to right in accordance with this equation then the mechanic energy transforms into electromagnetic energy. If it goes from right to left then the electromagnetic energy transforms into the mechanic energy.

In the case of usual sources of light (flame, light arc, spark, decaying object) which up to now were under the experimental investigation and the radiation properties of which were extrapolated on the case of emission by the elementary center in ether wave hypothesis the quanta come from many atoms. These quanta have on average the same values of the momenta which are distributed in all possible directions. Hence, the total value of the momenta $\sum mv$ and the total electromagnetic momenta $\int gdv$ of the sources of light are on average zero. Therefore on average the same value of radiation of some definite frequency is expected to be the same in all directions.

It is possible that we shall find some means later which would enable us to observe the radiation from the single electron. Then we could actually get the information about which of two hypothesis is correct. But up to now it is impossible to investigate because the energy which characterizes this elementary process is too small. Meanwhile we can try to come closer to understanding of the display of the elementary process by the following arguments.

Suppose that some big amount of the electrons $z$ have the momenta which are oriented in the same direction. It could be, for example, some beam of the cathode or channel electrons. Let these electrons be allowed to collide with some matter particles. It is evident that after the collision not all electrons will have an accelerations of the same direction and value. A big amount of the electrons will go out with accelerations of different absolute values and directions. If the momenta of the matter particles collided with in-coming electrons of the beam are distributed by on average symmetric way with regard to the axis of the beam (below we shall always imply this situation) then from simple symmetry arguments we can conclude that the distribution of the out-going electrons is also on average symmetric with regard to the beam axis. By other words, for those directions which have the same angle with the beam axis the amount of colliding particles with the same accelerations is also on average the same. Coming up to the distribution of the accelerations with regard to the plane which goes through the point of collision transversally to the beam axis (normal plane) we can say that the symmetric case is possible. It means that for the distribution of the accelerations this plane is the symmetry plane i.e. for the directions which have the same angle with this plane one has the same amount of out-going particles with the same accelerations. But we should note that the asymmetric case is also possible. It means that the amount of particles which have the accelerations oriented on some angle to the normal plane inside the front semi-sphere with regard to the beam axis does not coincide with amount of particles with the accelarations oriented inside back semi-sphere by the same angles to the normal plane. In this asymmetric case the distribution of the momenta also undergoes the influence in some extent by the feature of the elementary process already after the first collision.

For the case presented here when the beam of electrons with the same momenta after collision with matter particles gives rise to the electromagnetic radiation one can obtain the different consequences from the ether wave hypothesis and from the quantum hypothesis of light. In symmetric case the radiation intensity is the same for all directions of the emission according to both hypothesis. We come the same result for the asymmetric case also if we follow the ether wave hypothesis. Namely, the radiation has the same intensity and the same frequency for all emission directions. On the contrary, following the quantum hypothesis we come to conclusion that for this case there is an asymmetry in radiation with regard to the normal plane. It is true both for the intensity and for the frequency of the radiation. Namely, the intensity and frequency are different for those emission directions which have the same angle with the normal plane but are observed from the different sides. Let $z$ be the number of the in-coming momenta. Then in accordance with the ether hypothesis we have for the asymmetric case

$$zm_1v_1 + \sum m_2v_2 = \sum m_1v_1' + \sum m_2v_2'.$$

Since, $\sum m_2v_2 = 0$ we have $zm_1v_1 = \sum m_1v_1' + \sum m_2v_2'$ and $\int gdv = 0$.

Following to the quantum hypothesis we come for the asymmetric case to the following result

$$zm_1v_1 = \sum m_1v_1' + \sum m_2v_2' + \sum \frac{hn}{c^2}c$$

and

$$\int gdv = \sum \frac{hn}{c^2}c > 0.$$

## 2 The problem of producing the Röntgen radiation due to the cathode emission, the disturbing effects

All electrons of the cathode beam can have a velocities of the same absolute value and direction. They should falldown into the thin plate in normal direction. Then the individual electrons of the beam get the different accelerations in different directions after the collision with the matter particles because of the force of the interaction. So, we observe the velocity distribution of single electrons directly after the first collision. In Fig.1 the possible deviations of the cathode electrons are shown schematically. Absolute values and directions of the arrows show the absolute values and directions of velocities of the electrons and consequently their momenta before and after collision.

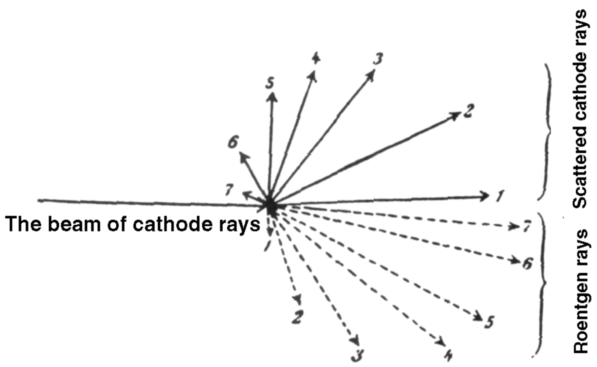



Figure 1:

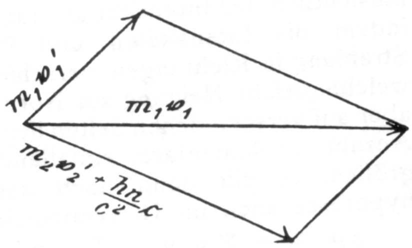


Figure 2:

In Fig.2 the parallelogram of mechanic and electromagnetic momenta of the quanta emitted after collision is shown. Here for the sake of simplicity the mechanic momenta of the matter particles before collision supposed to be zero in comparison with $m_1v_1$. The fact that we know nothing about the momenta $m_2v_2$ of the matter particles after collision hinders further exact discussion of the phenomenon. We can only be content with some approximation. Namely, let us limit ourselves to the case when mechanic momenta $m_2v_2$ are small in comparison with $\frac{hn}{c^2}c$. For this special case in Fig. 1 by dashed lines are shown the directions in which the quanta of the radiation are emitted because of the accelerating electrons. The length of arrows is proportional to the absolute value of the momenta. The space distribution of the radiation can be obtained by the rotation of the half-plane around the axis of the in-coming cathode rays. At first sight on the Fig. 1 it is striking that in accordance with the quantum hypothesis in this idealized case of the emission of the Röntgen radiation caused by the scattering of a cathode ray beam the radiation distribution is asymmetric with regard to the plane (normal plane) going through the collision point normally to the direction of falling beams. It is emitted almost completely in the direction of falling cathode ray beams and not in the opposite direction.

Furthermore there are other consequences which follow from the quantum hypothesis of light for the idealized case of the Röntgen radiation emission. For the different accelerations the absolute value $\frac{hn}{c}$ of the emitted electromagnetic momenta is also different. Since, $c$ and $h$ are constants then for different directions the Röntgen quanta emitted by the same material have a different frequency and different absorption properties. Therefore the intensity $J_n$ of the Röntgen radiation of some definite frequency is a function of the angle $\alpha$ between the direction of emission and direction of the falling cathode ray beams, of the frequency $n$ and actually of the velocity $v_1$ of some single cathode beam. So, it is $J_n = zf(\alpha, n, v_1)$.

Now the idealized case of the Röntgen radiation discussed above should be in reality essentially modified by taking into account some secondary effects. The first such an effect is that side by side with the electromagnetic momenta of the emitted Röntgen rays almost simulteneousely arise the mechanic momenta of the collided particles. Let us note that this effect results in some modification of the function $f(\alpha, n, v_1)$. But at the same time the whole picture of asymmetry in the intensity distribution of Röntgen radiation can not be drastically changed.

Another secondary effect which should be taken into consideration is that generally speaking during the first collision the single electrons do not loose so much of their momenta that during the next collision they could not produce more cathode rays anymore. It is much more likely that the cathode rays deviated partially or even completely from their original direction can produce the secondary cathode rays emitted in absolutely different direction in comparison with the idealized case. From the side of the scattered cathode rays this secondary Röntgen radiation can not increase but under some special circumstances can even reduce the asymmetry of the Röntgen radiation from the side of primary radiation.

The third secondary effect can reveal itself by producing the radiation with more frequency due to the re-emission of those atoms which were collided by primary or secondary cathode rays. As I have shown in my previous paper the atoms of some chemical elements being excited can produce the fluorescence with rather big frequency because of the irradiation by the cathode or Röntgen rays. From the fact that the fluorescent emissions of a big number of elementary atoms are disordered we conclude that the outgoing Röntgen radiation caused by the fluorescence of some object has on average the same intensity in all direction from the place of the collision (anti-cathode). This fluorescent emission of the Röntgen radiation is not able to reduce completely the asymmetry in the idealized case. The question of how small the relation between the intensity of front- and back-radiation is depends on how intensive is the radiation in comparison with the emission after the collision with the primary cathode rays. One can conclude from the experience with the polarization of the cathode radiation that in the Röntgen rays from the anti-cathode being built up from the element with big atom weight (for example, Platinum) the fluorescent radiation predominates. Therefore it is clear that Röntgen and Walter for anti-cathodes from the Platinum could not detect the dependence of the radiation intensity on the emission direction. Going ahead I can say that I have also obtained for the usual Röntgen tube that the intensity is the same for all emission directions in the frontside from the anti-cathode. The observation of the intensity with the same cassete has led to the same snapshots for an anti-cathode from the charcoal.

The last secondary effect which should be considered is the absorption of the Röntgen rays on the way from the anti-cathode to the place of observation.

Placing the anti-cathode in a center of spherical glassy tube with the wall of the same thickness everywhere one can reach that the penetration properties of the Röntgen rays are the same for all emission directions. Therefore Röntgen rays of the same frequency are reduced in the same way due to the absorption in the glassy wall. In contrast, Röntgen rays of different frequency are also reduced differently. Namely, the rays of grater frequency are reduced less than the rays of smaller frequency. If one would observe only one definite frequency then during the absorption in a glass the intensity asymmetry would not be changed. In contrast, one can observe the intensity of Röntgen rays independently of it's frequency by the produced fluorescence or the photographic effects. Then due to the absorption in glassy wall the asymmetry of ideal case is intensified or reduced if in the front side of normal plane (in respect to the in-coming cathode rays) will come respectively more or less of the smaller frequency Röntgen rays than into the back side. Taking into consideration the original emission symmetry for all frequencies one deduce that during absorption on the glass wall no asymmetry can be produced.

What was said above about the influence of the absorption of the spherical glassy wall with the same thickness in all directions is also suitable generally for each absorbing layer between emission center and observation point of the Röntgen rays. The requirement herewith is that the layer (of the aluminium tin, for example) should be everywhere of the same thickness and the form has to be spherical the center of which coincides with the emission center. This requirement of the same thickness of glassy wall was not fulfilled in the case of the usually used Röntgen tubes. Mr. Pohl has drawn my attention to one work of Walter (a. a. O) in which it was shown that the usual Röntgen tubes could have the glassy wall near the attaching place which contains the cathode itself of the essentially more thickness than in the opposite side of the tube. In spite of the fact that the tubes used in recent experiments were chosen by me very attentively the variation of the glassy wall's thickness on the plane going through the direction of the cathode rays revealed itself also. It was observed photographically. Nevertheless the condition that the cross section of this plane with upper half of the tube should be of the circular form was strictly fulfilled. The variation of the glassy wall's thickness in this plane is adduced in the table below.

**Table I.**

| Angle | Glass thickness mm | Angle | Glass thickness mm |
|---|---|---|---|
| −68° | 1.68 | −10° | 0.92 |
| −59 | 1.50 | 0 | 0.85 |
| −52 | 1.32 | +11 | 0.81 |
| −42 | 1.20 | +22 | 0.8 |
| −35 | 1.11 | +35 | 0.87 |
| −30 | 1.11 | +48 | 0.93 |
| −21 | 1.08 | +65 | 0.95 |
| −16 | 1.00 | +82 | 0.94 |

The emission angles have been calculated in respect to the normal plane. Namely, on the front-side the angles are taken with negative sign and the angles on the back side are positive. If not only thickness variation $a$ of the absorbing layer but also the absorption index $\kappa$ $(cm^{-1})$ for some type of Röntgen rays is known then one can correct the observed intensity $(J)$ to the intensity $J_0$ for the case of everywhere the same thickness $a_0$. Namely, it is $J_0 = Je^{\kappa(a-a_0)}$. I have introduced this correction for the observations of the intensity out of the Röntgen tube. As we shall see below the Röntgen rays variation observed directly does not depend drastically on the emission direction. It also follows from the comparison with the snapshots for which the influence of the glass absorption was switched off by making these photographic observation inside the Röntgen tube.

More important than the absorption in the glass wall is the absorption of the Röntgen rays on the way which they have to fly in the anti-cathode itself from the emission center to the observation point. Since the cathode rays used in the Röntgen tube have already been almost absorbed or scattered in the very tiny layer the colliding place of cathode rays and consequently the emission region are situated in an outer layer of the anti-cathode. Let the anti-cathode be some circular plate of thickness $a$ with the parallel surfaces in which center from the front-side the cathode beam falls. Let the thickness of the colliding place be $\Delta a$ and the angle between emission direction and the normal plane to the cathode beam be $\alpha$ and unreduced intensity of the Röntgen rays be $J_0$. Due to the smallness of $\kappa\Delta a$ we can neglect the absorption of Röntgen ray in the angle range from $-\pi/2$ until $-\delta\alpha$ where $\delta\alpha$ is very small angle connected with smallness of $\kappa$. From $-\delta\alpha$ till 0 the intensity decreases from $J_0$ to $J_0 e^{-\kappa r}$ where $r$ is the radius of circular anti-cathode. In the range from 0 to $\alpha_r = \arctan a/d$ the formula $J = J_0 e^{-\kappa r}$ is suitable with good precision for small ratio $a/d$. For the angle range from $\alpha_r$ to $+\pi/2$ we have

$$J = J_0 e^{-\kappa(a-\Delta a)/\sin\alpha}$$

or if $\Delta a$ is small in comparison with $a$

$$J = J_0 e^{-\kappa a/\sin\alpha}.$$

Therefore the ratio of the intensity of the Röntgen ray in two symmetric to the normal plane emission directions $-\alpha$ and $+\alpha$ is $J_{(+\alpha)}/J_{(-\alpha)} = J_{0(+\alpha)}/J_{0(-\alpha)} e^{-\kappa a/\sin\alpha}$. If the ratio $J_{0(+\alpha)}/J_{0(-\alpha)}$ is tigger than 1 as the quantum hypothesis demands for the ideal case discussed above then this asymmetry will be reduced through the absorption in the anti-cathode in accordance with the relation above. It will depend on on possibility to increase $\kappa a$ or even change the sign before it. In usual Röntgen tubes of $\kappa a$ is so big that on the back side from the normal plane almost no rays come to observer.

## 3 The method

Because of the reasons discussed above I arranged the experiment in such a way that it could be possible to observe the asymmetry emission of Röntgen rays. The most important thing here was to find such a material for the cathode which could limit the growth of influence of two last subsidiary effects. From this point of view it seemed to me that the coal from the beech wood was the most suitable. Since the cathode made from it has the thickness 2 mm the absorption of Röntgen rays is not big as for the reason of it's small weight as because of the small atom weight of the carbon. Then in accordance with my interpretation of the Herweg experiment [1] on polarization of the primary Röntgen rays from some coal anti-cathode it was also reasonable that the fluorescence of Röntgen rays in coal is not very intensive in comparison with the emission produced by collision. The last reason is that in a hiting place of the cathode rays the anti-cathode from coal can be heated until the brightly red decaying without the melting.

The coal anti-cathode had a form of the plate with parallel surfaces of the diameter 20 mm. In the first series of experiments the thickness of inner part with diameter 16 mm was 1 mm. It was surrounded by the ring with the width 2 mm and thickness 2 mm. The bigger ring was necessary because on the edge of coal plate the gutter with 1 mm of depth should be made. Into this gutter the platinum wire of 0.4 mm thickness strained tightly was inserted. It's ends were screwed on the length 25 mm in such a way that the coal plate with the platinum wire on the edges was catched and held by the 25 mm stick from the double platinum wire. In Fig.3 the normal cross section through the coal anti-cathode is shown. As it can be seen from this figure the platinum wire which holds the coal plate was inserted into some copper pin. The latter was squeezed tightly into the glassy tube.

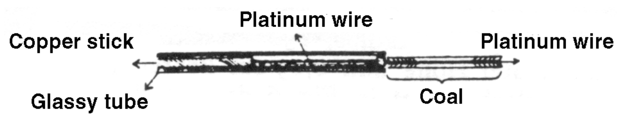



Figure 3:

In the second experiment series the coal plate was the 2 mm disk. It's fastening was the same as in previous case. So, this form of the coal anti-cathode is preferable because it allows easier measuring the absorption in the coal for different emission directions. Therefore I have adduced the measurements of only those snapshots which were produced with the help of the coal plate having thickness 2 mm. It was cuted from a piece of charcoal the broad side of which was parallel to the layers of the same age. The density was $0.4 g/cm^3$.

[1] J. Herweg, Ann. d. Phys. 29, 398, 1909

As the Röntgen tube was the spherical glassy tube with the radius 6.5 cm (Fig.4).

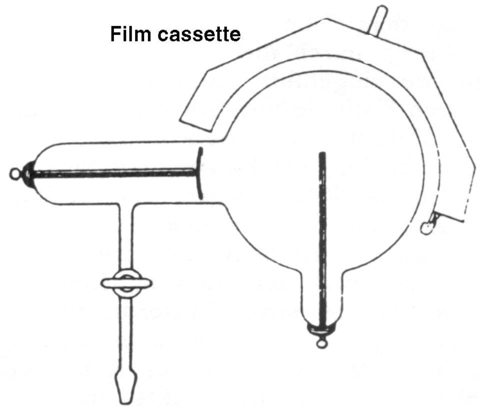



Figure 4:

From the entrance side (in the first experiment series without polishing, in the second one with polishing) the holder of the anti-cathode sticked out in such a way that the middle point of the coal plate coincided with the center of the tube. In position being normal to the coal plate and coaxially with it the concave aluminium anti-cathode was fastened in second entrance into the tube. It's length above the entrance was 29 mm.

Just for case, the tube was connected with the pump by the long lead with the crane to be able to pump out quickly the gas for the low pressure also. The pump was working perfectly. It's prevacuum was supported by a two-step oil pump. First of all, the tube was worked up during two hours. During this time it was undergone by the strong current from the big coil in such a way that it became warm. Then the coil was sweetched off or the current in the coil was so low that the pump could let out more gas than it was produced by the anti-cathode. In consequence of that the gas pressure was decreased quickly enough, the cathode dark space became longer. The cross section of the cathode beam became more narrow until few squared milimeters so that the whole glassy semi-sphere situated on the back side of the coal plate was screened from the cathode rays. In contrast, quitely bright fluorescence was produced on the front-side of the glassy semi-sphere by the further voltage increasing under the influence of the cathode rays being reflected in the front-side of the coal anti-cathode. These cathode rays were more striktly limited than it was usually observed in the ordinary

Röntgen tubes. As soon as this state came the coal plate had been decaying with the weakly dark red light from it's front-side on the $1 \div 3mm^2$ area. Then the emission of the Röntgen rays had to be registered with the help of a fluorescence background. Then the crane could be locked and if was possible to begin the observations. If the vacuum was getting worse because of the gas produced by the coal then the emission of the Röntgen rays stopped and the crane had to be unlocked. Then the voltage in the tube was reduced or switched off for a little while until the tube was refined again so that it could produce the Röntgen rays.

After long usage of the tube the coal plate crackled a little on the surface area where the cathode rays fallen especially if it was undergone by the strong voltage. With the help of a magnet the cathode rays could be directed a bit aside so that they could fall onto the part of the coal plate with initial properties.

During the most of observations the big coil was used as a current source. It was supplied by the mercury turbine interrupter. In front of the Röntgen tube some quitely powerful ventil tube was installed which led the remaining current into the secondary contour. Some experiment series was carried out with some influence machine having 20 plates. It was not observed some changes if the cathode was earthed or not.

For the observation of the fluorescence produced by the Röntgen rays the barium platinumzyan background was used. It had a width 3 cm, length 25 cm and was cuted from the fluorescence background for the Röntgen rays. It was bended into the semi-circle and fixed by the cutting of the opaque cardboard. This all was installed on some wooden stem. The background was installed co-central in front of the tube so that it's surface had the vertical position. The tube was installed in such a way that the cathode was horizontal and the holder of the coal anti-cathode was vertical.

For the photographic observation of the Röntgen emission was used the agfa-film of the width 3.9 cm and length 24.5 cm. It was inserted into the circular cassette from brass tin of the radius 8 cm (Fig. 5a) and covered by the sheet of black paper with the same size. Then it was fixed by some frame (Fig. 5b) with the cutting of the width 2.8 cm.

The frame was fixed by some hook from the one side and by the cassette from another side. Between film and the frame enclosed the strips of the same size from aluminium tin of thickness 0.4 mm could be so that some strip of 10 mm width with two 10 mm thick boxes from the aluminium tin were covered. As can be seen from Fig. 4 the film cassette was installed co-central with the Röntgen tube in such a way that the middle line of the circular cylindric films was directed into the symmetry plane of the Röntgen

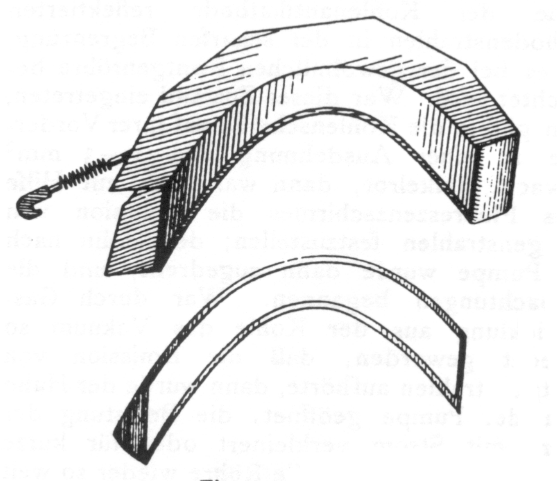


Figure 5: a, b

tube. The length of the film from the middle point of tube was 8 cm. The exposition time was between 2 and 10 minutes.

For making the snapshots of the Röntgen rays intensity inside the tube was used the circular cassette from the aluminium tin of the radius 6.1 cm, angle range $150^o$, height 1.1 cm and the depth 0.15 cm. It's normal cross-section is shown in Fig. 6.


Figure 6:

Some film strip of the width 1.1 cm and length 16.2 cm was enclosed to some thin opaque black paper. It was pressed in the back side of the cassette plate. Then they all together were enclosed into the cassette frame. Due to this arrangement of the cassette the front-side of the film was covered by the black paper in the middle of the area of the width 5 mm and by the aluminium layer of thickness 0.4 mm. From the edges it was covered in the area 4 and 2 mm respectively by the 0.8 mm aluminium layer. Therefore those Röntgen rays could be observed which penetrated through the 0.4 mm aluminium layer and also those one which came through the layer with double thickness.

The aluminium cassette loaded with the film was inserted into Röntgen tube through the polished opening symmetric in the plane going through the cathode and a stick of the anti-cathode. So, the tube appeared to be so that the cassette was on the bottom and the coal anti-cathode was sticked out from the up-side to the tube installed on the pump. Between the pump and the tube some small vessel with the fresh phosphor–pentoxyd was fixed. In consequence of the fact that the film inside the tube was for a long while under the influence of vapour this process was lasting more long time until the pressure in the tube became so small that the tube Röntgen rays were produced. It had to be pumped out at least 7 seconds until the tube could come to this state. Also then any high vacuum could not be achieved. So, it could be operated only with weak Röntgen rays for the relatively small cathode voltage. Moreover, also during the time when pre-pumps do not supply the tube by current the coal anti-cathode was not cleaned from the gas. Namely, I wanted to exclude some influence of the discharging on the film developing of the Röntgen rays.

Before the fluorescence method the photographic method of observation has the advantage of the objectivity and possibility of quantitative observation. In contrast, the fluorescence method has the advantage of more short observation time. The lack of both methods is that they provide only the rough measurement of the Röntgen rays intensity and do not allow to distinguish the rays of a different frequency.

## 4 Observations.

From the very beginning of the observations and during further observations both the fluorescence method and the photographic method gave the same result that the intensity distribution of the Röntgen rays was asymmetric in respect to the plane (normal plane) going through the collision place normally to the direction of the incoming cathode rays. The emission into the front side of the normal plane, i.e. in direction opposite to the cathode rays, was less than into the back side of the normal plane, i.e. in direction of the cathode rays.

From the first sight it was striking that during the observations inside and outside of the tube except the asymmetry in blackening the snapshots had the unblackened strip in place where the rays came with zero angle. In it's turn the fluorescence background had the dark stroke of the same width. It was a clear shadow imagination of the platinum wire with the thickness 0.4 mm which enveloped the coal plate from the edges and held it.

Then it was also striking on the snapshots which were made with the coal plates of the same thickness that the blackening was continuing from the side of positive angles after going through this shadow of the platinum wire to the area of the negative angles. But after this it increased rather quickly and then it was going to decrease again.

This area of the small blackening between the platinum wire and the area of the sharp increasing of the blackening was clearly produced by those Röntgen rays which were coming with the angles between the plane of the front coal surface and the surface of the cone which has the top in the collision place and touch the the platinum wire enveloping the coal. So, the place of the sharp increase of the blackening on the boundary of the coal anti-cathode shadows corresponds to the emission angle $\alpha = 0$.

On the best three snapshots the blackening was checked with the help of the Hartmann microphotometers. In the Table II those measurements of some photogramme are reproduced which were done with the Messing cassette (Fig.5) out of the tube. One third of the film width was covered by the aluminium tin of the thickness 0.4 mm.

**Table II.**

| Mark cm | Blackning unter 0.8 mm Al | Blackning unter 0.4 mm Al | | Blackning without Al |
|---|---|---|---|---|
| (Radius 8cm) | Observed blackening $S_b$ | Observed blackening $S_b$ | $S_\tau = S_b$ $-0.412$ | Observed blackening $S_b$ |
| 1 | 0.405 | 0.455 | 0.043 | 0.603 |
| 1.5 | 0.455 | 0.474 | 0.062 | 0.665 |
| 2 | 0.430 | 0.512 | 0.100 | 0.747 |
| 2.5 | 0.487 | 0.535 | 0.123 | 0.763 |
| 3 | 0.491 | 0.585 | 0.173 | 0.870 |
| 3.5 | 0.488 | 0.612 | 0.200 | 0.927 |
| 4 | 0.496 | 0.650 | 0.238 | 1.000 |
| 4.5 | 0.535 | 0.710 | 0.298 | 1.046 |
| 5 | 0.547 | 0.710 | 0.298 | 1.101 |
| 5.5 | 0.575 | 0.739 | 0.327 | 1.125 |
| 6 | 0.580 | 0.756 | 0.344 | 1.131 |
| 6.6 | 0.592 | 0.774 | 0.352 | 1.177 |
| 7 | 0.602 | 0.820 | 0.408 | 1.200 |
| 7.5 | 0.642 | 0.909 | 0.497 | 1.240 |
| 8 | 0.684 | 0.964 | 0.552 | 1.307 |
| 8.5 | 0.715 | 0.999 | 0.587 | 1.397 |
| 7.75 | 0.708 | 1.030 | 0.618 | 1.413 |
| 9 | 0.721 | 0.998 | 0.586 | 1.372 |
| 9.25 | 0.637 | 0.833 | 0.421 | 1.227 |
| 9.5 | 0.642 | 0.899 | 0.487 | 1.238 |
| 9.75 | 0.665 | 0.908 | 0.496 | 1.194 |
| 10 | 0.425 | 0.412 | 0.000 | 0.589 |
| 10.25 | 0.375 | 0.600 | 0.188 | 0.971 |
| 10.5 | 0.624 | 0.903 | 0.491 | 1.274 |
| 10.75 | 0.680 | 0.967 | 0.555 | 1.320 |
| 11 | 0.694 | 0.970 | 0.558 | 1.318 |
| 11.25 | 0.733 | 0.990 | 0.578 | 1.357 |
| 11.5 | 0.767 | 1.015 | 0.603 | 1.400 |
| 12 | 0.772 | 1.046 | 0.634 | 1.465 |
| 12.5 | 0.776 | 1.064 | 0.652 | 1.479 |
| 13 | 0.845 | 1.086 | 0.674 | 1.496 |
| 13.5 | 0.796 | 1.065 | 0.653 | 1.503 |
| 14 | 0.740 | 1.083 | 0.671 | 1.516 |
| 14.4 | 0.748 | 1.078 | 0.656 | 1.540 |
| 15 | 0.773 | 1.078 | 0.666 | 1.522 |
| 15.5 | 0.729 | 1.065 | 0.653 | 1.506 |
| 16 | 0.755 | 1.044 | 0.632 | 1.480 |
| 16.5 | 0.740 | 1.050 | 0.638 | 1.485 |
| 17 | 0.735 | 1.35 | 0.623 | 1.490 |
| 17.5 | 0.694 | 1.020 | 0.608 | 1.434 |
| 18 | 0.725 | 1.000 | 0.588 | 1.426 |
| 18.5 | 0.739 | 1.998 | 0.586 | 1.398 |
| 19 | 0.718 | 1.003 | 0.591 | 1.409 |
| 19.5 | 0.678 | 1.005 | 0.593 | 1.417 |
| 20 | 0.655 | 0.979 | 0.567 | |

One other third was covered by two layers of the same 0.4 mm aluminium tin and the last third in the middle of the film was covered only by the black paper.

In the Table III those measurements of some photogramme are shown which were done inside the tube with the aluminium cassette described above.

In the first approximation the assumption can be accepted that the blackening produced in some photographic layer is proportional to the absorbed energy of the Röntgen rays. In it's turn it depends somehow on the type of the rays. On the same conditions it's degree is more for the soft rays and less for the hard ones. First of all we would like to neglect the dependence of the blackening on the absorption index for the definite type of the Röntgen rays.

**Table III.**

| Mark cm | Blackening under 0.8 mm Al | | Blackening under 0.8 mm Al | |
|---|---|---|---|---|
| (Radius 6.1 cm) | Observed blackening $S_b$ | $S_\tau = S_b$ $-1.050$ | Observed blackening $S_\tau$ | $S_\tau = S_b$ $-1.100$ |
| 1 | 1.140 | 0.090 | 1.457 | 0.357 |
| 1.5 | 1.135 | 0.085 | 1.457 | 0.357 |
| 2 | 1.160 | 0.110 | 1.457 | 0.357 |
| 2.5 | 1.186 | 0.136 | 1.506 | 0.406 |
| 3 | 1.188 | 0.138 | 1.519 | 0.419 |
| 3.5 | 1.232 | 0.182 | 1.534 | 0.434 |
| 4 | 1.201 | 0.152 | 1.567 | 0.467 |
| 4.5 | 1.250 | 0.200 | 1.600 | 0.500 |
| 5 | 1.280 | 0.230 | 1.647 | 0.547 |
| 5.5 | 1.360 | 0.310 | 1.637 | 0.536 |
| 6 | 1.325 | 0.275 | 1.673 | 0.573 |
| 6.25 | 1.300 | 0.250 | 1.672 | 0.572 |
| 6.5 | 1.280 | 0.230 | 1.685 | 0.585 |
| 6.75 | 1.345 | 0.205 | 1.656 | 0.556 |
| 7 | 1.310 | 0.260 | 1.682 | 0.582 |
| 7.25 | 1.275 | 0.225 | 1.573 | 0.473 |
| 7.5 | 1.270 | 0.220 | 1.510 | 0.410 |
| 8 | 1.050 | 0.000 | 1.100 | 0.000 |
| 8.25 | 1.207 | 0.157 | 1.493 | 0.393 |
| 8.5 | 1.255 | 0.205 | 1.512 | 0.412 |
| 8.75 | 1.267 | 0.217 | 1.573 | 0.473 |
| 9 | 1.268 | 0.218 | 1.596 | 0.495 |
| 9.25 | 1.334 | 0.284 | 1.645 | 0.545 |
| 9.5 | 1.328 | 0.278 | 1.648 | 0.548 |
| 9.75 | 1.387 | 0.337 | 1.669 | 0.569 |
| 10 | 1.350 | 0.300 | 1.690 | 0.590 |
| 10.5 | 1.402 | 0.352 | 1.754 | 0.654 |
| 11 | 1.376 | 0.326 | 1.714 | 0.614 |
| 11.5 | 1.370 | 0.320 | 1.745 | 0.645 |
| 12 | 1.350 | 0.300 | 1.742 | 0.642 |
| 12.5 | 1.361 | 0.311 | 1.770 | 0.670 |
| 13 | 1.307 | 0.257 | 1.738 | 0.638 |
| 13.5 | 1.336 | 0.286 | 1.724 | 0.624 |
| 14 | 1.376 | 0.326 | 1.738 | 0.638 |

The observed blackening ($S_b$) is equal to the sum of the (reduced) blackening ($S_r$) produced by the Röntgen rays and the blackening produced by the background or diffusive secondary emission. For the latter case I took the smallest blackening of the snapshot in a place of the shadow from the platinum wire. Especially for snapshots which were done inside the tube the background was strong. Perhaps it was a consequence of the sharp drying up.

In order to correct the blackening of the table II for the same absorption in the glassy wall I defined the absorption index for the glass. It was done for the area of the film lying on the emission direction $\alpha = 30^o$ which was partially covered by the same glass of 0.4 mm thickness as in the tube. Then the blackening was compared for the areas which were covered by the glass and were not covered. So produced snapshot showed the same variation of blackening as in the Table II. The absorption index of the glass appeared to be $8cm^{-1}$. The absorption index could be obtained for each snapshot in the following way. Let $S_{-\delta\alpha}$ be the maximal (reduced) blackening for the emission near direction $\alpha = 0^o$ defined above and $S_{\delta\alpha}$ be the maximal (reduced) blackening near this direction. Then the absorption index of the anticathode is

$$\kappa = \frac{\log S_{-\delta\alpha} - \log S_{\delta\alpha}}{r \log e}.$$

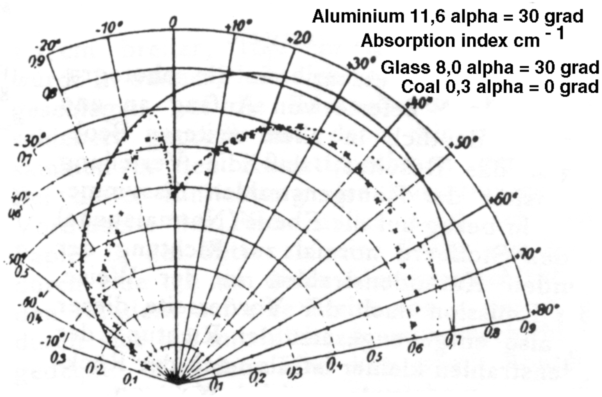
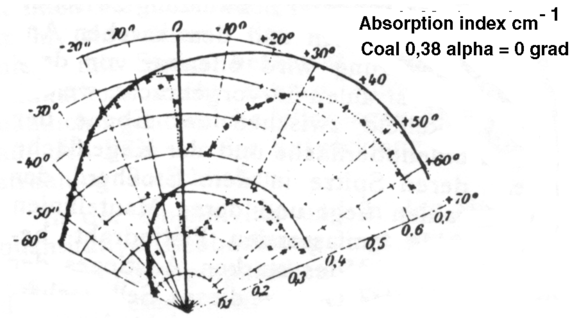



Figure 7:

In Fig.7 is shown the reduced blackening of the table II for the case of the aluminium tin. Graphically are depicted the emission directions for which an observed blackening curve is the blackening curve for the same glass absorption (glass thickness 0.81 mm) and the blackening curve for the same absorption in glass and for zero absorption in the coal anti-cathode.

Analogously in Fig.8 are shown the blackenings of the Table III. Only the correction for the absorption zero in the coal anti-cathode was important here.




Snapshots inside the tube; radiation going through the aluminium of thickness 0,4 and 0,8 mm; observed blackening curve ...., ..... corrected coal absorption.

Figure 8:

By the comparison of figures 7 and 8 first of all is remarkable the coincidence of as the corrected as the non-corrected blackening curves of two snapshots; one of those was done inside the Röntgen tube and another outside the tube.

The bare (corrected) blackening curves of the both figures show evidently that the emission intensity of the Röntgen rays being measured by the photographic effect is essentially asymmetric in respect to the plane going through the colliding place produced by the cathode rays and normally to it's direction. Namely, on the back side of this normal plane i.e. in the direction of the cathode rays it is emitted more Röntgen rays as in the front side of the normal plane i.e. opposite to the cathode rays direction.

From the measurements of the snapshots made inside the tube (Table III, Fig.8) it is possible to come to the following result. If one calculates the absorption index of the aluminium thickness from 0.4 to 0.8 mm for any emission direction by the following relation

$$\kappa_\alpha = \frac{\log S_{\alpha(0.4)} - \log S_{\alpha(0.8)}}{0.04 \log e},$$

then the absorption index is the function of the emission direction.

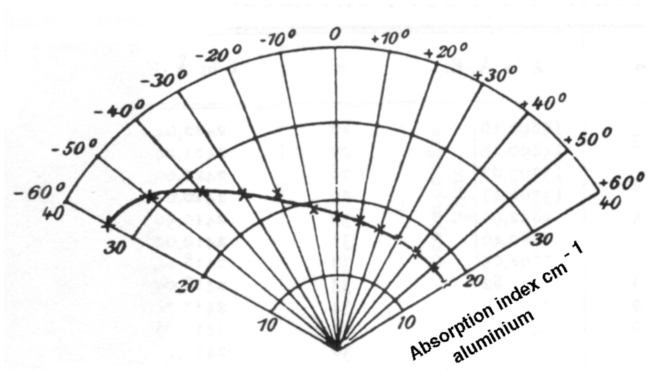



Figure 9:

As can be seen from Fig.9 there is some noticeable asymmetry to the normal plane of the Röntgen rays emitted by the coal cathode in respect to the absorption index as well. Namely, the Röntgen rays in the back side are more absorbable than in the front side.

My plan was to study the dependence of the intensity and the absorption index of the Röntgen rays on the emission direction for an observation of the different snapshots being made for the definite cathode beams. But for the arrangement used in the experiment it was not possible because during the making snapshots the gas pressure was not stable due to the gas income from the charcoal.

## 5 The conclusions

The presented observations showed that the emission of the Röntgen rays from the coal cathode is asymmetric in respect to the normal plane. It is true as for the intensity as for the absorption index. It is possible that this result was simulated by some other source which was not noticed by me. So, I would like to ask those people who suppose the origin of this source to inform me about it so that I could take these reasons into my consideration during the next experiments.

If we accept the asymmetry of the Röntgen rays emission produced by the cathode beams as being evidently observed then one can get from it some different theoretical conclusions. Of course, one could adduce some arguments against the possibility of clear decision between the ether wave hypothesis and quantum hypothesis of the light. One could say that it is doubtful if the Röntgen rays were polarizable electromagnetic radiation spreading with the speed of light or it were some matter radiation or it were the radiation of negative pairs (positive and negative electrons) in accordance with the Bragg hypothesis.

If one accepts that the Röntgen rays are electromagnetic radiation spreading with the speed of light and being polarizable then one can distinguish between the ether wave hypothesis and quantum hypothesis of the light using two facts. The first one is that due to the change of the momenta during the collision of electrons the cathode beam produces the Röntgen rays which have not the same intensity and absorption properties in all emission directions. Namely, into the back side of the normal plane come the radiation of more intensity and less absorbility than into the front side. The second fact [2] was noticed on the same time by myself [3] and it is important for the radiation theory. Namely, also for bigger distances from the emission center the Röntgen rays bring the cathode radiation with the energy produced by the emission of the single primary cathode electrons. It is impossible to compound these both facts in the framework of the ether wave hypothesis. In contrast, they can be naturally explained with the help of the quantum hypothesis of light. Namely, in accordance with this hypothesis the energy of electromagnetic radiation spread into the all directions of the hypothetic medium ether not in the same way but it concentrates in some finite packets the center of mass of which moves with the speed of light.

If the emission asymmetry of Röntgen rays in respect to the normal plane supposed to be accepted both for the intensity and for the absorption properties one can come closer to the study of some related phenomena.

The phenomenon of the emission of Röntgen rays due to the secondary cathode radiation because of the absorption has the same nature.

It is reasonable to admit that if the Röntgen rays are absorbed in some thin plate of some substance then more secondary cathode rays go out into the back side of the normal plane (plane being normal to the direction of Röntgen rays and going through the absorption place) than into the back side. Further the cathode rays emitted into the front side should have on average less speed than ones emitted into the back side.

The $\beta$-rays of radioactive elements are quicker cathode rays. Meanwhile, the $\gamma$-rays have probably bigger frequency. Analogously the $\beta$-rays going out from the atom of some matter bring very few of $\gamma$-radiation into the

[2] E.Dorn, Abh. d. Naturf.-Ges. Halle 22, 39, 1900; A. Bestelmeyer, C.R. 130, 1013, 1907.

[3] J.Stark, diese Zeitschr. 10, 579, 1909.

opposite direction of it's movement but much more $\gamma$-radiation into the back side in respect to the normal plane. In contrast, the $\gamma$-radiation of the radioactive elements during it's absorption in some matter bring more and quicker secondary $\beta$-rays alone it's emission than in the opposite direction.

The theory of the emission resulting from the electromagnetic momenta of collided electrons must be separately studied in accordance with the quantum hypothesis of light in the range of wave length 450-250 $\mu\mu$. [4]

Aachen, Technical high school, 5. November 1909.

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[4]The conclusion made above was used by Meyer and Steubing from my experimental date for the checking it.