the errors of the readings are less than $^1/_{1000}$ of the deviation, very different intensities may be determined with the same resistance to at least $^1/_{10}$ percent. In this case the current was weak, and it is clear, how with the quadrant-electrometer we may determine among others the constant of mirror galvanometers without any difficulty. If on the other hand we have a „Normal Widerstand" of 0.001 ohm, as it is constructed by SIEMENS and HALSKE for instance, a current of 1000 ampere may be measured with the same accuracy.

To conclude I shall point out a circumstance which may occur in some cases with such measurements, and which may cause very great mistakes, and has rendered a great many of my own experiments worthless. In this laboratory 30 accumulators are coupled in series, and different groups may be used in different rooms; in my experiments the current, which passed also through the resistance, mentioned on page 6; was taken from a group of 5 accumulators; one end of this resistance was connected with the earth, the other with the electrometer; when however in another room another group of accumulators is used at the same time and part of the circuit is in connection with the earth in that room too, or is not quite insulated, the end, connected with the electrometer may be between two points which are in connection with the earth, and the true difference of potential is not measured. A mistake of this kind is at once found when we change the direction of the current; moreover this mistake may be easily avoided by insulating the cells used.

Physical Laboratory. Groninghen.

Physics. — *„On the influence of the dimensions of the source of light in diffraction phenomena of* FRESNEL *and on the diffraction of X-rays."* (Third communication.) By Dr. C. H. WIND (Communicated by Prof. H. HAGA).

17. In my former communications on this subject [1]), I have pointed out (cf. Arts. 10 and 16) that the theory concerning the influence of the widening of the illuminated slit, in the simple form at least in which it was given there, cannot explain the fact that, when the diffraction slit gradually narrows towards one end, the two principal maxima continue to appear as two distinct bright or (on photographic negatives) dark lines, even after the point of inter-

[1]) Versl. K. A. v. W. 5, p. 448 and 6, p. 79, 1897.

secting. According to theory there should be soon after the point of intersection an area of nearly uniform maximal illumination in the middle of the diffraction image, covering the whole region between the two places where in fact the maxima are seen. This difficulty is solved by the optical illusion, which I have described in the Proceedings of the May-Meeting. In cases like that mentioned — viz: those, where a zone of uniform maximal illumination gradually passes on both sides into zones of continuously decreasing illumination — there are indeed two separate maxima to be observed on the borders of the bright zone (cf. fig. 9 and 10 in the former communication).

18. This proves already that the optical illusion mentioned may largely influence our observations of diffraction phenomena. As also appears from some experiments, which I have lately made for this purpose, this influence may even be so great, that the real distribution of light in the diffraction images can hardly be deduced from immediate observation in many cases. So, for instance, it has struck me repeatedly that the diffraction image of a slit still shows the principal maxima with great distinctness, even when the luminous slit has a considerable width, whereas theory indicates the excess of intensity in the maxima, compared with the field round them, to become smaller and smaller, when the slit is widened more and more. As we know now, that under the influence of the optical illusion distinct maxima of brightness are observed even on the borders of a zone of uniform illumination, provided that it passes into zones of decreasing intensity, we may by no means wonder, if we see the principal maxima apparently continue to be clearly visible, though their excess of intensity become very small. We may ask however, whether, because of the optical illusion, the place where we observe our maxima of *brightness* be still the same as the place where those maxima of *illumination* really occur. And without any doubt the answer ought to be: no. Yet it may be presumed and experiments have confirmed, that, as long as the principal maxima themselves are of a considerable distinctness (excess of *intensity*), their apparent place is only slightly influenced by optical illusion, that i. o. w. the place, where our eye observes a maximum of *brightness*, is chiefly determined by the principal maxima themselves. This explains why some measurements of secondary diffraction images, mentioned in my second communication on the subject, may have led to a taxation of the wave-length of light which was not quite wrong.

19. Another remark relating to my former experiments is this. The maxima observed in the secondary diffraction images are of a pure white, though we should expect them to be slightly coloured,

as their place, as deduced from the theory of those diffraction images, is not quite independent of wave-length. We now easily understand this particular to be also due to the optical illusion. The differences of colour, which should really exist to some extent, have intensities, which correspond to the real excesses of *illumination* in the principal maxima and by no means to the much greater excesses of *brightness*, which our eye perceives there.

20. Whereas our optical illusion leads in this way to the explanation of some difficulties, it compels us on the other hand to give up our former conclusion (cf. Art. 15), that the analogy between the shadow images of X-rays and of ordinary light justifies the supposition that the X-rays consist of undulations. The facts mentioned in my former communication sufficiently show, that even without a trace of diffraction the X-rays could produce shadow images, which present to our eye the well-known bright and dark fringes. The photo a reproduction of which is given in that communication as fig. 6 shows in originali a character which agrees perfectly with the (negative) X-shadow images, obtained formerly by FOMM and others. Its dark fringes are by no means less distinct than those of the X-shadow images mentioned; and on the other hand the latter show very distinct bright fringes on their outer sides — though there may have been paid little attention to these fringes hitherto —, these bright fringes being exactly those corresponding to the bright circular lines in fig. 6. Moreover it is by no means difficult — as I pointed out in Art. 8 of my former communication — to obtain the X-shadow images with the characteristic bright and dark fringes by using slits of a considerable width (cf. fig. 10 of that communication). This however would contradict with expectations founded on the supposition of those fringes being caused by diffraction.

21. The optical illusion alluded to leaves, of course, beyond all doubt the correctness of the theoretical considerations, communicated before, on the influence of the widening of the luminous slit on diffraction pheuomena. Especially the simple method, developed in order to take that influence into account, holds quite good as far as concerns an exact interpretation of the diffraction images observed and a calculation of the distribution of light, which may be expected in diffraction images under given conditions [1].

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[1]) It is easy to see that my method for calculating the influence of the widening of the slit on the distribution of light in diffraction images also applies, in principle at least, to other diffraction phenomena than those of FRESNEL, e. g. to those of FRAUNHOFER, and it is easy to conceive how this method is to be modified for being applicable to such cases.

The following question seemed rather important. What are the different stadia through which the primary diffraction image, (projected by the edge of a screen f. i.), the luminous slit being gradually widened, passes into the shadow image, belonging to a slit so wide that diffraction has finished to be of any consequence; and how does the diffraction image present itself to our eye in the different stadia under the influence of the optical illusion mentioned. In order to be able to answer this question I have photographed a series of fifteen diffraction images of a rather wide slit, the luminous slit having throughout the whole series an ever increasing width, but the conditions of the experiment being left quite unaltered in any other respect. The width of the latter slit ranged between such limits, that the space through which the primary diffraction curve must be displaced, in the construction of Art. 5, in order to obtain a correct geometrical representation of the secondary diffraction image we should expect, corresponded in the consecutive experiments to displacements of the starting-point of the effective arch on the spiral of CORNU, as by which the well-known quantity v of FRESNEL varied from 0,2 (when the slit was narrowest) to 8,4 (when the slit was widest). Applying the construction alluded to, I have on the other hand drawn common-type graphical representations of the distribution of light in the diffraction images belonging to the consecutive widths of the slit. It is not the place here for a description in details of the distributions of *light* expected and of the distribution of *brightness* observed on the negatives; it may be sufficient to remark that most of the plates of the series showed a considerable difference between the distribution of light and that of brightness, a difference even as concerns the general aspect of the image. There is, however, not a total want of regularity in these differences. I generally found that the eye perceives *maxima* resp. *minima* of *brightness* in those places of the zones of continually increasing intensity (transition zones), where — in consequence of undulations of the primary diffraction curve — the rate of increasing of the intensity changes considerably. For the rest the diffraction appeared to come forth pretty clearly in the first plates of the series (the luminous slit being rather narrow), so far as concerns the general aspect of the images, whereas its influence further on in the series decreases more and more and is at last scarcely recognised. The latter remark is of some importance especially with a view to the following considerations.

22. The leading idea of the whole investigation has always been the desire to get an estimation of the wave-length of X-rays, or

at least a determination of a possibly low upper limit for such a wave-length. With a view to this purpose Prof. HAGA and myself have continued the experiments begun by Mr. TIDDENS; in the beginning, however, always with a negative result.

Finally two experiments have been made these last days under the following conditions. In both of them the width of the luminous slit was $\sigma = 49 \mu$ and this slit received the radiation of an X-ray tube (with self-regulating vacuum according to the newest system of MULLER at Hamburg), placed in such a way that the anticathode made a very small angle with the axis of the arrangement (cf. Art. 1) in order to procure the greatest possible concentration of the pencil of X-rays, terminated by the slit.

One of the ends of the diffraction slit was narrower than the other, the latter being of a width of $\pm$ 400 μ, the other of a few microns only. In the experiment A the distances were: $a = 293$, $b = 298$ cM., in the experiment B: $a = 605$, $b = 615$ cM.

Both the slits as well as the sensitive plate were attached to firm stands, fastened by means of plaster to columns of compact lime-stone, which were attached with plaster to the pillars or the stone floor of the building. The time of exposition was a little more than 8 hours for the experiment A, 40 hours for the experiment B.

After development each of the two plates clearly showed a thin black line, sharpening towards one end and being the image of the second slit.

By first observation there is no influence of diffraction to be perceived on either of the plates, the borders of the black line mentioned appearing almost absolutely sharp defined and the line itself ending in a very sharp point. Closer observation, however, shows on both sides a transition zone limited by a dark line on the inner side, by a bright one on the outer side. Finally, by looking carefully at the lines under a microscope, magnifying about 14 times, I have been led to the following observations.

1°. On plate A the dark and the bright lines are pretty sharply defined, much like those appearing in transition zones, where there is no diffraction. The distance between the dark and the bright fringe has for each of the transition zones an average value of about 67 μ over nearly the whole plate, while on the other hand the width of the transition zones as calculated from the values of σ, a and b would amount to 50 μ, in the supposition of rectilinear propagation.

Comparing the plate with the series of images mentioned in Art. 21, one may feel inclined to assume that the difference between

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those 67 and 50 μ be possibly caused by diffraction; but at all events it is certain that the image of the slit on plate A does agree pretty well in its aspect with the images on those plates of the series for which $v > 2,3$, but does not agree with the other images — a peculiarity which is quite compatible with the rather small value of the difference just mentioned. Hence follows, however, as is easy to calculate, that — *if* we may speak of a wave-length of X-rays — we may assume:

$$\lambda_x < 0{,}2\,\mu\mu\ .$$

2º. The dark and the bright lines on plate B are less sharply defined; the dark lines seem even to have passed into rather broad bands with a gradual decay of darkness towards the outer side, the image beginning in this way to resemble, as far as concerns its general character, the former plates of the series of experiments mentioned in Art. 21. It might even be considered, from its general aspect, as being exactly similar to those of the images of the series, for which v is about 1,5. If we might take this similarity for granted, it would follow that

$$\lambda_x = \pm\ 0{,}18\,\mu\mu\,.$$

Influence of diffraction in this experiment is also made probable to some extent by the fact that there have been found values for the distance between the dark and the bright fringes in the transition zones, which range between 76 and 91 μ over nearly the whole plate and amount to 78 on an average, so as to point to a distance actually bigger than on plate A; in this respect we should, however, remember that the measurements could not be effected with a high degree of accuracy. On the other hand the point of intersection of the dark fringes on this plate correspond with a larger width of the diffraction slit than on plate A, which also seems to point out an influence of diffraction. Nevertheless, though all these particulars may be considered as possibly being caused by diffraction, we ought to be aware it being by no means impossible that they might have been caused by continual, though very slight, vibrations of one or more of the stands, if only the manner in which these stands have been mounted may have not quite prevented them from any such continual motion.

3º. In the neighbourhood of the point-end of the image of the slit on plate A, my attention was repeatedly drawn to something, that in my opinion may possibly be considered as a slight indication of a fan-like broadening of the image of the slit, chiefly manifesting itself in a diverging of the two bright lines of the outer side. If we might assume, that this fan-like broadening really exists and is a consequence of diffraction, and further that such a broadening of the image does not occur before the diffraction slit is so narrow as to correspond at the utmost to a value 2 for the quantity v, we should find by calculation, as the diffraction slit has proved by measurement to have a width of 2,3 μ on the spot where the phenomenon is seen:

$$\lambda_x > 0{,}12\,\mu\mu\ .$$

Though on one hand I am aware that what I have described as seeming to be a fan-like broadening of the image of the slit is in its appearance so utterly mean, that every one might feel justified in not accepting my interpretation, yet it is on the other hand of some importance, that this particular presented itself to my eye quite spontaneously, I having had not the slightest expectation to observe anything of the kind.

4°. After having observed the phenomenon mentioned under 3° on plate A, I tried to find something of the same kind on plate B, and indeed I succeeded in finding a place which gave an indication of a phenomenon somewhat like it. The phenomenon being even less distinct here than on plate A is in itself not astonishing at all, as plate B on the whole seems to be much less affected by the processus of insolation and development than plate A. The spot where I believed to observe the fan-like broadening lies higher here than on plate A, viz: on such a height as to correspond with a width of the diffraction slit of about 30 μ.

If the reality of this phenomenon might be accepted, we might deduce from it by calculation:

$$\lambda_x > 0{,}15\ \mu\,\mu,$$

suppositions of the same kind being made as before.

It is in agreement with the above remarks that the image of the slit extends considerably farther, at the point-end, on plate A than on plate B and less far on both the plates than would correspond to the real length of the diffraction slit. We may, however, not attach too much importance to this fact, 1°. because plate B shows on the whole a less intensive darkness than plate A, as has already been said, and 2°. because the diffraction slit becomes so exceedingly narrow on one end, that we could not expect much effect of the insolation on the corresponding parts of the negative, even if diffraction were to be excluded from before hand.

I do by no means intend to say that by what precedes the conclusion might be justified, that X-rays *are* diffracted and that *they have a wave-length of about* 0.1 *à* 0.2 $\mu\mu$. Yet, as we have arrived through two or three independent ways at results which agree pretty well, those results — though each of them, the first excepted, may separately be of nearly no value at all — if taken together make me believe, that the conclusion mentioned *may possibly be not very far from truth.* Moreover they make a further investigation in the same direction desirable. As to the result mentioned under 1⁰. I think it may be accepted without any restriction [1]).

Physics. — *The galvanomagnetic and thermomagnetic phenomena in bismuth*, by Dr. E. VAN EVERDINGEN JR. (*Communication* No. 42 *from the Physical Laboratory at Leiden*, by Prof. H. KAMERLINGH ONNES).

In order to explain the galvanomagnetic and thermomagnetic phenomena RIECKE [2]) assumes that a galvanic current is always accompanied by a current of heat, and a current of heat by a galvanic current. The basis of these hypotheses lies in WEBER's theory of the conduction of electricity and heat in metals; in this theory also the conduction of heat is ascribed to the motion of charged particles *alone.*

The velocities of the positive and negative particles are:
for a slope of potential of 1 C. G. S. unit per cM. u and $-v$
for a slope of temperature of 1° per cM. g_p and g_n.

In the magnetic field H a positive ion with the velocity U is acted upon by a force $H\,U$ for each unit of electricity.

RIECKE assumes further that the velocities in the direction of this force of the particles are zero in the state of equilibrium in the case of the phenomenon of HALL; the equilibrium is reached by the combined action of a difference of potential and of temperature between the sides of the plate.

In this way he finds for the coefficient of the galvanomagnetic

[1]) With great pleasure I acknowledge the assistance given by Mr. C. SCHOUTE in the measurements, necessary for the experiments.

[2]) Gott. Nachr. 1898.