ON MAGIC MIRRORS.

BY MM. BERTIN AND DUBOSQ.

The people of the far East, the Chinese and the Japanese, in bygone times were only acquainted with metallic mirrors; and even to-day they make only these. They are made of speculum metal, of various forms and sizes, but always portable. One of the faces is polished and always slightly convex, so that its reflection gives images which are reduced in size; the other face is plane or slightly concave, and always has cast on it ornaments which are in relief. Among the many mirrors thus constructed there are a few which possess a wonderful property: when a beam of the sun's light falls upon the polished surface and is reflected on to a white screen, we see in the disk of light thus formed the image of the ornamentation which is on the back of the mirror. The Chinese have long known of these mirrors and value them highly; they call them by a name which signifies *mirrors which are permeable to the light.* We, of the West, call them *magic mirrors.*

Magic mirrors are exceedingly rare. We only find mention of them four times in the *Comptes Rendus* of the French Academy of Sciences. The first was presented to the Academy by Arago, in 1844; the second and the third were brought to the notice of the Academy in 1847 by Stanislas Julien and by Person, and the fourth was exhibited before that society in 1853 by Maillard. It is true that even so far back as 1832 Brewster gave a theory of the phenomena of magic mirrors; but his explanation was made on the basis of the description of one of these mirrors which came from Calcutta, but which Brewster had never seen. Finally, in 1864 and 1865, M. Govi read before the Academy of Turin two papers on very beautiful experiments which he had made with three magic mirrors; this brings to seven only the number of these mirrors which, up to that date, had been seen in Europe since men have begun to observe facts in a scientific manner. Therefore very few persons had seen magic mirrors till the month of last April, when an English physicist, Mr. Ayrton, professor at the Polytechnic School at Yeddo, exhibited several of these mirrors, which he had brought with him from Japan. He experimented with them, and very successfully, before a small audience in the laboratory of M. Carpentier. He then left for London, and it will probably be a long time before we again have the privilege of seeing these marvelous mirrors.

In the meantime I received a visit from M. Dybowski, my former pupil, who had returned from Japan, where for two years he had been the colleague of Professor Ayrton. He brought back with him as objects of curiosity four *temple mirrors*—that is to say, antique mirrors; these are far superior to mirrors of modern production, for the manufacture of these mirrors has been nearly abandoned by reason of the introduction of the silvered mirrors of Europe. We tried them together; three were circular, and the thinnest of them, which is a disk of 15·3 centimeters in diameter, was found to be slightly magic.

To try such a mirror we reflect a sunbeam from its polished surface on to a white cardboard, about one meter distant. But to obtain the very best effects we must illuminate the mirror with a diverging pencil of light; this pencil is made still further divergent by reflection from the mirror, because its reflecting surface is convex. We can now receive the reflected rays on a screen at a greater distance, and we at once see distinctly the magnified image of the ornamentation on the back of the mirror. These raised designs appear on the screen in white on a dark ground. The image thus made by our mirror was confused, because the mirror was not a good one; it would have been sharply defined had the mirror been properly made. I then knew of no means by which I could make it give better effects.

The means by which the mirror could have been improved were first pointed out by M. Govi in the second of his two papers to which we have referred. It is a consequence of the true theory of magic mirrors. The theory was not reached at once.

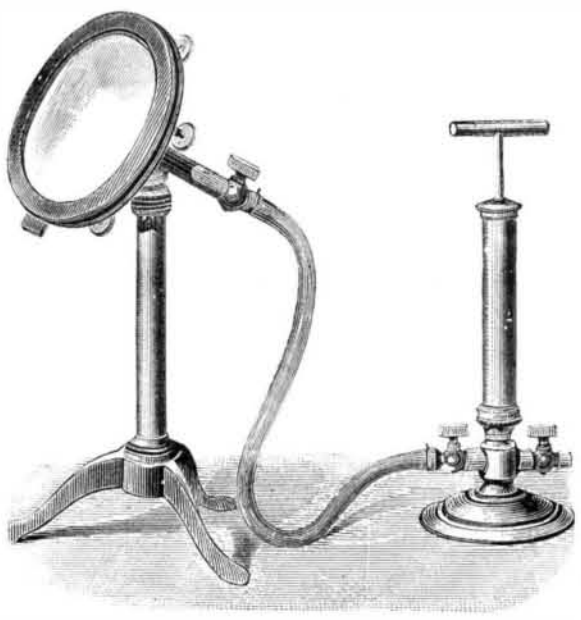
Stanislas Julien has found in the writings of a Chinese author of the twelfth century of our era an explanation of the wonderful effects of these mirrors. The author supposes that the designs in relief on the back of the mirror are reproduced by deep engraving on the front, and then a finer and more highly reflecting metal is poured into the lines of this engraving. On polishing the face of the mirror the magic effect is produced in the image by the greater reflecting power of the finer bronze.

The theory of Brewster does not differ substantially from that of the old Chinese. The polishing of the mirror effaces traces of the operation of engraving, rendering the surface the same throughout when inspected by ordinary light, but this engraving is developed when the sun's rays are reflected from the face of the mirror. But Brewster, who proposed this explanation, was not aware that this reflecting surface was really amalgamated.

This very ingenious theory was not known in France when they began to take interest in magic mirrors; if it had been it might have misled those who sought an explanation of these curious phenomena. The first French physicist, Person, who had the opportunity of experimenting with one of these mirrors, at once gave the true explanation of its action. He satisfied his own mind, by direct experiments, that the polished surface of the mirror was not regularly convex. It was so in all parts except those corresponding to the design on the back of the mirror. "The rays," says he, "reflected from the convex portions diverge and give but a feebly illuminated image; while, on the contrary, the rays reflected from the plane portions of the mirror preserve their parallelism and appear on the screen as an image by reason of their contrast with the feebler illumination of the rest of the image."

This irregularity of surface of these mirrors is brought about by the peculiar process adopted in working them, and which was explained to us by Professor Ayrton.

The mirror comes from the mould as a disk with a plane surface, and before it is polished this surface is scored in all directions with a pointed tool, and naturally it offers more resistance in the thick than in the thin parts. This operation tends to make a slightly concave surface, but the reaction of the elastic force of the plate makes this surface slightly convex; and this convexity is more pronounced in the thin portions of the plate than in those corresponding to the design on the back of the mirror. This irregularity of form of surface cannot be detected in diffused light, but it may, in the case of thin mirrors, produce the magic effect by the reflection of a very bright light, like that of the sun or of an oxyhydrogen jet. This is, indeed, the case with all badly wrought metallic mirrors; thus a plate of silver may give good reflected images, but on reflecting from it the sun's rays we will see on the image formed on a screen all the marks of the hammer which it received when it was being flattened. It is really a true magic mirror, only its reflected image is irregular and confused, while that of the magic mirror is regular like the design on its back.



THE MAGIC MIRROR

The experiments of Govi were made to overthrow the theory of Brewster and to establish that of Person. Though these experiments are very interesting, I shall not here describe them, because they have already been extensively published in the annals of science; I will only recall the last and the most curious of his experiments, that in which he heats the back of the mirror. The thin portions should heat more rapidly than those in relief; they will become more convex, the irregularities in the form of the surface will become more pronounced, and the magic effect will be increased; it may even be thus produced in mirrors which, without such treatment, are devoid of magic properties.

When I became acquainted with the papers of M. Govi, I proposed to M. Dubosq to associate himself with me, in order, first, to repeat the experiments of the learned Italian, and then to study generally the interesting phenomena of magic mirrors, in the hope of being able eventually to reproduce them in his workshops. At first we had at our disposal only the mirror brought from Japan by M. Dybowski, and which gave confused images with the reflected solar rays. These images became very sharply defined when we had heated the back of the mirror with a gas lamp, and the mirror gave very magic effects.

We then made a mould and reproduced this mirror, not in Japanese bronze, but in ordinary gun metal. The first copy was roughly worked on the lathe, after the Japanese manner, in order to render it magical, but this was broken. The second was worked carefully on an optical grinding tool; the surface was then polished and nickel plated, but it was not magical; but it acquired this property in a high degree when it was heated, and it even retained traces of this property after it had been repeatedly heated. Several Japanese mirrors which we have procured have given analogous results.

We then engraved letters on the back of little rectangular Japanese mirrors. On heating these the letters appeared in black in the reflected image. When we cut lines around the design on the back of the mirror, heat rendered them very magical, for the design stood out framed in the black lines which bordered the figures.

Thus it is seen that heat is very efficacious in rendering mirrors magical; but it is not without its inconveniences. First of all, it injures the mirrors, which thus lose their polish, especially when they have been amalgamated; also, the mirror is often not heated equally and the images are deformed. It occurred to us that the change of curvature which was required could be obtained more uniformly by means of pressure. M. Dubosq therefore constructed a shallow cylinder of metal, closed at one end by the metallic mirror, and at the other by a flat plate of brass, having in its center a stop cock, which we could attach by means of a rubber tube to a little hand pump. This pump could be made either to condense or rarefy air. If the rubber tube was attached to the pump, arranged as a condenser, a few strokes of the piston sufficed to compress sufficiently the air in the shallow cylinder; the mirror became more and more convex, the cone of reflected ray became more and more open, and in the image on the screen the design on the back of the mirror became more and more distinct. Our Japanese mirror, when thus treated, gave very fine images, and the copy which we had made, and which gave no result as ordinarily experimented with, now became a magic mirror as perfect as any of those which Professor Ayrton had exhibited before us. A mirror in brass, nickel plated, on whose back was soldered tin plate figures, around whose borders were cut lines, became very magical by pressure, and gave the design on its back in light surrounded by dark borders.

This is what I call the *positive image.* We can also obtain the *negative image,* or the inverse of the preceding one, by rarefying the air in the shallow box. To do this we have only to attach the rubber tube to the pump arranged as an ordinary air pump. On now working the lathe the air in the shallow box is rarefied, the mirror becomes concave, the cone of the diverging reflected rays close up, the image of the design is reduced in size, changes its appearance, and becomes an image of the design on the back of the mirror; but this now shows in shade bordered with bright borders.

These experiments require an intense light. A jet of coal gas is insufficient; but the oxyhydrogen light is sufficiently intense. We intercept it with a screen perforated with a small hole, so that the diverging pencil which falls on the mirror may not spread too much. The mirror is mounted on the top of a column, so that it can be made to face in any required direction. The effects are most brilliant and the best defined when we experiment with the rays of the sun. When we expose the mirror to the beam of the porte-lumière it is generally not entirely covered by the light; in this case it is best to use a diverging beam obtained by means of a lens placed between the porte-lumière and the mirror.

Thus we have seen that we can now make copies of the Japanese mirrors, some of which may be magical, but all may be rendered so by making them covers of the shallow box containing either compressed or rarefied air. This pressure box and its mirror, made in the Japanese style, certainly forms one of the most curious pieces of apparatus which is to be found in the cabinet of physics.

We shall not, however, stop here. One of these days, while our mirror is magical under the influence of pressure, we will take a cast of its surface, and then reproduce this by means of galvano-deposition. This surface will have all the irregularities of that of the magic mirror, and will produce by its reflected rays the image of a design which no longer exists on its back.—*Journal de Physique.*

Artificial Indigo.

Mr. Adolph Baeyer, of Munich, has discovered that by the action of sulphuric acid upon orthonitrophenylpropiolic acid a new product may be obtained which is capable of being converted into new coloring matters, or a dyestuff which he calls "artificial indigo."

The author says: "I take orthonitrophenylpropiolic acid, and in the cold I mix the said acid with sulphuric acid—say, for instance, with from about ten to twenty parts, by weight, of sulphuric acid of about 1·84 specific gravity to every one part, by weight, of orthonitrophenylpropiolic acid employed. In effecting the said mixture care is to be taken to avoid a considerable rise of temperature above, say, 20° Centigrade. The mixture thus obtained quickly assumes a bright yellow or orange color, and the reaction is allowed to proceed in the cold until a sample of the mixture, upon being tested for the presence of orthonitrophenylpropiolic acid by means of glucose and alkalies, no longer contains any appreciable quantity of the said acid. The sulphuric acid mixture thus produced is then submitted to the action of suitable reducing or deoxidizing agents in order to effect the conversion into artificial indigo.

"In practice I have found a great number of substances belonging to various classes of chemical compounds which act as deoxidizing agents upon the above-mentioned new product, and I may specially mention ferrous sulphate (green vitriol, copperas).

"As an example of the manner in which I prefer to conduct the aforesaid operation, I take the orange-colored mixture resulting from the treatment of one part, by weight, of orthonitrophenylpropiolic acid with about from ten to twenty parts sulphuric acid, as above described, and I mix the same with a solution containing about five parts, by weight, of ferrous sulphate. The mixture is then allowed to stand at the ordinary temperature until the blue color, which it quickly assumes, is fully developed, and the dyestuff or coloring matter thus produced may be separated out of the mass by diluting the result of the operation with water, by which the new dyestuff is precipitated, and may be filtered and washed. The dyestuff is then ready for use.

"The characteristics of my new dyestuff or coloring matter, prepared according to my above-described process, are the following: The dyestuff or coloring matter resembles in appearance vegetable indigo, and it can be used in dyeing in a manner similar to it; but it is in a great part soluble in aniline at an ordinary temperature, and also in an aqueous solution of sulphurous acid."