RADIO WORLD

REG. U.S. PAT. OFF.

THE HOW-TO-MAKE-IT MONTHLY—*14th Year*

JULY
1935

•
SOLDERING as a SCIENCE
•
4 TUBE PORTABLE
•
125 ILLUSTRATIONS

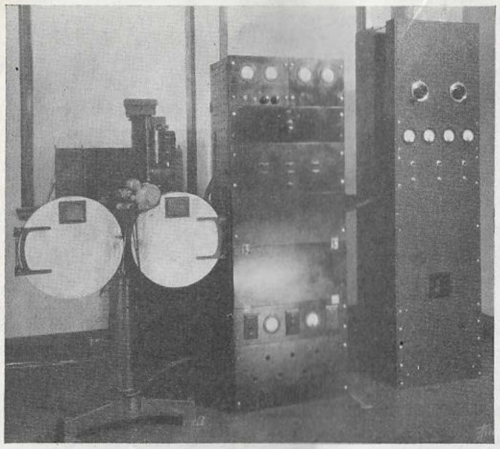
TELEVISION IN NATURAL COLORS

This is an actual photograph of a television receiver in which a mechanical method of scanning is used, producing black and white images. A method has been devised, based on the action of a Kerr cell on plane polarized light, for the production of images in natural colors. It is expected that this method will be perfected before the end of 1936. A girl's picture was superimposed on the screen in colors to represent the result expected to be achieved. See article on page 34

Television in Natural Colors

Selective Distortion of Kerr Cell Used

By J. E. Anderson



Movie reels, left, amplifier and, right, transmitter for television in colors.

TELEVISION in natural colors! Yes, indeed. It is possible, and it may not be long before it is realized. Heretofore we have had colored television, neon orange-red television, cathode ray green television, and we have even had white television. But not television in natural colors. When Dr. A. F. W. Alexanderson first demonstrated his method of television several years ago, a gentleman in the audience asked about the possibility of having television in colors, whereupon Dr. Alexanderson excited the risibilities of the listeners by saying it was time to think of that when they had mastered television in white and black. At that time it was the concensus that it would be possible by making use of the three primary colors, just as colored pictures are made, but there was no thought of television in natural colors.

If television in natural colors comes, it will undoubtedly be as the result of the application of a defect in the Kerr cell, a device now used for modulating the light at the receiver. Before we can speculate about the posibility of recreating television images in natural colors by means of this defect in the cell, let us describe briefly that cell.

The Kerr Cell

The Kerr cell is a small condenser immersed in one of several liquids having certain electro-optical properties. The most common liquid is nitrobenzene, because this liquid has the special property in a vastly greater degree than any other generally known. Let AA, Fig. 1, represent the plates of this condenser. The two metal plates and the nitrobenzene are not sufficient to make a Kerr cell modulator. There must also be a high potential difference, E, between the plates, so that there exists a strong electric field between the plates. The intensity of this field is $F = E/a$, where a is the distance between the plates. The field is usually expressed in electrostatic units of potential per centimeter. (One electrostatic unit equals 300 volts.)

Now suppose a beam of plane polarized light is passed between the plates AA. The plane of polarization of that beam will twist as the beam passes through. That is the effect that is utilized in modulating the beam of light, that is, in making it stronger or weaker.

We ought to say something about polarization. Light consists of vibrations in the ether, and they are electro-magnetic in nature. The electric force vibrates in one direction and the magnetic in a direction at right angles to that of the electric. Both are at right angles to the direction in which the wave moves.

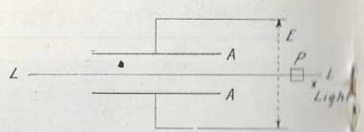


FIG. 1.
The principle of the Kerr cell. Two metal plates AA, immersed in a bath of nitrobenzene, are kept at a high potential difference E, and a beam of light, plane polarized by crystal P is sent between the plates.

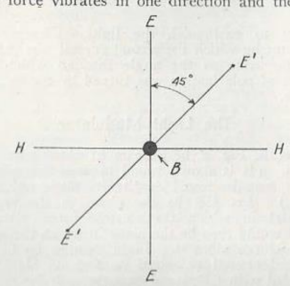
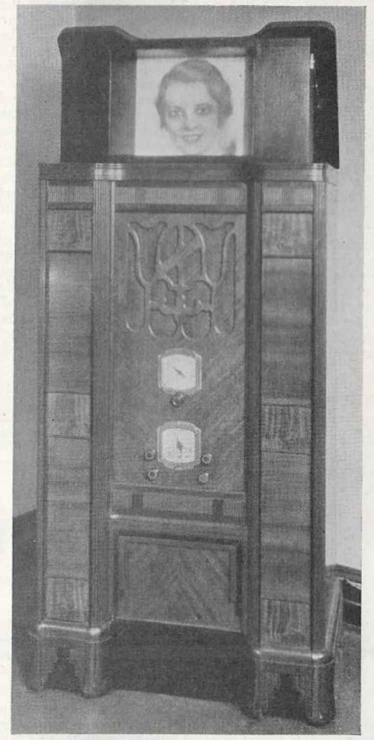


FIG. 2.
Looking head on into the beam of light as it emerges from the second crystal. EE is the electric axis of the second crystal and E'E' the plane polarization of the light beam B. Direction of E'E' is changed by the signal.



Appearance of the all-wave receiver developed for introduction to the Canadian market early next year, with provision for television. A wash drawing of a girl's head has been inserted on in the screen space to show where the picture will appear. The top cover is collapsible and may be kept down when the set is not being used for television.

The Electric Component Is Important

We are concerned now only with the electric part and the direction of propagation. When the light is unpolarized, the electric force does not vibrate in one plane only, but in all con-

(*Continued on next page*)

(*Continued from preceding page*)

ceivable planes, that is, in all planes that can be passed through the line LL. Such light is not suitable, and therefore the light beam from the source must be polarized.

Before we go on to say how this is done let us attempt to clarify the idea of polarization. Suppose we have a circular metal rod. It is the same in all directions and if we twisted that rod a little there would be no way of finding it out, especially if we could not see the rod. This rod is somewhat like a beam of unpolarized light. Now take a metal strip, thin and wide. If we twist that we can immediately notice it. It will become like a cork screw. This is somewhat like a beam of plane polarized light. The plane of polarization is the plane determined by the edges. We could describe a sine curve on one side of that strip, and that curve would represent the electric vibrations. We could not describe such a curve on the edge, if the strip were thin enough.

The light is polarized by passing the beam through a crystal of Iceland spar. The light that enters that crystal vibrates in all directions at right angles to the line of propagation, but the light that comes out vibrates in only one plane. It is about like passing a round rod through rollers, which make it flat.

Twisting the Plane

The light beam LL, Fig. 1, then is polarized. It has to pass through the strong electric field between AA, and as it passes the plane turns. When the liquid is nitrobenzene it twists a great deal, for a given field intensity. It twists more the stronger the field. In fact it twists in proportion to the square of the field, and that also means that it twists in proportion to the square of E, the voltage between the plates. Further, the twist is also directly proportional to the length of the condenser plates, that is, to the distance the light beam has to pass through the field.

We cannot tell by looking at the light whether it is polarized. Neither can we tell by looking that the plane of polarization has turned. To the eye the emergent light looks like ordinary light. The only apparent difference is that the polarizing crystal has cut out one half of the light. Also, the crystal and the liquid absorb some of the light. Hence as far as the eye can see nothing has happened to the light except that a little more than half of it has been removed. Maybe the eye can't observe that either, for the eye has the property of accommodation to different light intensities.

But suppose we put another crystal of the same kind in the path of the beam before we look at it. If this crystal is arranged optically the same way as the other, all the light that reaches it comes through. But if the second crystal is turned through a right angle, it cuts out all the remainder of the light. That is, as the second crystal is turned, the light grows weaker until it completely goes out. If the second crystal is turned still more, the light returns. This is the principle of the Kerr cell modulator. The amount of turning of the plane of polarization can be measured by first adjusting the two crystals so that no light comes through when there is no electric force between the plates, and then noting the amount of turning of the second crystal is necessary again to extinguish the light. Clearly, the amount by which the second crystal was turned is the same as the angle through which the plane of polarization was turned by the electric force.

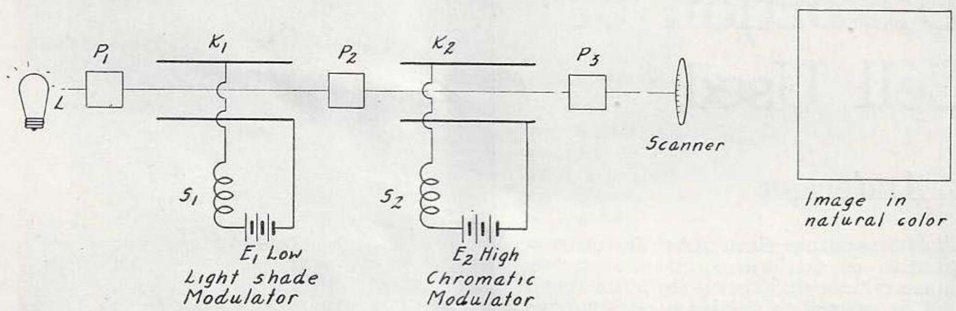


FIG. 3.
A suggested set-up for obtaining television images in natural color. P1, P2, and P3 are polarizing crystals. K1 and K2 Kerr cells, and S1 and S2 are coils by means of which the signals are superposed on the biasing voltages E1 and E2.

The Light Modulator

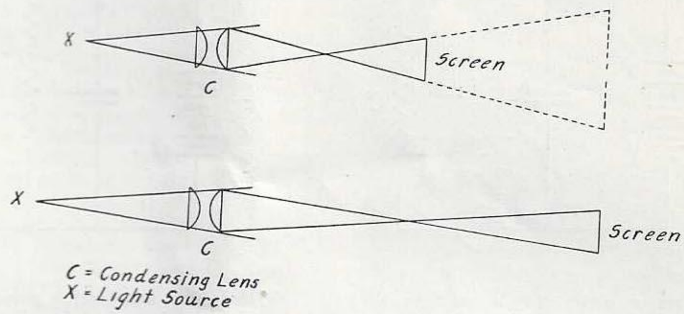
Let B, Fig. 2, be a beam of plane polarized light. (It is shown round because the spot of light may be round despite its plane polarization.) Let EE be the plane in the second crystal in which the electric force vibrates. HH would then be the plane in which the magnetic force vibrates. Light coming up to the second crystal polarized so that its plane coincided with EE would pass through the second crystal without loss. Light coming up to it polarized so that the plane coincided with HH would be cut out entirely. Now let E'E' represent the plane of polarization of the light for a given biasing force E across the Kerr cell. The second crystal can be adjusted so that this is the case. It is usual to adjust the crystal so that the plane of polarization of the light, E'E', makes an angle of 45 degrees with the polarizing plane of the second crystal. With this adjustment the crystal lets through one half of the light that reaches it, which is only one fourth of the original light.

Now let a signal voltage be superposed on E. If this is an increase, the plane of polarization turns more, in the direction EE. Then more than one half of the light comes through. If the superposed voltage is a decrease, the plane of polarization turns less, and E'E' lies closer to HH. Less light comes through. If the decrease is so large that E'E' coincides with HH, no light comes through and there is complete darkness. If the increase, on the other hand, is so great that E'E' coincides with EE, the emergent light beam has full brilliancy. The variation between full brilliancy, for the strongest contrasts in the image, can be adjusted by

in a lens or a mirror. If we are to have television in natural color, not only must a red turn out a red, a blue a blue, and so on, but the relative shades in each color must be retained.

Turning Affects Dispersion

The chromatic dispersion becomes greater the more the plane—the mean plane—is turned. If it is turned less than a quadrant, there is little difference, but if it is turned two or more quadrants, the effect becomes very marked. The total turning of the mean plane is controlled by adjusting the field strength in the Kerr cell that is, of E/a, and also by varying the length of the cell. It is proportional to the square of the field strength and directly proportional to the length of the cell. The field is limited by



Light varies inversely as the square of the distance. That is why the light intercepted by the small screen in the upper figure is greater than the same screen when placed in the lower figure. More light is intercepted by the condensing lens when it is close to the light.

varying the amplitude of the signal superposed on the biasing voltage.

Bringing Out the Color

The amount of turning of the plane of polarization is different for different colors. Thus the Kerr constant, which is a measure of the amount of turning, is inversely proportional to the wavelength of the light. When the liquid in the cell is nitrobenzene, the Kerr constant for a length of 6390 Angstrom units is 20.2 millionths and for 4670 Angstroms it is 31.1 millionths.

Thus for the same voltage the plane of polarization for the blue light turns more than that for the red. In a sense the light is broken up into a rainbow. However, this cannot be observed directly any more than the difference between polarized light can be told from ordinary light. But after the light that has been broken up in this manner has passed through the second crystal, it will contain a predominating color.

One color might come through with full brilliancy whereas other coolrs, higher and lower in wavelength than the favored color, will be partly blotted out. This predominating color has no relation to the color of the original image, but onlv to the values of lights and shades. As an example of what might happen, a light shade of blue might turn out to be a brilliant red, whereas a bright blue might turn out a pale orange. This color effect is obviously a defect, just as chromatic aberration is a defect

the electrical strength of the nitrobenzene but the length of the cell can be varied over wide limits. It is quite feasible to turn the mean plane so that the planes for the different visible colors are spread out over a whole quadrant.

This seems to offer a chance for television in natural colors but it is a problem for inventors to worry about.

It would seem that two cells in series would be necessary. There would first be a polarizing crystal. This would be followed by a Kerr cell in which the electric field was just sufficient to produce light and shade for all colors. This modulator would be operated in the first quadrant. This cell would be followed by a second in which the polarizing voltage was high so that the planes of polarization for the different colors would be spread out over a whole quadrant.

Amplitudes Used as Color Selectors

The light reaching the second cell would be polarized and modulated as to light and shade only. Terminating the series arrangement would be a third crystal which would let through onlv one color at a time, this color being determined by the intensity of the signal voltage superposed on the biasing voltage on the second cell.

There would have to be a correlation between the color of the original picture and the intensity of the signal voltage on the second cell. A weak signal would turn the blue sufficiently to let all the blue light through, but it would

(*Continued on next page*)

Color Difficulty in Television Wanes

(Continued from preceding page)

require a stronger signal to turn the plane of the red enough to let that through full strength. There would be comparatively little additional light loss as a result of the second cell, on any given color. There would be a little absorption in the second cell and in the third crystal. As an electro-optical feat, the reproduction of the original color seems to be much easier of accomplishment than the more complex electro-optical-mechanical feat of producing any kind of acceptable television images.