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BY

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In the study of the successive appearance of spectrum lines in spark and condensed discharges[1,2], it is desirable to study not only the beginning of a discharge but also any part of a discharge without the masking effect of the preceding and following stages. Also in determining the time between excitation and emission in fluorescence[3] as well as the time that the emission continues after the exciting light has been cut off, it is necessary to have an optical shutter which will open abruptly, remain open any desired time from 10^{-9} to 10^{-7} seconds and then close abruptly. For these purposes the method herein described has been developed.

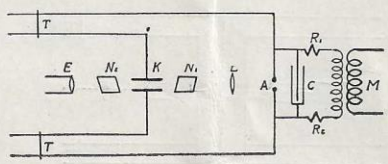

Fig. 1. *Electro-optical shutter.*

An electro-optical shutter (Fig. 1) which closes very abruptly has been previously described[1]. The arrangement is illustrated in Fig. 1. K is a "Kerr Cell" made by immersing two parallel plates of metal in a tube of carbon bisulphide. N_1 and N_2 are crossed Nicols, with their diagonals at 45° with the plates of K. If an electric field is applied across the plates of K, the carbon bisulphide becomes doubly refracting[4] and light passes N_2. If however the field across K is relaxed no light passes N_2. It was found that if the field in K was relaxed by the spark at A no light passed N_2 provided the leads from A to K were very short. By lengthening the lead wires from A to K light from the spark at A passes N_2. N_1KN_2 then is in effect, an electro-optical shutter, the closing of which can be advanced or retarded with respect to a spark by

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1 Brown and Beams, J.O.S.A. &.R.S.I., *11*, p. 11; 1925.

2 Beams, Phys. Rev. *28*, 8475; 1926

3 Hoxton and Beams, Abst. Phys. Rev., *27*, p. 245; 1926.

4 Kerr, Phil. Mag., *1*, pp. 337, 446; 1875; *7*, pp. 85, 229; 1879.

lengthening or shortening symmetrically the lead wires from A to K. In this shutter it will be noted that the field across K is applied slowly and hence the shutter opens slowly, its closing only being abrupt.

In the present arrangement (Fig. 2) S is a steady light source. N_1 and N_2 are crossed Nicol prisms, the diagonals of N_1 making 45° with the vertical. K_1 and K_2 are Kerr cells of practically identical dimensions (in most of these experiments each plate was 12 cm by 1 cm and the plates were 0.45 cm apart). The plane of the plates of K_1 was vertical while that of K_2 was horizontal. A is a spark gap which releases the electric field across K_1 and K_2. Connected across A is a source of high potential such as a 10000 volt 60 cycle transformer or induction coil. T_1T_1 and T_2T_2 are cross wires by which the lead wires from A to K_1 and from A to K_2 can be lengthened or shortened by the observer at E. If an electric field is slowly applied across A the electric fields in K_1 and K_2 are equal during the time of charging and hence,

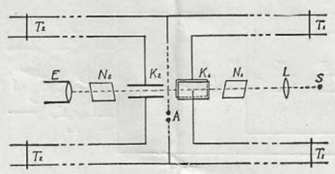

Fig. 2. *Electro-optical shutter which opens and closes abruptly.*

since K_1 and K_2 are identical and at right angles, the electric double refraction in K_1 is exactly compensated by that of K_2 and no light from S passes N_2. In the case of a sudden discharge of K_1 and K_2 through the spark gap A no light will pass N_2 if the lead wires from A to K_1 are equal and symmetrical with those from A to K_2, *i.e.*, the electric double refraction in K_1 at every instant is compensated by that in K_2. On the other hand if, by lengthening the lead wires from A to K_2, K_2 is made to discharge a certain time after K_1, light will pass N_2, *i.e.*, $N_1K_1K_2N_2$ acts as a light shutter which opens abruptly, remains open any desired time from 10^{-9} to 10^{-7} seconds and then closes abruptly. It will be noted that the charging of K_1 and K_2 is very slow in comparison to the discharge. This is necessary in order that K_1 and K_2 will be at the same potential during the charging when their lead wires to A are unequal. On the other hand it is desirable to charge them as many times per second as possible because this increases the number of light flashes and hence lessens errors of observation. The time required for the opening and for the closing of the shutter of course depends upon the capacity of K_1 and of K_2 and upon the length of the lead wires. With the dimensions used, a rough photometric study of the rate of increase of intensity of the light during the opening of the shutter shows that it completely opens in 10^{-9} seconds, and over ranges so far investigated the closing is almost as abrupt. The very quick opening and closing of this shutter results from the fact that the electric double refraction varies as the square of the electric field[4], and that the damping is sufficient to stop effective oscillations in K_1 and K_2.

The intensity of the light flashes depends upon the strength of the electric field in K_1 and K_2 and upon the intensity of the source S. A "tungs-arc" was used at S in most of the experiments, but it is not intense enough for many purposes.

The most intense source so far tested was made by picking out certain portions of the electric spark A placed at S. The brightness of A can be increased by placing Leyden jars in parallel with it and choosing desirable metals for electrodes. For light flashes over 5×10^{-8} seconds in length, unless considerable capacity is placed in parallel with A, the spark is unsatisfactory because of the variability of the intensity of the spark discharge. If a spectroscope is placed at E and the spectrum of the spark, say of zinc, examined, it is found that the air lines appear first with high intensity but very soon fade out. The spark lines next appear, followed by the arc lines, the spark lines fading out after the arc lines begin. It was found possible to pick out the (4912,24) spark lines of zinc practically alone and at this stage the zinc spark is probably at maximum brightness. The above observations are in general accord with those made by other methods.[5] A closer examination of both spark and condensed discharges is soon to be made.

Since the carbon bisulphide is opaque to the ultraviolet, a study of liquids to take its place has been made. It was found that chloroform made an excellent substitute for the carbon bisulphide. When pure it is a good insulator and has a negative Kerr constant[6] almost equal in absolute value to the positive Kerr constant of carbon bisulphide. Photographs of lines as short as 2558 AU have been made through the shutter when the Kerr cell was filled with chloroform and the Nicol prisms replaced by Foucault prisms. As is well known, if large Focault prisms are not available the Canada balsam in the Nicol prisms can be replaced by glycerine for work in the ultraviolet.

[5] See Baly, "Spectroscopy," p. 406, Longmans, 1912.
[6] Schmidt, Ann. d. Physik, 7, p. 142; 1902.

The question naturally suggests itself as to how long the electric double refraction in K_1 and K_2 remains after the electric field is removed. The above arrangement gives a method of determining the difference in this lag of the Kerr effect in any two liquids. A very rough test was hurriedly made with carbon bisulphide and chloroform. The zinc spark lines (4912,24) were used as a light source. K_1 and K_2 were first filled with carbon bisulphide and the lead wires so adjusted that no light passed N_2. The carbon bisulphide was then removed from K_2, chloroform was substituted, and the plane of the plates of K_2, rotated approximately 90° until complete compensation was secured while the cells were being charged. The arrangement, thus modified permitted light to pass N_2 but that a slight shortening of a few centimeters of the lead wires AT_2K_2 lessened its intensity, a minimum occurring at about one hundred centimeters decrease of lead wire. The reason that the light could not be completely extinguished when chloroform was substituted for carbon bisulphide was that the time of discharge of K_2 was changed (because of the difference in dielectric constants of carbon bisulphide and chloroform). This source of error however is very small and could not completely account for the observed lag. However the experiment definitely shows that the difference in the lag of the Kerr effect in carbon bisulphide and chloroform is at most very small, and less than $4 \cdot 10^{-9}$ seconds if we assume that the fall of potential travels along the lead wires at about the velocity of light. The writer hopes to carry out further experiments with different liquids under better experimental conditions.

In conclusion, it is a pleasure to acknowledge my indebtedness to Professor L. G. Hoxton for many valuable suggestions and criticisms, also to Messrs. A. T. Bishop and T. E. Gilmer for aid in investigating liquids for use in the ultraviolet, and to Mr. A. J. Weed, instrument maker, for help in the construction of apparatus.

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