## Transmission Line Kerr Cell

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# Letters to the Editor

## Transmission Line Kerr Cell*

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IF plane-polarized light with the plane of polarization at an angle (45°) to the electrical field passes through a liquid showing the Kerr electro-optical effect, the component parallel to the field travels at a different velocity from the component perpendicular to the field so that the light emerges elliptically polarized. The phase retardation $D=2\pi BlE^2$, where $l$ is the length of the light path through the electrical field $E$, and $B$ is the Kerr constant which varies with different substances, temperatures, and wavelengths of the light used. In many liquids no time lag has been observed between the change in the field and the change in the Kerr electro-optical effect, so that this effect has been used widely to make a light shutter (Kerr cell) which responds almost instantaneously to electrical control.[1] Usually a Kerr cell consists of a parallel plate condenser immersed in a liquid and placed between crossed Nicol prisms or polaroids. If the field is on, light will pass the combination, but if the field is off, no light can pass through. For very fast acting Kerr cell light shutters, it has been necessary to select a liquid with a large Kerr constant $B$ in order to get high light transmission (large $D$) at reasonable fields $E$. Also the dielectric constant must be small in order to reduce the circuital capacity to a minimum so that the cell may be operated with sufficient speed. In most applications, it has been necessary to use nitrobenzine in Kerr cells, as no other available transparent liquid possesses a large enough Kerr constant for practical use. Unfortunately, nitrobenzine is unstable chemically and is relatively conducting and relatively opaque in the violet. Furthermore, the dielectric constant is so high that the plates of the Kerr cell must be very small (which, in turn, gives rise to an inhomogeneous field) in order to avoid large circuital capacity.

The purpose of this report is to describe a very fast acting Kerr cell light shutter arrangement in which almost any liquid showing the Kerr effect may be used and in which the Kerr constant and dielectric constant are of much less importance than in the standard Kerr cell. In Fig. 1, AC is a parallel plate transmission

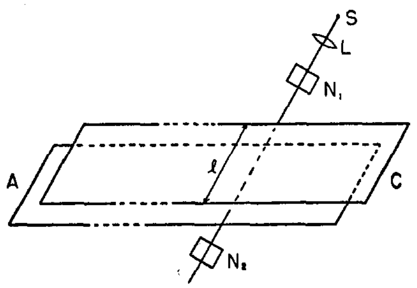


FIG. 1.

line with a transparent liquid showing the Kerr effect between the plates. The phenomena to be observed is at S, L is a lens, and $N_1$ and $N_2$ are Nicol prisms so oriented that the plane of polarization makes an angle of 45° with the lines of force between the plates. This arrangement clearly acts as a Kerr cell light shutter which can be opened and closed by electrical impulses on the transmission line AC. It will be observed that the velocity of an electrical impulse on such a line depends upon $(LC)^{-\frac{1}{2}}$, where $L$ and $C$ are the inductance and capacity per unit length. This ratio is independent of the width of the transmission line (neglecting edge corrections), so that the effective light path through the Kerr cell may be made as long as desired without introducing harmful capacity effects, etc. As a result, clear liquids which have high dielectric strength and are transparent in the ultraviolet or infrared as well as in the visible may be used instead of nitrobenzine. In our experiments the aluminum parallel plates of the transmission line were 335 cm long, 15.3 cm wide, and spaced 4.6 mm apart. The liquid between the plates was Halowax oil No. 1007, which has a dielectric constant of 5.13 at one megacycle. The total capacity of the line measured at 1000 cycles was $5.2\times10^{-9}$ farads. The velocity of the electrical impulse on the line was $1.32\times10^{10}$ cm/sec, and the surge impedance was about 5 ohms. Several pairs of strain-free glass windows were provided along AC, one pair being at C. So far the above arrangement has been used to study rapidly occurring phenomena at S. The Kerr cell was actuated with transients put on the line AC by a large capacity, low impedance, double spark gap impulse generator timed to open and close the cell at the desired instant. However, it is clear that the Kerr cell may be actuated by standing waves on the transmission line or that the shutter may be composed of two similar transmission lines of different length with their fields perpendicular, discharged at the same time, etc. The above arrangement will be described in more detail elsewhere.

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[1] J. W. Beams, Revs. Modern Phys. 4, 135 (1932). For references see Rev. Sci. Instr. 1, 780 (1930).

## Temporary Enhancement of Hysteresis in Barium Titanate Samples

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(Received January 31, 1951)

RZHANOV[1] has recently reported aftereffects as a result of application of high ac fields to polycrystalline barium titanate samples at room temperatures. We have also found such effects and have observed, in addition, that they become more pronounced if the field is applied while the sample is heated above the Curie temperature and then cooled to room temperature (see Fig. 1). It can be seen that the maximum polarization is

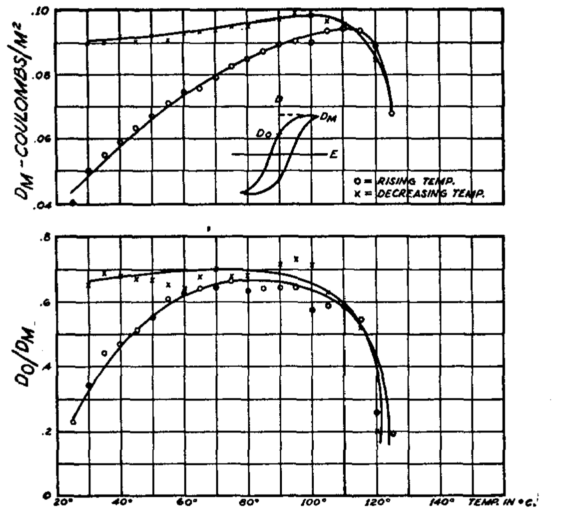


FIG. 1. $D_M$ and $D_O/D_M$ plotted as a function of temperature showing effects of treatment. Electric field strength $=8.34\times10^5$ volts per meter peak.

increased after treatment and that the hysteresis curve becomes more nearly rectangular.

If this is done with a dc field, the hysteresis curve appears highly unsymmetrical owing to the polarized nature of the dielectric; however, heating to only 50°C in the presence of an ac field will restore symmetry, and the hysteresis characteristic will be the same as if it were treated by an ac field to 120°C. If the sample, after treatment, is heated to 400°C, without field applied, for one hour, it does not revert to its original state.

This modification is not permanent as can be seen in Fig. 2, where the decay is shown to occur in some hundreds of hours and

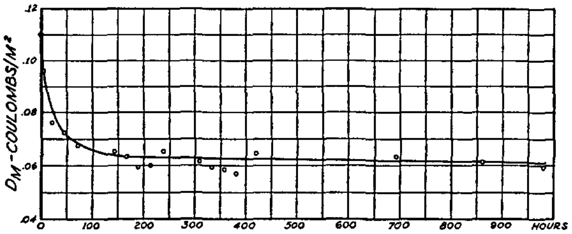


FIG. 2. Maximum $D$ as a function of time. Field applied $=8.34\times10^6$ volts per meter.

varies from one sample to another. No dependence of decay rate on temperature has been found.

The author is indebted to Dr. Hans Jaffe of The Brush Development Company for calling his attention to the work of Rzhanov.

[1] A. V. Rzhanov, Zhur. Eksp. Teoret. Fiz. **19**, 335–45 (1949).

## Difference between Turbulence in a Two-Dimensional Fluid and in a Three-Dimensional Fluid

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THE difference between a two-dimensional and a three-dimensional fluid can easily be seen from the vorticity equation given as

$$\dot{\boldsymbol{\omega}}+(\mathbf{v},\nabla)\boldsymbol{\omega}=\nu\Delta\boldsymbol{\omega}+(\boldsymbol{\omega},\nabla)\mathbf{v}, \tag{1}$$

where $\boldsymbol{\omega}$, $\mathbf{v}$, and $\nu$ are the vorticity, velocity, and kinematic viscosity of the fluid. In the two-dimensional case, $(\boldsymbol{\omega},\nabla)\mathbf{v}$ is identically zero. Hence, if one neglects viscosity in a system moving with the fluid, the vorticity never changes, and the scattering of energy between eddies does not lead to any change in vorticity. This conservation law forbids the fulfillment of an ergodic hypothesis for a two-dimensional fluid. Indeed, if one raises the same arguments to a two-dimensional case, as in the current theory of statistical turbulence,[1] a contradiction can readily be found.

On multiplying Eq. (1) by $\boldsymbol{\omega}$ and transforming it to the wave number space, we can write

$$-\frac{\partial}{\partial t}\int_0^\infty F(k)k^2dk=2\nu\int_0^\infty F(k)k^4dk, \tag{2}$$

where $F(k)$ is the energy spectrum of a two-dimensional turbulence with $k$ as the wave number. For definiteness, we shall use Heisenberg's[2] form of energy transfer between eddies which, for a steady state of turbulence, yields the form of $K(k)$ as

$$F(k)=\tfrac{1}{3}v_0^2k_0^{2/3}k^{-5/3}\quad\text{for}\quad k_0\leqslant k<k_s, \tag{3}$$

and

$$k_s/k_0=0.22(R_0\kappa)^{3/4},$$

where $\kappa$ is the coefficient of eddy viscosity, and $R_0$ is the Reynolds' number given as $\pi v_0/\nu k_0$.

For a steady state of turbulence, we have

$$-\frac{\partial}{\partial t}\int_0^\infty F(k)k^2dk=-\frac{\partial}{\partial t}\int_0^{k_0} F(k)k^2dk<k_0^2\epsilon, \tag{4}$$

where $\epsilon$ equals the total energy supply per unit volume to the fluid and is given as[2]

$$\epsilon=\sqrt{3}k_0v_0^3\kappa/8. \tag{5}$$

On the other hand, the right-hand side of (2) is always greater than

$$2\nu\int_{k_0}^{k_s}F(k)k^4dk\cong\frac{\nu}{5}v_0^2k_0^{2/3}k_s^{10/3}. \tag{6}$$

Hence,

$$\frac{-\frac{\partial}{\partial t}\int_0^\infty F(k)k^2dk}{2\nu\int_0^\infty F(k)k^4dk}<56R_0^{-3/2}\kappa^{-3/2}. \tag{7}$$

We can easily see that (7) is in direct contradiction to (2). Since (7) is obtained by using only the behavior of $F(k)$ in the Kolmogoroff region ($F(k)\propto k^{-5/3}$), this contradiction will hold as long as one assumes the existence of a Kolmogoroff region for two-dimensional turbulence.

In the three-dimensional case, the vorticity may be changed by the extension of the vortex filament, and the application of the vorticity equation does not lead to any contradiction.[3]

The author wishes to thank Professor W. Heisenberg for an illuminating communication.

[1] A. N. Kolmogoroff, Compt. rend. acad. sci. U.R.S.S. **30**, 301 (1941); **32**, 16 (1941); L. Onsager, Nuovo Cimento **6** (9), 279 (1949); C. F. von Weizsäcker, Z. Physik **124**, 614 (1948).
[2] W. Heisenberg, Z. Physik **124**, 628 (1948).
[3] T. D. Lee, Phys. Rev. **77**, 842 (1950).

## The Generality of Mixed Gas Flows

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W. R. SEARS, in the August, 1950, issue of this Journal, speaks out in favor of neighbors, but still seems to reserve some doubts about the existence of neighbor solutions of mixed flows; that is, of solutions for neighbor contours. The following argument should convince him that neighbors are positively the rule, particularly with plane two-dimensional flows.

These flows are linear in the hodograph and, therefore, admit these superpositions. In the physical plane, the composite flow assigns, to each velocity vector, the center of gravity of the points occupied by the same vector in the constituent flows. Now superpose thus to the mixed flow a weak secondary constituent flow single valued through the pertinent portion of the hodograph. All velocities of the secondary flow taking part in the superposition will be contained within a small area in the physical plane. An immense variety of such secondary flows is available. Each gives rise to a different neighbor solution with the composite contour as close to the initial contour as desired.

The composite flow will be free of limiting lines in general. The discriminant, which becomes zero at the limiting line, is linear in the hodograph. (See reference 8 of Sears.) It is related to the angle between the streamline image and the characteristic line in the hodograph. This discriminant can be supposed to be larger than zero throughout the flow and also through a strip within a certain distance from the contour. The secondary constituent discriminant is finite and small, and by making the secondary constituent smaller and smaller the composite discriminant may be kept from becoming zero.

The composite flow will include an unbroken contour. For not only the legendre reciprocal potential but also the stream function is linear in the hodograph plane. The two impact points, having initially equal velocity and equal stream function, will, therefore, be transformed into two composite impact points having equal stream function.