Multiple Kerr-Cell System With Square Shuttering Characteristic

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A cable-shaped Kerr-cell shutter has been constructed, using solely plug-in parts. A delay cable, with built-in pressure spark gap, forms a square pulse of 40 kv and 50 mμsec duration. This pulse passes without reflection through a flexible 15-ohm cable and one or several Kerr cells, interconnected by flexible cables, and then the pulse disappears in a terminal resistor. This device features a square shuttering characteristic and great mobility. Multiple cells permit simultaneous photography of a subject from several angles. Using delay cables the Kerr cells operate at preset intervals depicting successive stages of the event.

Owing to the very low capacity of the pulse-forming cable, recharging of the system is rapid; thus the picture-taking rate is limited only by the quality of the quenching spark gap. The pulse can also be guided through the cell along meander-shaped electrodes, making possible the construction of large-size cells. Delay units can also fire cell systems at any desired picture-taking rate. When synchronized with high-frequency spark light sources (such as the Strobokin ultra-rapid flasher) an appreciably shortened square exposure time is achieved. For the ultraviolet range a similar Kerr-cell system with phenyl isocyanate is available.

A KERR-CELL SHUTTER designed entirely in cable form is the subject of the present paper. The operating principle of this shutter is as follows: a 15-ohm cable is charged to a high potential. A second 15-ohm cable (which is flexible) is connected to the first by way of a coaxial spark gap. The flexible coaxial cable is connected at its other end to the Kerr cell which in turn is connected to a terminal resistor. The Kerr cell was designed so that when filled with nitrobenzene as a dielectric, it constitutes a short length of 15-ohm transmission line. The terminal resistor is likewise designed to appear electrically as a 15-ohm impedance, so that the entire shutter system constitutes a line terminated in its characteristic impedance.

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If the 15-ohm pulse cable is charged to a potential of 80 kv, and the spark gap is fired by a triggering pulse, an electromagnetic wave of 40 kv passes through the cell. The duration of the pulse that appears across the Kerr cell is double the one-way transit time of the wave in the pulse cable. The electric field generated in the Kerr cell is directed from the outer electrodes to the middle electrode, and its field strength is such that the cell is completely opened.

The leading edge of the voltage pulse is distorted by any local disturbances of the characteristic impedance of the cable system. Local reflections as the wave travels through the disturbance will give a staircase waveform as shown in Fig. 1. The length of each step of this

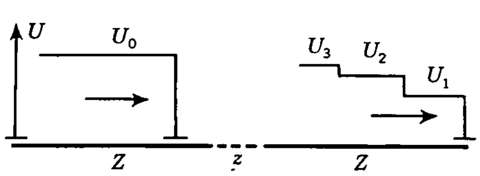

Fig. 1. Change of a steep impulse at a local disturbance.

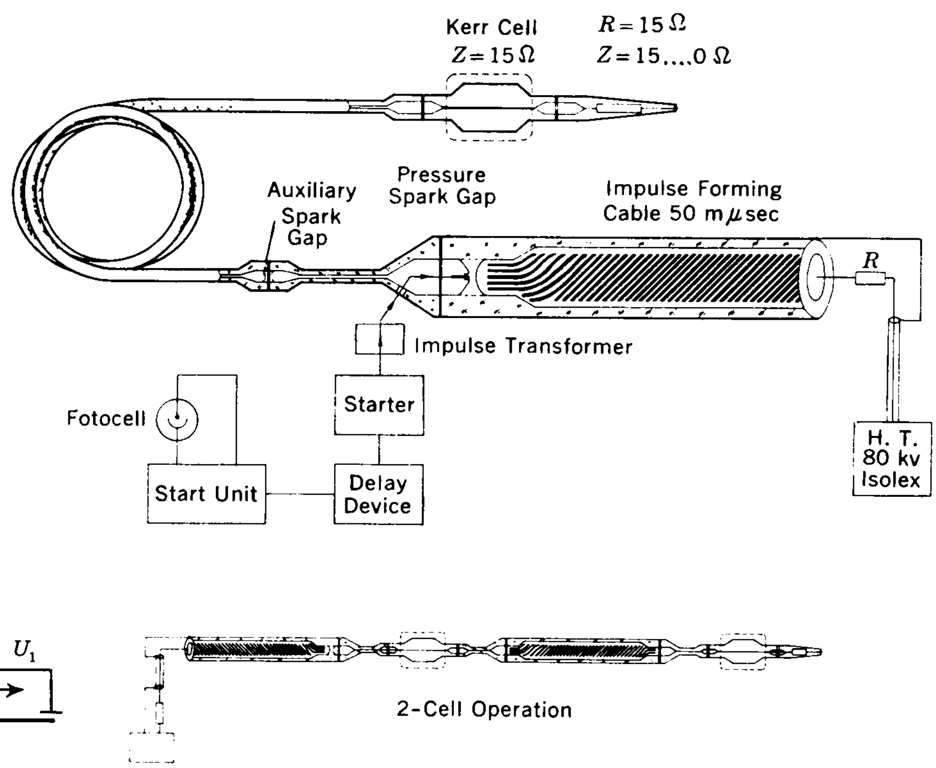

Fig. 2. Block diagram of the Kerr-cell shutter.

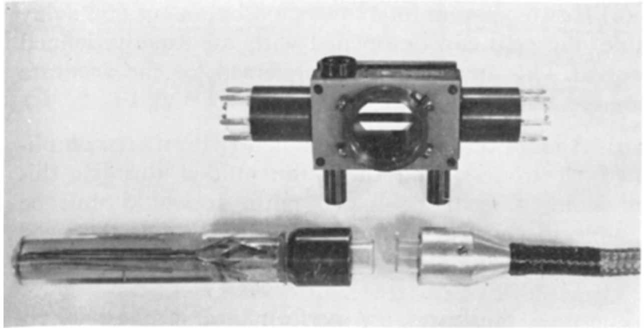

Fig. 3. Kerr cell, terminal resistor (lower left) and flexible cable (lower right).

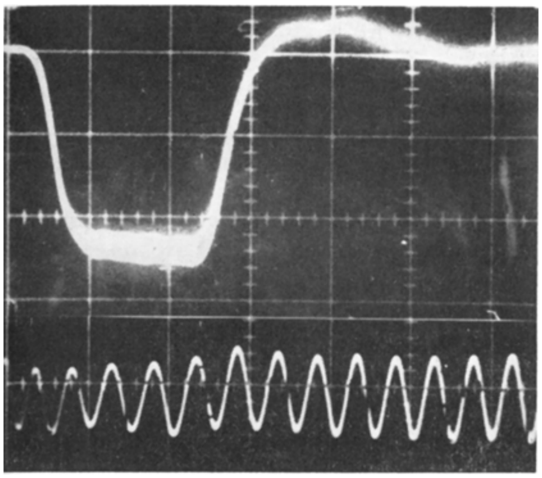

Fig. 5. Current through the shutter.

staircase is equal to double the transit time through the local disturbance. The amplitude of the *n*th step is

$$U_n = U_0 \left\{1 - \left(\frac{Z - z}{Z + z}\right)^{2n}\right\}$$

The spark gap is an example of such a local disturbance of the characteristic impedance since the impedance of the spark gap is some 100 ohms, because of the narrow spark channel. From the above reasoning, one could reasonably expect a rise time of a few millimicroseconds for this shutter system.

The details of the design of this Kerr-cell shutter may be explained by reference to Fig. 2.

(a) Each impulse-generating cable is designed as a delay-cable for a fixed impulse duration. Pulse cables are available for durations of 10 to 50 mμsec.

(b) The spark gap is designed to work at a pressure of 10 atm of nitrogen in order to keep the local disturbance of the characteristic impedance as short as possible. By special circuitry, the gap can be triggered with a precision of 10 mμsec.

(c) The Kerr cell itself is made of solid brass with plane windows. Its characteristic impedance is carefully adjusted.

(d) The terminal resistor is a special carbon resistor, sealed in Araldite. The outer conductors that are connected to the resistor are tapered like a wedge so that no reflections can occur. The pulse cable, the spark gap, the flexible cable, the Kerr cell and the terminal resistor are all designed as plug-in units. Figures 3 and 4 show the components of the Kerr-cell shutter.

Figure 5 shows the current as a function of time during one operation of the shutter. The measurement is made

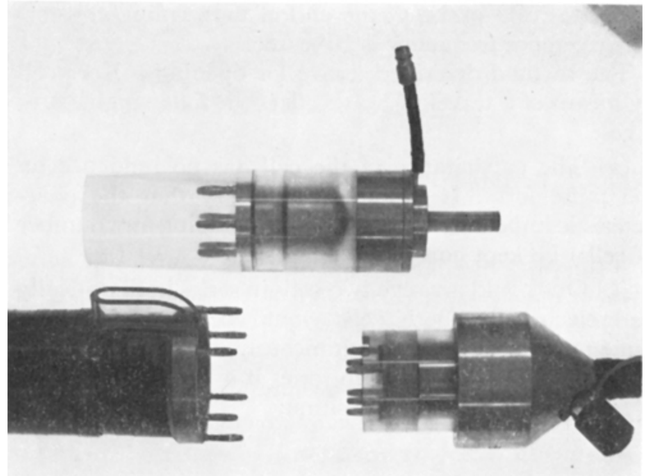

Fig. 4. Impulse-forming cable, spark gap and flexible cable.

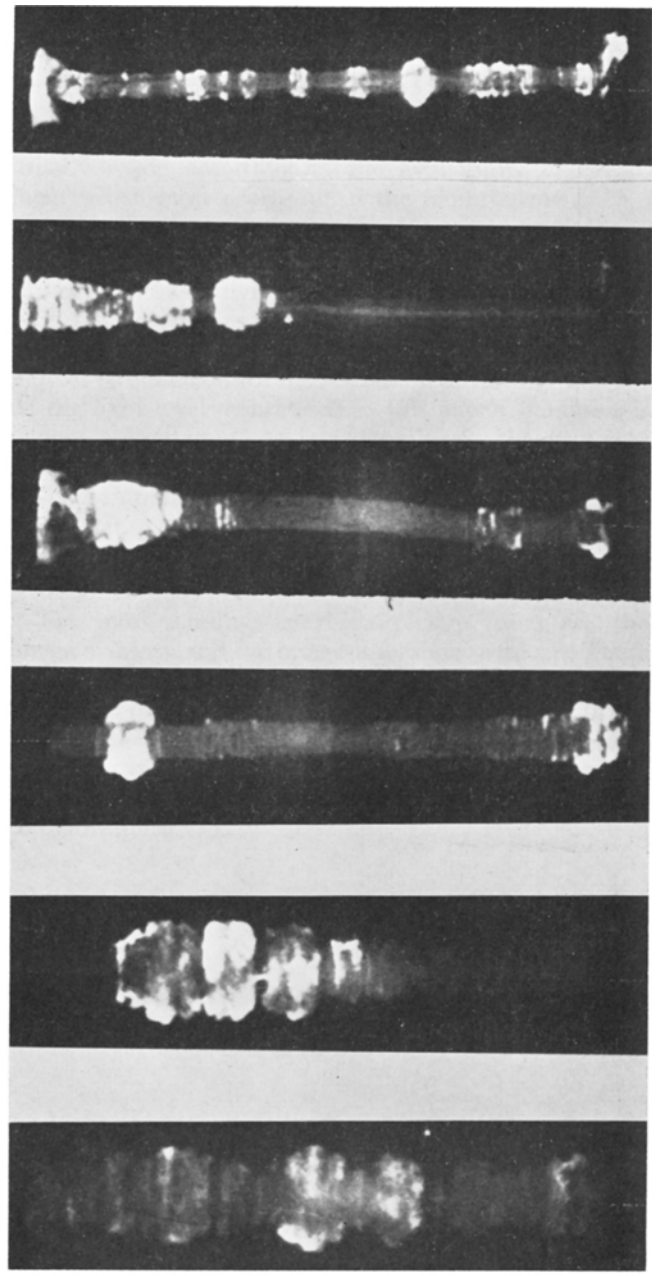

Fig. 6. Various stages of the explosion of a wire; diameter of wire 0.11 mm; length of wire, 38 mm; material of wire, copper; exposure time for each picture, 50 × 10^{-9} sec.

by means of a probe at the end of the terminal resistor. The reference frequency is 10^8 c/sec.

The method described above for opening a Kerr cell by means of a traveling wave offers the following advantages:

(a) The capacitance of the cell has no influence on the pulse form. It is merely necessary that the characteristic impedance of the system (including any number of cells) be kept constant.

(b) One could arrange two cells in series both optically and electrically. Both cells would be opened by the same pulse practically simultaneously. It is advantageous to put two cells optically in series if a very high density is required in the closed position.

(c) If two cells are interconnected by means of a delay cable, the cells can be opened with an exactly defined interval. This arrangement is preferred for the accurate measurement of velocities.

(d) A large cell could be designed (with more complicated electrodes), and the pulse guided through this cell along a meander-shaped path. It would thus be possible to construct large-sized cells without the need for modifying any of the other parts of the system.

Figure 6 illustrates the performance of these Kerr-cell shutters. The six pictures were all taken within an interval of 100 μsec. They show stages of the explosion of a wire.