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Electric Breakdown of KDP Crystal at Optical Frequencies

Measurements of the flux density threshold for electric breakdown of KDP crystal in a powerful ruby laser beam yielded a value of 105 GW/cm^2 ($7.3 \cdot 10^6$ V/cm).

Electric breakdown of solids in a powerful laser beam plays an important role in the phenomena of light propagation. Among transparent dielectrics, KDP appears to be the most interesting because of its useful applications in nonlinear optics and electrooptics.

The purpose of this work was to determine the threshold for breakdown caused by the electric field of a ruby laser pulse. A ruby laser, Q-switched by means of a cryptocyanine cell, was used. The generated giant pulse had a half-power width of 20 ns; the total emission was 40 ns. The pulse shape, displayed on an I 2–7 nanosecond USSR made oscilloscope, is shown in fig. 1. In the detection system a special high power rapid photocell was used. The diameter of the laser beam, when measured at the output mirror, amounted to 6 mm. The beam was then focused within the KDP crystal by means of a single lens ($f = 45$ mm). The focus diameter D was very carefully measured; its value was 0.14 mm. If the focus volume is defined as $\pi(D/2)^2 \cdot 3D$, its numerical value is $3.3 \cdot 10^{-6}$ cm^3. Energy of the laser pulse was measured using a "rat nest" calorimeter. Pulses of energies from 0.2 to 0.4 J were applied, corresponding to a laser pulse power from 10 to 20 MW. In the focus, the flux density attained values from 65 to 130 GW/cm^2. When the flux density was raised from 50 to 130 GW/cm^2, the following phenomena were observed with increasing power of the beam

1. A strong red beam in the focus area was clearly visible. After the shot, small pencil-shaped damage in the crystal was observed.

2. Strong white-and-blue radiation from the focus area was associated with larger damages. Cracks appeared in the crystal in the perpendicular direction also.

3. Electric breakdown in the focus. A typical spark, accompanied by a very characteristic shock acoustic wave was observed. Damage to the crystal was very serious and covered a volume of several mm in diameter and about 20 mm in height.

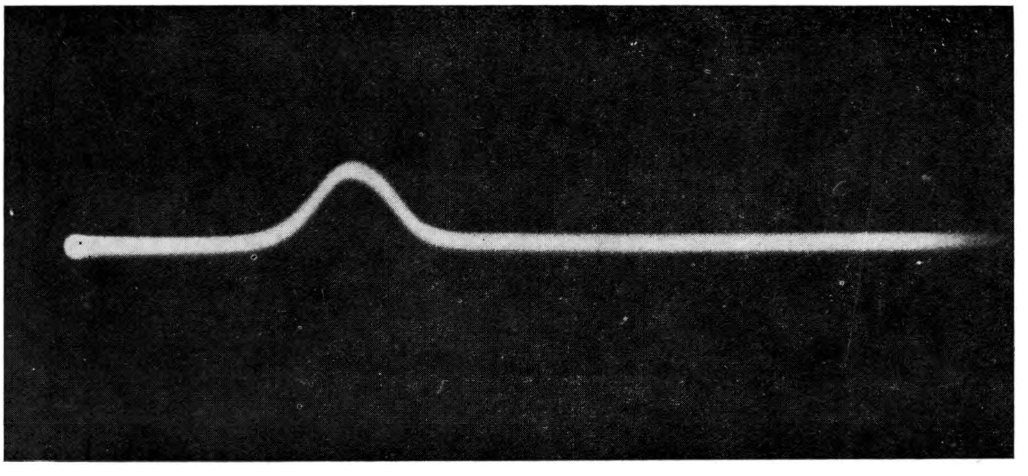

Fig. 1. Picture of a giant laser pulse of 40 ns total duration

The light path within the crystal for energies below the threshold for breakdown is illustrated in fig. 2. Fig. 3 shows a crystal completely damaged after several successive laser shots.

The threshold energy causing electric breakdown amounts to 0.33 J; this corresponds to a flux density

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Fig. 2. Light path within the KDP crystal observed below the threshold for breakdown

I of 105 GW/cm^2. The electric field strength in the focus is [1]:

$$E \simeq \frac{27.46}{\sqrt{n}} \sqrt{I\left(\frac{W}{cm^2}\right)} = 7.3 \cdot 10^6 \ V/cm,$$

where n is the refractive index of KDP; $n = 1.5$.

laser. Surface damage is rather small in this case [2, 3]. It should be pointed out that the threshold for damage of KDP crystal is of the order of several tens of GW/cm^2 for a 20 ns laser pulse. The breakdown threshold for KDP crystal can not be compared with any theoretical value because no such theory has been developed as yet.

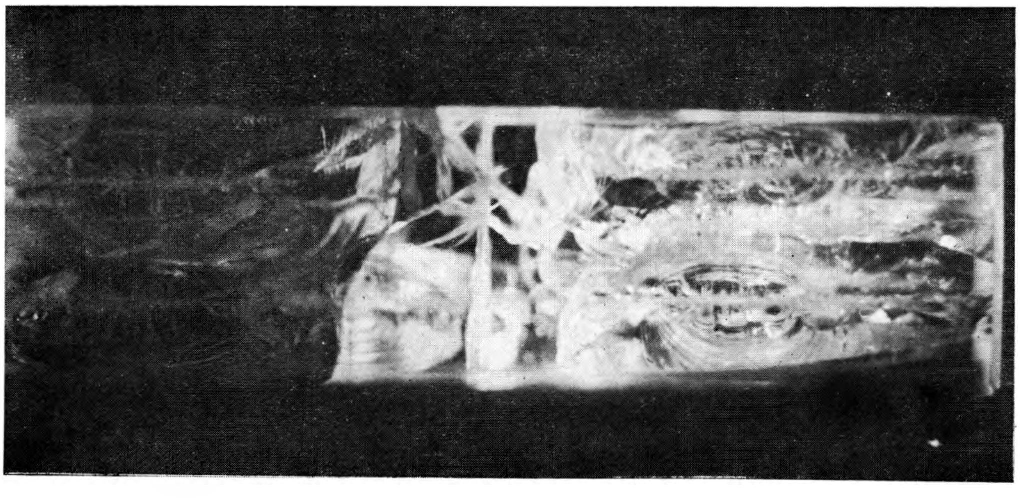

Fig. 3. KDP crystal, completely damaged by several laser shots, each of a flux density of the order of 100 GW/cm^2

This threshold is relatively high, much higher than the threshold for breakdown at the surface of the crystal. During our experiments, breakdown at the surface was very often observed if the focus of the lens was located in the vicinity of the surface (at less than 10 mm). Breakdown at the surface generates a large spark which moves in the direction of the

References

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