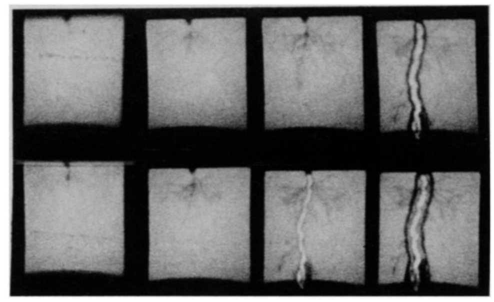
Flashback Photography

Scientists are snapping pictures of events already past



Eight of the 10 pictures taken of electrical discharge using the optical delay. When the first picture is recorded on film, the spark is actually in a state just after the one shown in frame 8.

By CHRISTOPHER VAUGHAN

Imagine yourself sitting by a still mountain lake at sunset. You are trying to photograph the silvery fish that lunge into the air after insects, but every time one jumps you aren't ready to shoot. Frantically you jerk the lens this way and that, snapping away. When you develop the film, you find only pictures of rippled water. Wouldn't it be nice if the jumping fish circled around in the air for a bit while you got the camera pointed and focused, then snapped the shutter?

A similar problem confronted physicist Edward Kelley in a scientific setting. His innovative solution gives researchers a new tool for high-speed photography that, among other uses, should provide a better understanding of how high-voltage sparks form in liquids and solids, leading to longer-lasting, more reliable insulators in everything from transformers to satellites.

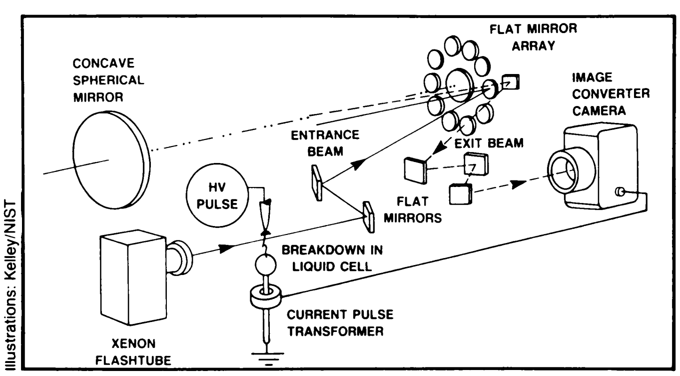
The "fish" Kelley sought to catch on film was the formation of a high-voltage bolt of electricity as it sparked the gap between two electrodes. But the event happens so unpredictably and so quickly – lasting only a few millionths or billionths of a second – that it is nearly impossible to capture it on film.

Leaving the shutter open for a long time would catch the spark itself, but blur together all the events surrounding its formation. High-speed movies can't be used because a camera's film and shutter can't be moved fast enough, Kelley says. So he invented an "image-preserving optical delay" system to hold the image until the camera is ready to photograph it. Then he built the device in his laboratory at the National Institute of Standards and Technology in Gaithersburg, Md.

The magic is all done with mirrors. The trick is to bounce an image of the spark through a system of mirrors so that the light has to travel an extra 385 feet before reaching the camera lens. Meanwhile, the spark also has triggered a much more direct electrical circuit that trips a special camera to start recording 10 sequential images on one sheet of film. The result: a series of pictures of the event taken after it has actually happened.

Researchers have crafted optical delays before, but the notable aspect about this device is its relatively small size, Kelley says. An ingenious configuration of curved and flat mirrors allows him to compress the 385-foot optical path into a area about 13 by 1½ feet.

Kelley's optical delay reflects the image off one concave mirror 16 times by bringing the light to the mirror "off-axis," or at an angle. One off-axis reflection produces a distorted image, but when an array of flat mirrors is used to distort the image equally in all directions, the final picture looks normal, he says. Other devices bounce the image once off one concave mirror, so the path can only be twice as long as the device, Kelley says.



Illustrations: Kelley/NIST

The delay works by bouncing light from the spark between one large mirror and a roseate array of smaller mirrors, while another signal takes a shortcut to trip the camera.

The fact that the light in Kelley's device takes 390 billionths of a second to wend its way through this mirror maze – while it takes only 100 billionths of a second to trigger the shutter – allows him to get pictures of events that occur up to 290 billionths of a second before the spark jumps the gap and signals the camera. Kelley describes this as photographing an event "before it occurs and after it happens." This neat trick explains Kelley's interest in using the camera to study electrical discharge.

Just before a bolt of electricity flashes across the gap between the electrodes, ionized gases branch outward from one of the electrodes. "It looks just like a tree growing," Kelley says. The first branch to touch the opposite electrode becomes the path the spark follows, he says. The same thing occurs before lightning strikes during thunderstorms, he adds.

The growth of the channels lasts only a few millionths of a second, so getting exactly the right shot before was "one in a million," Kelley says. Now, "it's really spectacular for every shot to be exactly the photograph you're looking for."

Kelley and electrical engineer Marshall Pace of the University of Tennessee in Knoxville have used the optical delay to study how electrical insulation fails or is damaged by near-failure. By overloading electrical insulation with a high-voltage charge and then photographing the process, they hope to learn how the insulation breakdown occurs.

A better understanding of the physical mechanisms behind electrical insulation failure would lead to better predictions about how long insulation will last, how well it can be repaired and how it will stand up under the extremes of heat, cold or pressure in electrical equipment. "The hope is to design things smaller than they are now and retain the same longevity and integrity," Kelley says. "This information would be especially useful in satellites, which have to last a long time."

The optical delay can record any number of events that happen very fast but at unpredictable times, Kelley says. For example, a larger system might allow sound to trigger the camera, enabling researchers to see how an engine stressed to failure actually breaks down. The optical delay could be "used with any number" of recording techniques in many research settings, he says. □