tron densities at the ^{73}Ge nuclei is $(|\psi_{GeO_2}(0)|^2 - |\psi_{Ge}(0)|^2) = -5.6\times10^{25}$ cm^{-3}. With these assumptions the change in nuclear radius is $\Delta R/R = +1\times10^{-3}$. A small isomer shift between Ge absorbers and germanium in chromium targets, $\delta = +0.17 \pm 0.07$ mm/sec, indicates a reduction in s-electron density for germanium in chromium.

We cannot exclude the possibility of radiation damage in the chromium from our present results. However, no changes in the Mössbauer spectra were observed during an irradiation time of approximately one week. It may be assumed that any radiation damage occurring in the target takes place in a time short compared with a few hours.

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LASER-PRODUCED DIELECTRIC BREAKDOWN IN LIQUIDS WITH RESULTING ABSORPTION OF A SECONDARY LIGHT BEAM

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We have observed phenomena in various liquids which we attribute to laser-produced dielectric breakdown. They are (a) a long-lived attenuation of a secondary light beam, (b) a small amount of forward scattering of the secondary light beam, (c) a distortion of the trailing edge of the laser pulse, and (d) a luminescence, coincident with the laser pulse, and having a low-intensity long-lived tail. The breakdown we believe is localized at particle sites in the liquids and results in pockets of dense plasma. In a liquid with particles of well-defined size, we observe a threshold in laser power below which no luminescence is seen and the other effects are also apparently absent. A threshold in field strength for luminescence is strongly suggestive of dielectric breakdown. These effects are produced at relatively low laser powers of the order of a few megawatts per square centimeter depending somewhat on the liquid and the number and size of nucleating sites. No extensive macroscopic cavitation occurs.[1]

A xenon flash tube together with a monochromator was used as a secondary source. The flash-tube output of approximately 2-μsec duration was made to coincide with the output pulse of a Pockels-cell, Q-switched ruby laser, OTI Model 130. The attenuation of the secondary beam was monitored with an RCA 1P28 photomultiplier. The laser and flash tube beams could be made to intersect in the sample cell at various angles and over path lengths from 0.5 to 10 cm. Changes in intensity of 0.3% in the secondary beam could be measured reliably.

The most striking phenomenon is the attenuation of a secondary light beam (see Fig. 1). The attenuation rises sharply coincidentally with the laser pulse and decays slowly with a time constant of a few hundred nanoseconds

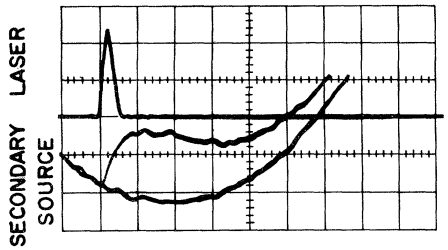

FIG. 1. Oscilloscope photograph tracing. Double exposure showing laser pulse on upper beam, and the peak of the secondary source, negative-going, on the lower beam. The undeflected lower trace shows the secondary-beam peak intensity in the absence of the laser pulse. The deflected lower trace shows a decrease of the secondary-beam intensity in the presence of the laser pulse of approximately 30 mV. The major part of the secondary source pulse, peak intensity 650 mV, was balanced off in the Tektronix type-*W* plug-in differential amplifier. The decrease shown represents approximately 4% attenuation of 4500-Å light in a solution of phenanthrene in benzene. Sweep speed is 100 nsec/division.

which is approximately the same for all liquids studied. The percent attenuation is independent of wavelength of the secondary beam from 3500 to 6500 Å. The attenuation, which can be as large as 50%, varies with laser power as I^n, where n varies between 1 and 3 for different liquids. There is an associated scattering of the secondary beam with the same time behavior. The scattered light, however, accounts for only 10% of the attenuated light and is concentrated within 10° of the forward direction. Scattering with this angular dependence is characteristic of small particles. From Mie theory[2] we crudely estimate the size of the laser-activated scattering centers to be of the order of 1 μ.

The measurements on the distortion of the laser pulse were made with an ITT 114 biplanar photodiode and a Tektronix 519 oscilloscope. They indicated that the attenuation begins approximately at the peak of the laser pulse and results in a net narrowing of the pulse by approximately 10%.

The emission or luminescence was observed photographically. That part of the liquid in the path of the laser beam appeared weakly illuminated. The time behavior of the emission was measured with a 1P28 photomultiplier using a broad pass-band (blue) filter (combination of Corning 4-70, 4-71, and 4-72 filters). The emission was sharply peaked initially, with half-width of approximately 20 nsec followed by a long, low-intensity, exponential tail with a time constant very similar to that observed in attenuation. We have observed these effects in many liquids including benzene, water, carbon disulfide, 2-molar solution of phenanthrene in benzene, and a 0.1-molar benzanthracene in benzene. We suggest that the phenomena are common to all liquids.[3]

Dielectric breakdown resulting in dense plasma formation appears to us to be the most likely explanation of these results. Many investigators have reported breakdown in gases and at gas-solid interfaces using focused laser beams with powers in the neighborhood of 10^{11} W/cm^2.[4] Production of plasma and laser-pulse attenuation occur. Attenuation by a dense plasma of free electrons and ions appears to be the only possible explanation of the essentially wavelength-independent broad-band absorption that we observe. Mechanisms depending on absorption via multiphoton-produced excited states or photodissociation products are ruled out on the grounds of the wavelength-independent absorption and the similarity of absorption in all liquids. In particular, the threshold (described below) for emission and absorption is not explained by such mechanisms.

Dielectric breakdown occurred at low powers (~10^7 W/cm^2), apparently in the region of particles in suspension. After successive filtering of the liquids through Millipore filters ranging from 5.0 to 0.01 μ (100 Å) in pore size, the absorption of the secondary beam is sharply reduced and is unobservable at low laser powers. Studies with uniform-sized particles in colloidal suspensions confirmed the breakdown theory. We examined three suspensions of Ludox silicate spheres in water, having mean diameters of 70, 150, and 250 Å. The Ludox solutions, which contained a well-characterized distribution of uniform-sized particles, exhibited a clearly defined threshold in laser power for emission, absorption, and scattering. Figure 2 illustrates this threshold for the 150-Å Ludox spheres. At 5 MW/cm^2 of laser power there was no detectable emission and the attenuation was below our sensitivity. The existence of a threshold for emission is particularly strong evidence for dielectric breakdown, and the correlation of absorption and emission lends strong support to the notion that the absorption is due to the resulting plasma. We found also that for approximately equal concentrations of silicate particles,

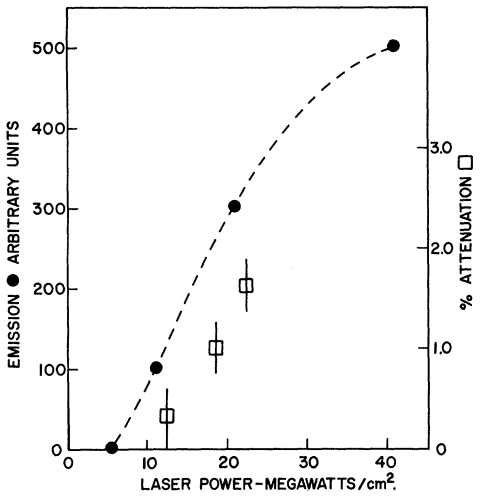

FIG. 2. Plot of percent attenuation (right-hand scale, squares) and emission (left-hand scale, black circles) against laser power for a 150-Å Ludox sample.

the absorption increased with particle size. The absorption varied roughly as the concentration of the particles. Also, the threshold for breakdown appeared to be inversely related to particle size in the range studied.

Dielectric breakdown in the neighborhood of a particle may occur for the following reasons. If the particle is opaque, rapid heating with release of electrons can occur in the field of an intense laser pulse.[5] If the particles are essentially transparent, the intense laser beam may induce a photoconductivity[6] leading to absorption. The creation of free electrons which subsequently absorb laser light may be facilitated by the presence of the colloidal double layer. Also, as is well known, a conducting sphere in an electric field concentrates or focuses the field at its surface by a factor of 3. This would facilitate breakdown.

In summary, we believe that the absorption, scattering, and emission result from dielectric breakdown at particle sites in the liquids. Careful filtering reduces these effects. We have not, even with the most careful preparation, been able to eliminate them entirely for powers above 100 MW/cm².

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POSSIBLE OBSERVATIONS OF COLLISIONLESS ELECTROSTATIC SHOCKS IN LASER-PRODUCED PLASMAS

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In an investigation of laser-produced plasmas, granules of LiD have been irradiated by 15-nsec, 3-J pulses from a ruby laser. The target material consisted of a cluster of 5- to 25-μ diam solid particles which were injected into the 400-μ diam laser focal region by an electromechanical apparatus. Expansion velocities of the luminous boundary of the high-density plasma were measured from streak photographs with an image-converter camera.[1] A similar phenomenon has been investigated by other authors.[2,3]

The apparatus is shown in Fig. 1. Langmuir probes with faces 1.6 mm diam separated by 1 cm were located 6.3 cm from the laser focal spot, and the signals to these biased probes were recorded on oscilloscopes. No magnetic fields were present and provision was made to produce a dc glow discharge in the chamber.

The purpose of this note is to describe some preliminary results of an experiment in which