proximately 120 times larger, whereas that of the sodium atom is 0.3 times as large. This result together with the above value for the EDM of the cesium atom leads to a new upper limit to the EDM of the electron (at 90% confidence level) of

$$|d_e| < 3 \times 10^{-24} e \text{ cm}.$$

Work on this experiment is continuing and an apparatus with an even longer distance between the oscillatory fields is under development. It is hoped that the experimental error can be reduced by at least a factor of 10 with the new apparatus and certain other improvements.

The authors wish to thank A. T. Ramsey and R. Golub for many helpful discussions.

*Work supported by the National Science Foundation.

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OBSERVATION OF OPTICAL PULSE SHAPING BY THE SELF-FOCUSING EFFECTS*

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We report the observation of time distortion of intense laser pulses due to the self-focusing effect. The on-axis shape of pulses propagating in nitrobenzene was measured and compared with a computer solution of the nonlinear wave equation.

We have observed pronounced distortion of the time contour of intense light pulses propagating through nitrobenzene. This effect, which occurs for peak powers below the level required to form trapped light filaments within the liquid cell, is a consequence of the dynamical self-focusing of intense optical beams.[1-3] Previous measurements[4] of optical self-focusing phenomena have relied upon determination of the input power threshold for the onset of stimulated inelastic scattering. However, most such scattering is known to occur within the complicated and poorly understood region of "small scale" or filamentary self-trapping.[5] The measurements reported here are independent of filament formation mechanisms and can be compared directly with numerical solutions of the nonlinear wave equation thought to describe self-focusing.

A simple analysis[6] of the time dependence of the on-axis intensity of a pulse propagating in a medium with positive nonlinear refractive index shows that substantial sharpening of the time contour can occur. The effect is largest for path lengths near the self-focusing length. This prediction was verified by detailed measurements on the shapes of intense optical pulses passing through a 18.8-cm cell of nitrobenzene. The source was a passively Q-switched ruby laser operating in a single axial and transverse mode with a peak power of 1 MW in a single pulse. The time contour of the laser pulse was nearly Gaussian with a 10-nsec full pulse width at half-intensity. The nitrobenzene cell was sufficiently removed from the laser (0.4 Rayleigh distance) so that the spatial intensity profile of the beam at the cell entrance window had nearly a Gaussian distribution with a variance of 0.45 mm. This profile was accurately determined by scanning the beam with a pinhole. Every portion of the input beam had the same time dependence.

A fraction of the laser beam was sent through an optical delay path (30 nsec) so that the incident pulse was detected by the same photodiode (ITT F4000-S1) and displayed on the same oscilloscope trace (Tektronix 519) as the pulse transmitted through the nitrobenzene. A pinhole aperture (0.12-mm-diam) was located on axis in the beam transmitted through the nitrobenzene. As expected, no pulse shaping occurred without this exit pinhole aperture. Thus, the time evolution of the pulse as it entered the material was compared with that of the axial intensity of the pulse after it had passed through the material. A typical oscilloscope trace is drawn in Fig. 1, where

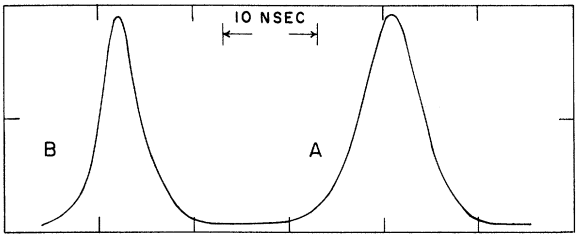

FIG. 1. Typical oscilloscope display showing sharpening of the output beam B compared with the incident beam A.

pulse A is the input pulse and pulse B, attenuated to give the same maximum deflection, is the transmitted pulse. The pulse shaping was measured as a function of input power, where the input power variation was accomplished by varying the concentration of copper sulfate solution in a fixed cell. The laser energy was monitored with a RCA-7102 phototube, calibrated by a TRG ballistic thermopile.

Several control experiments were conducted to insure that self-focusing was the cause of the pulse shaping. Investigation of stimulated Raman and Brillouin scattering indicated that these processes were not operative at the input powers used in this work. The time contour of the axial intensity of the transmitted pulse became highly irregular and unpredictable when the input power was above the threshold for filament formation within the cell and therefore for stimulated inelastic scattering; indeed, this irregular behavior was a sensitive indication that such processes were present.

The distortion of the on-axis intensity pulse may be regarded in analogy with electronic circuit theory as arising from the nonlinear response function, or "characteristic curve," of the medium. This curve, simply the output on-axis intensity versus the input intensity, may be constructed from numerical solutions of the self-focusing equation for different input powers but constant Gaussian input shape. Using numerical tables compiled by Dawes[7] we obtained the curve shown as a solid line in Fig. 2. On the same scale we have plotted experimental points obtained from the peaks of oscilloscope traces such as that of Fig. 1. No data points were discarded

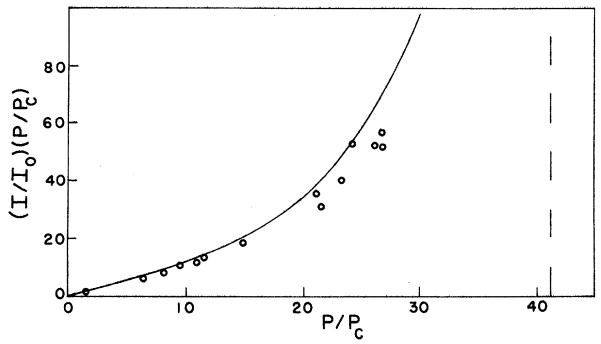

FIG. 2. Transmitted axial intensity I versus incident axial intensity I_0, normalized to be dimensionless. P is the incident power and P_c is the critical power. The solid line represents the computer solution (focusing at the dotted line) and the circles represent the experimental data.

to decrease scatter. For the critical power P_c, which fixes the scale of the theoretical curve, we used Wang's[4] experimental value of 19 kW. There are no remaining free parameters and, consequently, Fig. 2 represents the agreement between our absolute measurements and the best available theoretical "self-focusing characteristic curve."

More extensive results and direct determinations of P_c from our data will be included in a forthcoming publication. We are indebted to E. Dawes and R. Johnson for their assistance in obtaining the numerical characteristic curve.

*Work partially supported by the Joint Services Electronics Program Grant No. SF-AFOSR-496-67.

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