A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR -86-1202

CONF-851052 -- 6

RECEIVED BY OST MAY 12 1986

Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405-ENG-36

TITLE: TRANSIENT ABSORPTION OF LIGHT INDUCED BY RADIATION

LA-UR--86-1202

DE86 010173

AUTHOR(S): R. Godwin
F. B. Harrison
A. Larson

SUBMITTED TO: Optical Materials for High-Power Lasers
October 28-30, 1985
Boulder, CO

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

By acceptance of this article the publisher recognizes that the U S Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U S Government purpose.

The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U S Department of Energy

Los Alamos Los Alamos National Laboratory
Los Alamos, New Mexico 87545

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Transient Absorption of Light
Induced by Radiation

R. Godwin
F. B. Harrison
A. Larson

Los Alamos National Laboratory
Los Alamos, New Mexico, 87454

We have measured two components in the radiation-induced absorption of 250-nm light in fused silica. For the first, the time constant is 48.3 ± 1.3 ns and the absorption coefficient is 6.68 ± 0.37 cm⁻¹ per Mrad. For the second, the time constant is long compared to 3 μ s, and the absorption coefficient is 1.65 ± 0.36 cm⁻¹ per Mrad. The errors quoted are purely statistical.

1. Introduction

We have measured the absorption of 250-nm light in Corning 7940 fused silica, under irradiation by 2-MeV electrons from a Febetron 705 accelerator. The samples were 0.5 mm thick, held at 45° to the electron beam. The light source was a xenon flashlamp excited by a current of 10 kA to an estimated brightness temperature of 25,000° K. The light passed through the sample at an angle of incidence of 45°. The detector was an ITT planar photodiode. In front of the photodiode was an interference filter with a 30 nm wide passband centered at 250 nm.

The radiation dose, as measured by radiochromic film, was 760 krad at the front face of the sample and 410 krad at the back face, giving an average dose of 585 krad. The radiation pulse length was 30 ns.

Because of the 45° angle of incidence, the path length of the light in the sample is 0.565 mm. The data show a radiation-induced absorption with two time constants. One is long compared to the 3 μ s duration of the measurement (but short compared to the time between shots, which was a few minutes). The other time constant is short. An analysis of the data is presented below.

2. Derivation of Equations

The fraction of light transmitted

$$I = e^{-\sigma_1 n_1(t)\delta} \cdot e^{-\sigma_2 n_2(t)\delta} \quad ; \quad (1)$$

is

$n(t)$ = number density of absorption centers (cm^{-3}),
 σ = absorption cross-section (cm^2), and
 δ = window thickness (cm).

Subscript (1) refers to centers that recover, subscript (2) to "permanent" damage centers, i.e., with time constants long compared to measurement times. The rate of recovery is given by

$$\dot{n}_1(t) = K_1 \dot{D}(t) - L n_1(t) \quad ; \quad (2)$$

where

$\dot{D}(t)$ = dose rate (rads/s),
 K = production constant (centers/rad) and,
 L = decay rate (s^{-1}).

For the "permanent" term

$$\dot{n}_2(t) = K_2 \dot{D}(t) \quad . \quad (3)$$

Equation (2) has the solution

$$n_1(t) = K_1 n^{-L t} \int_0^t dt' \dot{D}(t') e^{-L t'} \quad . \quad (4)$$

Let t^* be the time when $\dot{D}$ goes to zero and stays there. Define

$$\hat{D}(L) = \int_{-\infty}^{t^*} dt' \dot{D}(t') e^{Lt} \quad (5)$$

Then

$$n_1(t) = K_1 \hat{D}(L) e^{-Lt}, \quad t > t^* \quad (6)$$

Equation (3) has the solution

$$n_2(t) = K_2 \int_0^t dt' \dot{D}(t') = K_2 D(t) \quad (7)$$

From Eqs. (1), (6), and (7)

$$\ln \tau = -\sigma_1 K_1 \hat{D}(L) e^{-Lt} - \sigma_2 K_2 D(\infty), \quad t > t^* \quad (8)$$

For $t \rightarrow \infty$, we have

$$\ln \tau(\infty) = e^{-\sigma_2 K_2 D(\infty)} \quad (9)$$

From Eqs. (8) and (9)

$$\ln \left(\frac{\tau(t)}{\tau} \right) = -\sigma_1 K_1 \hat{D}(L) e^{-Lt}, \quad t > t^* \quad (10)$$

and

$$\ln \Gamma = -\sigma_2 K_2 D(\infty) \delta, \quad t > \tau^* \quad (11)$$

Data Analysis

Set

$$f(t) = \ln \left[-\ln \frac{1}{\Gamma} \right] = A - Lt, \quad (12)$$

where the zero of time is set at the peak of the dose rate curve, and

$$A \equiv \ln (\sigma_1 K_1 D_0)$$

Examination of the Febetron pulse shape and the absorption data indicates that the formulas outlined above should apply from about 30 ns after the peak of the radiation pulse, and that 100 ns later the transient absorption is no longer detectable. On this basis, we have performed a least squares fit to the data.

Averaging data for 21 points in 10 ns increments between $t = 150$ and 350 ns, we find

$$\Gamma = 0.947 \pm 0.011 \quad (13)$$

Using this value of Γ in equation (11), we made a least squares fit to the data from $t = 30$ to 140 ns in 10 ns increments, and found

$$L = (2.07 \pm .05) \times 10^7 \text{ s}^{-1}$$

$$\text{or } L^{-1} = 48.3 \pm 1.3 \text{ ns} \quad (14)$$

for the attenuation decay constant, and

$$A = -(1.17 \pm 0.04) \quad (15)$$

The excellent nature of the fit to the data from $t = 30$ to 130 ns is shown in figure 1.

The errors quoted in equations (13), (14) and (15) are those arising from the statistical analysis; these take no account of systematic errors, which will be discussed qualitatively. Carrying the statistical errors forward, we find from equation (11)

$$\sigma_2 K_2 = (1.65 \pm 0.36) / (\text{Mrad cm}); \quad (16)$$

taking the total effective dose to be $D_0 = 0.585 \text{ Mrad}$.

From equation (12)

$$\sigma_1 K_1 = \frac{1}{D_0 \delta} \exp A \quad (17)$$

$\hat{D}_0$ contains any uncertainties in $D_0 \delta$ plus knowledge of the shape and time of the radiation pulse. We estimate that

$$\hat{D} = 1.405 D_0 = 0.822 \text{ Mrad}$$

and that errors due to inaccurate information on the pulse shape and time are less than 10 percent. With this $\hat{D}$ and equations (15) and (17), we find

$$\sigma_1 K_1 = (6.68 \pm 0.37) / (\text{Mrad.cm}) \quad (18)$$

Measurements at Sandia¹ at 257 nm gave an attenuation constant $\mu = 0.045 \text{ cm}^{-1}$ with a radiation dose of 30.3 krad in a pulse about 300 μs long. Using our value for $\mu = \sigma_2 K_2$ (equation 16), we predict for the Sandia measurement,

$$\mu = (0.050 \pm 0.011) \text{ cm}^{-1}$$

in good agreement with their result. This suggests that the recovery time of the "permanent" darkening is at least several hundred microseconds.

$$1.65 \pm 0.36 \text{ cm}^{-1} \text{ per Mrad}$$

Reference

- [1] J. Brannon, private communication

FIGURE 1: $f(t)$ VERSUS TIME (SEE EQUATION 12). THE CIRCLES ARE DATA POINTS.