

TECHNICAL LIBRARY  
U.S. ARMY NATICK DEVELOPMENT CENTER  
NATICK, MA 01760

INCREASING LUMINESCENT YIELD BY PULSED LASER EXCITATION

KEYWORDS: Spectra, pulsed laser, luminescent yield

Elliot F. Wyner,\* John A. Sousa and Joseph F. Roach  
U.S. Army Natick Development Center  
Clothing, Equipment and Materials Engineering Laboratory  
Natick, MA 01760

Abstract

Luminescence of dyed systems induced by laser irradiation has been studied. Significant increases in luminescence yield have been observed as the laser pulse width decreases. For nanosecond pulses, the weaker emitting systems had the highest percentage of increase. For short pulses, metastable species are not expected to build up and quench the emission.

Introduction

An experiment has been performed to investigate the luminescence of a dyed system when light pulses as short as 5 nanosec in duration are used for excitation. Significantly enhanced output with the nanosecond pulses over that obtained with continuous (CW) excitation was considered possible, because with the short times involved, metastable species were not expected to build up and quench the fluorescent emission.<sup>1</sup> The idea is analogous to the situation with an organic dye laser, in which many dyes lase when pumped for periods of 10 nanosec or less, that do not when pumped for microsecond durations with a flash lamp. In the latter case, the build up of the triplet state is thought to inhibit the lasting action by

absorbing either the pump radiation or the dye fluorescence. In either situation, the flux of fluorescent radiation emanating from the dye is decreased.

### Experimental

Luminescence from samples excited by 5 nanosec pulses, 625 microsecond pulses, and CW were compared. The nanosecond pulses were obtained from a dye laser which was pumped by an ultraviolet (337.1 nm) nitrogen laser at 50 pulses per second. An argon-ion laser, operated at 465.8 nm, was used for continuous irradiation and also, by chopping the beam, for 625 microsecond excitation. The dye laser was adjusted to be at the same wavelength ( $\pm 1$  nm) as the argon laser.

A block diagram illustrating the apparatus is shown in FIG. I. The circular laser beam was adjusted optically into the image of a slit and focused at the sample. The luminescent emission from the sample was collected and focused onto the entrance slit of the first of two monochromators, the second monochromator being necessary to sufficiently discriminate the luminescence from the laser light. The light exiting from the second monochromator was converted by a photomultiplier into an electrical signal that was then amplified. For CW excitation, an electrometer-amplifier was utilized. For the dye laser and with the chopped-beam argon laser, synchronous detection with a lock-in amplifier was employed. When using the dye laser, the sweep output of an oscilloscope provided the reference signal to the lock-in; the laser pulse, when fed directly from a PIN photodiode to the lock-in amplifier, would not properly cycle the amplifier's reference channel.<sup>2</sup>

### Results and Discussion

The luminescent samples under study were dyed fabrics,<sup>3</sup> the first two having dyes known to be fluorescent; the other two would be considered "non-fluorescers". The techniques involved measuring the

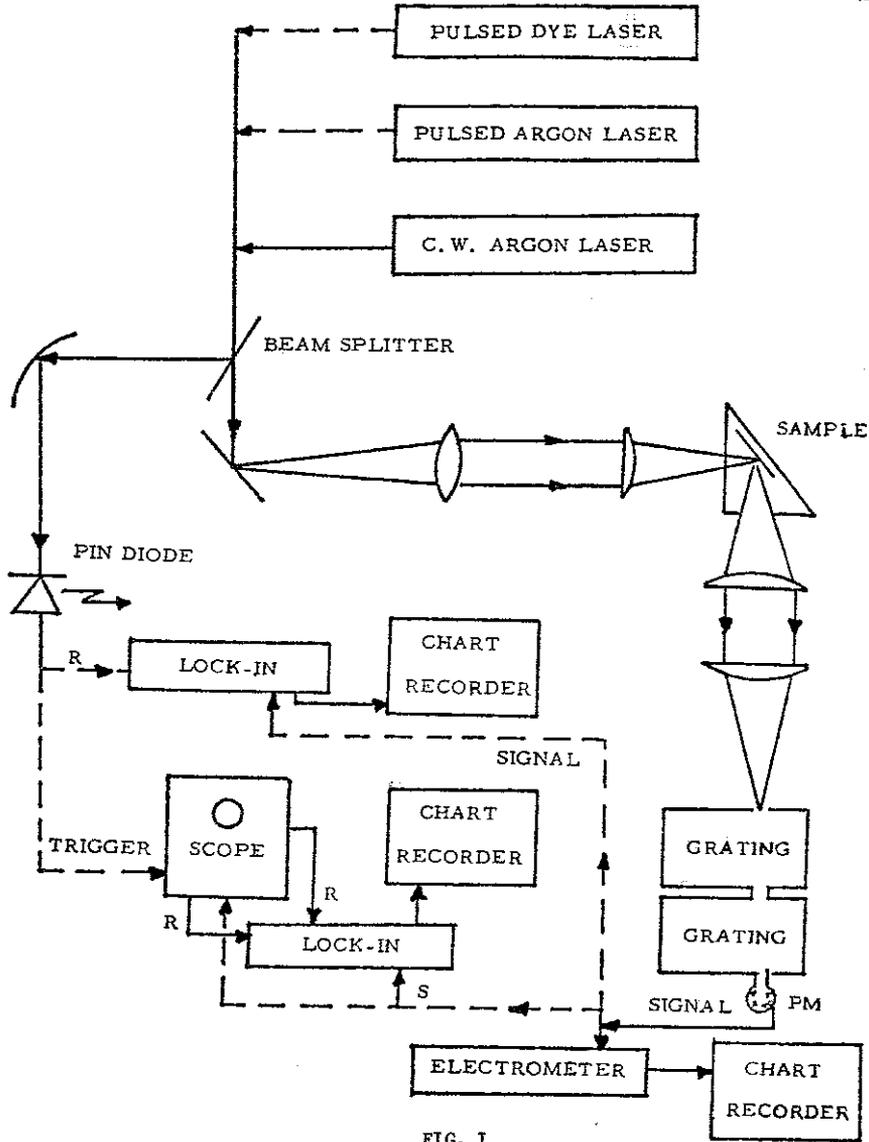


FIG. 1

Experimental Set-up for Measuring Laser Induced Luminescence.

reflected laser signal and the induced luminescence spectrum for each fabric using the different laser sources. The reflected laser signals are proportional to the excitation intensity, and were normalized to a common value. The proportionality statement is valid since the reflection coefficient is unaltered with the laser time constant and intensities being employed. Absorption, the complementary process of reflection, occurs over times normally associated with a Frank-Condon transition; around  $10^{-15}$  seconds. The difference in time constants thus between  $10^{-9}$  sec and CW would not affect the absorption process. Depletion of the absorbing levels by the laser pulse, which could alter the reflection coefficient, was negligible, or non-linearities with incident intensities would have been observed.

The luminescence spectra, which have been scaled using the same factors, were compared. By using a single detector and optical system for all measurements, neither the system spectral response nor the optics employed will affect the comparison. Since with each measurement, the laser and luminescence are measured using the same electronic instrumentation set at the same scale setting, spurious instrumental effects associated with the different time scales of the excitation sources were not a factor. The excitation and luminescence signals under comparison occur for the same time duration except for the nanosecond excitation, where the luminescence is approximately 0.5-2 nanoseconds longer than the exciting 5 nanosec pulse. However, both the signals will appear to be of the same duration to the detection system which has a microsecond response time (1 Megohm load).<sup>2</sup>

Figures 2 and 3 show the luminescence spectra of four samples. While the emission spectra remained basically the same, the luminescent intensity yield, light out/light in, was found to be enhanced by factors of 0.5 to 3 when pulsed laser excitation of five nanoseconds in duration

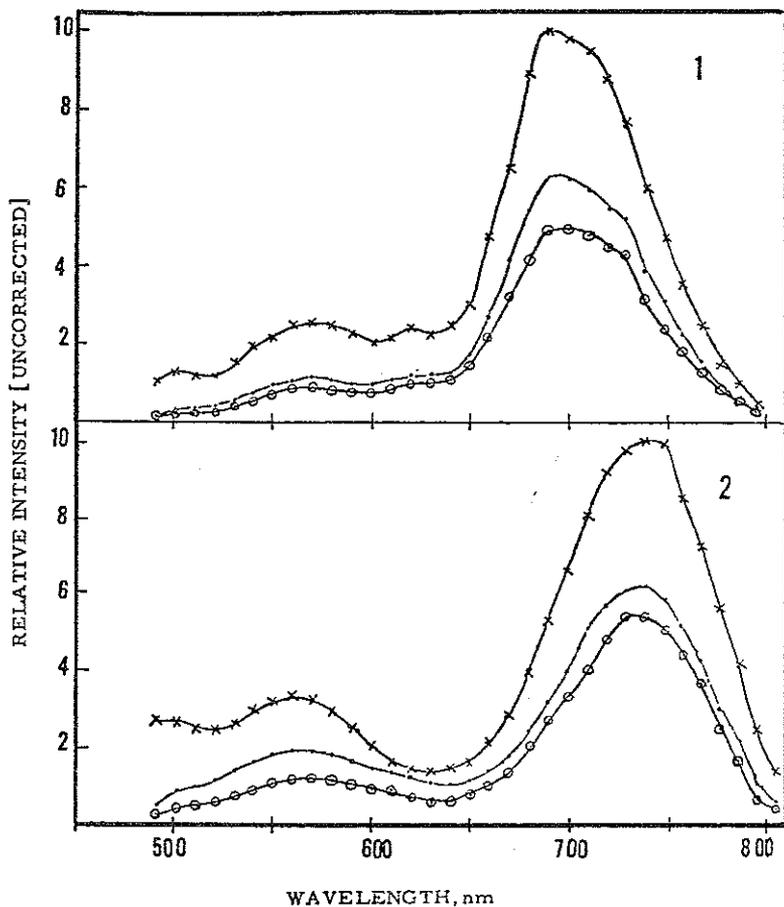


FIG. 2

Luminescence Spectra of Relatively Strong Emitting Dyed Fabrics. The -x- are for 5 nanosecond laser pulses, -- for 625 microsecond pulses and -o- for CW.

was used rather than CW. Intermediate increases were obtained for the 625 microsecond pulse. The spectra of the fabrics were not noticeably shifted in wavelength in going from CW to nanosecond pulses. However, the relative magnitude of the peaks did vary. For instance, with sample 2, FIG. 2, the pulsed intensity is 1.8 times the CW at 740 nm, but at

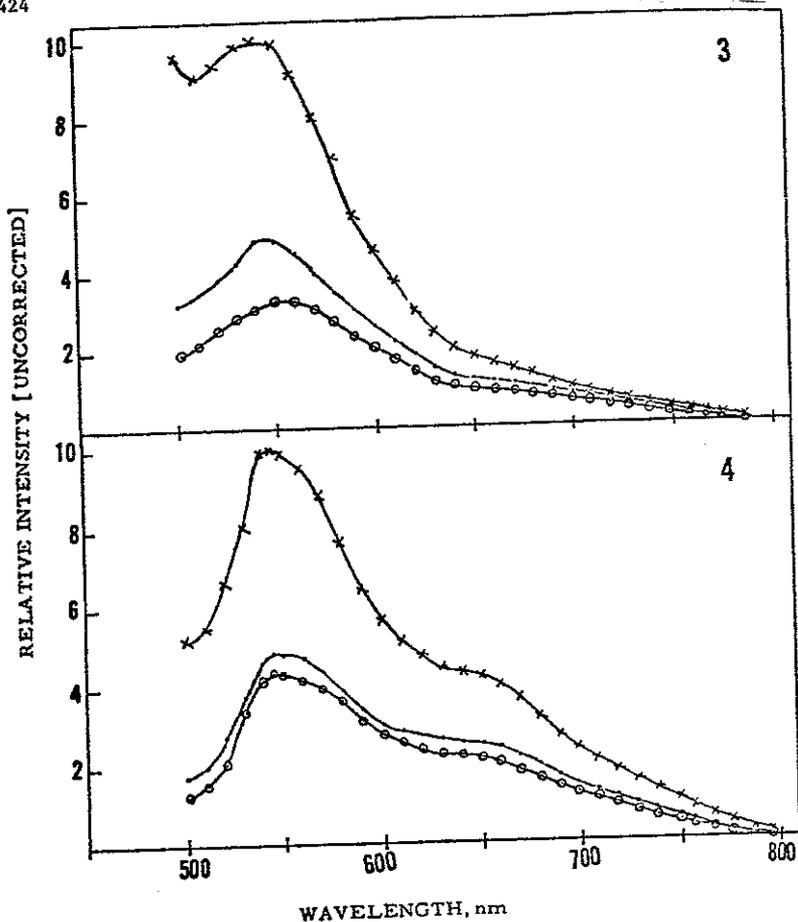


FIG. 3

Luminescence Spectra of Relatively Weak Emitting Dyed Fabrics. The -x- are for 5 nanosecond laser pulses, -- for 625 microsecond pulses and -o- for CW.

560 nm, it is 3 times as great. In general, the weaker emitting sample or spectral region of sample was enhanced greater by the high speed pulse than those which were already intense emitters under CW illumination.

For many applications, whether in the physical or biological sciences, the luminescence yield of the sample is a major factor in determining

whether there is sufficient sensitivity to detect luminescence. The data presented show that for the more weakly luminescing fabrics, up to a factor of three improvement in yield was obtained by excitation with a nanosecond laser pulse rather than with CW. For this reason, the use of a laser light source in luminescence studies is particularly desirable when the sample is a weak emitter.<sup>3</sup> The improvement in yield is of importance in evaluating the merits of different types of laser sources, since both CW and nanosecond pulsed lasers of the type used in these experiments are readily available commercially.

\*Present address: Elliot F. Wyner, Sylvania Corporation, Danvers, MA.

#### REFERENCES

1. B. B. Snively, *Electro-Optical System Design*, 30-36, April 1973.
2. E. F. Wyner, J. A. Sousa, and J. F. Roach, *Optical Engineering*, 13, 154-158, March 1974.
3. E. F. Wyner, J. A. Sousa, J. F. Roach, and M. Nakashima, *American Dyestuff Reporter*, 62, 11-21, November 1973.

Received March 29, 1975

Accepted April 28, 1975