scope at the University of Toledo[1] and has been selected for several other installations.

This letter gives the transmittance of Cer-Vit material, type C-101, between 0.1920 μm and 1200 μm, and the index of refraction between 200 μm and 1200 μm. Measurements were made on 1.125 ±0.005-mm and 0.290 ±0.005-mm-thick samples of this material between 0.1920 μm and 2.7 μm with a Perkin-Elmer 450 spectrophotometer and between 2.5 μm and 50 μm with a Beckman IR-12 spectrophotometer. These data are given in Fig. 1. The transmittances of 0.290 ±0.005-mm and 0.49 ± 0.02-mm-thick samples were measured on a vacuum submillimeter spectrometer. This is a single beam, $f/2.2$, echelette grating instrument covering the range of 40–1200-μm wavelength with a resolving power of about 100–200 using a Golay cell detector. Its source and output are similar to those of Russell and Strauss,[2] its chopper is similar to that of Bell and Gilmer,[3] its monochromator is similar to that of Richards,[4] and its filtering is as by Bell et al.[5] These data are shown in Fig. 2. No transmission was observed between 6.5 μm and 200 μm. The gap between 420 μm and 500 μm is due to poor grating overlap where the transmitted intensity was too low to obtain meaningful results. This is indicated by a single averaged datum point with appropriate error bars.

Note that the channel spectra were observed in the 200–1200-μm range, enabling the index of refraction to be calculated from the relation[6] $m = 2nd/(\lambda)/(\cos \phi)$, where m = order number, n = index of refraction, d = sample thickness, ϕ = angle of refraction, and λ = wavelength. Since the angle of refraction was calculated to be less than 4°, $\cos\phi$ was taken as 1. The values of index of refraction using the first five order peaks of the 0.29-mm-thick sample are given in Table I.

It is to be noted that smoothing out the transmittance data results in a transmittance curve similar to that of other glassy

Table I. Index of Refraction Values

Order number	Wavelength (μm)	Index of refraction
1	1160	2.0
2	630	2.2
3	440	2.3
4	340	2.3
5	265	2.3

materials, as obtained by McCubbin and Sinton[7] and Dianov et al.[8]

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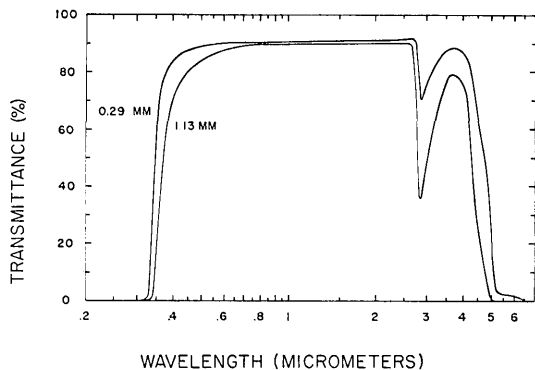8. E. M. Dianov, N. A. Irisova, and V. N. Timofeev, Sov. Phys.-Solid State **8**, 2113 (1967).

Fig. 1. Transmittance of Cer-Vit glass-ceramic in the uv, visible, and ir wavelength regions.
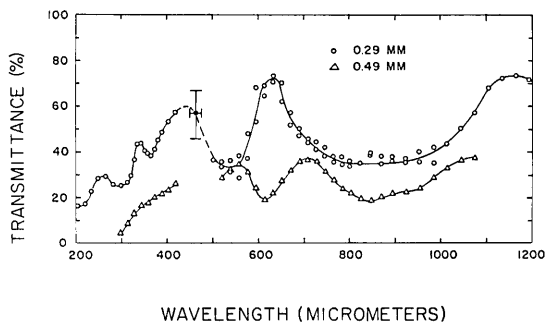

Fig. 2. Transmittance of Cer-Vit glass-ceramic in the submillimeter wavelength region. The oscillations exhibit interference phenomena.

Continuous Recording and Averaging of Spectra From Repetitive Nanosecond Signals

R. R. Alfano and N. Ockman

General Telephone & Electronics Laboratories, Incorporated, 208–20 Willets Point Boulevard, Bayside, New York 11360.
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The purpose of this note is to introduce the optical spectroscopist to a powerful technique of scanning and averaging spectra of pulsed light sources of short pulse width. The method to be described combines the well-known techniques of sampling and time averaging[1-5] to improve the signal-to-noise of repetitive signals having durations ranging between nanoseconds and milliseconds. Examples occur in the spectra induced by pulsed lasers (nonlinear optical response), pulsed semiconductors (recombination in avalanching diodes), and other transient light sources. This method has been used to obtain the emission spectrum from a bulk sample of n-GaAs excited by a 100-nsec voltage pulse.

A significant advantage of this technique is that it utilizes relatively inexpensive commercially available equipment. One can sample spectra at any time during the emission pulse. In addition, this method allows one to obtain the average pulse shape of fast signals as a function of time, which would be useful for the measurement of short decay times.[1-5] The ordinary way to obtain pulsed spectral measurements involves photographing the light spectra or the laborious process of averaging several measurements at each wavelength.

The setup for the continuous recording of a light pulse at a given time within its duration is shown in Fig. 1. The signal was obtained from bulk n-GaAs ($\rho = 0.11$ ohm cm) excited by a 200-V pulse of 100-nsec width. The radiation was passed through a spectrometer and detected by an RCA 7102 photomultiplier. The output voltage from the photomultiplier was amplified by a
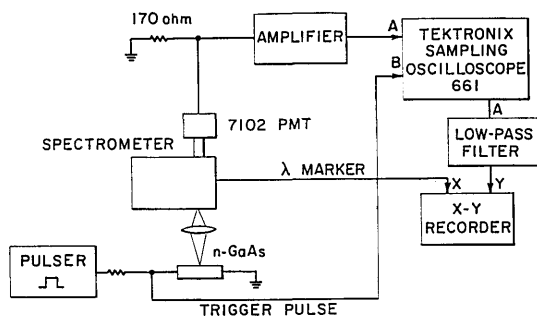
Fig. 1. Experimental setup for continuous averaging of nano-second light spectra.

factor of 100 by a Tektronix 1121 wide-band (17-MHz) amplifier and fed into channel A of a Tektronix 661 sampling oscilloscope. This oscilloscope was equipped with a 4S–1 sampling plug-in and a 5T1A sampling sweep trigger plug-in. The triggering signal was obtained from the applied voltage pulse that was fed into channel B of the oscilloscope. The sampling sweep can provide for either manual or external scanning of the sampling position. In the measurements presented, the sweep control was manually adjusted to sample the 100-nsec light pulse at the 50-nsec position. Hence, for a 20-nsec/cm sweep rate, the signal sampling dot was positioned 2.5 cm from the start of the light pulse on the screen. Thus, every time the scope was triggered, the signal was sampled 50 nsec after the start of the pulse. An output jack on the oscilloscope provides a voltage corresponding to the voltage of the signal at the moment of sampling. The signal was then fed to a low pass RC filter with a sufficiently long time constant τ to average over a number of voltage samples. In effect, the filter output that is fed to the Y channel of an X–Y recorder represents the intensity of the light pulse at a fixed point in the pulse (the 50-nsec point in our case) averaged over $m\tau$ pulses, where m is the repetition rate. A spectrum was obtained by scanning the line with a spectrometer and driving the X channel of the recorder at a sufficiently slow rate to realize the available resolution.

The improvement in the signal-to-noise voltage S/N obtained by this method arises from the filtering of the output of the sampling oscilloscope by the low pass filter. For repetition rates m of 5/sec and 10/sec and values of τ varying from 10^{-5} sec to 1 sec, it was found that S/N increases with $m\tau$ approximately as $[1 + (m\tau)^{\frac{1}{2}}]$. Typical spectra are shown in Fig. 2.

To obtain the shape of the light pulse as a function of time, the sampling sweep can be externally swept by a motor driven potentiometer. The integrated signal voltage would be fed into
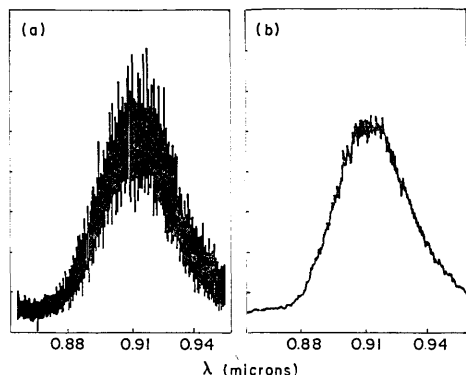
the Y channel and the scan rate into the X channel of the X–Y recorder. Therefore, a noise-reduced signal presentation would be readily obtained that gives lifetimes for rapidly decaying light signals. The minimum lifetime measurable is limited by the response of the photomultiplier and associated circuitry.

Signal averaging of nanosecond pulses can also be done by coupling expensive commercially available digital oscilloscopes[4] or pulse height analyzers[2] to the sampling oscilloscope. The method discussed in this note is less expensive and does not involve the construction of additional circuitry for synchronizing the trigger of the sampling oscilloscope and the other units.

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Fig. 2. Emission spectra from n-GaAs under 100-nsec pulse at 50-nsec sampling position: (a) $\tau_{RC} = 0$ sec, $m = 5$ sec; (b) $\tau_{RC} = 1$ sec, $m = 5$ sec.

Electroluminescence in Potassium Dihydrogen Phosphate

David E. Downie and Melvin P. Klein

Lawrence Radiation Laboratory, University of California, Berkeley, California 94720.
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Electroluminescence is a frequently occurring phenomenon that may be attributed to a number of mechanisms. These include transitions involving impurity levels, lattice vacancies, and band gap emission.[1] This phenomenon has now been observed in electrooptic light modulators (EOLM) composed of KDP (KH_2PO_4) and KD*P (KD_2PO_4). Although we are unsure of the mechanism operative in these materials, we emphasize that they contain impurities. (Subsequent to these observations, A. Carlson of the Clevite Corporation informed us that a number of impurities are intentionally introduced into the starting materials to facilitate the growth of large crystals along selected axes. The specific identity of these impurities is considered proprietary information and was not made available to us.)

The characteristics of the electroluminescence are presented in Figs. 1–3. Figure 1 illustrates the time dependence of the phenomenon; each half cycle of the exciting voltage produces a pulse of radiation from the EOLM. The peak intensity of the luminescence varies with the magnitude and frequency of the applied field, as shown in Fig. 2. The data for this figure were obtained by measurements on crystal B (see Table I). The field strength can be determined from the equation $E = V/t$. The intensity of the light varies as the inverse square of the distance between crystal and photomultiplier. Lastly, the wavelength of the emission has been roughly localized with interference filters, the data points having been corrected for filter transmission and the spectral sensitivity of the photodetector. The peak of intensity is at approximately 3270 Å, as is shown in Fig. 3.