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Detecting Near Ultraviolet Radiation in the Presence of Visible Light*

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ABSTRACT

We describe a system which suppresses the detection of visible sodium vapor light by a factor of about 10^8 relative to near ultraviolet radiation.

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It occasionally may be useful to detect very low level ultraviolet radiation in a brightly illuminated room. For instance, a scientist wishes to stimulate a microscopic organism to emit ultraviolet light. He might want to see the organism and simultaneously detect the ultraviolet radiation which he stimulates.[1]

Our interest in this problem arose from the need to detect Cherenkov radiation in a large room enclosing the 15-foot bubble chamber at the National Accelerator Laboratory.[2] The room must be illuminated at all times to permit monitoring and servicing the bubble chamber. The spectrum of the Cherenkov radiation, however, extends into the ultraviolet. It should be possible to provide visible sodium vapor light for humans, while at the same time detecting the Cherenkov radiation with a detector which is sensitive only to ultraviolet and not to visible radiation.

Although the cost and inconvenience of converting numerous existing incandescent lamps to sodium vapor lights has caused us to abandon the scheme, there may be sufficient interest in the general problem to justify this report on our technique.

The detector consists of a fast, bialkali, ultraviolet-sensitive photomultiplier tube (Amperex 56DUVP)[3] which is shielded from sodium light by an ultraviolet transmitting, visible absorbing glass filter (Corning Color Specification 7-54).[4] The spectral characteristics of the filter and of the photomultiplier are shown in Fig. 1. Note that fortuitously the transmission of the filter drops to a minimum just at 590 nm, the wavelength of the Na-D lines. A figure of merit (FM) of the detector is given by the ratio of the quantum efficiency (QE) for the near ultraviolet (250 nm - 380 nm) to that at 590 nm. By inspection of Fig 1, it may be seen that the theoretical figure of merit is

$$FM_{th} = \frac{QE_{uv}}{QE_{NaD}} = \frac{10^{-1}}{10^{-14}} = 10^{+13}.$$

This attenuation is quite respectable. The level of illumination in most laboratories is 500 lumens per meter squared or about 30×10^{14} visible photons per centimeter squared second. If all these photons were coming from the Na D-lines, the laboratory would appear well illuminated although colorless. The detector, however, would register only 3 photoelectrons per centimeter squared second, a rate well below the typical background noise rate.

EXPERIMENTAL TEST

The difficulty whith the proposed scheme is that a sodium vapor light does not emit solely Na D-lines. Although the only strong visible lines of sodium are in the neighborhood of the D-lines and consequently are strongly attenuated by the detector, lines of the inert carrier gases, argon and neon, can be transmitted at reduced attenuation. Green and blue lines may be eliminated by placing a sharp, short wavelength cut off yellow filter in front of the lamp. There are, however, no colored glass filters which sharply eliminate the red part of the spectrum. (See Fig. 2)

We have obtained a spectrogram of the light emitted from a commercially available sodium vapor lamp used to provide bright yellow light for photographic dark rooms.[5] The unit consists of a sodium vapor light which is viewed through a diffusing screen and a short wavelength cutoff yellow filter. The spectrum from this lamp, shown in figure 3, clearly indicates prominent red lines having a wavelength near 700 nm.

These lines are from the neon carrier gas and have an intensity about 10^{-3} relative to that of the Na D-lines. Using this observation and the spectral sensitivity of the detector as presented in figure 1, we find a corrected figure of merit

$$\text{FM(corrected)} = \frac{\text{QE(near uv)}}{\text{QE(700 nm)} \times \text{Number red lines} \times \text{Rel. Intensity}}$$

$$= \frac{10^{-1}}{10^{-5} \times 10 \times 10^{-3}} = 10^{6}.$$

By placing a yellow "traffic shade" filter (CS 3-68, Fig. 2) and a blue-green filter (CS 4-76, Fig. 2) in front of the source, this figure of merit may be improved a factor of 100 to

$$\text{FM(Na D isolated)} = 10^{8}.$$

We have confirmed these figures of merit experimentally by exposing the 56 DUVP photomultiplier to the yellow safelight. The response of the photomultiplier when it was shielded by the CS 7-54 filter was compared to that obtained when it was shielded by neutral density filters.

We conclude by noting that "solar blind" photomultiplier tubes have been used for some years to detect ultraviolet radiation in the presence of visible light. These tubes are manufactured with various photocathodes having long wavelength cutoffs from about 150 nm to 1100 nm. The cutoff of a photocathode, however, is generally not as sharp as that of the CS 7-54 filter. The cutoff of the EMR F type photocathode,[6] for instance, is shown in Fig. 3. When compared to the detector described here, such a tube has a similar figure of merit but a lower quantum efficiency for near-ultraviolet radiation. If a solar blind tube is used together with an ultraviolet transmitting filter, the figure of merit should increase substantially, but the lowered efficiency in the near ultraviolet would remain.

SUMMARY

Because of the radiation from the neon carrier gas, the figure of merit (FM) of a practical system is reduced from the theoretical value of 10^{13} to 10^{8}. Even this lowered value, however, may be useful in systems where multi- rather than single ultraviolet photons are being detected.

We are most grateful for technical information supplied by R. C. Saxton of Corning Glass Works, Donald A. Steen of Amperex Electronic Corporation, and Robert L. Wisner of EMR Photoelectric. We also thank Gerhard Schultz for technical support.

FOOTNOTES

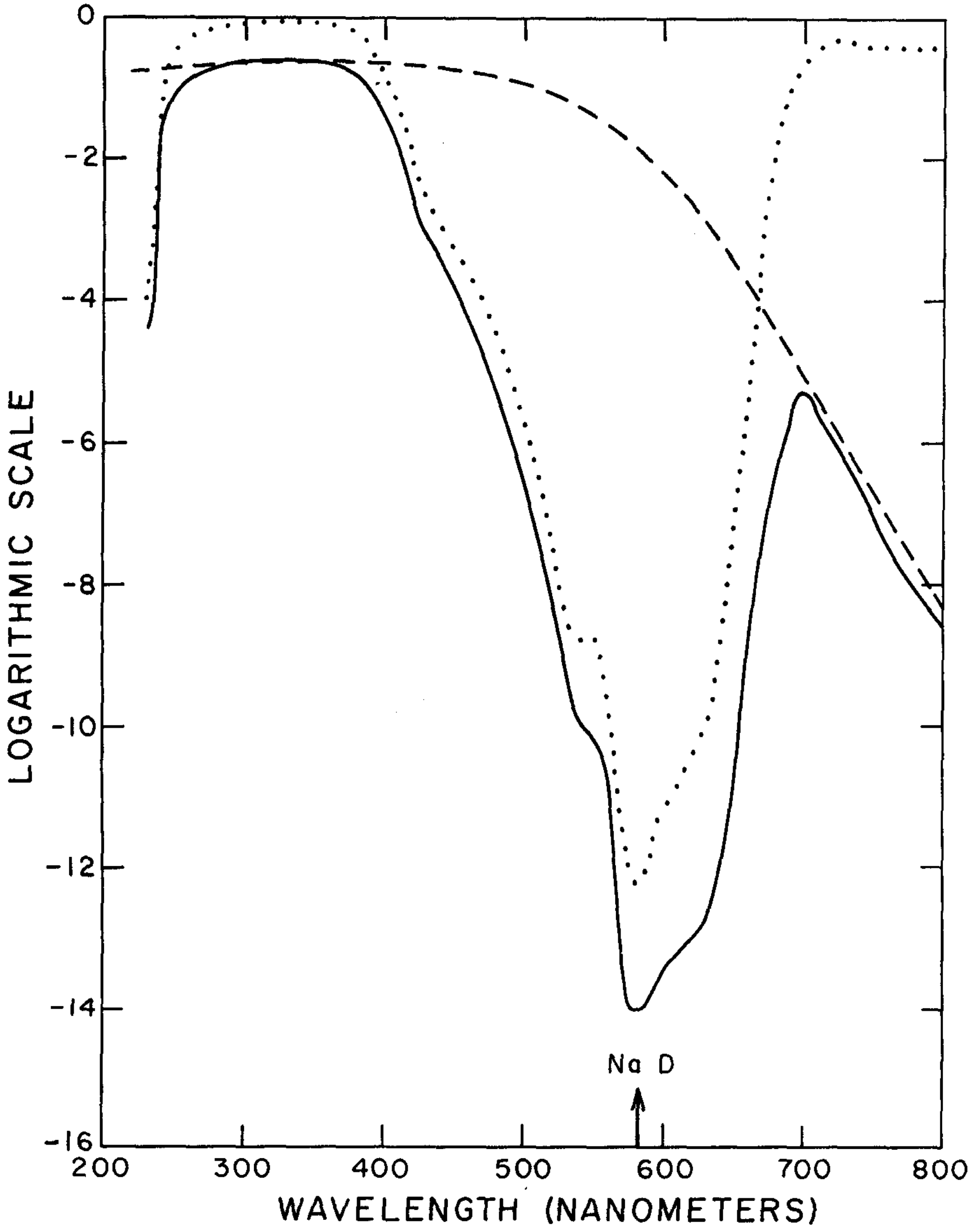
1. A related problem, that of isolating blue light from red, is encountered in astronomy and has been solved by the development of a copper sulphate filter. (See E. J. Wampler and I. I. Papiashvili, Publications of Astronomical Society of the Pacific 80, 624 (1968)).
2. D. F. Bartlett and M. G. White, Proposal #202, National Accelerator Laboratory, Batavia, Illinois 60510, (unpublished).
3. Amperex Electronic Corporation, Hicksville, New York 11802.
4. Corning Glass Works, Corning, New York 14830.
5. Thomas Industries Inc., 49 West 23rd Street, New York, N. Y.
6. EMR Photoelectric, P. O. Box 44, Princeton, New Jersey 08540.

FIGURE CAPTIONS

Fig. 1. The spectral response of an ultraviolet transmitting, visible absorbing colored glass filter (CS 7-54, dotted curve), of a bialkali photomultiplier (56 DUVP, dashed curve), and of the filter in series with the potomultiplier (solid curve). The curve for the filter shows absolute transmission; that for the photomultiplier shows quantum efficiency. The data for the filter between 480 nm and 680 nm and for the photomultiplier above 650 nm is representative only and was given in private communication from R. C. Saxton and D. A. Steen respectively. The rest of the curves are from the manufacturer's catalogues.

Fig. 2. (Solid Curve). -Isolating the D-lines of the sodium vapor spectrum by using a short wavelength cutoff (CS 3-68) and a long wavelength cutoff (CS 4-76) colored glass filter. Data for the CS 3-68 below 520 nm was supplied by R. C. Saxton. (Dashed Curve). -Long wavelength cutoff of a solar-blind photocathode (EMR - F). Data supplied by R. L. Wisner.

Fig. 3. The observed spectrum of a Thomas Duplex, sodium vapor, safelight. The spectrum is of the lamp itself without the diffusing screen and yellow filter which are normally supplied and which suppress the blue argon lines. The lines having wavelengths in the regions 380-450 nm, 460-620 nm, and 630-760 nm are from argon, sodium, and neon respectively.



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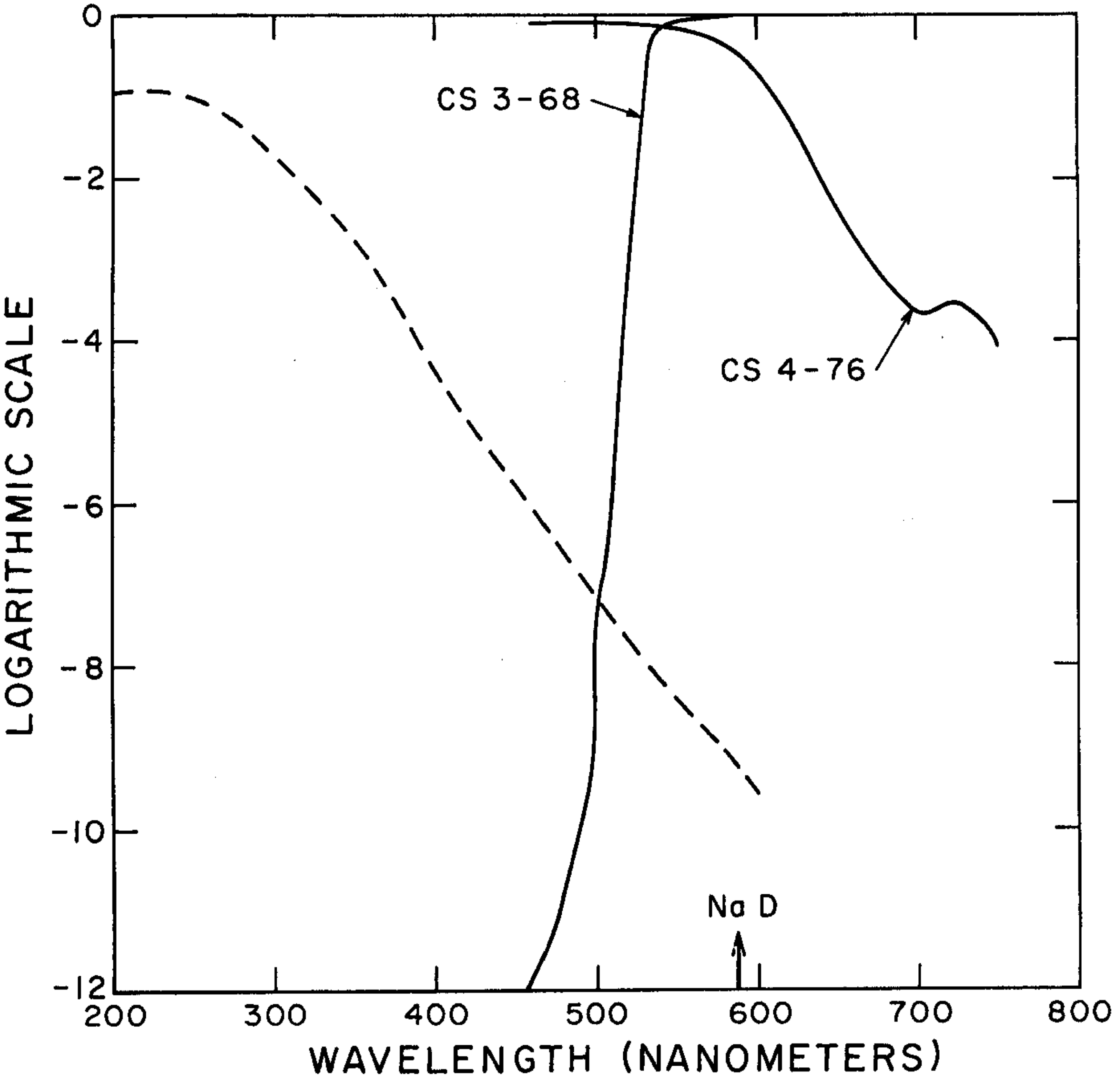
WAVELENGTH (NANOMETERS)
Na D

fig 1



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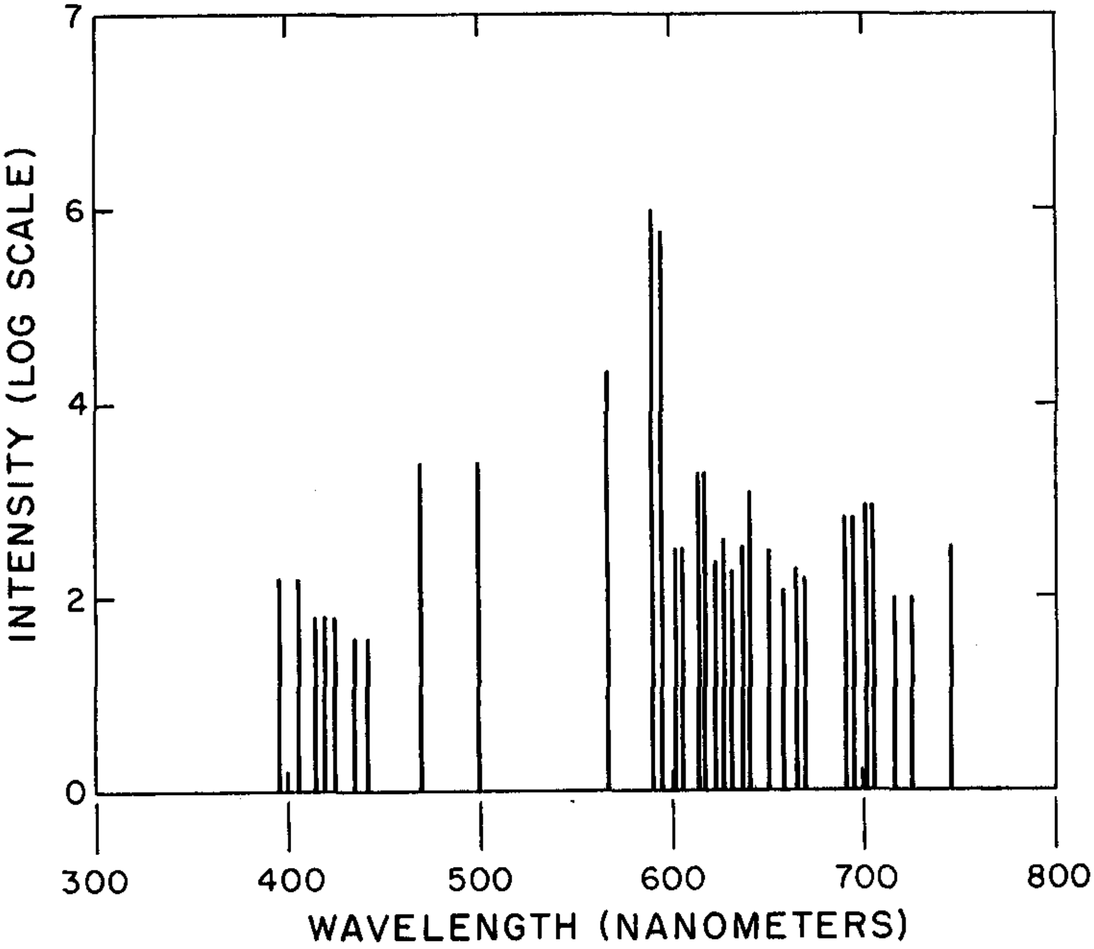
WAVELENGTH (NANOMETERS)
CS 3-68
CS 4-76
Na D

fig. 2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WAVELENGTH (NANOMETERS)

fig 3