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WL-TR-92-5020

HIGH RESPONSIVITY UV PHOTOCONDUCTORS
BASED ON GAN EPILAYERS

LARRY F. REITZ
ELECTRO-OPTICS DETECTORS BRANCH
ELECTRO-OPTICS DIVISION

JULY 1992

Final Report for Period 19-24 July 1992

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LARRY F. REITZ PROGRAM MANAGER	CHARLES H. STEVENS, CHIEF ELECTRO-OPTICS DETECTORS BRANCH ELECTRO-OPTICS DIVISION

C. Richard Lane

C. RICHARD LANE, ACTG CHIEF
ELECTRO-OPTICS DIVISION
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92 JULY Final, 19-24 JULY 1992

High Responsivity UV Photoconductors Based on GaN Epilayers

PE - 62204F
PR - 2001
TA - 05
WU - 03

Larry F. Reitz (513) 255-5147

Electro-Optics Detectors Branch
Electro-Optics Division (WL/ELO)
Solid State Electronics Directorate
Wright Laboratory
Wright-Patterson AFB OH 45433

WL-TR-92-5020

PUBLISHED IN: SPIE Conference, Optical Applied Science and Engineering; San Diego CA 19-24 July 1992.

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This paper will describe a new ultraviolet (UV) sensitive photoconductive detector based on gallium nitride (GaN) Material. Data will be presented on devices fabricated over the past several months. These devices have a high responsivity between 200 to 360 NM with a sharp long wavelength cutoff at 360 NM. The detectors have measured gains in excess of 6000 and frequency responses of greater than 100 Hz. The devices have measured dynamic ranges of over four orders of magnitude and operate with bias voltages of 5 to 10 volts. Device designs will be shown that can be utilized in the development of a large monolithic focal plane for UV imaging.

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ACKNOWLEDGMENTS

The author wishes to thank Dr. Asif Khan and his staff at APA Optics, Blaine MN for their help in preparing this paper.

HIGH RESPONSIVITY UV PHOTOCONDUCTIVE DETECTORS

This paper describes data taken on several gallium nitride (GaN) photoconductive detectors obtained from APA Optics Inc. and characterized at Wright Laboratory. The devices were grown on sapphire using a low pressure metal organic chemical vapor deposition (MOCVD) system. The contacts were on the top surface of the GaN material and consisted of an electrode pattern as shown in figure 1. The devices were 1 square millimeter in size.

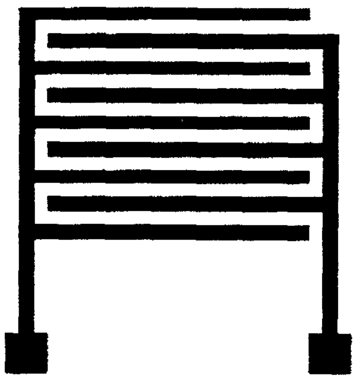

Figure 1. Detector contact pattern

Figure 2 shows the spectral response from detector APA769. The spectral response is fairly flat from 200 NM to 360 NM, then drops rapidly at 360 NM. The monochromator at Wright Laboratory is not yet calibrated below 200 NM; therefore, no measurements were taken below this wavelength. Figure 3 is the figure 2 data plotted on a log scale. This shows the sharpness of the long wavelength cutoff. The data beyond 375 NM consist of noise from the detector contacts.

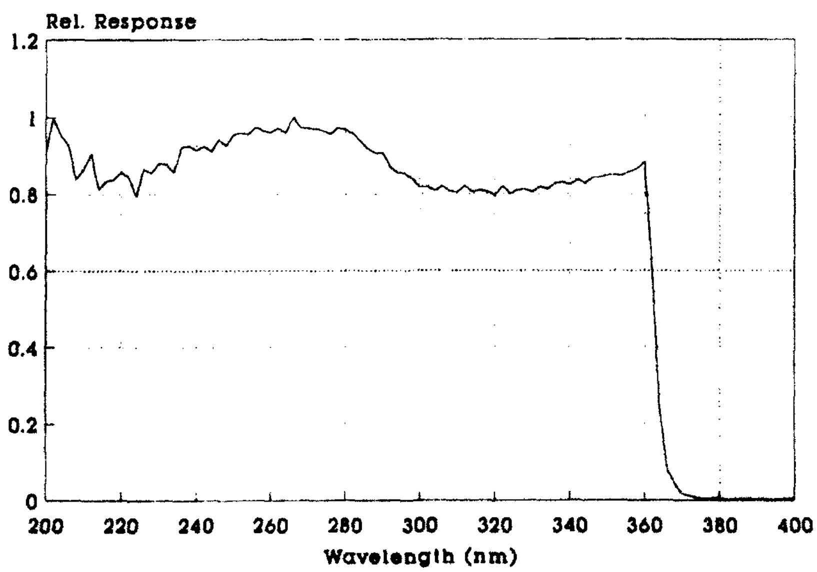

Figure 2. Spectral response of detector APA769

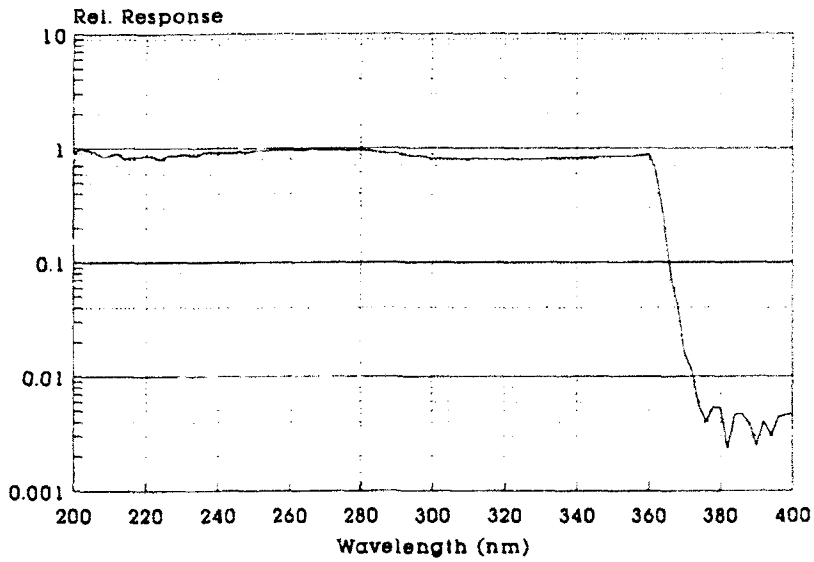

Figure 3. Spectral response (log plot) of detector APA769

Figure 4 shows the dynamic range characteristics of detector APA769. The two lines on the graph represent the detector with and without light bias. The output of this device is superlinear without light bias and close to linear with a light bias. Figure 5 is an expansion of the linear dynamic range curve (detector APA769 with light bias) that shows that this detector is linear over 4 1/2 orders of magnitude of input light. The limitation on these data was device noise at the low end and source intensity at the high end.

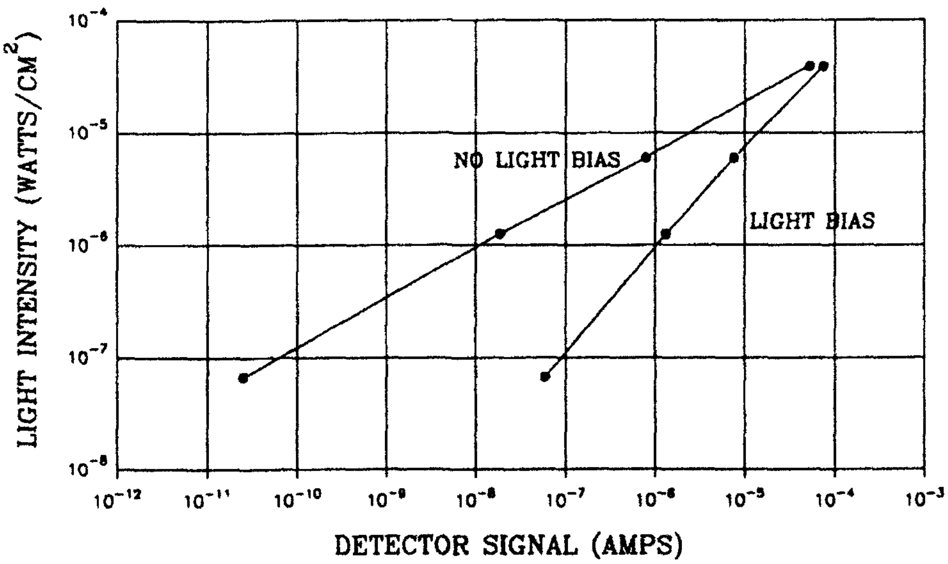

Figure 4. Dynamic range, detector APA769

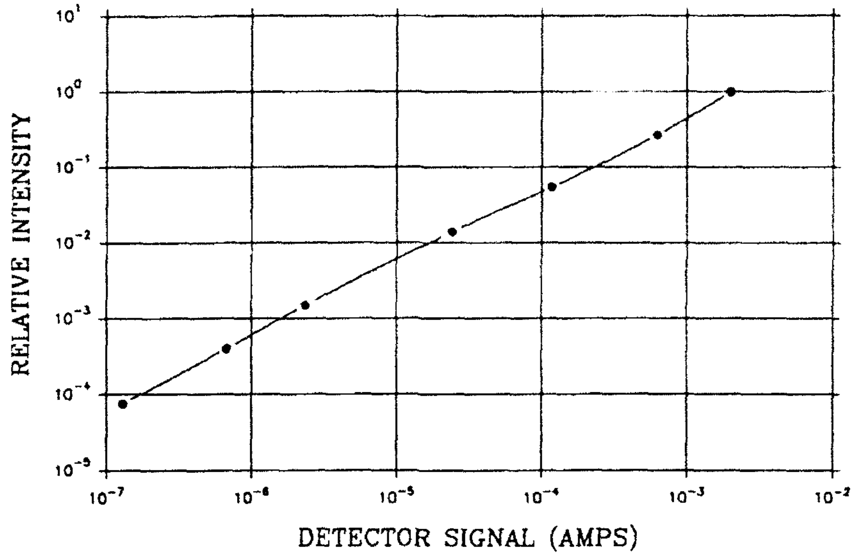

Figure 5. Dynamic range, detector APA769

Detector APA769 has an internal gain of 6000 and a dark impedance of 3 X 10^{9} ohms. Under light bias conditions, the device impedance dropped as low as 100 K ohms. In general, the detectors characterized were found to have an operating impedance in the 100 K ohm to 500 K ohm range.

Figure 6A shows the output from detector APA769 to an 11 Hz chopped input light signal at 254 NM. The detector has a comparatively slow rise time. In comparison, figure 6B shows the output of detector APA221 with the light source being chopped at 200 Hz. This detector is much faster than the previous one, but only has an internal gain of 1. This concludes that there is a real gain-bandwidth trade-off in these devices. Caution should be taken in this conclusion since the two detectors used in this experiment were fabricated under slightly different conditions hence the processing could be playing a factor on the speed as well as device gain.

In dealing with wide bandgap semiconductors, one is always interested in seeing how these devices operate at high temperatures. The next two figures show how the dark current (7) and the signal (8) varied with device temperature up to 200 ^{o}C. The device (detector APA221) worked well with the signal actually increasing with temperature. Noise in these devices was not thermally limited so that little difference in noise level was noted during the thermal tests. The noise level in the devices characterized up to this point appears to be dominated by contact noise. The noise level has changed with different contact designs. Further development effort is going to be expended in this area to understand the relation of device noise and contact design.

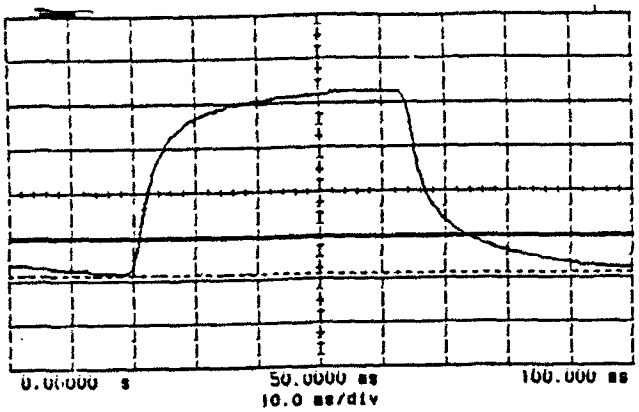

Figure 6A

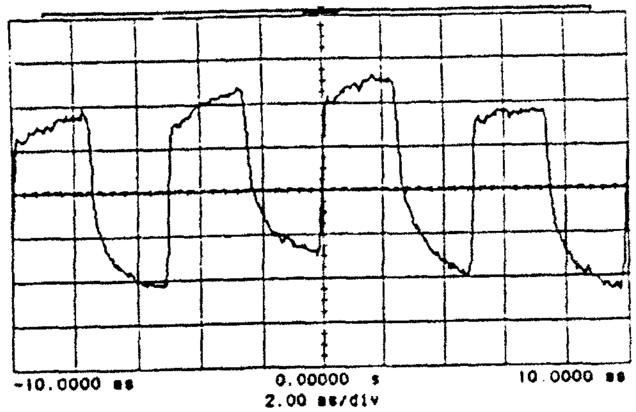

Figure 6B

Comparison of detector rise times

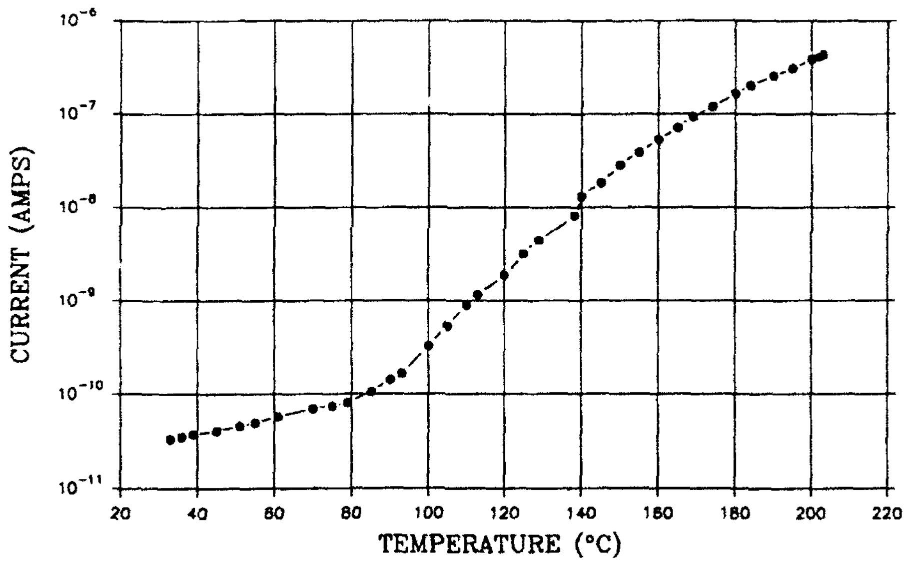

Figure 7. Detector APA221 dark current vs. temperature

Figure 9 shows a noise spectrum of detector APA769 taken on a spectrum analyzer. The spectrum covers 0.5 Hz to 195 Hz. The detector is operating under signal condition so that the spike at 12 Hz is the input signal frequency and the 60 Hz spike is just power line interference. The signal spikes beyond 12 and 60 Hz are harmonics of these signals. When the optical signal was removed from this detector, the noise spectrum went down to the basic instrument level. Of primary interest in this experiment was the evaluation on 1/f noise in these devices. As can be seen, the 1/f noise was not a prime factor.

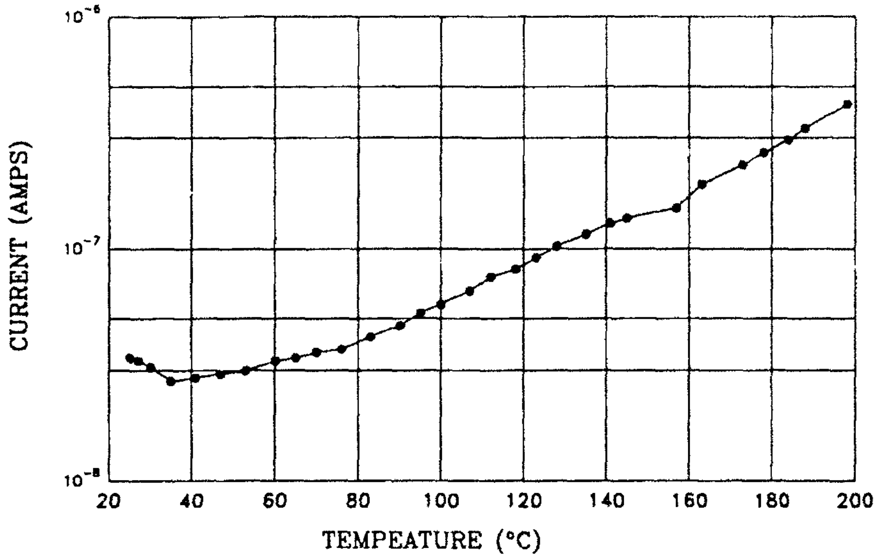

Figure 8. Detector 221 signal vs. temperature

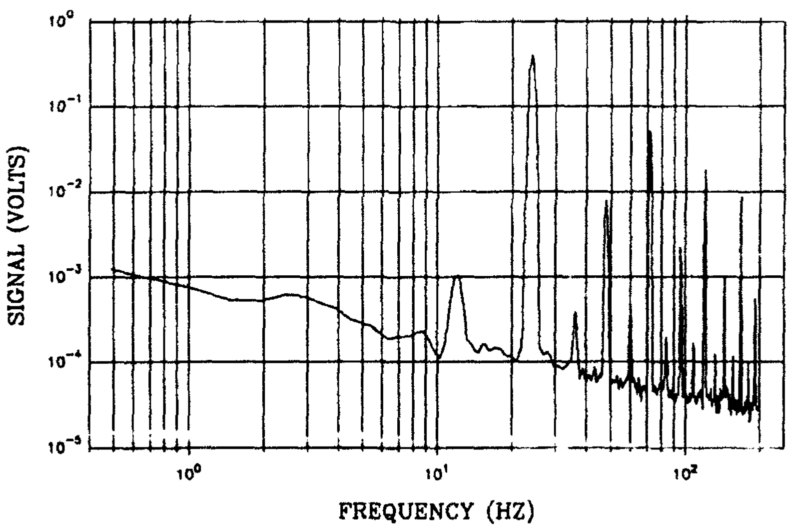

Figure 9. Detector APA769 noise spectrum

As stated before, these detectors were grown on sapphire so they could be illuminated from either side. The original detectors tested saw little difference in characteristics, whether the light came through the substrate or top of the device, but in detector APA175 a difference was noted. Figures 10A and 10B show this difference. Figure 10A is detector APA175 illuminated from the top, and figure 10B is detector APA175 illuminated through the substrate. This detector was a much thicker detector (5 microns) than those previously tested. The spectral response of this device could be changed by increasing the bias on the device. The influence of bias on these devices has yet to be fully explored.

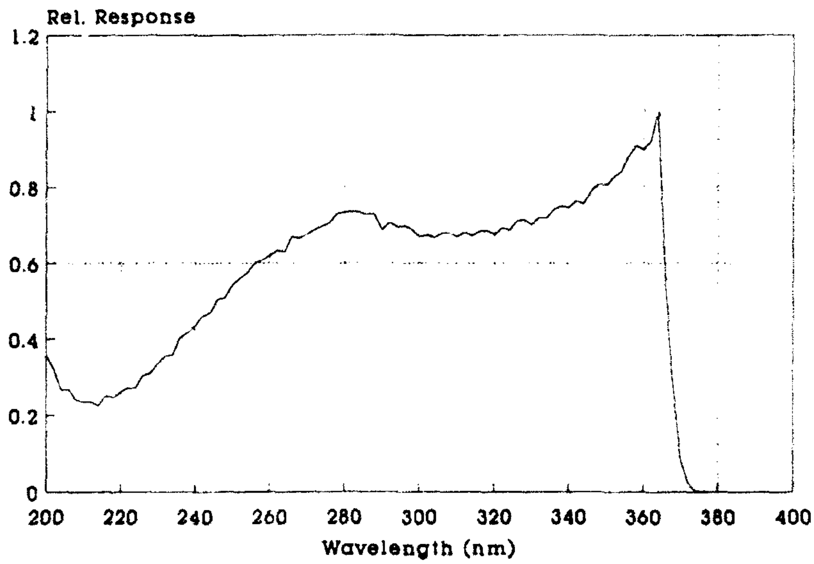

Figure 10A. Detector APA175, spectral response from top

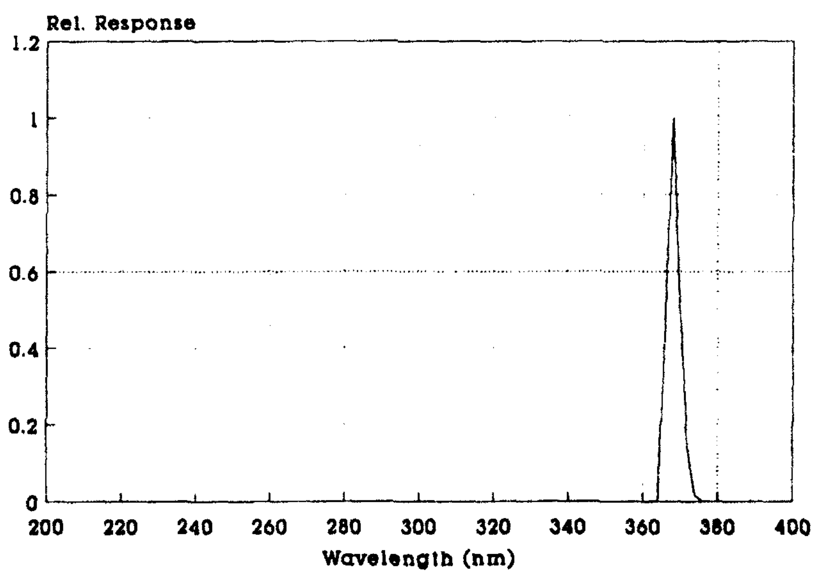

Figure 10B. Detector APA175 spectral response thru substrate