Use of AL307 light-emitting diodes as photodetectors for diagnostics of femtosecond light pulses

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(Submitted June 24, 1997)
Pis'ma Zh. Tekh. Fiz. **24**, 62–65 (January 12, 1998)

A nonlinear electrical response has been observed for the first time from AL307 light-emitting diodes exposed to femtosecond light pulses. When used in an unconventional fashion as unbiased photodiodes, these AL307 light-emitting diodes give an electrical response proportional to the square of the recorded radiation intensity of ultrashort light pulses. Autocorrelation functions are given for femtosecond pulses obtained using AL307 light-emitting diodes in the autocorrelator instead of the conventional photodetector and nonlinear crystal system.
 [S1063-7850(98)01201-4]

An AlGaAs light-emitting diode (LED) used as an unbiased photodiode to record optical radiation, may give a nonlinear electrical response proportional to the square of the incident radiation intensity. This effect was first demonstrated in Ref. 1 when an RS Components LED, having a radiation peak at 660 nm (Catalog No. 564-015) was exposed to 80 fs and 1 ps light pulses from a Ti:sapphire laser. It was assumed that the nonlinear electrical response of these photodiodes was either caused by direct two-photon absorption of radiation in the diode or by second harmonic generation in GaAs.

We observed a similar effect with Russian AL307 LEDs having radiation peaks at 666 nm (AL307BM) and at 666 and 566 nm (AL307EM). Here we report results of a direct experimental comparison between the characteristics of AL307 and 564-015 LEDs when used as photodetectors for the diagnostics of ultrashort light pulses.

For the experiments we used the FEMTIS femtosecond Ti:sapphire laser (pulse length 110–130 fs, pulse repetition frequency 108 MHz, and average radiation power up to 500 mW in the 780 nm range) and an FS-PS scanning autocorrelator with the data recorded by computer (the apparatus was built in the Laser Technology Department of Novosibirsk State University[2]). The LEDs being studied were used in the autocorrelator, replacing the conventional nonlinear crystal and photodetector system. The FS-PS autocorrelator was based on a Michelson interferometer, and a variable time delay of the pulses in one of the interferometer arms was provided by a pair of parallel mirrors which could be tilted by an angle up to $\pm 4°$. The range and scanning frequency of the autocorrelator are 0.02–30 ps and 0.01–20 Hz, respectively, with 15 fs time resolution.

Figure 1 gives interference autocorrelation functions obtained using a nonlinear BBO crystal (100 μm thick) and a Burr-Brown OPT-301 photodetector (a), the RS Components LED (b), and the Russian LEDs Al307–AL307BM (c), and AL307EM (d).

The LEDs were used in two modes.

1. In the usual form, where radiation was fed into the diode along the axis of symmetry of the polymethylmethacrylate package across the spherical surface, with the radiation prefocused by a spherical lens of 35 mm focal length.

2. With the upper part of the package removed, where radiation could be fed into the diode through a flat transparent (or colored for the AL307 diodes) polymethylmethacrylate surface positioned around 1 mm from the diode. In this case, the radiation was focused using lenses of 35 and 15 mm focal length.

The nonlinear electrical response was recorded for all the LEDs in both modes, but in mode 2 this response was slightly higher than that in mode 1 (for the same incident radiation powers). In our view, this behavior is attributable to the better focusing of the radiation. The load resistance of these photodetectors was set at 680 kΩ, and the output signal began to fall off appreciably and become distorted when the autocorrelator scanning frequencies exceeded 10–15 Hz. Note that with a load resistance of 680 kΩ for the RS Components LEDs in mode 2, we obtained output signal amplitudes three times higher than those in Ref. 1—150 mV when the radiation power incident on the photodetector was 7 mW. When the load resistance was increased, the amplitudes of the output signals increased but the response time of the photodetectors decreased. The amplitudes of the output signals from the AL307 LED photodetectors with modified package geometry were 25 mV for an average power of the recorded femtosecond radiation pulses of 7 mW.

Figure 1 gives autocorrelation functions obtained using LEDs with unchanged (Fig. 1b) and modified package geometry (Figs. 1c and 1d). All the autocorrelation functions are almost identical and in our opinion, the slight differences in the profile are attributable to a corresponding slight deformation of the femtosecond pulse shape caused by the different tuning of the titanium sapphire laser at different measurement times.

The relatively arbitrary choice of Russian LEDs made by us, suggests that there is evidently a class of LEDs having a nonlinear electrical response when used as unbiased photodiodes to record ultrashort light pulses. There is clearly a need for a detailed study of this phenomenon, and to continue our search for, and study of, various LEDs suitable for use as photodetectors for the diagnostics of light pulses of different duration and power in different spectral ranges.

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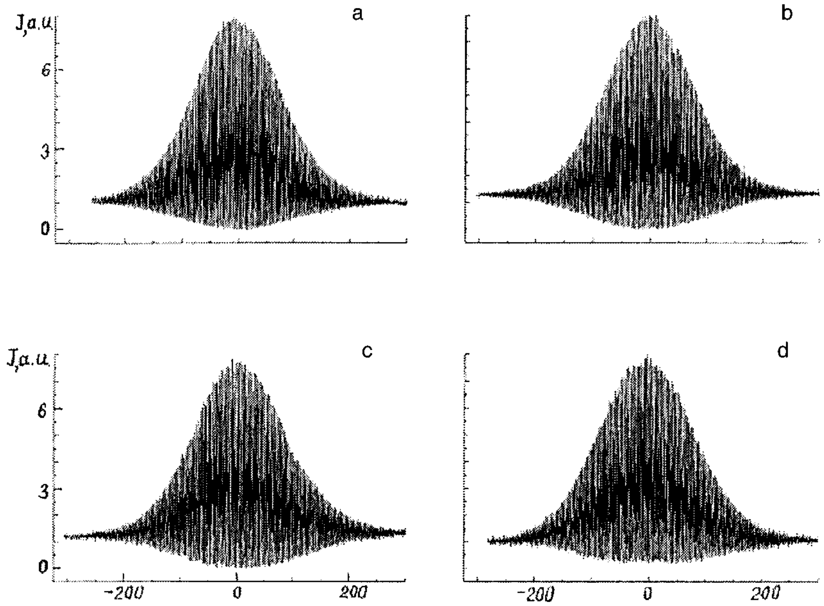

FIG. 1.

Note that an effect associated with the photoconduction of a semiconductor (ZnSe) induced by two-photon excitation during the recording of ultrashort light pulses was observed in Ref. 3. As in our experiments, the radiation source was a Ti:Sapphire laser (pulse length 120 fs, repetition frequency 76 MHz, central wavelength 800 nm). According to the data given in Ref. 3, the output signal from a specially fabricated ZnSe-based photodetector was 0.7 V (without amplification) and 60 mV when the average power of the recorded radiation was 10 mW and 1 mW, respectively. The mechanism responsible for the nonlinear electrical response of the AL307 LEDs exposed to ultrashort light pulses may be similar to that described in Ref. 3.

Since these AL307 LEDs are extremely cheap and readily available, and they are also easy to use and fairly sensitive as photodetectors, they can completely replace the conventionally used nonlinear crystal and photomultiplier, or photodiode systems in scanning autocorrelators, at least in the middle infrared, for measuring the length of ultrashort light pulses from Ti:Sapphire, Cr:LiSAF, Cr:LiS GaF, and other lasers. These LEDs may also be used as sensors for electronic display systems and for automatic triggering of mode self-locking in various lasers.

[1] D. T. Reid, M. Padgett, C. McGowan, W. E. Sleat, and W. Sibbett, Opt. Lett. **22**, 233 (1997).
[2] Novosibirsk State University Laboratory of Laser Systems Internet home page, URL: http://www.cnit.nsu.ru/nwww/lls/english/index.htm
[3] W. Rudolph, M. Sheik-Bahae, A. Bernstein, and L. F. Lester, Opt. Lett. **22**, 313 (1997).

Translated by R. M. Durham