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# EMISSION OF MEASURING SIGNALS WITH PULSE-DRIVEN LEDs

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*Abstract: The subject of the paper is focused on novel utilization of super-efficient light-emitting diodes (LEDs) as measuring sources of optical radiation when the determined current pulses are used to drive them. The relationships between input electrical pulse parameters, such as the amplitude and duty factor, and output optical power are studied. Results of LEDs dynamics analysis and experiments made on representative elements are reported. An especially designed generator was used to obtain standard rectangular current pulses needed to evaluate LEDs optical responses.*
*Keywords: measuring light emitters, LED, dynamic properties*

## 1 INTRODUCTION

The basic elements of optical data transmission channels are: electrically controlled sources of radiation, elements used to process or transmit optical signals (e.g., waveguides, modulators, deflectors, directional couplers, etc.,) and elements which convert optical radiation into electrical signals (photodetectors). In many situations, using light-emitting diodes (LEDs) as measuring sources of optical radiation has potential to be great alternative when compared to laser diodes and a number of conventional lighting sources [1-3].

Development of measuring systems to which the super-efficient LEDs may contribute as semiconductor light sources is currently considered as one of very ‘hot’ areas in photonics and optoelectronic metrology. Numerous applications include spectrophotometry, monitoring of biooptical signals, emission of measuring information for optical communications, sources of the determined input signals in optical fiber sensors. For instance, LEDs emitting 660 and 940 nm make the photoemitter in optoelectronic sensors used in pulse oximetry where are able to fulfill the requirements connected with effective light propagation through tissues [4]. Great attention is now turned to LEDs emitting blue light and UV radiation because of their usefulness in fluorescence-based studies [5]. Wide band gap II-VI semiconductor compounds are promising materials for blue LEDs as well as laser diodes (LDs).

Laser radiation has a series of unique characteristics, the most prominent of which are high spectral brightness and narrow spectral lines. An LED operates similar to a laser diode, however, compared to the latter, there are some specific differences in parameters. The spontaneous light emission from LEDs suffers from the spectral width which is not so much to be considered fully monochromatic and can limit a range of applications. But on the other hand, the LED possesses greater simplicity in driving what is a very desirable advantage from the metrological point of view. The subject of this paper concerns with characteristics of LEDs when driven by controlled current pulses to generate measuring optical responses which are able to meet requirements of high optical power efficiency.

## 2 METROLOGICAL ATTRIBUTES OF LIGHT-EMITTING DIODES

A light-emitting diode is made of semiconductor diode designed so that electrical current through a P-N junction in the forward bias direction produces the emission of optical radiation. That spontaneous emission is known as electroluminescence which efficiency depends upon the semiconductor materials used and the fabrication of the device. An LED does not require an optical cavity and mirrors to provide feedback of photons, can be more reliable than a laser diode because it operates at lower powers and its light-current characteristic may be less sensitive to temperature than that in LD. Two types of LEDs which are frequently used are surface-emitting and edge-emitting devices. The optical power of the edge-emitting device is generally a few times lower than that of the surface-emitting diode.

LEDs have several features such as low optical output power (0.1 to 3 mW), large spectral width (30 to 50 nm at room temperature), slow rise time (>10 ns), low modulation bandwidth and harmonic distortion. On the other hand, they have low temperature dependence, high reliability and low cost and simple driving. One of most important parameters of a light emitter to be used for measurement purpose is optical power efficiency which means the ratio of the optical power emitted by a source to the electrical input power to the source. An LED as a semiconductor source of light operates similar to a laser diode, however, compared to this one, the LED possesses on the one hand greater simplicity, and on the other hand, about 10 times the spectral width of its radiation. The spectral range of emission is limited, but not so much to be considered fully monochromatic. The peak position of the electroluminescent spectrum slightly shifts toward the higher energy side with increasing diode current, while the emission intensity increases linearly with the current.

The LED output power can be quite easily driven by a continuous electrical current, however, the intensity of emitted light is commonly low; only the superluminescent diodes (SLEDs) can emit a higher optical power, for example, 22.5 mW at injection current 100 mA. Thus, a very desired increase in radiation power is possible when to use current pulses to drive LEDs, however, there is still difficult to obtain rectangular optical pulses from LEDs for times of duration $T_i$ below 1ms because of limited diode dynamics resulting in its optical response settling time. The accessible data on LEDs dynamics mainly concern applications for optical communication and are not sufficient for measurement purposes. The authors of this paper deal with a question connected with utilization of pulse-driven LEDs to generate measuring optical signals of sufficient and known level of intensity. What was assumed here that input electrical pulses are rectangular, and relationships between input pulse parameters, such as the amplitude and duty factor, and output optical power are evaluated.

## 3 RESULTS OF EXPERIMENTS

Metrological properties of LEDs for spectrophotometric and all other applications where pulse mode of operation is desired, are not known exactly. The dynamic properties available in the literature are mainly useful in telecommunication and signaling systems. The authors made analysis and measurements for estimation of a given LED dynamics, basing on its optical response to the input current step function.

An input pulse is temporal variation of the amplitude of a current, and this variation must be short relative to the time of interest. An LED operating in high power pulse mode requires a special kind of electronic driving circuits in order to generate a current of several amperes. During experiments, an especially designed generator was applied. This generator make it possible to obtain rectangular current pulses to drive LEDs and evaluate their optical response. It will be well to emphasize that current switching applied to replace a 'traditional' current turn-on and turn-off is an important metrological advantage. It was assumed here that a given diode has to be tested at the input current significantly larger than those permissible during its continuous operation. Limitations determining the allowable amplitudes $I_m$ of driving signals, as well as impulse duration $T_i$, were formulated. The rectangular electrical input signal i(t) was represented by the parameters of the current pulses such as the amplitude $I_m$ and duty factor $DF=T_i/T$ (Figure 1).

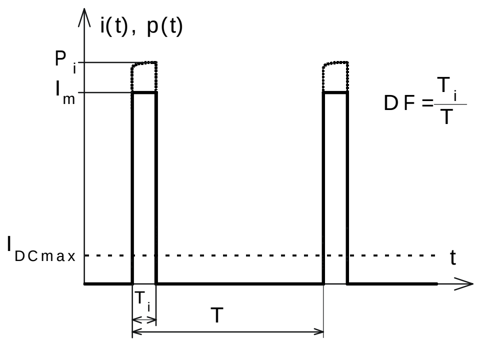


**Figure 1.** Illustration of parameters specifying relationship between electrical and optical parameters of a light-emitting diode.

It was shown, that using an input current of amplitudes large enough ($I_m > 5A$) is only possible at very low values of the duty factor. If this factor is sufficiently low, a significant increase in optical power may be performed. The optical power from a given LED was measured indirectly by a sensitive, reverse biased PIN photodiode, cooperating with a high-performance amplifier and digital oscilloscope equipped in a system conditioning processed signals. A relative inaccuracy of time measurement was no more than 0.005% of a value indicated. The amplitude $P_i$ of optical power pulses p(t) was related to the power $P_{DCmax}$ achieved at the continuous nominal driving current $I_{DCmax}$. The relationship between the power of optical output achieved and amplitude of electrical pulse input was studied for a lot of different LEDs. A permissible pulse operation range can be known for each one, taking into account relation between the duty factor DF and the increase factor $K_i$. The latter indicates to what extent $I_m$ may grow when related to $I_{DCmax}$. The representative results evaluated for one of the measured LEDs emitting radiation in the near-infrared region, at the wavelength 940 nm, have been collected in Figures 2 and 3.

Many applications of light emitters do not depend on knowledge of the absolute value of the output optical power. In the Figure 2, the output optical power obtained during a pulse of the input electrical current has been related to the optical power to be acquired for the continuous nominal current and displayed versus the input pulse amplitude. Although the presented relation $P_r = P_i / P_{DCmax} = f(I_m)$ is not linear, pulse driving LEDs can be recommended to use to increase the emitted optical power for needs of optical measurement techniques and applications.

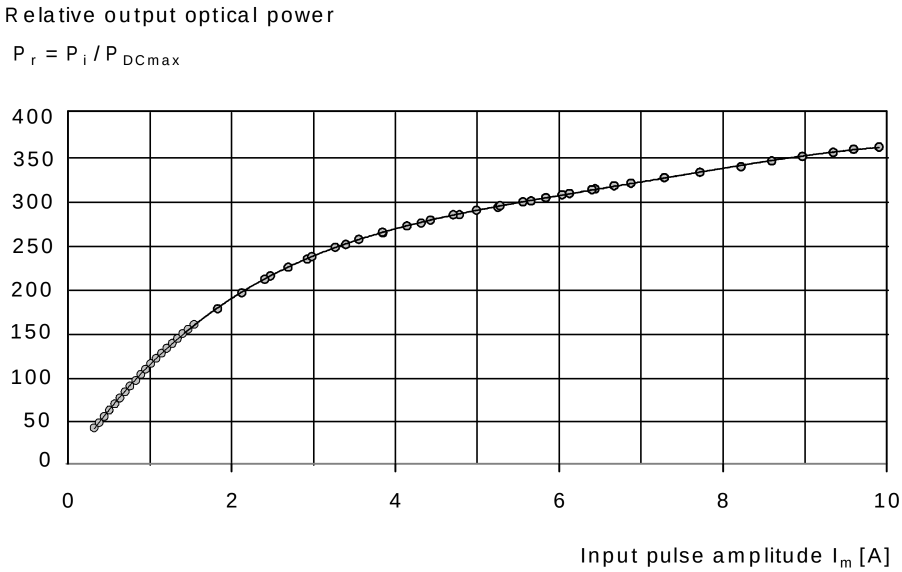


**Figure 2.** Relationship between relative optical power and current pulse magnitude measured for a given LED emitting light at the wavelength $\lambda = 940$ nm.

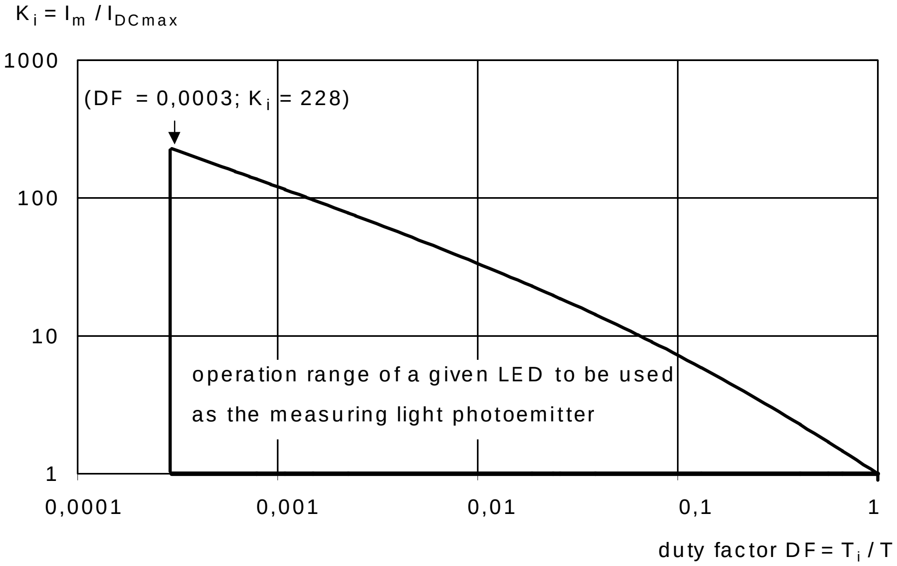


**Figure 3.** Illustration of the permissible range of pulse operation determined for a given LED emitting light at the wavelength $\lambda = 940$ nm.

The relationship between the input current amplitude and the duty factor can be formulated as

$$I_m = \frac{-U_F + \sqrt{U_F^2 + 4 \cdot P_{AV} \cdot r_d \cdot \frac{1}{DF}}}{2 \cdot r_d}, \qquad (1)$$

where $U_F$ and $r_d$ are the elements of the substitute diagram scheme of an LED while $P_{AV}$ is the average value of the electrical power emitted in the P-N junction. The principal parameters of the tested diode were: $I_{DCmax}$ =20 mA, $r_d$ = 5.5 w, $U_F$ = 1.7 V, $P_{AV}$ = 36 mW, response settling time $t_s$ = 0.301 µs. The temperature coefficient for the wavelength considered is rather small and does not very much between individual diodes. The general equation (1) can be written as follows

$$I_m = \frac{-17 + \sqrt{17^2 + 0.8 \cdot \frac{T}{T_i}}}{11}. \qquad (2)$$

The operation range distinguished in Figure 3 is specific for a given LED and limits application this one as the measuring light photoemitter. It was shown that at the repetition time T= 1 ms, a value of the driving current may be significantly increased in comparison to the continuous operation. Reliable LED operation needs to limit a maximum instantaneous value of the electroluminescent junction temperature. In the area beyond the determined pulse operation range, the LED can be damaged.

## 4 CONCLUSION

The considered questions are connected with dynamic properties of pulse-driven LEDs from the point of view to utilize such light emitters to generate measuring optical responses. The presented results have potential to be of significant analytical as well as practical importance for purposes of optoelectronic metrology. Measuring optical signals can be obtained with LEDs to drive them in pulse mode. The obtained values of the response settling time were included in the range from 301 to 1036 ns.

Many interesting new application possibilities of LEDs that have been demonstrated in the last few years, include medical applications, alarm systems, remote control systems. Pulse-driven LEDs may be more cheaper and reliable alternative in comparison to laser diodes (LD) at continuous wave (CW) in such applications which accept use of discontinuous optical radiation, e.g. spectrophotometric investigations, lightwave communication, light sources in optical fiber sensors and biosensors. For reliable operation of an electroluminescent junction, maximum values of instantaneous temperature must be lower than limiting. Pulse operation depends on the maximum allowable input current as a function of duty cycle and frequency. A modern, high-efficient and properly driven light-emitting diode can generate optical power of values comparable with levels acquired from CW laser diodes but without serious problems with temperature which can very influence LD characteristics.

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