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Structures and Characteristics Features of Light-Emitting Diodes for Optical Communication

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Abstract

In this paper it was estimated the optimum choice of parameters values for LED's design, taking in consideration the optimum operational parameters. The results of frequency properties of LED for optical fiber cables were studied. and the equations that describe the relation of LED parameters(thickness of an active layer, and the concentration of majority charge carriers in this layer) with boundary frequency were shown.
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Keywords: light Emitting Diode, Optical Fiber, Structure.

1 Introduction

Light-Emitting Diodes LED's are usually the alternative optoelectronic devices for optical communication, and there are widely used as incoherent light sources in applications such as lighting and short-distance optical fiber communications. Moreover, LED's can be used as a wireless communications transmitter, and this is not possible for any other kind of lamps in broadband transmissions. [1, 2, 3].
Also LED’s used in many other engineering branches, for example in the civil engineering(construction, building design, architecture) we can use LED for replacing traditional fluorescent light fixtures with LED light fixtures in windowless environments. and the LED lighting systems were also found to be more environmentally friendly as they do not contain any harmful mercury gases and require less energy to operate.

So the further development of microelectronics and optoelectronics is connected with size reduction of their elements. And this lead to increase the estimation role of optimum choice of Light-Emitting Diode LED parameters, taking in consideration the operation parameters.

Light-Emitting Diodes LED's, which intended for use in optical fiber communication lines, defers from the display LED's in structure, because in LED's which used in optical fiber communication there is a necessity to receive a small sizes of shone spot and sharp diagram of routing, when a high power of emitting is needed. therefore the optical communication LED's usually contains one or several layers which are alloyed in non-uniform on the plane of p-n transition. Besides, the LED's operates at higher current density comparing with display LED's [4]. All these factors serve as additional sources for degradation phenomena in optical fiber LED's.

In the operating process of LED for fiber optics communication lines, there is a necessity to preserve the linear interval width of output capacity dependence on the current, and the preservation of radiation capacity at the fixed working current is needed too. the default of this condition cause to decrease the dynamic range of optical fiber lines. Besides, for LED's of optical communication and from efficiency point of view, there is a necessity to preserve the parameters of volt-ampere characteristics in the operating range of currents, because any changes in these parameters cause the instability of transfer coefficients of optical fiber lines [5,6].

The choice of LED as light source is defined by characteristics requirements of the system (light emitting diode-optical path-photo detector). the basics requirements to such system are the transfer coefficient of current and the boundary frequency.

It is necessary, that the transfer coefficient of current (I_{output} / I_{input}) was close to 1 or more [7]. Boundary frequency is also one of important parameters of LED, and there are two definite factors which influence on this parameter.Firstly,boundary frequency is limited to time constant which depend on the category of p-n transition capacity through the contact resistance.Secondly,boundary frequency depends on lifetime of charge carriers in the active layer of LED[8].

In modern literature there is insufficient attention to the frequency properties of LED for optical fiber lines. and therefore the purpose of the given work is to give a results of frequency properties research of LED for optical fiber cables , and to show equations that describe the relation of LED parameters (thickness of an active layer, and the concentration of majority charge carriers in this layer) with boundary frequency.

2 Research Method

The recombination speed in an active layer R equal to:

$$R = B(N_o + \Delta n)(P_o + \Delta n) - BN_oP_o = B(N_o + P_o + \Delta n)\Delta n \qquad (1)$$

Where N_o, P_o -the concentration of electrons and holes at thermal balance.

Δn - Redundant of carriers concentration.

B - Recombination constant.

Taken in consideration that $P_o > N_o$ in P-layer, it is possible to neglect N_o

from (1),then $R = B(P_o + \Delta n)\Delta n$ (2)

In general view the lifetime τ defined as:

$$\tau = \frac{\Delta n}{R} = \frac{1}{B(P_o + \Delta n)}. \qquad (3)$$

The injected carriers are recombining in the area, which adjoining to an active layer, and the density of injected carriers Δn, can be defined as:

$$\Delta n = \frac{j.\tau}{q.d} \quad (4)$$

where j -density of injection current.

d -thickness of active layer.

q -charge value.

From (3) and (4) we can get, that:

$$\tau = \frac{-B.P_o.q.d + \sqrt{(B.P_o.q.d)^2 + 4.B.j.q.d}}{2.B.j}. \qquad (5)$$

3. Results and Discussion

Equation (5)shows the radiation lifetime is strongly decreases with reduction of thickness d and growth of current density j, and when the thickness d bigger than diffusion length of charge carriers, the concentration of injected carriers Δn in active layer is much less than concentration of majority carriers, then from (3), the carriers lifetime is given by a simple parity:

$$\tau = \frac{1}{B.P_o}. \qquad (6)$$

The boundary frequency of LED, under the condition of small signal modulation:

$$f_s = \frac{1}{2.\pi.\tau}. \qquad (7)$$

where the value τ undertakes from (5) and (6).Figure.1 shows the boundary frequency dependence on the concentration of holes in active layer. Curves are calculated and constructed by the second author using the formulas (5),(6),(7) and mathematical simulation approach for various thickness of an active layer of LED's.the boundary frequency increases with growth of holes concentration P_o .theoretical curves are adjusted to simulated points by the parameter $B = 1{,}1.10^{-10} cm^3 / c$.

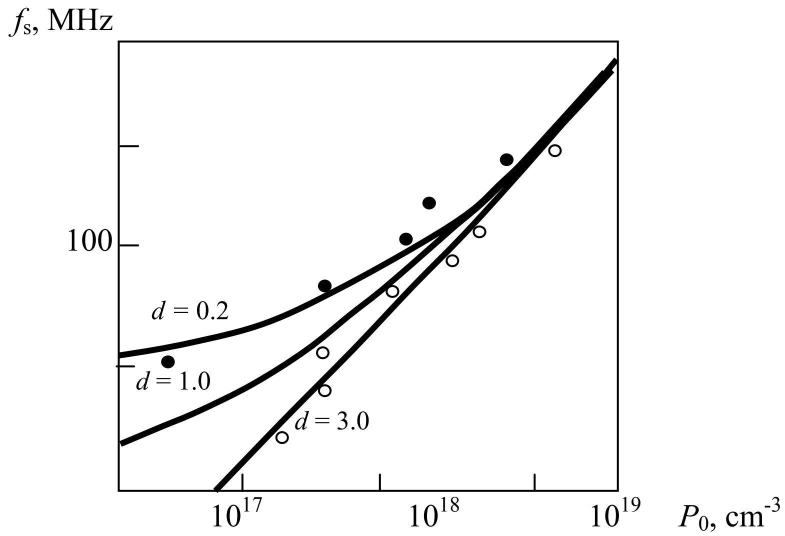
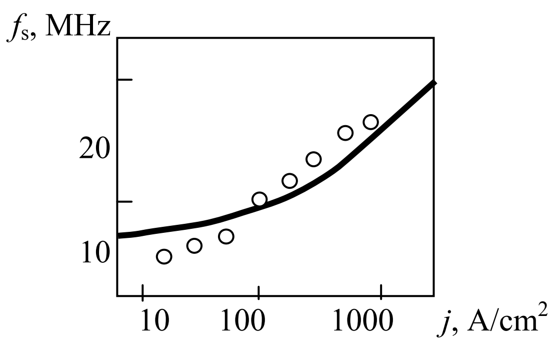


Figure. 1 – Dependence of f_s on P_o concentration

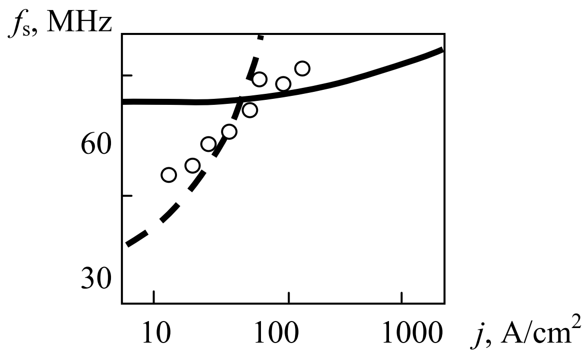
(o – $d > 1\ \mu m$; • – $d < 1\ \mu m$; ▬ – theoretical)

This figure shows that, due to reduction of active layer thickness, the boundary frequency can accept great values (even in LED's with low holes concentration).

The boundary frequency dependence on the current density through LED is shown on fig.2, so from figure.2 we can see the holes concentration P_o renders a strong influence on the boundary frequency.



(a)



(b)

Figure.2- Dependence of boundary frequency f_s on current density j

When $d = 1.0\mu m$ and $B = 1{,}1.10^{-10} cm^{-3}$

(a)-at $P_o = 3.10^{17} cm^{-3}$ (b) - at $P_o = 3.10^{18} cm^{-3}$

For example, with small concentration $P_o = 3.10^{17} cm^{-3}$ (fig.2-a), the simulated points will be not bad coordinated with theoretical curves. While with greater concentration $P_o = 3.10^{18} cm^{-3}$ (fig.2-b), the f_s is sharply increased, but already there is no such concurrence of simulated and theoretical points, which caused by the influence of volumetric charge capacity of active layer on the boundary frequency f_s (the dotted curve on fig.2-b).

4. Conclusion

We can note that, using equations (5),(6),(7), it is possible to choose the optimum values of parameters for LED design, such parameters as P_o and d, adjusting them under the optimum operational parameters, such j and f_s.

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