Light Emitting Device with Increased Modulation Bandwidth

Robert D. Koudelka and Prof. Jerry M. Woodall
Department of Electrical Engineering, Yale University

How fast is a LED?

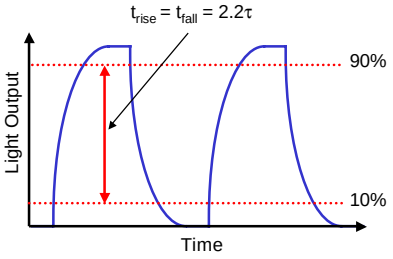
- The small signal modulation bandwidth of a light emitting diode (LED) is determined by the minority carrier lifetime, τ, in the light-emitting 'active' region.

$$f_{3dB} = \frac{1}{2\pi\tau} \text{ Hz}$$

- The light output is proportional to the charge concentration in the active region. τ determines the rate that the charge concentration builds up and decays and so determines the rise and fall times.
- Under large signal modulation, the rise and fall times are equal and each are approximately 2.2τ seconds.
- Typically τ is greater than about 100 ps in III-V materials with high radiative efficiency thereby limiting the modulation bandwidth of efficient LEDs to less than 2 GHz.

Why do we want faster LEDs?

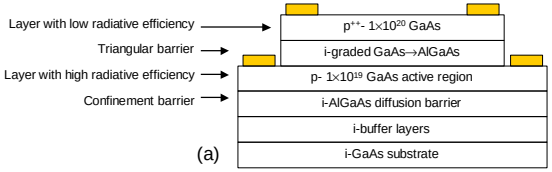
- LEDs are reliable, surface emitting, and easy to fabricate. These qualities make them an attractive candidate for short-reach optical communication links.
- However, the low modulation bandwidth of conventional devices make them unsuitable for high bit-rate links.
- This work aims to design LED-like devices suitable for short-reach links that operate faster than 1 Gb/s.

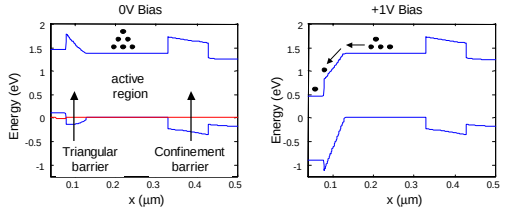


The light output of a conventional LED in response to a square-wave current waveform has equal rise and fall times. The goal of this work is to design a device with a decreased fall time.

Our Approach

- A triangular barrier, formed by compositional grading, is used as a voltage controlled carrier confinement barrier on one side of the active region.
- An applied voltage lowers the triangular barrier and decreases carrier confinement. Photogenerated minority carriers can then transport into a region with lower radiative efficiency and the photoluminescence (PL) intensity decreases.
- With suitably thin epilayers, the carrier transport time out of the active region is faster than the radiative decay time in the active region so the light output fall time is decreased.
- This differs from simply reverse biasing a conventional p-n junction LED in that the carrier injection source and the modulation mechanism are de-coupled.





(a) The epitaxial structure of the triangular barrier device. (b) With the barrier raised, photogenerated electrons are confined to the active region and recombine radiatively. (c) With the barrier down, electrons transport out of the active region and the light output decreases.

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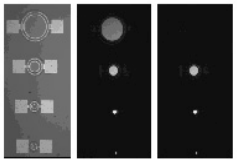
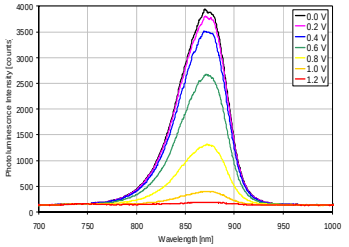
PL Intensity vs. DC Bias

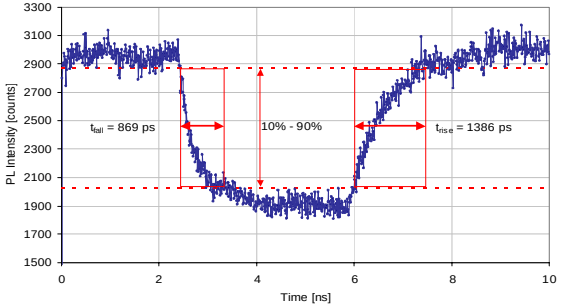
(a) Grouping of devices under white light illumination. (b) Infrared emission measured with no applied voltage to any device, and (c) infrared emission measured with 1V applied to the top device.





The room temperature PL vs. voltage is measured using a 660 nm CW laser pump and DC voltage source. The output intensity is nearly extinguished with an applied voltage of 1.2V.

Time Resolved Edge Measurement



Rise and fall times are measured using time resolved PL (TRPL). A CW laser pump photogenerates minority carriers and an electrical pulse source modulates the triangular barrier. The observed fall time is ~40% shorter than the rise time indicating that the applied voltage increases nonradiative recombination in the device. By decreasing the fall time, the modulation bandwidth of the device is increased. Ongoing work is geared toward the design of structures to decrease the rise time as well as the fall time.