Extinction Ratio of Stripe-Geometry DH AlGaAs Lasers with "Soft" Turn-On

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Abstract—The effect of high spontaneous emission on the extinction ratio of modulated laser-diode signals is discussed. A calculation based on the spectra taken from oxide-defined narrow-stripe lasers at "on" and "off" levels shows that high spontaneous emission at the "on" level can degrade the apparent extinction ratio of the source, due to material dispersion in optical fibers, and affect transmission bandwidth and useful device lifetime.

STRIPE-GEOMETRY lasers are promising light sources for light-wave communication systems using multimode optical fibers because they are easy to fabricate and because they are less susceptible to modal noise and reflection-induced noise [1], [2]. Recent studies have indicated that a stripewidth of 3-4 μm yields the best performance in terms of lasing stability and long-term reliability [2]-[4]. One of the inherent properties associated with the stripe-geometry lasers with narrow stripewidth is the "soft" turn-on behavior near threshold. The softness is a result of incomplete gain saturation above threshold due to the nonuniform gain profile in the lateral direction. The spontaneous emission, instead of being fully clamped as expected of an ideal laser, continues to grow with increasing current. On the other hand, when the laser ages it also tends to become softer and, for a given power, emits more spontaneous light [5]. These properties have caused some concern in applications that require high extinction ratios.

The extinction ratio, in its simplest form, is the ratio of the power out of the laser when the laser is "on" to that when the laser is "off." In many optical communication systems, an extinction ratio of 10 to 15 is preferred. In principle, one can bias the laser near threshold or at a level where the spontaneous light is fully clamped, and apply high current pulses to achieve the prescribed extinction ratio. However, in reality, the "on" and "off" powers are subject to restrictions based on reliability and maximum tolerable background noise. In addition, high spontaneous emission intensity coupled with material dispersion may cause the extinction ratio measured after a length of fiber transmission to be worse than that measured near the light source. So far, very little work has been done on the effect of high spontaneous light on extinction ratios. In this paper, we describe a study of the effect of spontaneous emission on the extinction ratio of oxide-defined narrow-stripe DH AlGaAs lasers modulated by square-wave current. We feel that a better understanding of this problem is important for more realistic projection of useful device life and transmission bandwidth.

Manuscript received August 3, 1981.
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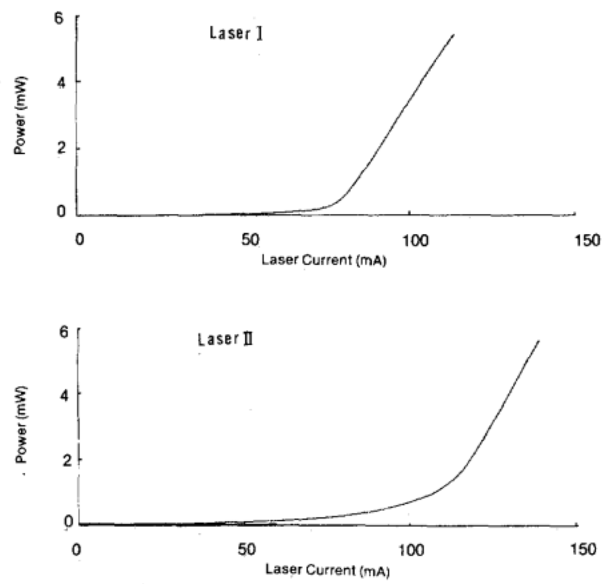

Fig. 1. Light–current characteristics of two oxide-defined narrow-stripe lasers coupled to a multimode optical fiber with 50 percent coupling efficiency. Laser I has normal turn-on behavior, while Laser II has soft turn-on and high spontaneous light.

We will consider a modulation scheme in which the laser is modulated by 50 MHz square-wave current between 200 μW and a 3 mW fiber-optic output to give rise to an extinction ratio of 15. Assuming a laser-fiber coupling efficiency of 50 percent, the actual laser "on" power of 6 mW is considered reasonable from a reliability point of view. For simplicity, we assume that the refractive-index profile of the multimode fiber is "ideal" so that the intermodal dispersion is negligible.

We have studied two oxide-defined narrow-stripe (6 μm) DH AlGaAs lasers, one with normal turn-on and the other purposely selected for soft turn-on and high spontaneous light. The characteristics of the latter resemble those of some aged devices. The light–current curves of these two devices, when coupled to a short multimode graded-index optical fiber with 50 percent coupling efficiency, are shown in Fig. 1. Their CW spectra at different fiber-optic output powers are shown in Fig. 2. To facilitate the analysis described below, the spectra were taken with low spectrometer resolution so that the average power over every 5 Å interval was measured. One can see that the spontaneous light for Laser II, represented by the 150 Å-wide baseband, continues to grow and constitutes a sizable fraction of total emission.

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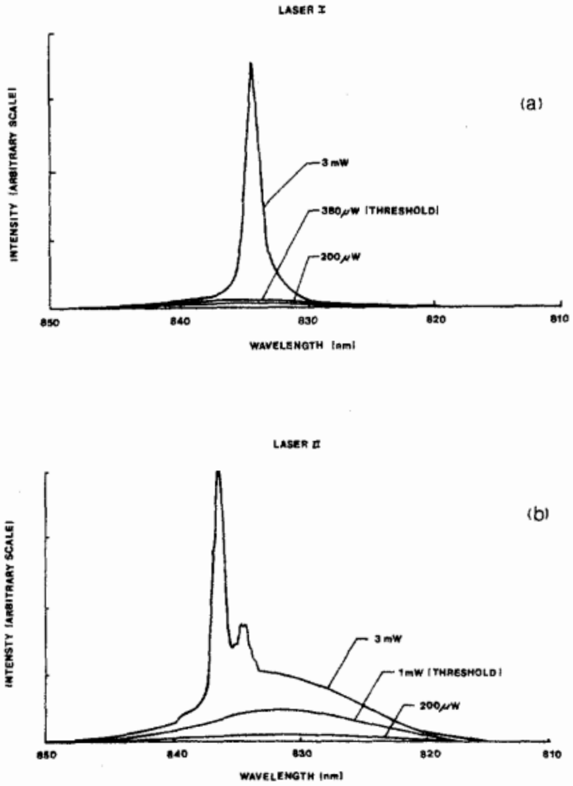

Fig. 2. Spectra of Laser I and Laser II taken at different fiber-optic output powers. The wavelength resolution is about 5 A.

Considering a 50 MHz square-wave light output from the source, as shown in Fig. 3, the waveform at a distance from the source can be calculated by numerical integration, based on the spectra of the "on" and "off" levels and the well-known material dispersion constant of ~0.1 ns/km · nm at 820 nm for ordinary graded-index multimode fibers. The calculation procedure involves dividing the square wave into many 100 ps "pulses," each of which broadens itself in optical fibers according to its spectra content. The resultant waveform after a length of fiber transmission is the convolution of the square wave and the broadened pulses. The calculated waveforms at the output end of a 5 km optical fiber for both lasers are plotted in Fig. 3. The deterioration of the extinction ratio for Laser II is clear. Although the calculation was made for a modulation speed of 50 MHz, the result is valid for other modulation speeds having the same frequency-distance product. The calculated extinction ratio versus distance relations for Laser I and Laser II are plotted in Fig. 4.

The calculation indicates that the apparent extinction ratio measured near the light source deteriorates with a rate depending on the "softness" of the source. One therefore needs to pulse the soft laser to a higher "on" level in order to maintain the prescribed extinction ratio. The amount of spontaneous light can also affect the transmission bandwidth in a fiber-optic transmission system. For example, the 3 dB transmission bandwidth of a multimode optical fiber at which the pulse broadening due to material dispersion becomes comparable to that due to intermodal dispersion is ~200 MHz · km

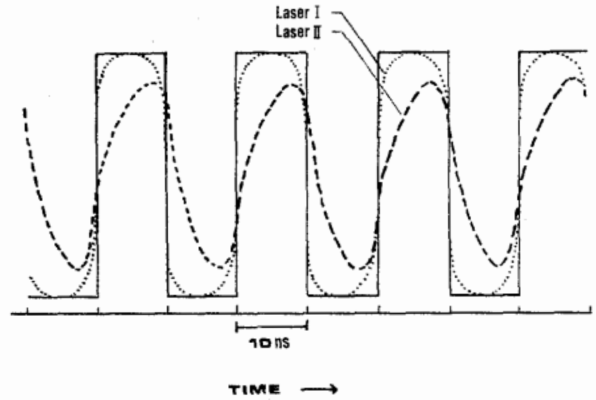

Fig. 3. Curves showing a 50 MHz square wave with an extinction ratio of 15 (solid curve) and calculated waveforms after a 5 km optical fiber transmission for Laser I (dotted curve) and Laser II (dashed curve.)

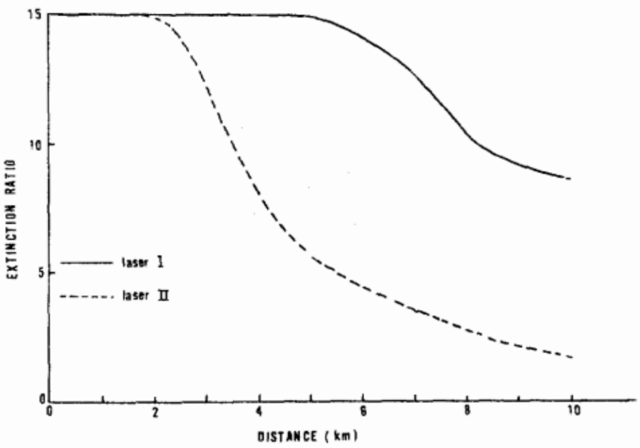

Fig. 4. Calculated extinction ratio versus distance relation for Laser I and Laser II modulated by 50 MHz square wave with an initial extinction ratio of 15.

for Laser II and over 600 MHz · km for Laser I. For high data rate and long-distance applications, a more stringent selection criterion against softness may be necessary. In addition, since aged devices often exhibit softer turn-on, the useful device lifetime will be shorter than estimated, based purely on the ability to emit "power."

References

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