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Variation of Kink power with cavity length in weakly index guided semiconductor lasers

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A periodic dependence of kink power on laser length is observed and explained. Weakly index guided high power stripe lasers in the AlGaAs, InGaAlP and InGaAlAs material systems are studied and periods of 100 to 350 μm are found. The observations indicate that phase locked fundamental and first order modes exist at certain laser lengths. This new model fully explains the oscillatory behaviour of the kink power and the correlated changes in lateral far field distributions at the front and rear mirror facets.

For many applications it is required that narrow stripe high power laser diodes emit their power in a stable diffraction limited far field. As a result of mode instabilities and output power fluctuations at high injection currents, high power narrow stripe diodes appear limited in maximum diffraction limited output power. The transition from diffraction limited to non-diffraction limited operation is observed as a kink in the light versus current curve. In this paper, the limits on kink power are investigated for high power lasers in the wavelength range between 670 and 980 nm.

The waveguide structures studied here can be classified as weakly index guided. The designs however are quite different: for $\lambda = 780$ nm, a ridge-type waveguide structure with a bulk AlGaAs active layer, for $\lambda = 670$ nm a buried-ridge type structure with strongly absorbing GaAs current blocking layers and a double quantum well strained InGaP/AlInGaP active layer, and for $\lambda = 980$ nm a buried-ridge type structure with transparent InGaP current blocking layers and a double quantum well strained InGaAs/AlGaAs active layer are studied, respectively.

Figure 1 gives typical L/I and dL/dI curves of a 780 nm laser. Above the kink power level the far field is observed to shift. Figure 2 gives kink power data as a function of laser length for the 670, 780 and 980 nm devices, respectively. Clearly a periodic variation of kink power as a function of laser length is observed with periods of 350 μm , 110 μm and 100 μm , respectively. The data in figure 2 show a common systematic large variation of kink power level with laser length for very different waveguide geometries and material systems. The results indicate that the kink mechanism is of the same origin for all laser types. Such systematics and the corresponding kink mechanism have, up till now, not been reported in the literature.

A new model is proposed to explain the kink behaviour. This model assumes that phase locked fundamental and first order lateral modes propagate in a laser above the kink power level. A necessary additional condition for phase locking is that both fundamental and first-order modes, with respective propagation constants β_0 and β_1 , simultaneously have to satisfy the cavity roundtrip phase condition. The beat length $L = \frac{2\pi}{\beta_0 - \beta_1}$ therefore plays a decisive role in kink phenomena. More extended modelling results describing these

phenomena will be presented and compared with experimental data. Above the kink, the combination of fundamental and first order modes results in a hybrid mode zig-zagging periodically through the laser cavity along the laser length. Depending on the number of periods in the cavity the mode patterns at front and rear mirror should subsequently appear identical or be each others mirror image. The lateral far field shift directions at front and rear mirrors must therefore be correlated. In figure 3 the experimentally observed lateral far fields below and above the kink power level for a 670 nm wavelength laser are given at different laser lengths. The results are seen to confirm the model prediction.

Figure 1

L/I and dL/dI curves of ridge waveguide laser with a kink at 20 mW.

Figure 2

Kink Power versus laser length for devices with a wavelength of a) 670 nm, b) 780 nm and c) 980 nm.

Figure 3

Front and backfacet Far Field for laser lengths of a) 300 μm , b) 600 μm and c) 950 μm .