DFB lasers with 25 mW power level for CATV

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1. Introduction

AM-USB fiber optic systems have assumed a major role in cable TV network (CATV) planning for bandwidth expansion, system rebuilds and strategic positioning for new enhanced services.

During previous years, considerable debate centered on issues related to transmission technology such as wavelength (1.3 μm vs. 1.55 μm), modulation technique (direct vs. external modulation) and erbium-doped fiber amplifiers (how well do they work?). For MSO planners and engineers, the debate has centered on the question: What transmission technology will meet my network requirements for the foreseable future?

2. DFB meets needs

The DFB performance results, discussed in this article, strongly suggest that 1300 nm DFB laser technology will be more than adequate to do the job.

The performance of 1300 nm DFB lasers is continually improwing. Initial performance goals a few years ago to transmit 40 channels with 4 mW to 5 mW optical power. Two years ago, 60 channels with 6 mW to 8 mW were considered standard. Single DFB lasers carrying 80 channels were then produced, delivered and field installed.

CW output powers are climbing even higher. This article presents test results from an 18 mW lasers and predicts that 25 mW is a realistic production goal for single lasers. The test results discussed below were measured on a standard production DBF laser.

3. High power DFB results

An average CATV laser has a threshold current of 20 mA, is biased at approximately 60 mA total current, and emits a CW optical power of about 6 mW. But what happens at higher current levels?

Fig. 1 shows the light power vs. current characteristic for a packaged DFB laser that launches 18 mW of CW optical power into the fiber at a bias current of 100 mA. At the standard bias point, 40 mA above threshold, the output power would be approximately 9 mW. This laser has a RIN of −161 dB/Hz at 18 mW output power and was tested with 62-channel loading at a modulation depth of 5.25 percent per channel.

The optical receiver used a matching transformer and low noise amplifier design to achieve a noise figure of 4.5 pA/Hz$^{1/2}$. The worst case CSO and CTB levels were −67 dBc and −70 dBc, respectively. When tested over 20 km of standard single-mode fiber, the link CNR was 59.5 dB at 9 dB loss. With extra attenuation added to develop 20 dB total loss (same distance), the link CNR was 50.5 dB.

Fig. 2 shows the projected performance of this link as a function of optical loss, based on the measured results. This performance is quite interesting from the standpoint of achieving higher optical loss budgets to transmit long distances, or to achieve a high level of splitting to reduce equipment cost per node.

4. Practical limits to optical power

The 18 mW DFB laser described above was a "best result to date" achievement. Was this a fluke, or could cable operators expect such power such power levels routinely some day? Since experience has shown that todays best results often become tomorrows standard performance after one to two years, let us ask what we can cexpect for "ultimate performance" from DFB lasers. Also, what practical obstaclesstand in our way?

First, let us consider some practical issues:

4.1. Distortion

We have found that all semiconductor lasers produce unnacceptable levels of second-order distortion at high bias currents. While we can optimize certain design parameters to increase the linear operating current, there will always be an upper limit. Typically the upper limit is seen at 80 mA to 100 mA of bias current, but we have also seen some devices that remain linear up to 130 mA. Improvements to the laser chip design could increase the yield for such "high current" lasers.

4.2. RF drive amplifiers

The RF power needed to modulate the laser to a given modulation depth increases as the square of the bias current. Feedforward amplifiers can provide +46 dBmV per channel with 60-channel loading. With a DFB input impedance of 25 Ω, and using a 25Ω/75Ω impedance transformer at the input to the laser, 6.5 mA/channel is available to modulate the laser. This is

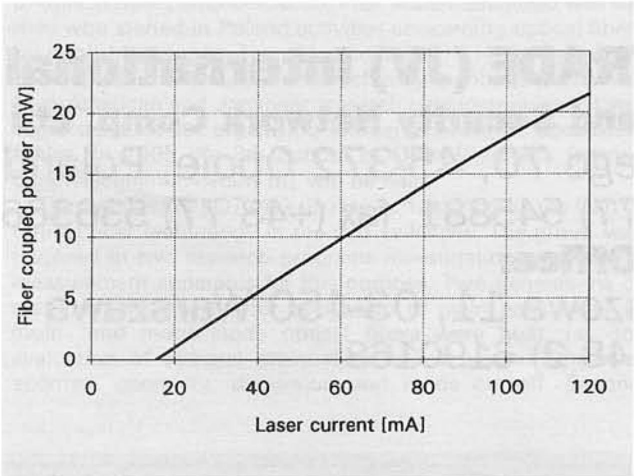

Fig. 1. High power AM 1310 DFB laser characteristic

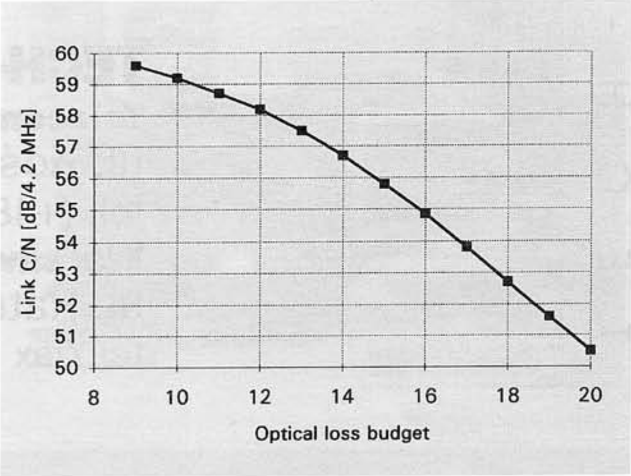

Fig. 2. High power 62-channels AM link

enough to provide optimum performance at bias currents up to 100 mA above threshold, but would be inadequate at 150 mA above threshold.

4.3. DFB laser reliability

Lase cannot be operated at currents that result in unacceptable degradation of long-term performance. It was not clear what is the maximum reliable DC current for a CATVquality DFB laser. Existing data would indicate that 100 mA is an acceptable bias level, with no adverse effect on longterm stability. Further work was needed to determine the upper limit to reliable CW operation.

How much average power can be expected from production 1300 nm DFB lasers in the future? The optical output power from a packaged laser is the product of three quantities:

$$P_0 = (LE) \cdot (CE) \cdot (I_0 - I_{th})$$

where LE is laser chip efficiency, CE is fiber coupling efficiency, I_0 is operating current and I_{th} is threshold current.

Realistically, what are the highest numerical values that we can expect for these paramaters in production lasers? A good approach is to look at todays best results as an indication of what to expect in the future. The following list shows the best performance achieved to date for each of these parameters (not all were achieved on the same laser):

- Laser chip efficiency = 0.51 mW/mA
- Fiber coupling efficiency = 67%
- Linear bias current = 130 mA (I_{th} = 20 mA)

If a single laser could achieve all three values simultaneously, the optical power would be:

$$P_0 = (0.51\ \text{mW/mA}) \cdot (0.67)\ (130\ \text{mA} - 20\ \text{mA}) = 27.6\ \text{mW}$$

When we compare this with the "best laser" result achieved to date, we can clearly expect further advances in the output power performance of 1300 nm lasers.

5. Conclusion

While routine production of 38 mW DFB lasers for CATV applications may still be a distant goal, the available evidence is that transmit powers from single laser has become a realistic. Other advances in DFB performance are also seen, such as increased bandwidth and channel capacity. It is quite realistic to expect single laser to carry full spectrum from 50 MHz to 1 GHz before long, with a combination of traditional AM signals and digitally compressed signals.

The next generation of 1300 nm DFB lasers, with 7 dB higher power and twice the bandwidth, is cornerstone of network designa that serve the traditional CATV market, plus enhanced services that are on the drawing boards today.

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