LINEARITY CHARACTERISTICS OF DFB LASER DIODES AT HIGH OUTPUT OPTICAL POWERS

Ernest M. Kim, S. Lee Cummings, and Mark E. Tucker

TACAN Corporation

Thomas J. Gibbs

Raynet Corporation

ABSTRACT

Long wavelength Distributed Feedback (DFB) laser diode linearity characteristics under modulation at high output optical powers are investigated. Chirp, emission wavelength, and thermal characteristics have been measured.

It was found that the laser diodes tested had "sweet-spots" of average power which yielded the highest linearity. Second order distortion was reduced dramatically for low temperatures.

INTRODUCTION

State-of-the-art CATV fiber optic systems are, in many cases, limited by the performance of the semiconductor laser diode source. One of the major limitations is the low average launched optical power for the linearity required for high quality multichannel CATV transmission.

In this paper, we report on a study in which the linearity of a 1300 nm distributed feedback (DFB) laser diode was examined as a function of average optical power and temperature. The optical spectra of the DFB laser diode, both with and without modulation, at various operating temperatures and average optical powers were determined.

EXPERIMENTAL SET-UP

The linearity of the laser diode was determined by the two-tone measurement method. In this method, two frequencies of equal radio frequency (RF) power is used to drive the laser diode. The RF power of each frequency is adjusted such that, at the optical output of the laser diode, the optical modulation index per channel (or frequency), OMI/ch, is 0.4. For two tones, the overall OMI is 0.8. This OMI/ch was chosen so that the laser diode could be characterized as having approximately a quasi-linear transfer function. If the total OMI exceeds 0.9, there is increasing deviation from the quasi-linear approximation.

The experimental set-up is shown in figure 1. Two RF frequency sources are used to excite the laser diode. The output of each RF source is passed through a 10 dB attenuator and then amplified using a standard hybrid CATV amplifier with a gain of approximately 17 dB. The outputs of the amplifiers are combined and two frequencies are used to excite the laser diode. The attenuators and amplifiers are used to isolate the source from any reflected signal from the combining process. Without this isolation the combined signal could distort the source frequencies, yielding false laser diode linearity data. The output signal from the combiner was characterized by an RF spectrum analyzer. The second and third order intermodulation distortion was found to be greater than 80 dB below carriers.

The laser diode was driven through a wideband bias-T with a constant current drive. The optical signal from the laser diode was measured with a Hewlett-Packard lightwave signal analyzer. The analyzer determined was used to determine the OMI/ch and the linearity of the laser diode.

The temperature was controlled by driving the thermo-electric cooler packaged in the laser diode module to the desired operating temperature. Measurement of the operating temperature was performed by the in-package thermistor.

Second and third order intermodulation distortion ratios (IMD2 and IMD3, respectively in absolute dB from carrier) were measured using the two-tone method for the following two pairs of frequencies:

199.25 MHz & 205.25 MHz
535.25 MHz & 541.25 MHz.

The measurements were taken at 0, +2.7, and +5 dBm average optical power. Each measurement was made at both 0 and 25 degrees Celsius.

After each distortion test, the optical spectrum of the laser diode was recorded. The experimental setup is identical to that of figure one with the exception that an optical spectrum analyzer is used instead of the lightwave signal analyzer.

EXPERIMENTAL RESULTS

The results of the two-tone tests for 0 and 25 degrees Celsius are presented for the low and high frequency pairs in figures 2 and 3, respectively. At 25 degrees, the best performance in terms of IMD3 was for and average optical power of +2.7 dBm. At +25 degrees and +2.7 dBm optical the IMD3 for the lower frequency pairs are 73 dB, and 68 dB for the upper frequency pairs. IMD2 was 38 dB for the lower tones and 38 for the upper tones. At 0 dBm optical, the IMD2 was better by 10 dB than that for the +2.7 dBm case. However, at 0 dBm optical the IMD3 was degraded by 14 dB. Curiously, at +5 dBm optical the distortion, as a function of frequency, was similar to that at +2.7 dBm.

At 0 degrees Celsius and 2.7 dBm optical, we find an increase in IMD2 of 10 dB and a slight decrease in IMD3. However, the distortion is still relatively constant over frequency. Significant change in either IMD2 or IMD3 is not evident at 0 and +5 dBm from the 25 degree Celsius operation.

The optical spectra for 0, +2.7, and +5 dBm operation with modulation with two tones (at 0.4 OMI/ch) at 25 degrees Celsius are shown in figures 4a, b, and c respectively. Note that there is some spectral broadening and better definition of the chirp. The amount of spectral broadening at the high optical powers will not significantly affect the propagation characteristics through the optical fiber. The amount of chirp exhibited was approximately 0.4 nm at 35 dB from the peak emission wavelength. As such the amount of chirp is not of any significance. In each case, there was a broadening of the optical spectrum and a slight increase in chirp amplitude when the laser diode was modulated.

What is interesting is that when the laser diode is operating at 25 degrees Celsius and +2.7 dBm optical and is driven with 40 channels (figure 4d), its optical spectrum is nearly identical to that of the two channel case at +5 dBm optical. This indicates that under large channel count modulation, there is increased spectral broadening and chirp.

Similar results were evident at 0 degrees Celsius. As expected, the spectral widths were slightly narrower than for the 25 degree condition.

SUMMARY

Distortion measurements using the two-tone method was performed on a state-of-the-art long 1300 nm DFB laser diode. Because of the high linearity and low intrinsic noise characteristic of this class of laser diodes, they have become an attractive source for high quality CATV fiber optic transmission systems.

One of the limiting characteristics of the CATV fiber optic systems is the low launched optical powers required for the high linearity desired. In this paper, we have reported on the performance of a DFB laser diode at varying average optical powers and temperatures. The results indicate that there is a "sweet-spot" for maximum linearity, regardless of temperature. At that operational optical power, the distortion was relatively flat over frequency. Additionally, second order distortion was dramatically reduced when operated at 0 degrees Celsius at the "sweet-spot." The average optical power for optimum performance was +2.7 dBm.

The optical spectrum did not vary significantly for varying average optical powers or temperature. However, we observed that there was slightly increased broadening for higher operational temperatures, higher average optical powers and large number of channels.

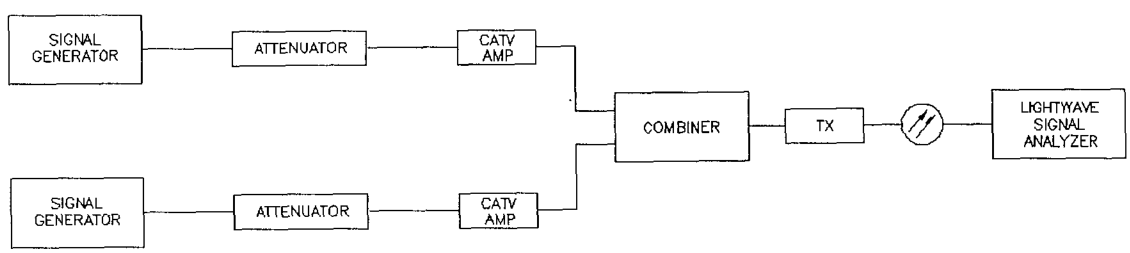

FIGURE 1:
TWO-TONE LASER DIODE MEASUREMENT SETUP

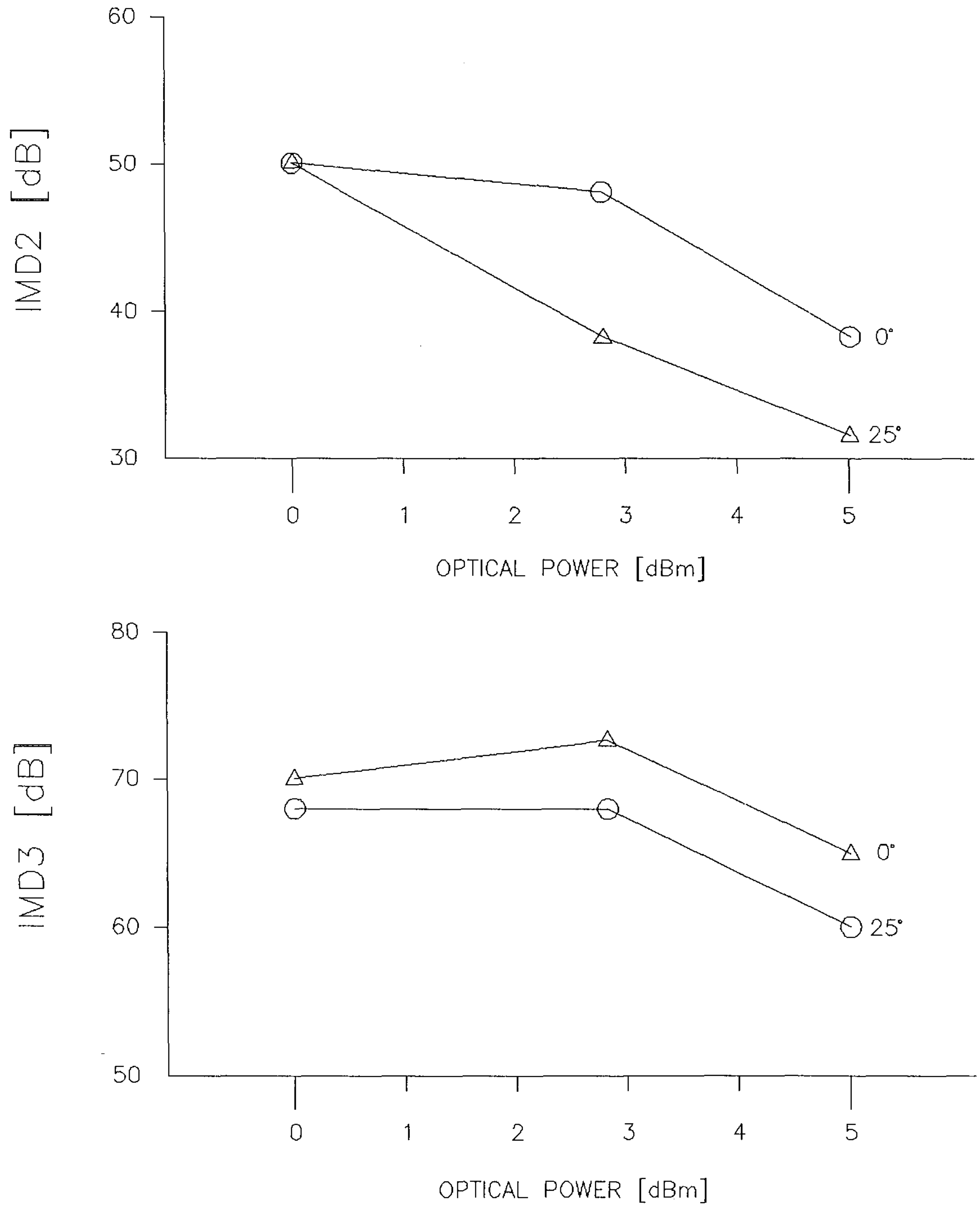

FIG 2:
IMD2 AND IMD3 FOR THE LOWER FREQUENCY PAIR

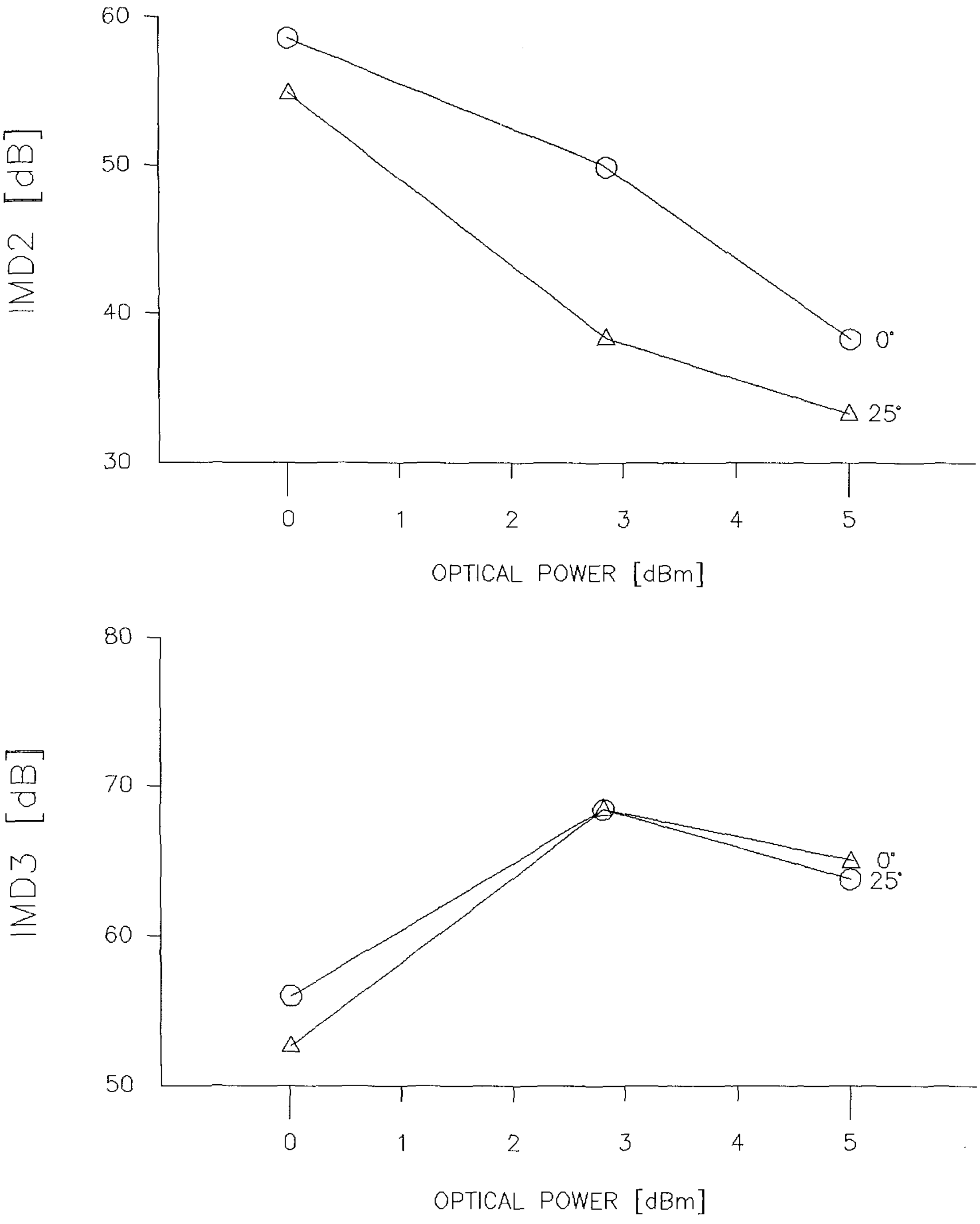

FIG 3:
IMD2 AND IMD3 FOR THE UPPER FREQUENCY PAIR

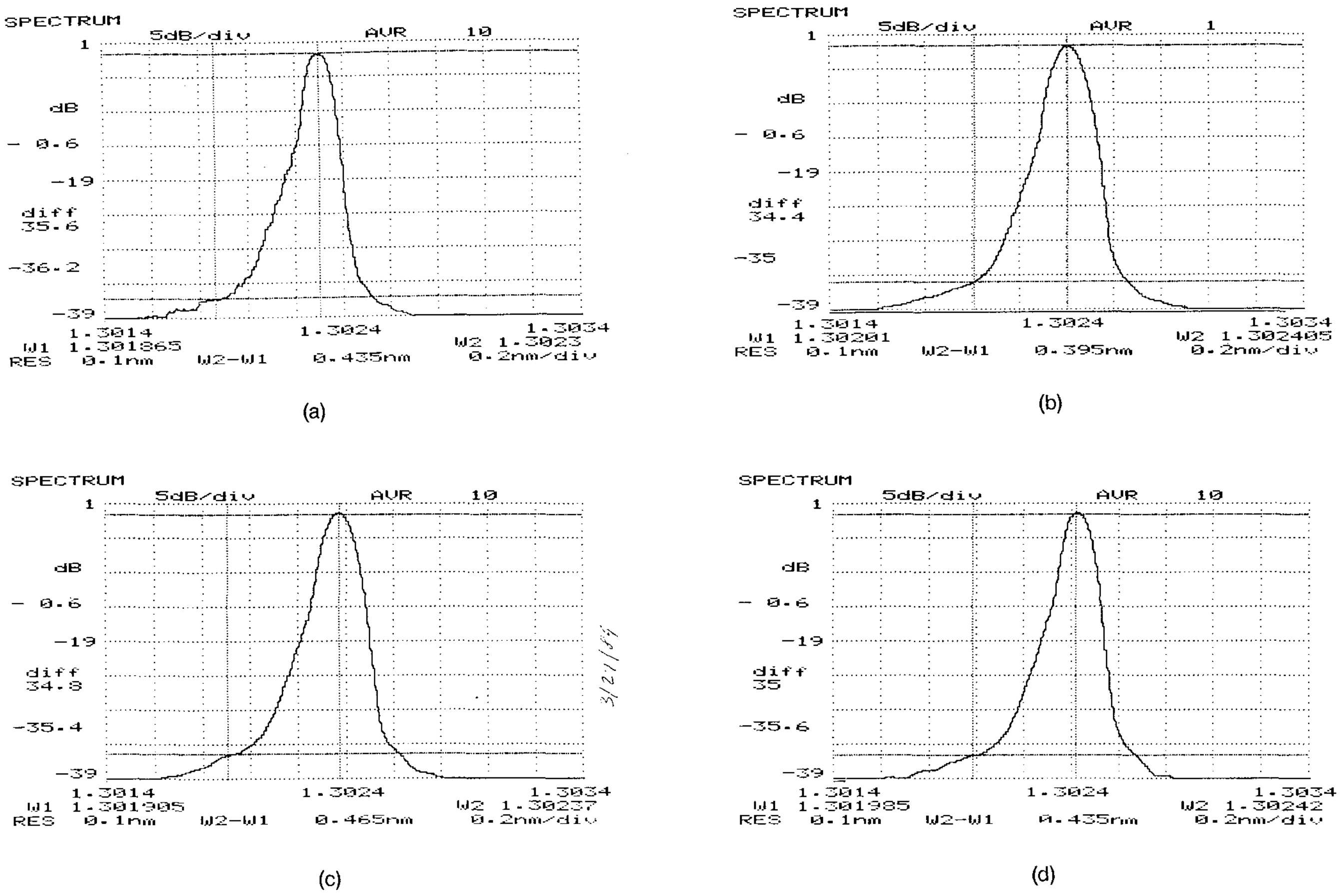

FIGURE 4
Optical Spectra For A DFB Laser Diode Operating At 20 Degrees C Under Two-tone modulation at: (a) 0dBm, (b), +2.7 dBm, (c) +5dBm, and (d) 40 channel modulation at +2.7 dBm.