In usual electronic systems negative feedback is used to improve either the linearity or the frequency characteristics of electronic amplifiers [1]. Similarly, negative electronic feedback may also be applied to laser diodes to improve their modulation characteristics [2–4]. If the optical frequency of the laser emission is detected, a negative electronic feedback may also be applied to stabilize the emitted optical frequency. Research work has been directed with respect to both the long term stability [5–13] as well as to reducing the short term fluctuations for achieving narrow laser spectra [14–18].

Bearing these applications in mind, the characteristics of laser diodes with negative electronic feedback will be studied in this chapter.

10.1 Modulation Characteristics of Laser Diodes with Negative Electronic Feedback

A laser diode with negative electronic feedback is shown schematically in Fig. 10.1. A variation of the injection current $I_L$ through the laser diode yields a variation of the emitted optical power $P$ and the optical emission

![Schematic representation for a laser diode with negative electronic feedback.](image)
frequency \( \nu \) (or the optical phase \( \phi \)). If part of the laser light output is fed to a receiver, which either detects \( P \), \( \nu \), or \( \phi \), the output of the receiver may be used for closing a negative feedback loop. Depending on whether \( P \), \( \nu \), or \( \phi \) is detected the respective modulation characteristics may be tailored.

Most simply, the optical power \( P \) may be detected for the feedback loop. One may then obtain a reduction of the nonlinear distortions with respect to the intensity modulation. However, only very little work has been devoted to such an idea; the reduction of nonlinear distortions of LEDs with negative electronic feedback has been reported in [19] and a modified scheme, applied to laser diodes, has been presented in [20]. These negative electronic feedback schemes suffer from the limited loop bandwidth which usually extends at most up to several 10 MHz. Therefore, for reducing non-linearities feed-forward schemes are sometimes used instead [21, 22].

With respect to frequency modulation, there is an interest in negative electronic feedback schemes since it then becomes possible to achieve a flat frequency versus current modulation characteristics [2]. We shall therefore study the negative electronic feedback scheme according to Fig. 10.1 in more detail for the case of frequency modulation.

The variations in optical frequency \( \Delta \nu \) are related to the variations in the laser diode injection current \( \Delta I_L \) via a transfer function \( H_\nu(j\omega_m) \) as

\[
H_\nu(j\omega_m) = \frac{\Delta \nu}{\Delta I_L} \quad (10.1)
\]

with the (circular) modulation frequency \( \omega_m \).

For the receiver a suitable detection scheme for the optical frequency \( \nu \) must be employed, where either a heterodyne detection scheme [2] or an optical filter with a strong wavelength selectivity [17] like a Fabry-Perot-resonator may be used.

In the feedback loop a frequency variation \( \Delta \nu \) is transferred to a current variation \( \Delta I_F \) via a transfer function \( H_F(j\omega_m) \) as

\[
H_F(j\omega_m) = \frac{\Delta I_F}{\Delta \nu} \quad (10.2)
\]

For a negative feedback the laser current variation \( \Delta I_L \) is related to the modulation current and the feedback current variations \( \Delta I_M \) and \( \Delta I_F \), respectively, as

\[
\Delta I_L = \Delta I_M - \Delta I_F \quad (10.3)
\]

and combining eqs. (10.1)—(10.3) yields the final transfer function

\[
\frac{\Delta \nu}{\Delta I_M} = \frac{H_\nu(j\omega_m)}{1 + H_F(j\omega_m)} \quad (10.4)
\]