9. Tutorial on Optical Sources and Detectors

July 3rd 2012

Problem 1:   Amplitude-phase coupling

Modulating the injection current of a semiconductor laser affects both the real part and the imaginary part of the complex refractive index $\underline{n} = n - jn_i$ within the active zone. To a first-order approximation, the change of n and n_i are linked by the so-called Henry-factor α_H,

$$\alpha_H = \frac{\partial n/\partial n_c}{\partial n_i/\partial n_c} \; .$$

The imaginary part of the refractive index is connected to the material gain g and the gain rate G by

$$g = -2k_0 n_i; \quad G = v_g g \; ,$$

where v_g denotes the group velocity of the signal. If the refractive index in the active zone changes by a small amount, then the effective index of the guided mode changes by $\Delta n_e = \Gamma \cdot \Delta n$, where Γ denotes the field confinement factor.

a) How does the change of n influence the emission frequency, when assuming that the laser always emits in the same longitudinal mode? Show that the change $\Delta \omega$ of emission frequency can be expressed by

$$\Delta \omega = -\frac{\omega}{n_{eg}} \Delta n_e,$$

where $n_{eg} = n_e + \omega \frac{\partial n_e}{\partial \omega}$ denotes the effective group refractive index of the mode.

b) Calculate the instantaneous deviation $\Delta \omega$ from the steady-state emission frequency as a function of the instantaneous laser gain rate $G(t)$. Start from the definition of the Henry-factor. During the derivation use the solution obtained from part a) and the fact that $\Gamma G_0 = 1/\tau_P$ in steady-state. The resulting equation can be brought to the following form:

$$\Delta \omega = \frac{\alpha_H}{2} \left(\Gamma G - \frac{1}{\tau_P} \right)$$

c) What are the consequences of this behavior for a time dependent optical signal, which was generated by directly modulating the injection current of a laser?

Problem 2:   Sensitivity of a photodiode

a) A photodiode has a sensitivity of $S = 1\,\text{A/W}$ and is illuminated by an optical signal with power of $-30\,\text{dBm}$. What is the photocurrent generated by the device?

b) The data sheet of a newly developed Si pin photodiode claims a sensitivity of $S = 0.7\,\text{mA/mW}$ at a wavelength of $\lambda = 0.8\,\mu\text{m}$. Comment this statement.

Questions and Comments:

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