Bonus Exercises on Optical Sources and Detectors

July 17th 2012

Problem 1: Noise properties of photodetectors

The signal-to-noise ratio (SNR) is a measure of the quality of the detected signal. For a given detector bandwidth Δf the SNR can be calculated by relating the mean electrical signal power to the electrical noise power, which consists of shot noise and thermal noise from the load resistor R_L. For a PIN diode this results in:

$$SNR = \frac{\overline{i^2}}{\overline{\delta i^2}} = \frac{\left(SP_e\right)^2}{2eSP_e\Delta f + \dfrac{4kT\Delta f}{R_L}}.$$

The quantity S denotes the responsivity for the detector, P_e the external optical power, kT the thermal energy, and Δf the electrical detection bandwidth. In the following we consider a photodiode which is specified with a responsivity of $S = 0.95\,\mathrm{A/W}$. Perform the subsequent calculations for two different load resistors, $R_L = 50\,\Omega$ and $R_L = 100\,\mathrm{k}\Omega$.

a) Shot-noise-limited operation is obtained when the shot noise exceeds the thermal noise. Calculate the signal power that is necessary to obtain shot noise limited operation at room temperature.

b) The bandwidth f_{BW} of a photodiode can be approximated by its RC time constant

$$f_{\mathrm{BW}} = \frac{1}{2\pi R_L C}.$$

Calculate f_{BW} for a parasitic capacitance of C = 1 pF. Which load resistance would you choose for highly sensitive and which one for high-speed detection?

c) How does the SNR increase with P_e above and below the shot-noise limit. Sketch the SNR [dB] as a function of P_e [dBm].

Questions and Comments:

Matthias Lauermann
Building: 30.10, Room: 2.23
Phone: 0721/608-48954
Email: Matthias.Lauermann@kit.edu

Jörg Pfeifle
Building: 30.10, Room: 2.23
Phone: 0721/608-48954
Email: Joerg.Pfeifle@kit.edu