DESCRIPTION FOR THE GENERAL PUBLIC

Dynamic Model of VCSELs for Short-Distance Optical Interconnects

The very quick development of the Internet we have observed since the 1990s is possible partially as a result of the development of optical data transfer systems. Basically, such systems work as follows. A light source is driven by a modulated electric current, and generates modulated light—the higher the current is, the stronger the emitted radiation. If we consider the simplest situation, when we utilize only two levels of the current and light intensity, we get a system which turns an electrically encoded sequence of zeros and ones into the same sequence, but in the form of an optical signal. The light emitted is transported through an optical fiber. At the other end of the fiber there is photodetector which changes the optical signal back to an electric signal, hopefully identical with the original. Why would we turn an electric signal into light when in the end we have to do the opposite thing, since an electric signal can also be sent with the speed of light through copper wires? Sending electric impulses through wires which was used (and still is in many applications) to send information, generates many problems, especially when the transmission speed (frequency of the impulses) is very high or the distances are big. This a result of the resistance of the wire, presence of parasitic capacitances and inductances, skin effect etc. Except resistance, all these phenomena are stronger when the current frequency is higher. Additionally such a signal can be easily disturbed by an external electromagnetic field which can be generated, for example, by a signal sent through another wire in the same cable. In such a case this effect is called crosstalk. Light sent through an fiber is immune to external distortion and does not cause such effects, capacitance and inductance do not apply to light. The attenuation of light in a fibre for certain wavelengths is lower (and independent on the modulation frequency) than attenuation of electric signals in a wire. The minimal attenuation of a glass fibre is for the infra-red wavelength of 1550 nm. However capacitance and inductance do not influence light, they do influence the electrically driven light emitter and are one of the reasons why the original electric signal may be different than the optical signal.

In practice, in long-distance telecommunication optical systems, as the light sources, semiconductor laser of a special type (so called DFB lasers), emitting at around 1550 nm, are mainly used. Semiconductor lasers, in general, are light sources of wall-plug efficiency which is unavailable for other devices, very small dimensions (usually less than 1 mm in each direction) and can be easily modulated by an electric signal.

Recently, so called data centers are developing fast. They are big buildings, where thousands of computers exchange information with themselves and with the external world. Data transfer at short distances, such as between computers in data centers, can be performed through copper wires or optical links. The optical links which are used in the long-distance applications are not suitable in such applications, because (among other reasons) the cost of DFB lasers is much too high. If we want to connect thousands of computers with each other a huge number of leasers is needed, so their price must be as low possible, but they must also have a very good efficiency and modulation properties. We can, however, resign from using the wavelength of 1550 nm, because the distances which the signal covers are limited and the increased attenuation may be acceptable. A natural candidate for such applications are semiconductor vertical-cavity surface-emitting laser (VCSELs) emitting wavelengths in the range of 800–1100 nm. Such lasers in mass production are very cheap and their driving currents are very low. Moreover, for these wavelengths cheap silicon-based photodetectors which are the receivers of the optical signals, are available. Nowadays, copper wires are being partially replaced by optical links based on such lasers, in the described applications. Optimization of two parameters of these lasers is crucial for further development of such optical systems: the maximum bit rate and the energy efficiency (the amount of head dissipated per a bit of information). The bit rate is limited by,for example, capacitance of the laser and the fact that photons are emitted after random times from the moments they were generated.

The goal of this project is to create an suitable computer model and its application in simulations of VCSELs leading to deeper understanding of phenomena impeding the anticipated improvement in the bit rate and efficiency. As a result, an optimized VCSEL construction will be designed.