High-Frequency Performance Optimization of DFB Laser Integrated Electroabsorption Modulators

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Distributed feedback (DFB) lasers monolithically integrated with electroabsorption modulators (EAMs) are promising devices for optical telecommunication applications owing to their potential for high-speed operation and low-cost fabrication. The modulation bandwidth of traditional lumped EAMs is usually limited by the RC time constant, but the effective resistance $R$ and capacitance $C$ are not easily extracted for advanced device geometries. In this paper we investigate the modulator section of a 1.3 μm wavelength DFB–EAM device fabricated by Infineon [1].

2-D simulations based on the finite-difference method have been performed to numerically solve the well-known continuity (Laplace) equation

$$\nabla_T \circ \vec{j} = \nabla_T \circ (\sigma \vec{E}) = \nabla_T \circ (-\sigma \nabla_T V) = 0$$

with complex conductivity $\sigma = \sigma + i \omega \epsilon_0$. For a given voltage $U_{\text{mod}}$, the solution yields the electric field distribution $\vec{E}(\vec{r}, \omega)$ and the impedance $Z_{\text{mod}} = U_{\text{mod}}/I$ with the Gaussian integral $I = \int \vec{j} \circ d\vec{S}$ over the current density $\vec{j}$. Both are required to identify the limitations of the electro-optical response.

In the present work, a 100 μm-long EAM with an 8 μm wide intrinsic region shown above (left) is analyzed. Simulated evenly spaced equipotential lines at 1 GHz modulation frequency pass through the intrinsic area and are drawn in the same diagram. The electric field intensity in the intrinsic area is shown on the right-hand side. As expected, at low frequencies, the electric field is rather homogeneous. With increasing frequency, the field concentrates in the center and phase shifts occur at the edges. The modulation phase is equal to the phase of the electric field and is thus not uniform along the intrinsic region. Overall, this strongly affects the shape of the modulation response (see left figure below), which is calculated with a Gaussian lateral optical power distribution and a detailed absorption model for the quantum wells. Impedance variations shown below (right) in addition cause a decay of the response function since the modulator voltage $U_{\text{mod}} = U_0 Z_{\text{mod}}/(Z_{\text{mod}} + 50 \Omega)$ approximately equals the generator voltage $U_0$ for $|Z_{\text{mod}}| \gg 50 \Omega$ but decreases by 3 dB for $|Z_{\text{mod}}| \approx 50 \Omega$.

As shown below (left), measured and simulated electro-optical responses deviate by less than 2 dB for frequencies up to 15 GHz, indicating that the main reasons for the rapid decay of the response are included in the model. A distinct improvement is expected with a new design (ND) incorporating a narrow intrinsic region. According to the left-hand figure below, the 3 dB corner frequency should increase to about 25 GHz, which could enable 40 Gbit/s operation.


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