Corrections

Corrections to "Physically Rigorous Modeling of Internal Laser-Probing Techniques for Microstructured Semiconductor Devices"

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The following typesetting errors are in the original version of this article published in [1].

- Equation (9) on p. 63 and equation (37) on p. 68 should be

$$M_{k,2}\boldsymbol{U}(z_{k+1}) = M_{k,1}\boldsymbol{U}(z_k). \tag{1}$$

- The reference in the fourth line of the last paragraph on p. 65 should be Fig. 6.
- On p. 63, the subsections of Section II-C2 "Boundary Conditions in Propagation Direction," should be:
  a) Boundary condition in the k_x–z-space;
  b) Matrix representation of the boundary conditions in real space.
- In the Appendix, the correct plot for Fig. 12 is missing. Fig. 12 is reprinted here.
- In the Appendix, the section numbering was incorrect. The Appendix should be as follows.

APPENDIX A
PROPAGATOR MATRICES

To derive the propagator matrix, (7) and (8) are integrated analytically over the interval $[z_k, z_{k+1}]$, assuming a linear interpolation of the computational variables $E^{F,B}$ and the dielectric constant ε_R. The resulting summands comprise products of $E^{F,B}(x, z_{k,k+1})$, $\varepsilon_R(x, z_{k,k+1})$, and $\mathrm{e}^{i\kappa z_{k,k+1}}$. Sorting by $E^{F,B}(x, z_k)$ and $E^{F,B}(x, z_{k+1})$ transforms (7) and (8) to a matrix equation of the following form:

$$\begin{pmatrix} A_k(x) - \frac{i\Delta z_k}{4\kappa}\partial_x^2 & B_k(x) + K_k\partial_x^2 \\ C_k(x) + K_k^*\partial_x^2 & D_k(x) + \frac{i\Delta z_k}{4\kappa}\partial_x^2 \end{pmatrix} \begin{pmatrix} E^F(x, z_{k+1}) \\ E^B(x, z_{k+1}) \end{pmatrix} = \begin{pmatrix} \tilde{A}_k(x) + \frac{i\Delta z_k}{4\kappa}\partial_x^2 & \tilde{B}_k(x) + \tilde{K}_k\partial_x^2 \\ \tilde{C}_k(x) + \tilde{K}_k^*\partial_x^2 & \tilde{D}_k(x) - \frac{i\Delta z_k}{4\kappa}\partial_x^2 \end{pmatrix} \begin{pmatrix} E^F(x, z_k) \\ E^B(x, z_k) \end{pmatrix}. \tag{33}$$

In this equation, the constants K_k and $\tilde{K}_k$ are functions of ω, κ, z_k, and z_{k+1}, while $A_k(x), B_k(x), C_k(x), D_k(x), \tilde{A}_k(x), \tilde{B}_k(x), \tilde{C}_k(x)$, and $\tilde{D}_k(x)$ additionally depend on $\varepsilon_R(x, z_k)$ and $\varepsilon_R(x, z_{k+1})$.

Finite difference discretization at $x = x_j$ yields three terms at each side of the equation referring to the positions x_{j-1}, x_j, and x_{j+1}

$$M_{k,j}^1 U(x_{j+1}, z_{k+1}) + M_{k,j}^2 U(x_j, z_{k+1}) + M_{k,j}^3 U(x_{j-1}, z_{k+1}) = M_{k,j}^4 U(x_{j+1}, z_k) + M_{k,j}^5 U(x_j, z_k) + M_{k,j}^6 U(x_{j-1}, z_k) \tag{34}$$

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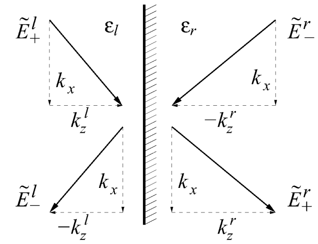

Fig. 12. Impinging and emerging waves with wave vector component k_x at an interface $z = 0$ between two regions of different dielectric constants.

with

$$U(x_j, z_k) = \begin{pmatrix} E^F(x_j, z_k) \\ E^B(x_j, z_k) \end{pmatrix}. \tag{35}$$

The complex 2×2 matrices $M_{k,j}^{1\ldots6}$ can be straightforwardly derived from (33). Defining the vector of unknowns [cf. (10)] by

$$\boldsymbol{U}(z_k) = \Big(E^F(x_1, z_k), E^B(x_1, z_k), \ldots, E^F(x_{N_x}, z_k), E^B(x_{N_x}, z_k)\Big)^T \tag{36}$$

we finally obtain the relation

$$M_{k,2}\boldsymbol{U}(z_{k+1}) = M_{k,1}\boldsymbol{U}(z_k). \tag{37}$$

With the complex 2×2 matrices $M_{k,j}^{1\ldots6}$ [cf. (34)] as their coefficients, the matrices $M_{k,2}$ and $M_{k,1}$ are band structured with only one occupied superdiagonal and subdiagonal line. Thus, the propagator matrices $P_k = M_{k,2}^{-1}M_{k,1}$ can be calculated very efficiently by multiplying band-structured matrices.

APPENDIX B
BOUNDARY CONDITIONS IN PROPAGATION DIRECTION

The impinging and emerging waves at an interface between the regions with dielectric constants $\varepsilon_{l,r}$ (cf. Fig. 12) are related by the refraction law [44]

$$\begin{pmatrix} \tilde{E}_+^l(k_x, 0) \\ \tilde{E}_-^l(k_x, 0) \end{pmatrix} = \begin{pmatrix} \frac{k_z^l + k_z^r}{2k_z^l} & \frac{k_z^l - k_z^r}{2k_z^l} \\ \frac{k_z^l - k_z^r}{2k_z^l} & \frac{k_z^l + k_z^r}{2k_z^l} \end{pmatrix} \begin{pmatrix} \tilde{E}_+^r(k_x, 0) \\ \tilde{E}_-^r(k_x, 0) \end{pmatrix} \tag{38}$$

with $k_z^{l,r} = \sqrt{\varepsilon_{l,r}k_0^2 - k_x^2}$. To derive the boundary conditions, the travelling waves have to be expressed in terms of the electric field E_y and the magnetic field B_x and finally in terms of the computational variables $\tilde{E}^F$ and $\tilde{E}^B$ [cf. (6)].

At the entrance plane $z = z_1$, the field $\tilde{E}_+^l$ is equal to the incident field $\tilde{E}_i$, while $\tilde{E}_-^l$ represents the unknown reflected wave. ε_l is given by the dielectric constant ε_a in front of the entrance plane (i.e., for $z < z_1$). We thus get the boundary condition at the left hand boundary of the simulation domain (12) and the conditional equation of the reflected wave (13) with $k_z^a = \sqrt{\varepsilon_a k_0^2 - k_x^2}$.

For a compact notation, the components $\tilde{E}_i(k_x)$, $\tilde{E}_r(k_x)$, and $\tilde{E}_t(k_x)$ are summarized in the vectors $\tilde{\boldsymbol{E}}_i$, $\tilde{\boldsymbol{E}}_r$, and $\tilde{\boldsymbol{E}}_t$, respectively. Defining $N_x \times 2N_x$ matrices $\tilde{B}_{\pm}^{a,b}$ by

$$\begin{aligned} \left[\tilde{B}_{\pm}^{a,b}\right]_{i,2i} &:= \frac{1}{2}\left(1 \pm \frac{\kappa}{k_z^{a,b}}\right) \\ \left[\tilde{B}_{\pm}^{a,b}\right]_{i,2i+1} &:= \frac{1}{2}\left(1 \mp \frac{\kappa}{k_z^{a,b}}\right), \quad \text{for } i = 1, \ldots, N_x \\ \left[\tilde{B}_{\pm}^{a,b}\right]_{i,j} &:= 0, \quad \text{otherwise} \end{aligned} \tag{39}$$

transforms the boundary conditions to the form listed in (14).

REFERENCES

[1] R. K. Thalhammer and G. K. M. Wachutka, "Physically rigorous modeling of internal laser-probing techniques for microstructured semiconductor devices," *IEEE Trans. Computer-Aided Design*, vol. 23, pp. 60–70, Jan. 2004.