

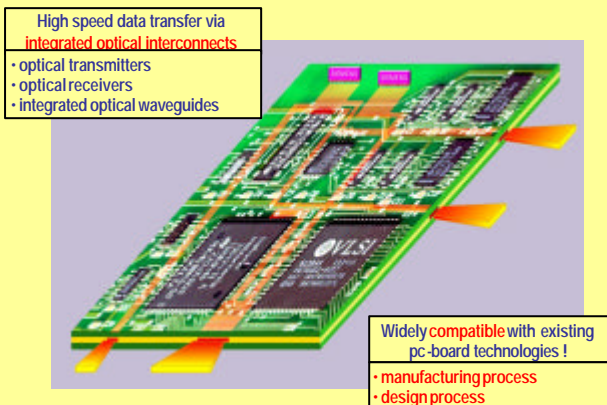
Improved time domain simulation of optical intrasystem interconnects



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Vision:

PCB with embedded optical interconnections (multimode waveguides).



Design of optical interconnections:

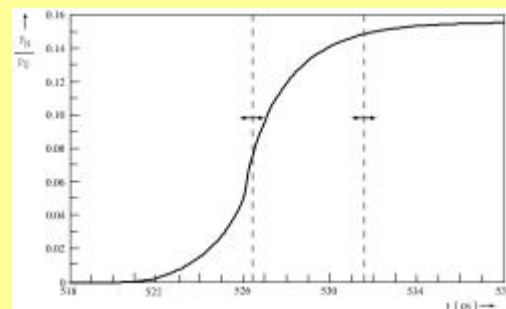
Efficient tools for simulation of transmission behavior of optical waveguides are needed (FEM/BPM are not applicable).

Approach:

- Characterization of waveguides (step responses) by extended ray tracing analysis.
- Improved approximation of step response.
- Recursive convolution algorithm to compute transmission behavior.

Approximation:

Characteristic step response:



- Dashed lines show arrangements of intervals for e.g. 3 intervals.

Approximation approach:

- Sum of exponential functions used to approximate step response:

$$\tilde{a}(t) \approx \sum_{p=1}^P \tilde{a}_p(t) \cdot \exp(-t/t_{p,begin}) \cdot \exp(t/t_{p,end})$$

- Step response is divided into intervals
- Approximation with one exponential term per interval:

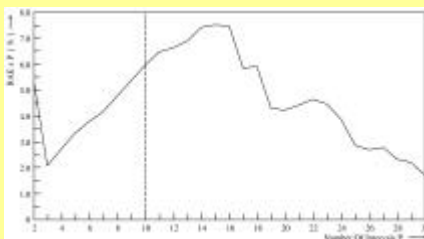
$$\tilde{a}_p(t) \approx \tilde{a}_{p,0} \cdot \exp(-t/t_{p,begin})$$

- Number and arrangement of intervals have great impact on accuracy and computing time.

Improved approximation algorithm:

- Calculate best approximation with minimum number of intervals.
- Algorithm calculates:
 - Loop over number of intervals P (e.g. 2 ≤ P ≤ 30).
 - At each P approximate for all possible arrangements of intervals $A_{r,P}$.
 - Relative Approximation error $E_r(A_{r,P})$.
 - Minimum relative approximation error $E_{r,min}(A_{r,P})$ for each P.
 - Cost function $C(A_{r,P}) \approx E_{r,min}(A_{r,P})$.

Example of cost function:



Every approximation left of the dashed line is applicable (good mixture between accuracy and minimum number of intervals).

- Minimum of cost function represents best approximation with a mixture of minimum number of intervals and a good accuracy of the approximation.

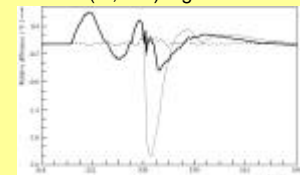
Result and conclusion (example):

- Accuracy and relative approximation error:

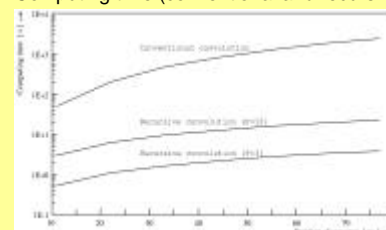
Accuracy between original and approximated step response:



Relative approximation error improved (→, P=3), old (→, P=10) and old (... , P=3) algorithm:



- Computing time (conventional and recursive convolution):



- Speedup: 5 times faster with improved approximation algorithm. (In comparison to conventional convolution speedup: 15...100).

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