Computer Aided Design for Free Space Optical Interconnected Systems

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Chatoyant is a software tool developed to meet the needs of mixed technology optoelectronic systems designers. We introduce component models and analysis techniques that enable our tool to support free-space optoelectronic interconnect system design.

We are developing a mixed signal CAD tool, capable of performing end-to-end system simulations of free space interconnection systems composed of optical, optoelectronic, electrical, and mechanical components. By including a variety of modeling techniques and multiple abstraction levels, Chatoyant has the ability to support design trade-offs by performing bit error rate (BER), insertion loss, crosstalk, and tolerancing analyses. [2]

Optoelectronic systems are composed of 3D objects where, unlike electronic systems, relative physical position matters. Therefore, we are developing a graphical user interface (Figure 1) that allows the user to choose from libraries of three-dimensional objects which can then be placed into a three dimensional "virtual world". The interface allows the user to set the order of the system components, which controls signal propagation between components. The advantage of using a web based 3D interface is that objects can be created and placed so that they match their real world counterparts. This results in a simpler, more intuitive interface. Further, this allows platform independent remote use of Chatoyant running on a compute server.

Components in the system can be based on three modeling techniques. The first uses analytic models based on underlying physical models of the devices. These can be very abstract "0^{th}-order" models, or more complex models involving time varying functions, internal state, or memory. The second class of models is based on empirical measurements from fabricated devices. These models use measured data and interpolation techniques to directly map input signal values to output values. The third class is derived from lumped parameter models, often called reduced order or response surface models. For these models, we use the results of low level simulations, such as finite element solvers, or simulators, and generate a reduced order model, which covers the range of operating points

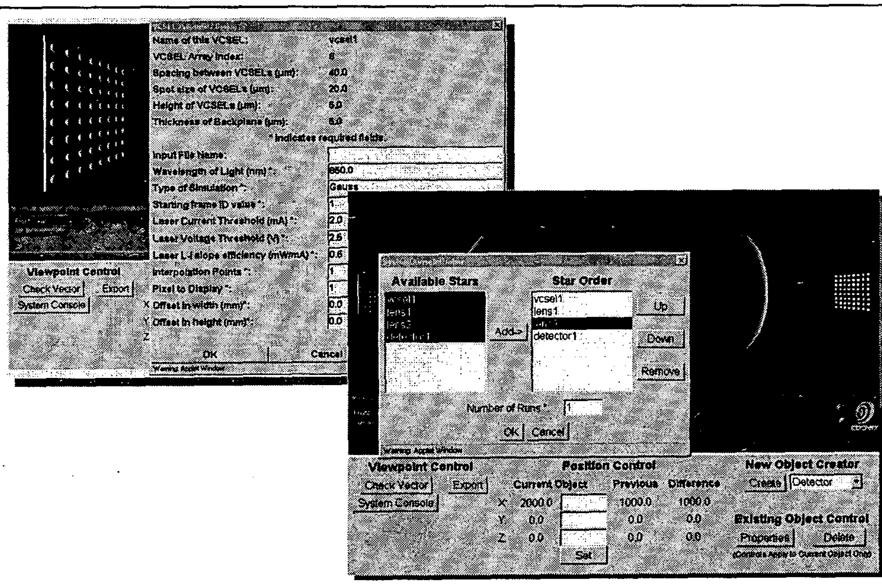

Figure 1 Chatoyant3D Graphical User Interface

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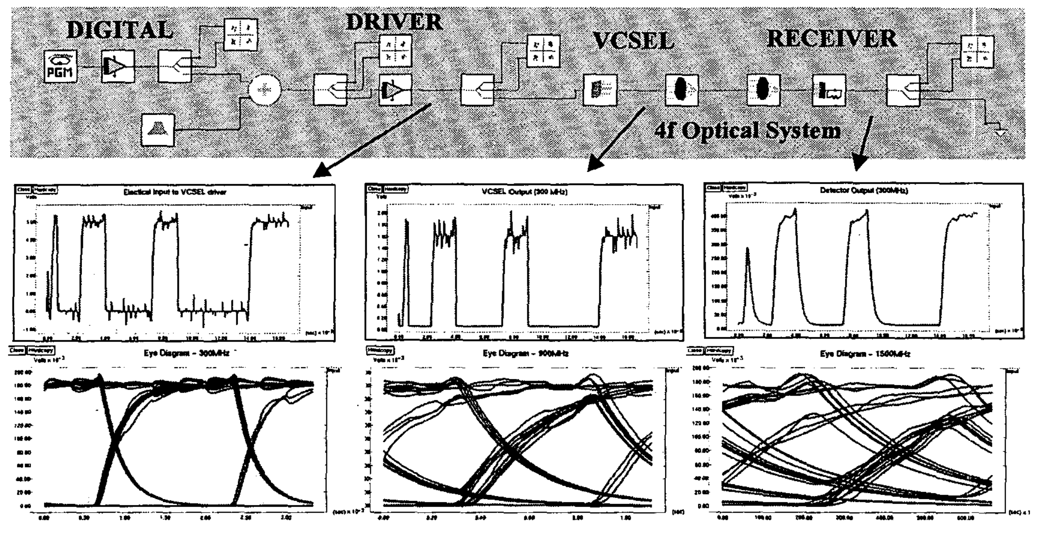

Figure 2 Optoelectronic *4f* system link performance at 300, 900, and 1500MHz

for the component by producing a polynomial curve fit, or simple interpolation over the range of operation. For all of these models we use a piecewise linear model of the dynamic behavior of the components and signals.

As an example, a complete optoelectronic simulation of a *4f* optical communication link is presented in Figure 2. The top half of the figure shows the system as represented in Chatoyant. This representation is from the older 2D interface to the Ptolemy simulation engine. [1] Each icon represents a component model, and each line represents a signal path (either optical or electrical) connecting the outputs of one component to the inputs of the next. Several of the icons, such as the VCSELs and receivers, model the optoelectronic components themselves, while others, such as the output graph, are used to monitor and display the behavior of the system. The input to the system is a digital signal at speeds in the range of 100MHz to 1.5GHz.

A Gaussian noise with variance of .5V has been added to the multistage driver system to show the ability of our piecewise linear models to respond to arbitrary waveforms. In the figure, several snapshots show the behavior of the CMOS electronic drivers under a 300MHz noisy signal. Noise with levels over the threshold cause an effective change in state in the drivers. Interesting effects to note are the difference in amplifications in the noise depending on the output level, the immunity to noise and recovery of the signal offered by the CMOS sections, and the clipping of negative noise spikes in the source because of the VCSEL threshold.

The three eye diagrams (at 300MHz, 900MHz, and 1.5GHz) in the lower part of the figure show the effects of frequency on the quality of the received signal. For the component values chosen, the system operates with reasonable BER (10^{-9}) up to about 1GHz. Of course, many factors affect this performance and by making different assignments of component parametric and parasitic values, we can simulate systems with arbitrarily good (or poor) performance.

However, our goal here is to show how we can model a variety of systems with different components and component values. This allows the system designer to perform trade-offs by varying such parameters as VCSEL efficiency and thresholds, optical system design, detector technology and receiver circuit design. Further, by performing Monte Carlo simulations with parameter ranges, the designer can determine critical parameter tolerances and design more robust systems.

Acknowledgments

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References

1. Buck, J., Ha, S., Lee, E.A., Messerschmitt, D., "Ptolemy: a framework for simulating and prototyping heterogeneous systems," Int. J. Computer Simulation, Vol. 4, 1994, pp. 155-182
2. Levitan, S.P., Kurzweg, T.P., Marchand, P.J., Rempel, M.A., Chiarulli, D.M., Martinez, J.A, Bridgen, J.M., Fan, C., McCormick, F.B., "Chatoyant: a computer-aided design tool for free-space optoelectronic systems," Applied Optics, Vol. 37, No. 26, September, 1998, pp. 6078-6092.