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Modeling free space optoelectronic interconnection systems

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Abstract

We have developed a system level simulation and analysis tool suite called *Chatoyant* that provides designers with first order modeling capabilities for free space optoelectronic interconnection and information processing systems.

Modeling free space optoelectronic interconnection systems

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We have developed a system level simulation and analysis tool suite called *Chatoyant* that provides designers with first order modeling capabilities for free space optoelectronic interconnection and information processing systems.

Figure 1 shows a *4f* system as modeled in *Chatoyant* using the Ptolemy environment[1]. Ptolemy is a generalized simulation framework used for rapid prototyping of digital signal processing systems[2]. We have developed models for components such as laser sources, modulators, lenses, and receivers. Each icon, or "star," represents a basic optoelectronic component or input/output function. The VCSEL input star allows us to simulate arrays of arbitrary data patterns that are modulated by an array of lasers. For the simulations, the VCSEL array interpolates a sequence of arrays of bit patterns (read from a file) into piece-wise linear voltage waveforms that drive the VCSEL models. The resulting optical intensity waveform is passed through the lens models using Gaussian propagation equations. The GaussCross and XMgraph stars display the optical beam waist of a single pixel during simulation. The PowerGrid star is used to observe power in a cross-section of the optical signals. Additionally, it shows the placement and power received by a set of ideal detectors. On the other hand, the DetectArray star (not shown) models the dynamics of receivers by first integrating the intensity from each Gaussian beam over the area of each detector, and then transforming the piece-wise linear optical power waveforms into voltages.

Figure 2A graphically illustrates modulation voltages for nine data channels in a 3×3, 20µm spot-size, 40µm spacing, VCSEL array. Black squares represent 10mW and white squares represent 50mW electrical modulation power. Figure 2B shows the point-to-point interconnection system rendered using POV[3]. Figure 2C shows the received optical data overlaid on the surface of a 3×3 array of 35µm detectors, one for each of the nine channels using the PowerGrid star.

Figure 3 shows the "Gaussian beam waist" of one of the nine optical beams, in cross section, as it travels from source-to-lens, lens-to-lens, and lens-to-detector array. In this example, the 40µm lenses used in the lenslet array are too small to provide perfect imaging. In fact, the Gaussian beams which have a waist diameter of 33µm are clipped by the lens arrays and lose 5.9% of their power[4]. Further, diffractive effects distort the beams and cause the final waist to be expanded from 20µm to 24µm.

Table 1 shows the electrical modulation power (in mW) driving the VCSELs, the optical power generated by the VCSELS and the power detected after the light has passed through the system.

Chatoyant can also be used to model the dynamic behavior of the system. Figure 4 shows one piece-wise linear signal at 300MHz at two monitor points: Figure 4A the output of one of the modulators, showing power in mW, and Figure 4B showing the output of one of the detectors, in Volts. Figure 4C shows an "eye" diagram for the received waveform.

[1] S. P. Levitan, et al. *Second International IEEE Workshop on Massively Parallel Processing Using Optical Interconnections.* 239-245, San Antonio, TX, October 23-24, 1995.

[2] J. Buck, et al. *Int. Journal of Computer Simulation*, special issue on "Simulation Software Development", January, 1994.

[3] D. Wells and C. Young. *The Waite Group's Ray Tracing Creations.* Waite Group Press, 1993.

[4] F. B. McCormick, et al. *Optical Society of America Proceedings on Photonic Switching*, Vol. 8 1991.

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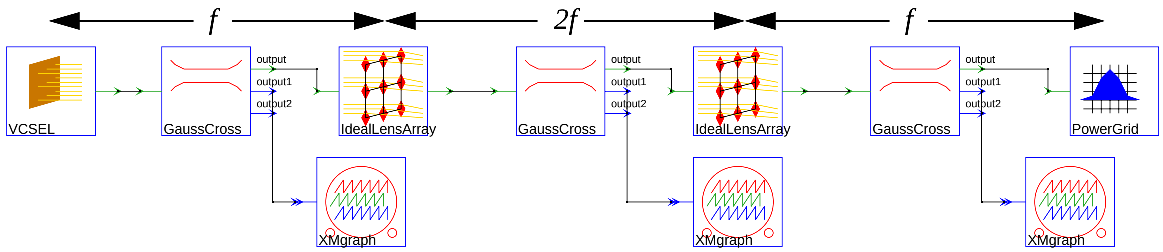
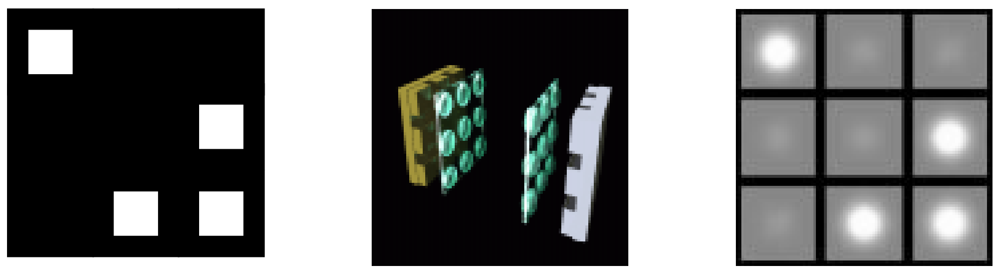


Figure 1: Ptolemy schematic of *4f* system



A: Input pattern B: 3d representation B: Output pattern

Figure 2: Modeled System

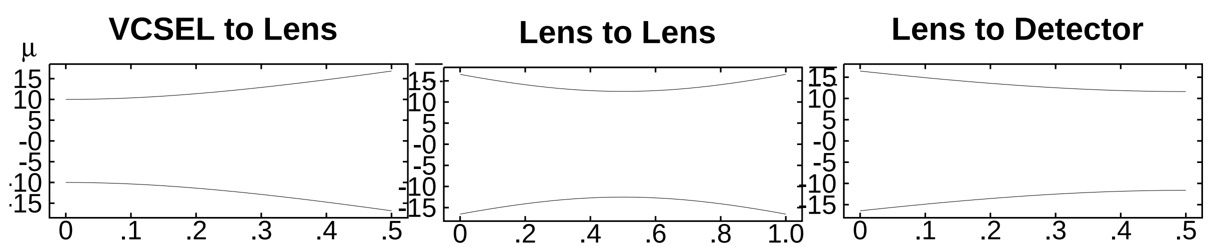
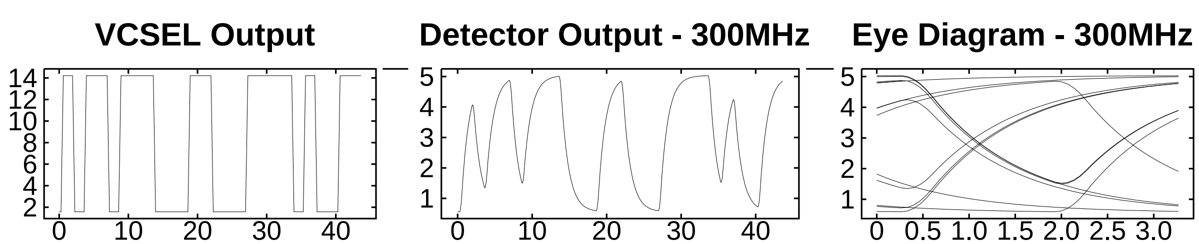


Figure 3: Beam waists (X in mm)

Table 1: Electronic modulation and optical signal power (mW)

Drivers			20μm VCSELs			35μm Detectors		
50	10	10	14.2	1.57	1.57	12.6	1.39	1.39
10	10	50	1.57	1.57	14.2	1.39	1.39	12.6
10	50	50	1.57	14.2	14.2	1.39	12.6	12.6



A: (X in ns, Y in Mw) B: (X in ns, Y in Volts) C: (X in ns, Y in Volts)

Figure 4: Single channel waveforms