Computer Aided Design for Free Space Optoelectronic Information Processing Systems

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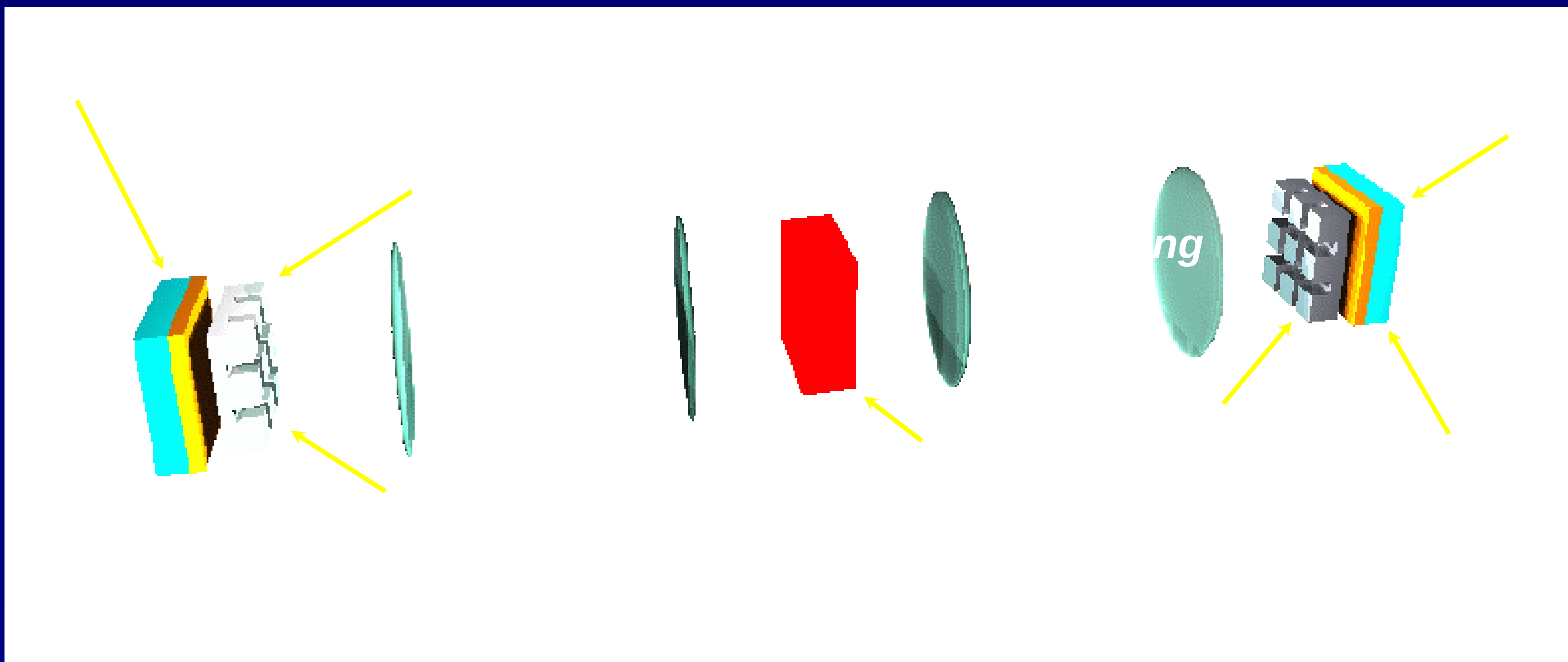
Overview

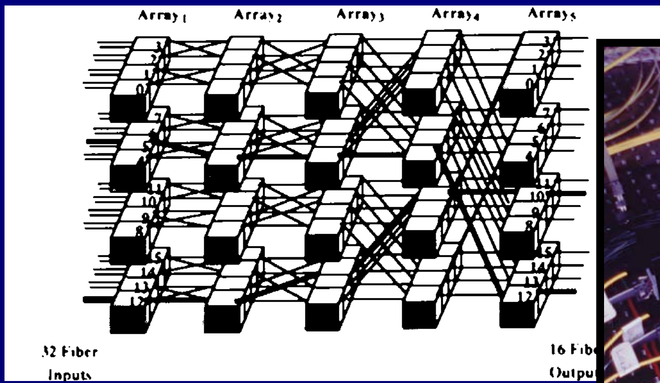
- **Chatoyant is a computer aided design tool for the design of Free Space Optoelectronic Information Processing Systems**
  - **Simulation**
  - **Analysis**
  - **Synthesis**
  - **Interface**
- **Goal: Enable the modeling of FSOI systems without costly prototyping**

What's the problem?

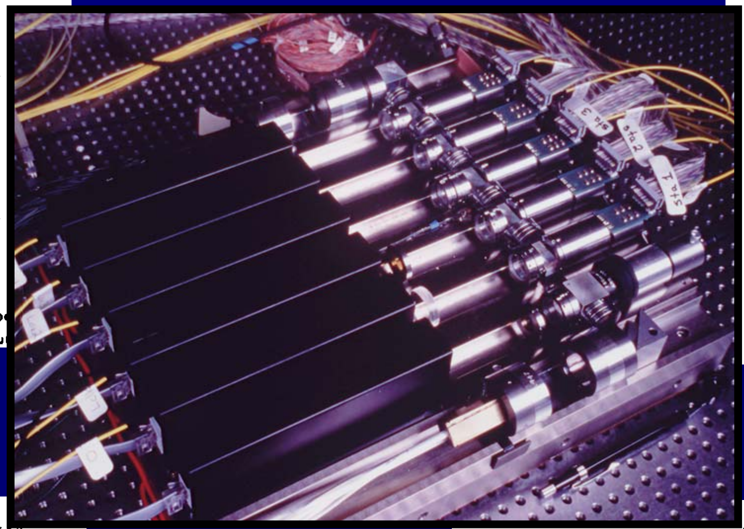
- **O/E information processing systems are hard to design:**
  - **Heterogeneous systems**
  - **Expensive to prototype**
  - **Hard to simulate**



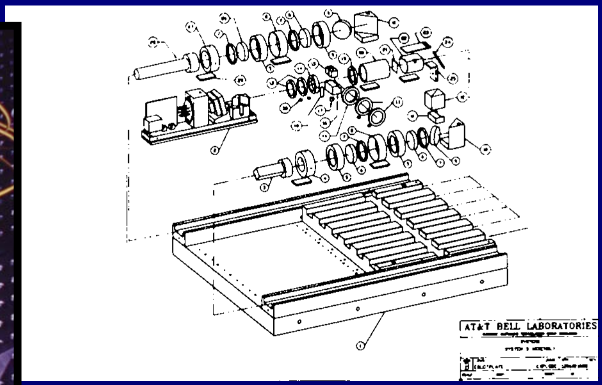
Example: "System V"



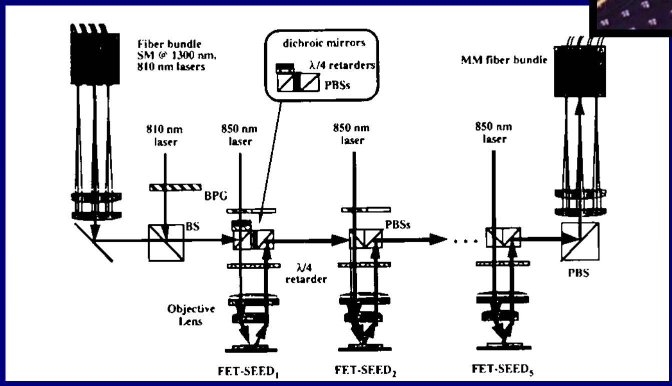
Functional



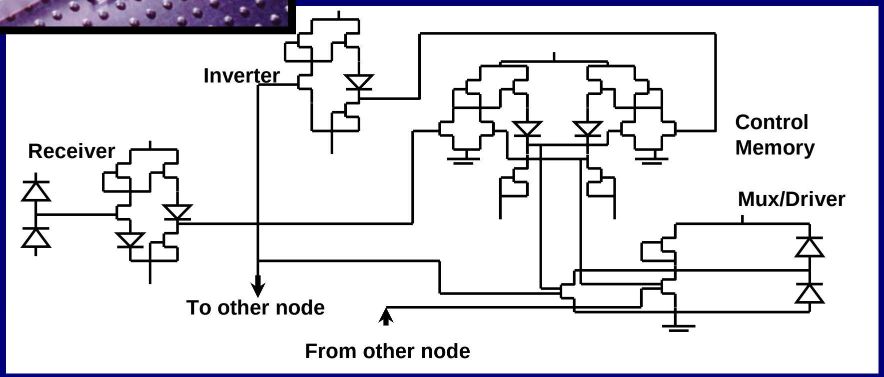
Mechanical



Optical



Electrical



F.B. McCormick, et al, **"Five-stage free-space optical switching network with field-effect transistor self-electro-optic-effect-device smart-pixel arrays,"** Appl. Opt. 33, 1601-1618 (1994).

FSOI CAD Issues

System Simulation Backbone

Electronics	Optoelectronics devices & circuits	Optics	Packaging	Tolerancing
Functional level (VHDL)	Analytical models	Image formation	Area, volume, weight, cost	Misalignment
Logic (Gatesim)	Numerical & statistical models	Gaussian beam propagation	1st order thermal	Noise & crosstalk
Gate (SPICE)	Physical Models (Experimental Data fitting)	Ray tracing Diffraction analysis	Auto-CAD Light Tools	Finite element analysis

BER, power, area, volume weight, cost

Trends 1st order trade-offs

Interfaces, optimization

Increasing Accuracy& complexity

- to be developed
- under development
- commercial software

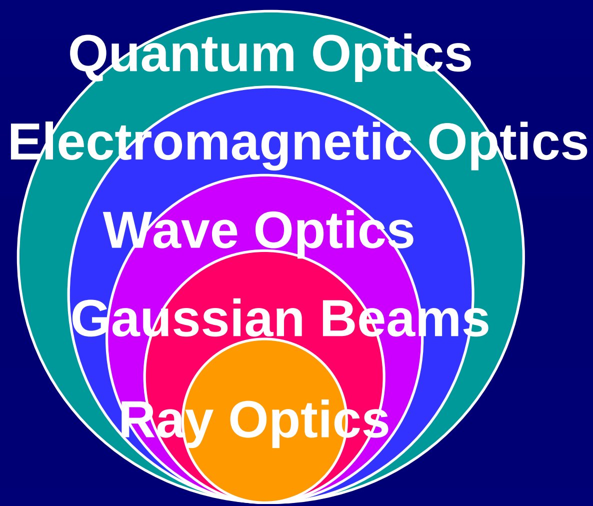
Approach

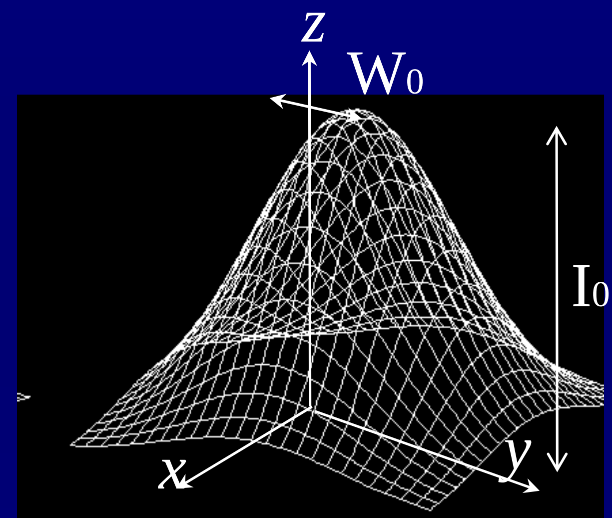
Build a system level CAD tool to predict performance & analyze technology vs. architecture trade-offs

- **Develop 1st order analytical models for optoelectronic components**
- **Develop & integrate numerical/physical models for optoelectronic devices**
- **Develop a hierarchical & modular software tool using Ptolemy engine**
- **Provide interfaces to existing tools (Spice, Code V, etc.)**

Optical Signals

- Use Ray Optics for modeling center of the beam
- Use Gaussian Beams for modeling the propagation of light

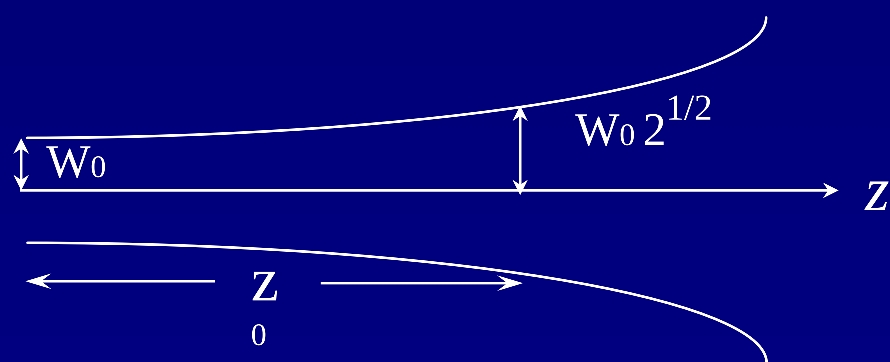




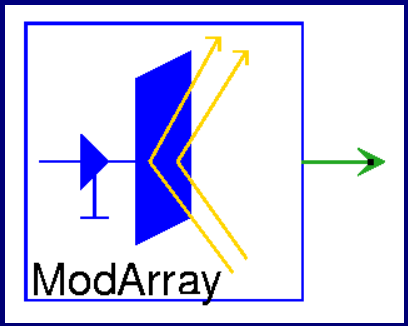
$$I(r,z) = I_0 \left[\frac{W_0}{W(z)} \right]^2 \exp\left[-\frac{2r^2}{W^2(z)} \right]$$

$$W(z) = W_0 \left[1 + \left(\frac{z}{z_0} \right)^2 \right]^{1/2}$$

$$z_0 = \frac{\pi W_0^2}{\lambda}$$

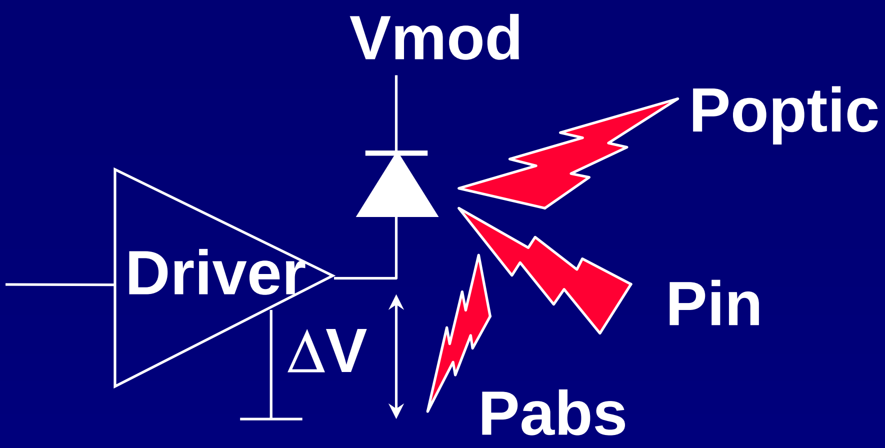


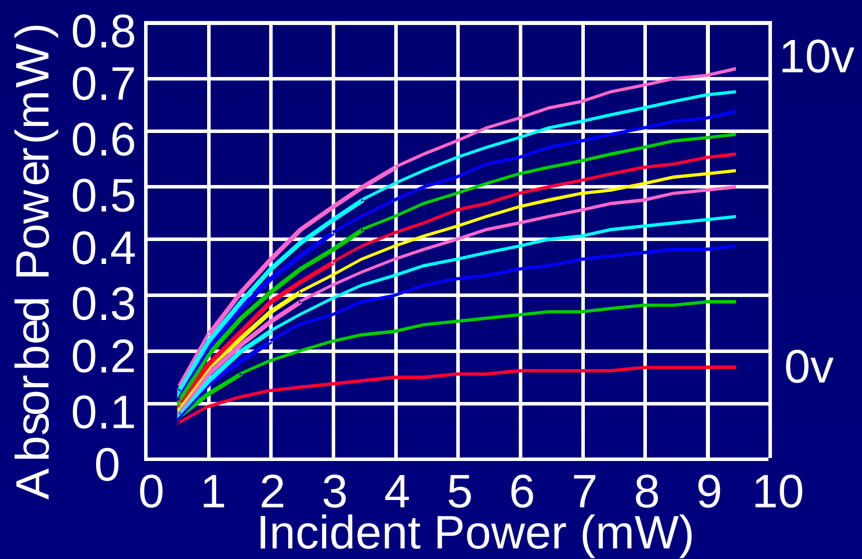
MQW Modulator Model



$$P_{abs}(V) = \frac{P_{in}\, k(V)}{1 + \dfrac{P_{in}}{A \cdot I_s(V)}}$$

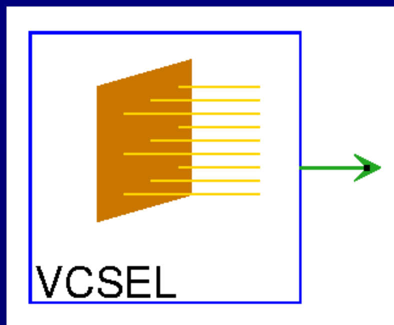
$$P_{optic} = P_{in} - P_{abs}$$



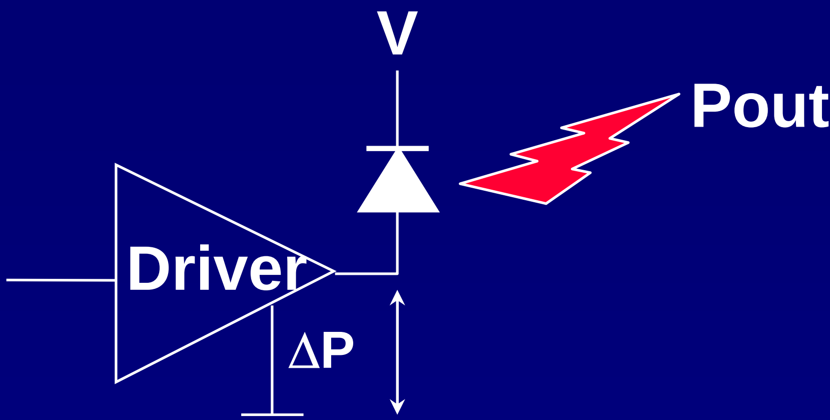


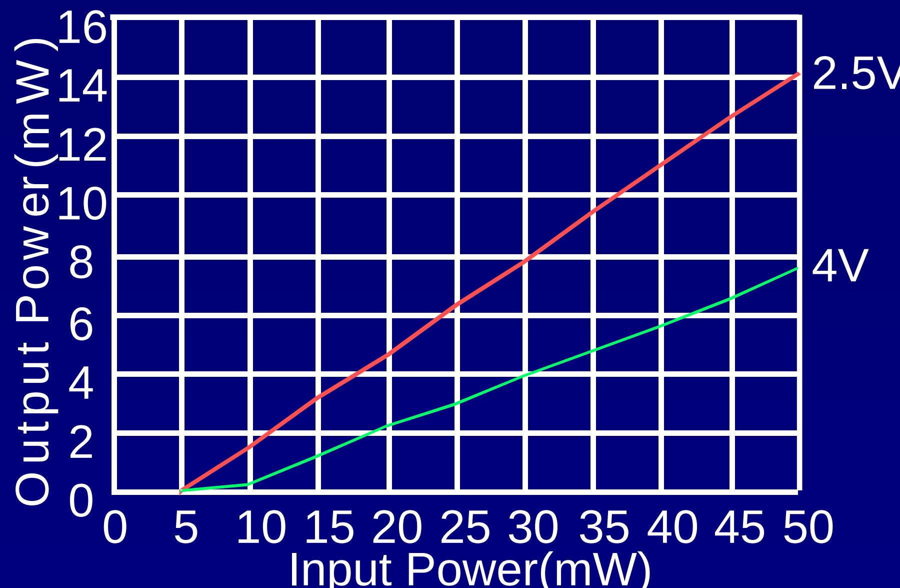
Empirical Modeling - Experimental data fitting

VCSEL Model

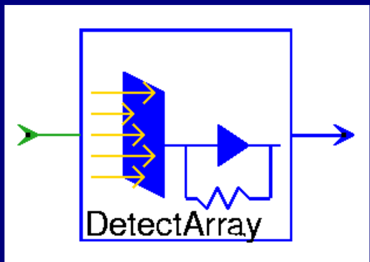


$$P_{out} = \frac{\eta_{LI} / V_{th}}{(1 - \eta_{LI} / V_{th})} (P_{in} - I_{th} V_{th})$$

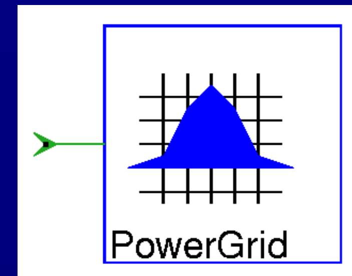


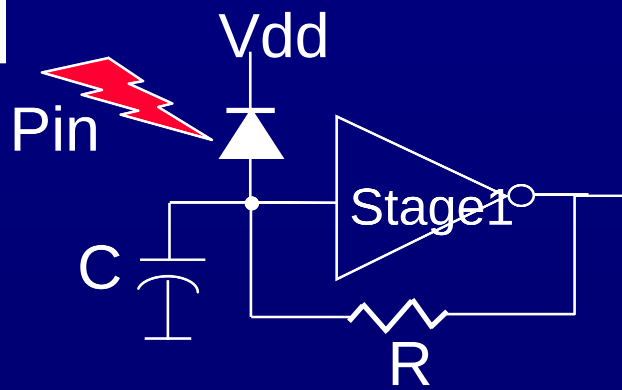


Analytic Modeling - Physics based



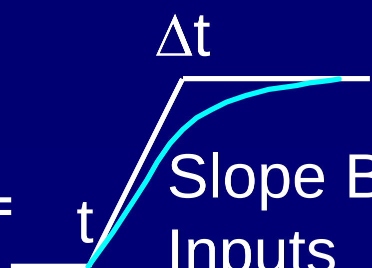
Receivers





$$V_0(s) = \frac{R_f}{1 + \left(\frac{R_f C}{A}\right) s} \cdot P_{optic}(s)$$

$V_{out}(t+\Delta t)$ =



Slope Between Inputs +

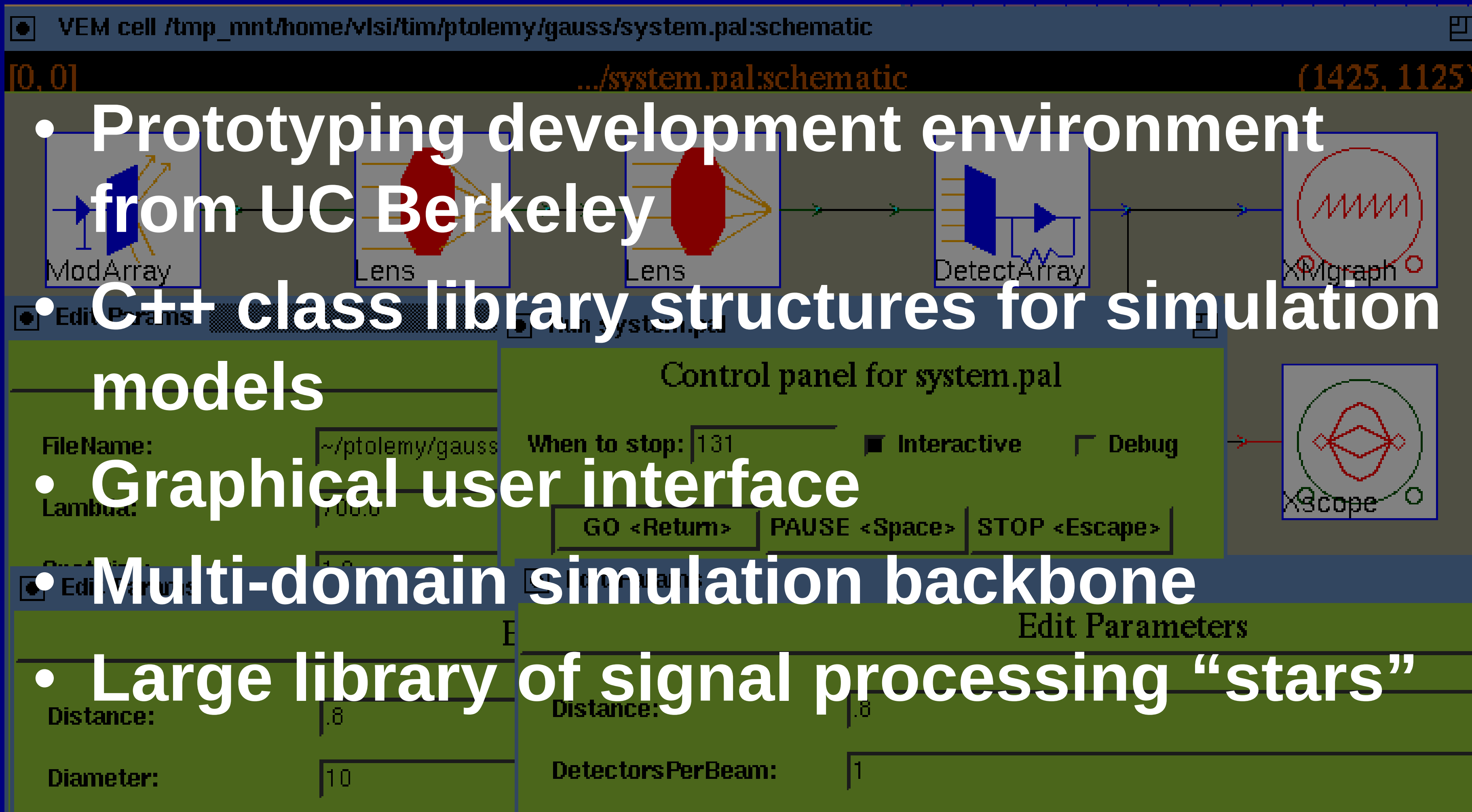
DC Biasing Voltage + Past Output of Amplifier

$$V_{out}(t+\Delta t) = XR\left[\frac{RC}{A}(e^{-y} - 1) + \Delta t\right] + P_{in}(t)R(1 - e^{-y}) + V_{out}(t)e^{-y}$$

$$X = (P_{in}(t+\Delta t) - P_{in}(t))/(\Delta t) \qquad y = \Delta t \frac{A}{RC}$$

Derived Modeling - Parametric models extracted from lower level tools

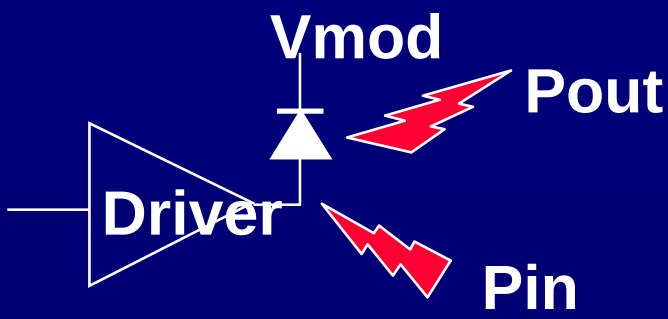
Ptolemy

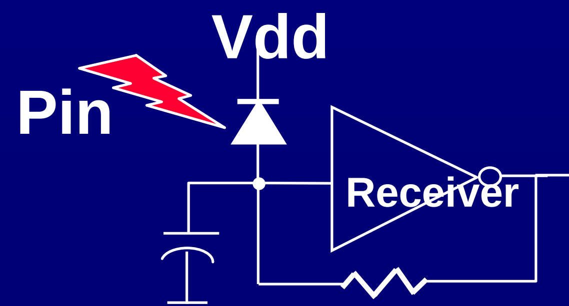


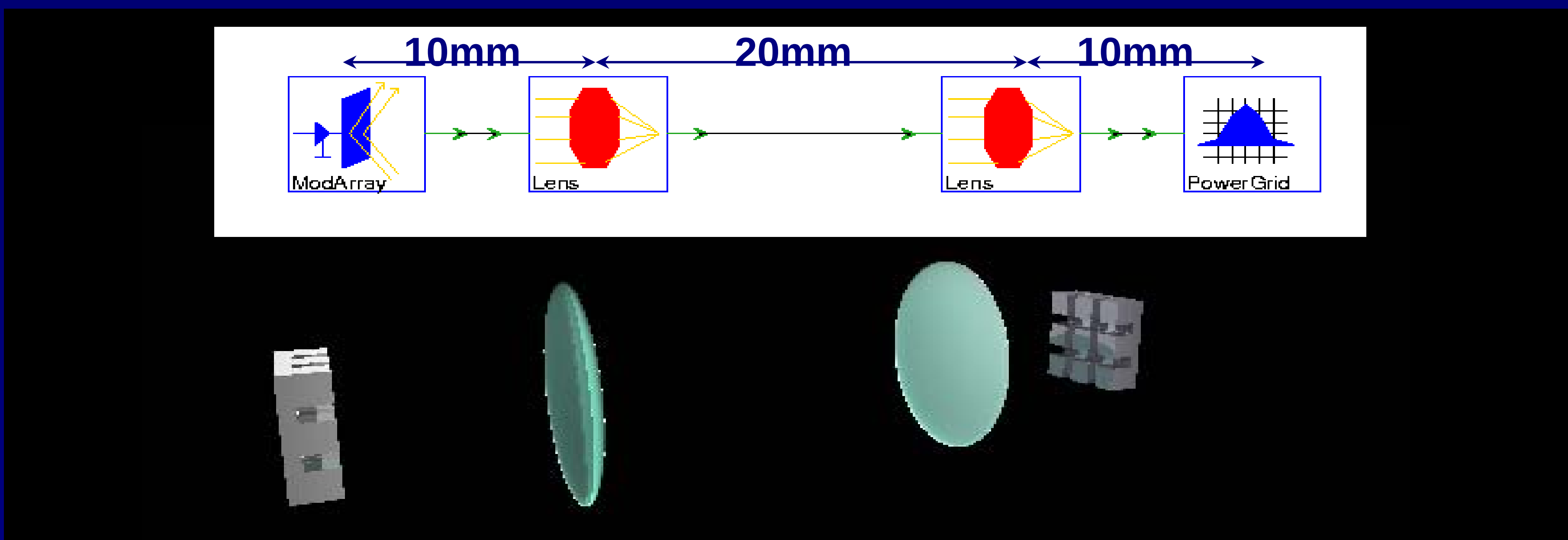
- Prototyping development environment from UC Berkeley
- C++ class library structures for simulation models
- Graphical user interface
- Multi-domain simulation backbone
- Large library of signal processing “stars”

J. Buck et. al **“Ptolemy: a framework for simulating and prototyping heterogeneous systems,”** Int. J. Computer Simulation, Jan. 1994.

End - to - End Link Simulation and Auto Rendering

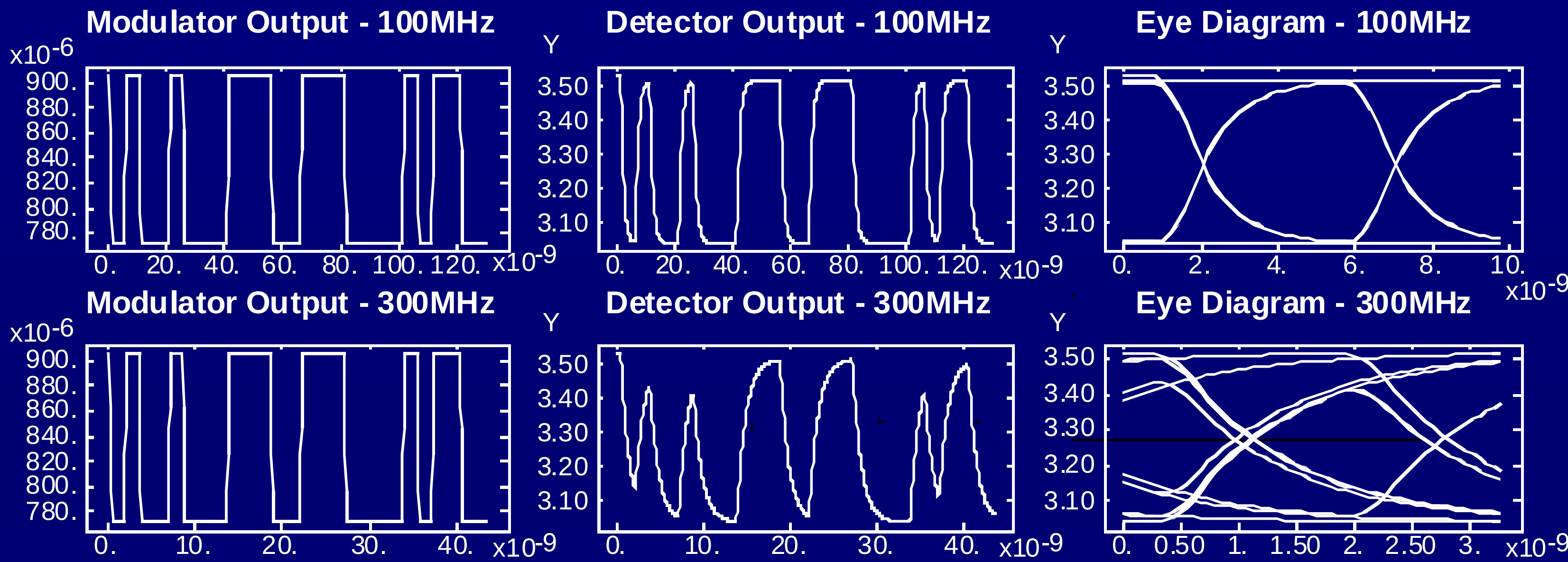




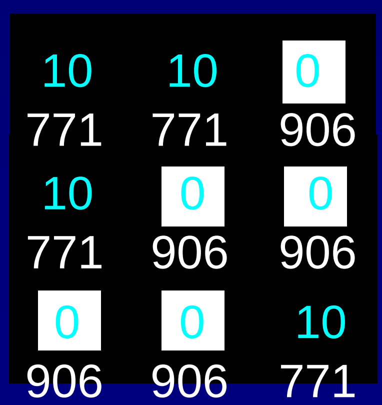


D. Wells and C. Young, *The Waite Group's Ray Tracing Creations.* Waite Group Press, 1993.

Dynamic and Static Simulations

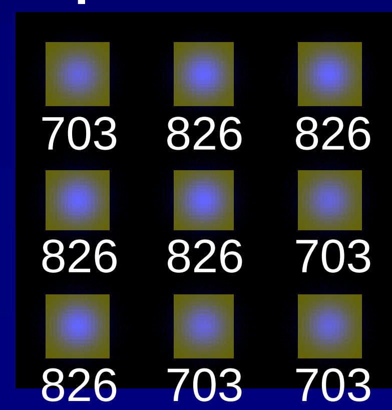


20 µm Modulators

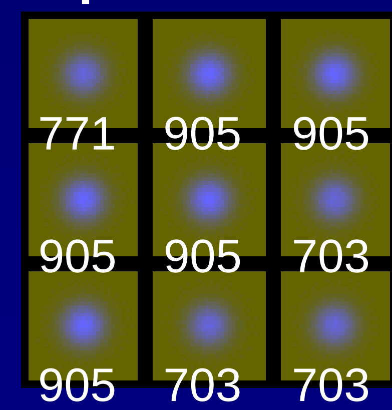


10 µm Detectors

20 µm Detectors



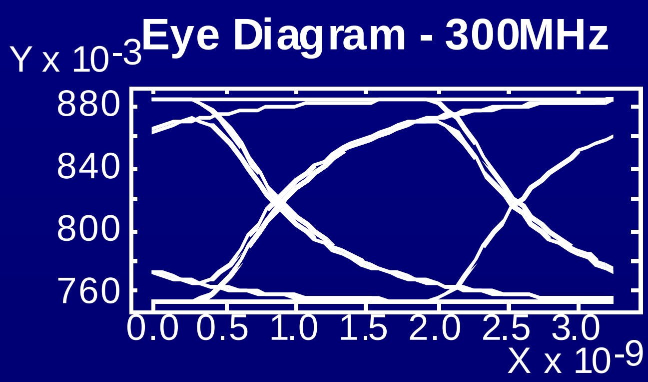
35 µm Detectors

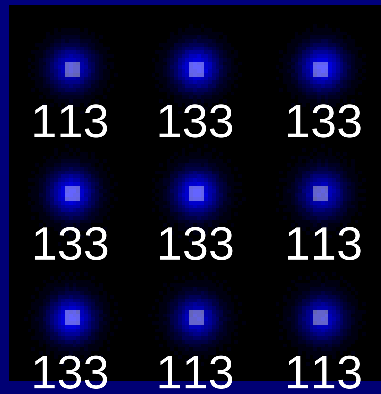


Modulation (Volts)

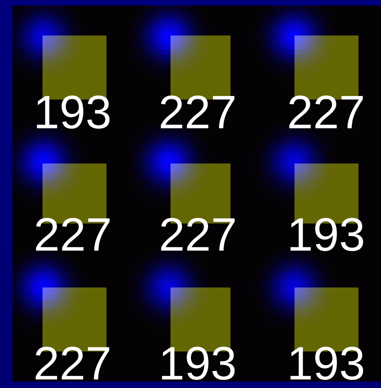
Power (µWatts)

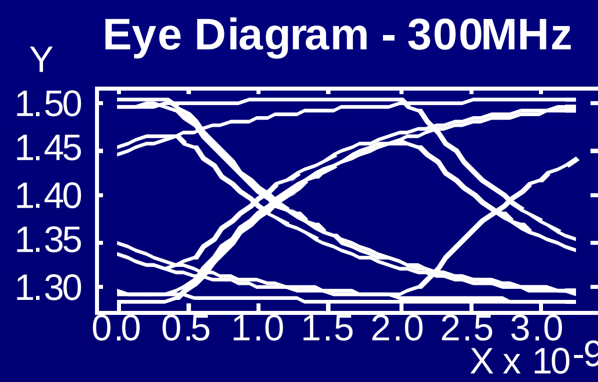
Trade off Simulations





5 µm Detectors

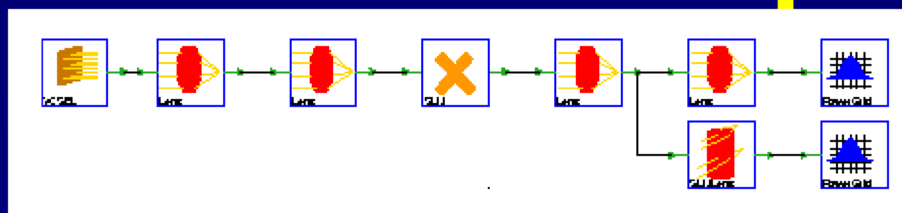


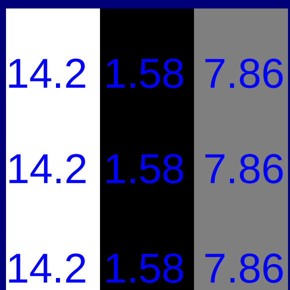


Effect due to Lens Misalignment

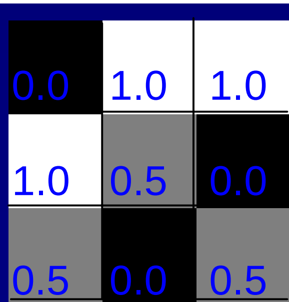
SLM as a Multiplier

Powers are shown in µW



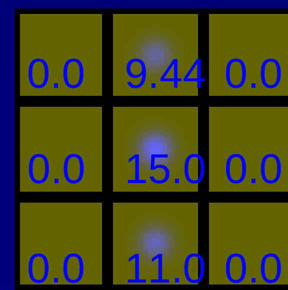


Input



Multiplier

Product Terms



Sum of Products

Conclusions

- Optoelectronic devices and integration technologies are available now
- Tools are necessary to enable the transition from devices to systems without costly and time consuming physical prototypes
- A system level tool provides for performance analysis, with extensions to/from “point tools”
- Interactions with industry device and system designers is critical

Please come see our paper presentation Thursday at 4:30 during paper session 49.1