Chatoyant

Diffractive Optical Propagation Techniques for Mixed-Signal CAD Tools

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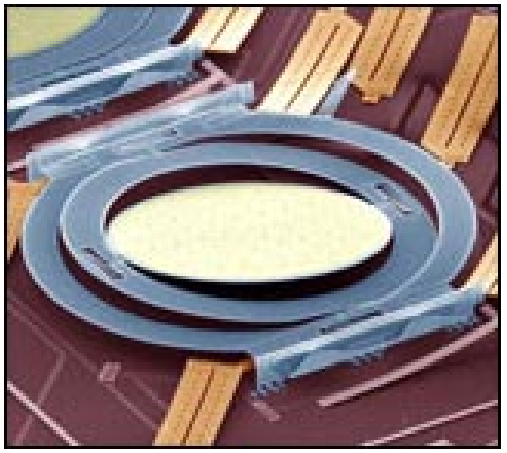
Outline

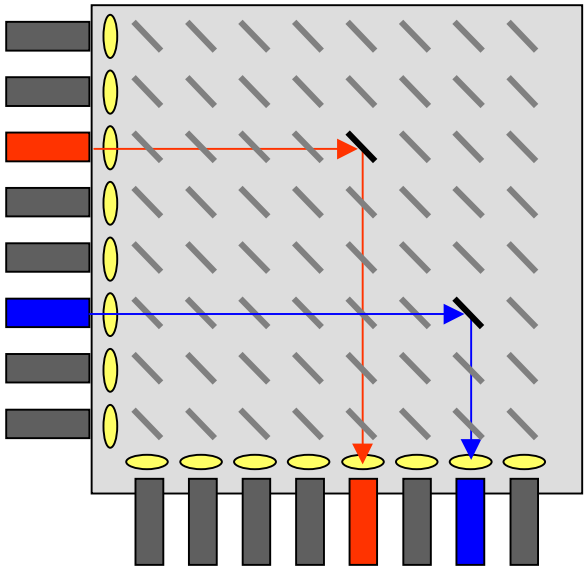
- Motivation: CAD for Micro-Optic Systems
- *Chatoyant*
- Diffractive Optical Propagation
- Simulations & Results
- Conclusions & Future Work

Motivation for Micro-Optic Systems

- Mixed-Technology Micro-Systems (e.g., Optical MEM Switches)
  - Smaller, Faster, Cheaper
  - No O/E conversion
  - Reduce insertion loss and crosstalk
  - Lower power consumption
- CAD for Optical MEM Systems
  - Need mixed-signal analysis
    - Have single domain tools
  - Need interactive design
    - Have slow computation tools
  - Need system-level analysis
    - Have device-level models

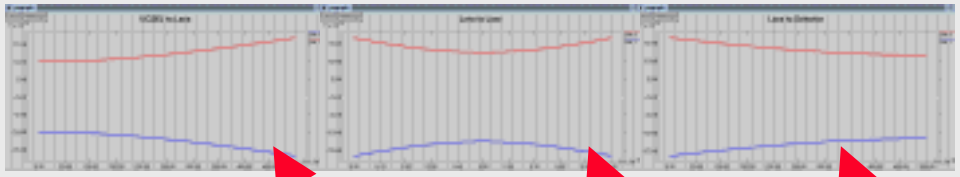


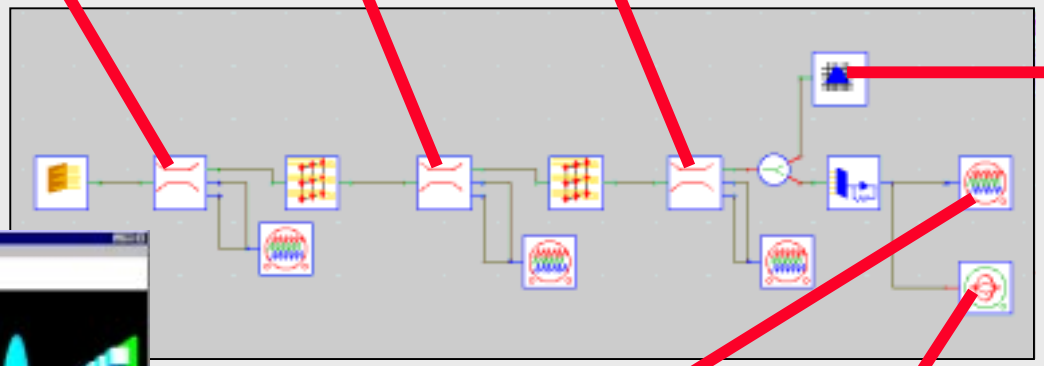
Lucent - http://www.lucent-optical.com/

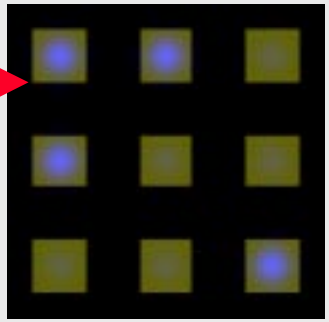


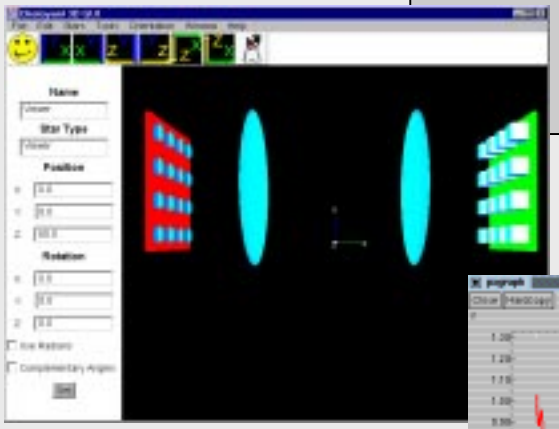
Lin et al., IEEE Phot. Letters, April 1998.

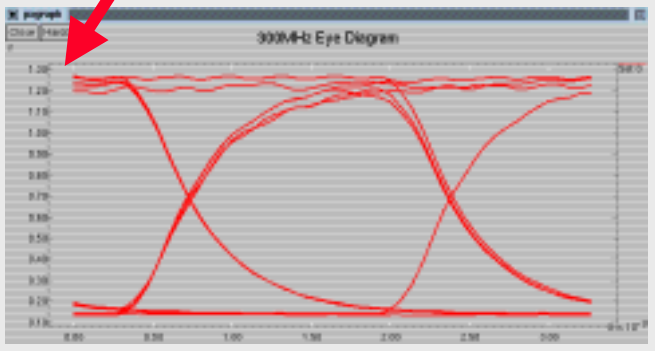
Chatoyant



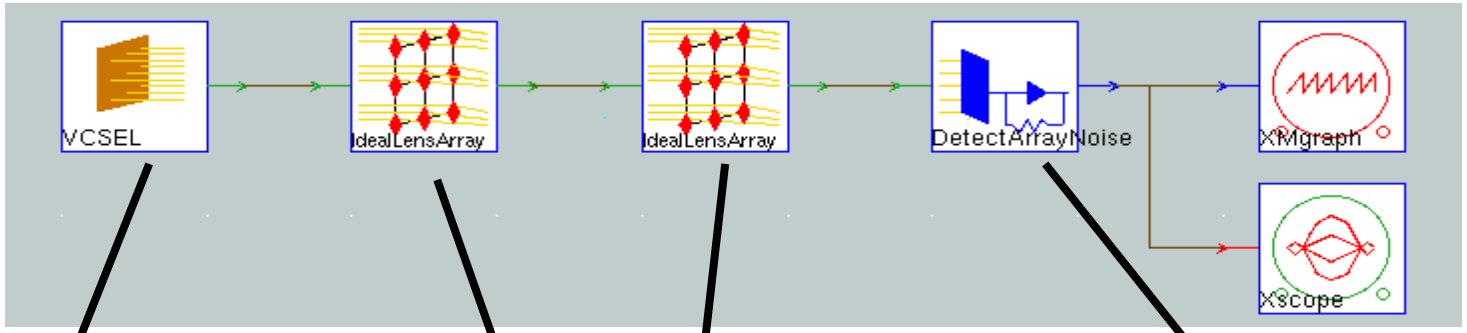




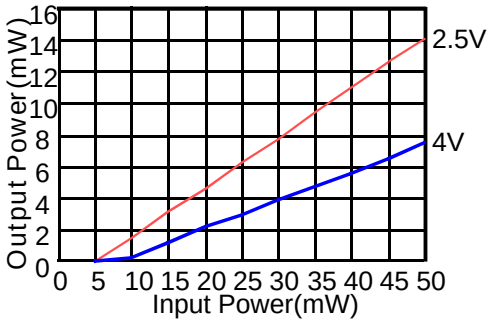




Chatoyant - O/E CAD Tool



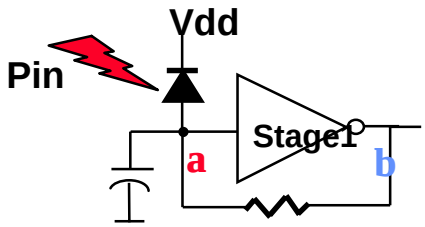
Empirical models



Analytic models

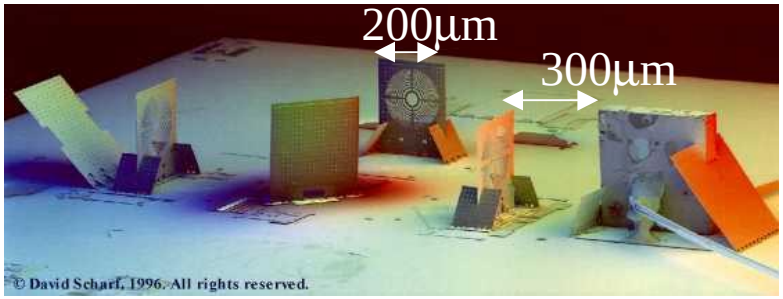
$$I(r,z) = I_0\left[\frac{W_0}{W(z)}\right]^2 \exp\left[-\frac{2r^2}{W^2(z)}\right]$$

Derived models

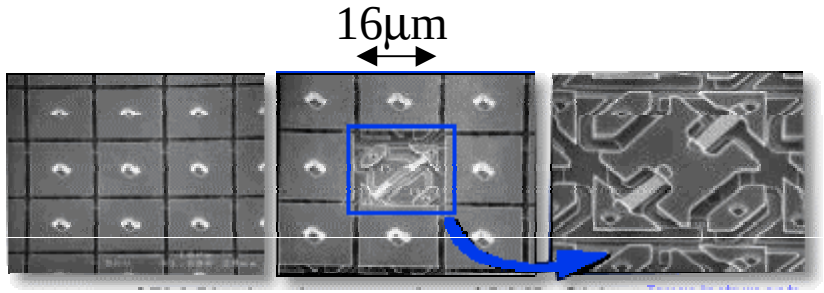


Extending Chatoyant for Optical MEM Systems: Optical Propagation

- Optical MEM System Requirements
  - Refractive and diffractive components
  - Component sizes and propagation distances ~10-1000 μm
  - Interface with fiber based tools



UCLA - Integrated Free-Space Optical Disk Pickup Head
http://www.ee.ucla.edu/labs/laser/



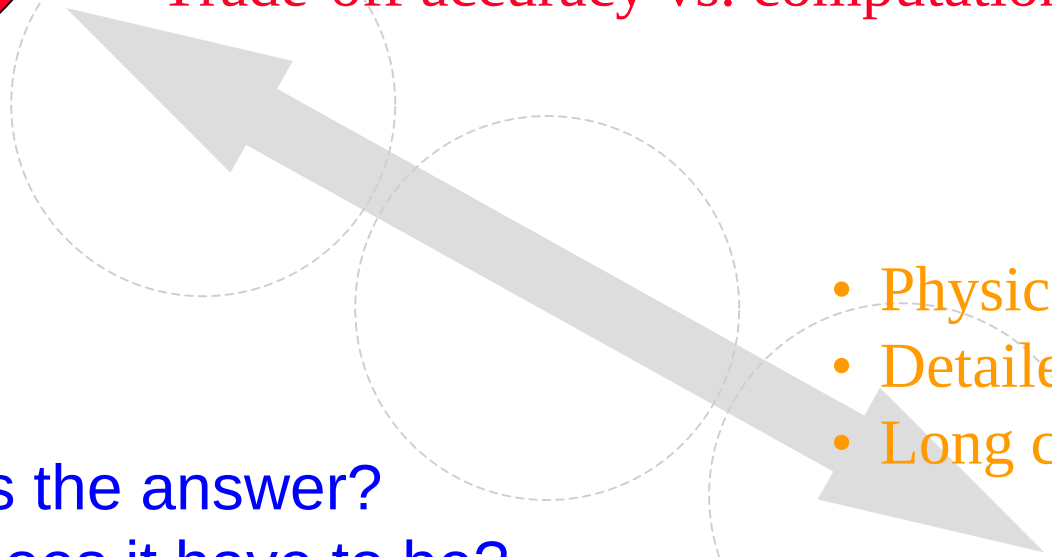
Texas Instruments - DMD - From DARPA
http://www.darpa.mil/ETO/MOEMS/DMD/index.html

- CAD Tool Requirements
  - Interactive, fast simulation
  - Support for optical power, intensity, phase, etc.

System Level vs. Device Level

System Level

- Top-down, interactive simulation
- Model large systems and interactions between domains
- Trade-off accuracy vs. computation time



- Physics based models
- Detailed & exact
- Long computation time

Device Level

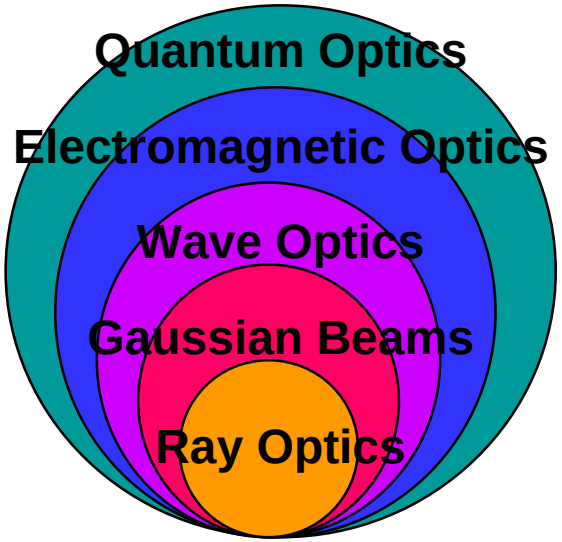
How good is the answer?

How good does it have to be?

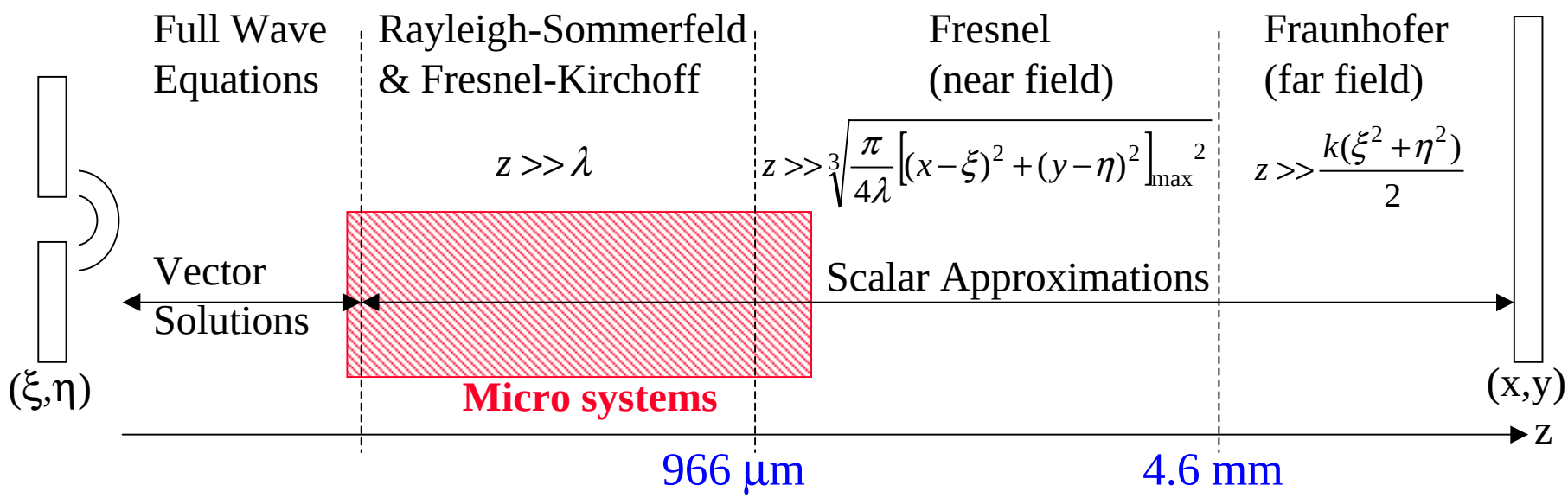
- More detailed models at higher levels
- Reduced order models
- Physical prototyping

Optical Propagation Models

- Ray Propagation
- Gaussian Propagation
  - 9 scalar parameters - z_0, x, y, λ, etc.
  - Fast simulation - no wavefront integration
  - Laser sources
  - Limited diffraction modeling
- Scalar Propagation
  - 2D complex wavefront
  - Propagation by summation of wavefronts
  - Supports diffraction
  - Validity of approximation techniques
- Vector Solutions
  - Computationally intensive



Validity of Scalar Models



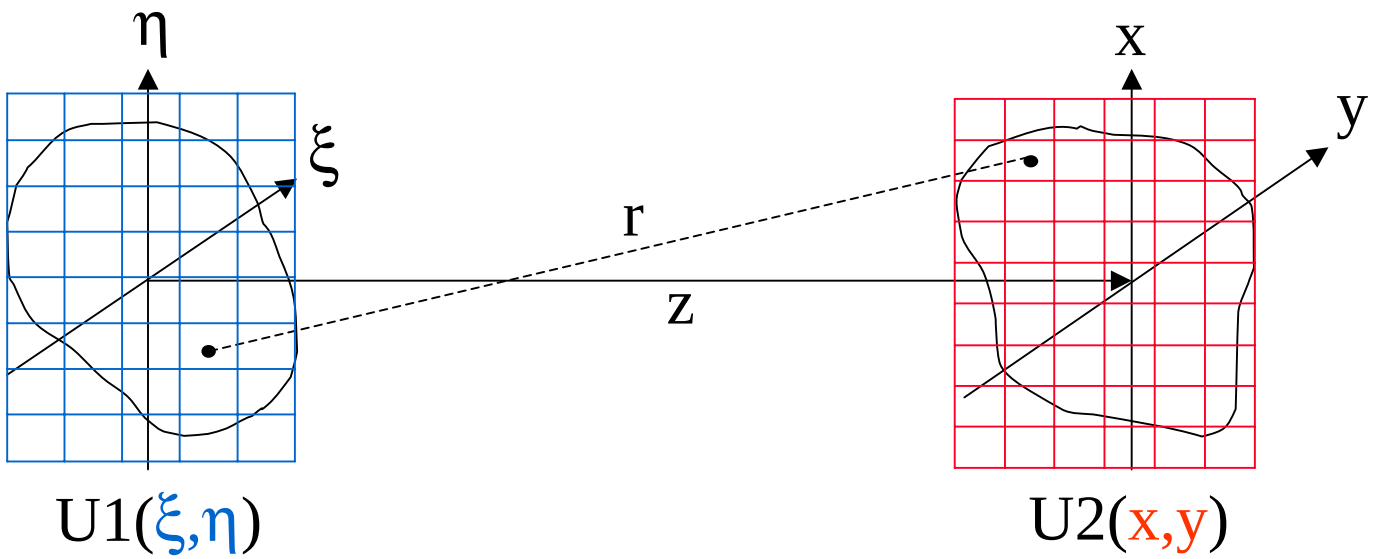
Example: 50 μm Aperture, 200 μm Observation, λ=850 nm

- Fraunhofer Approximation - Assume planar wavefronts
- Fresnel Approximation - Assume parabolic wavefronts
- Rayleigh-Sommerfeld Formulation - Spherical wavefronts

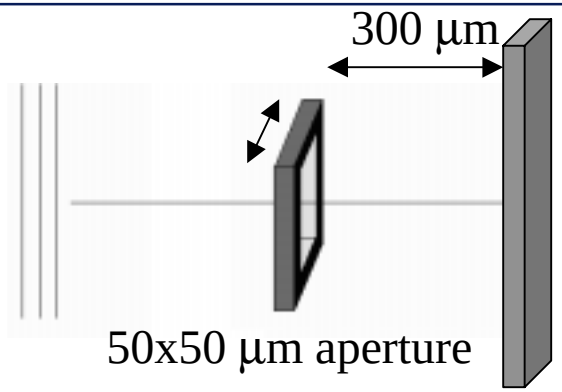
Rayleigh-Sommerfeld Formulation

- Scalar Diffraction - Rayleigh-Sommerfeld Formulation
  - Diffractive component >> λ
  - Distance to observation plane >> λ

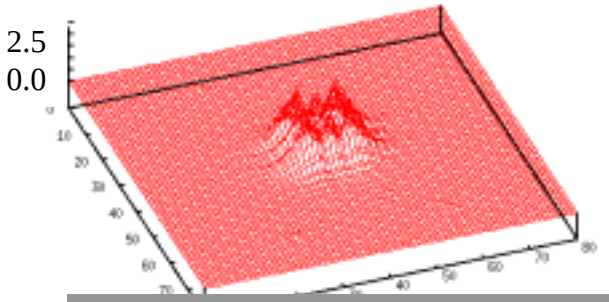
$$U2(x,y) = \frac{z}{j\lambda}\iint U1(\xi,\eta)\frac{e^{jkr}}{r^2}\partial\xi\partial\eta$$



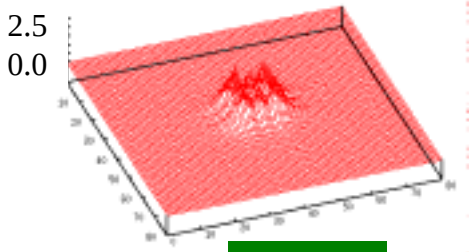
Computation Performance of Scalar Diffraction



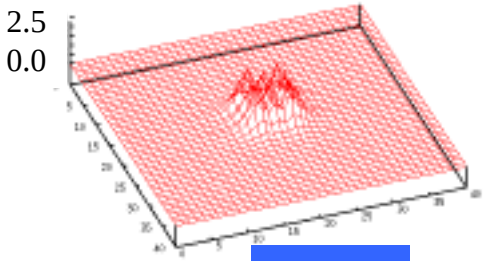
200x200 µm observation plane



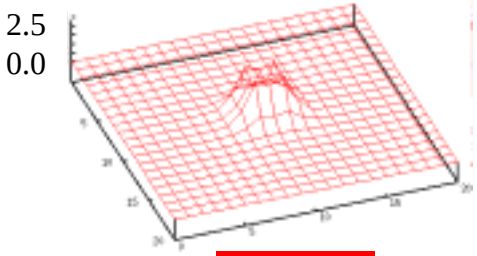
80x80 MathCAD - Base Case



80x80



40x40



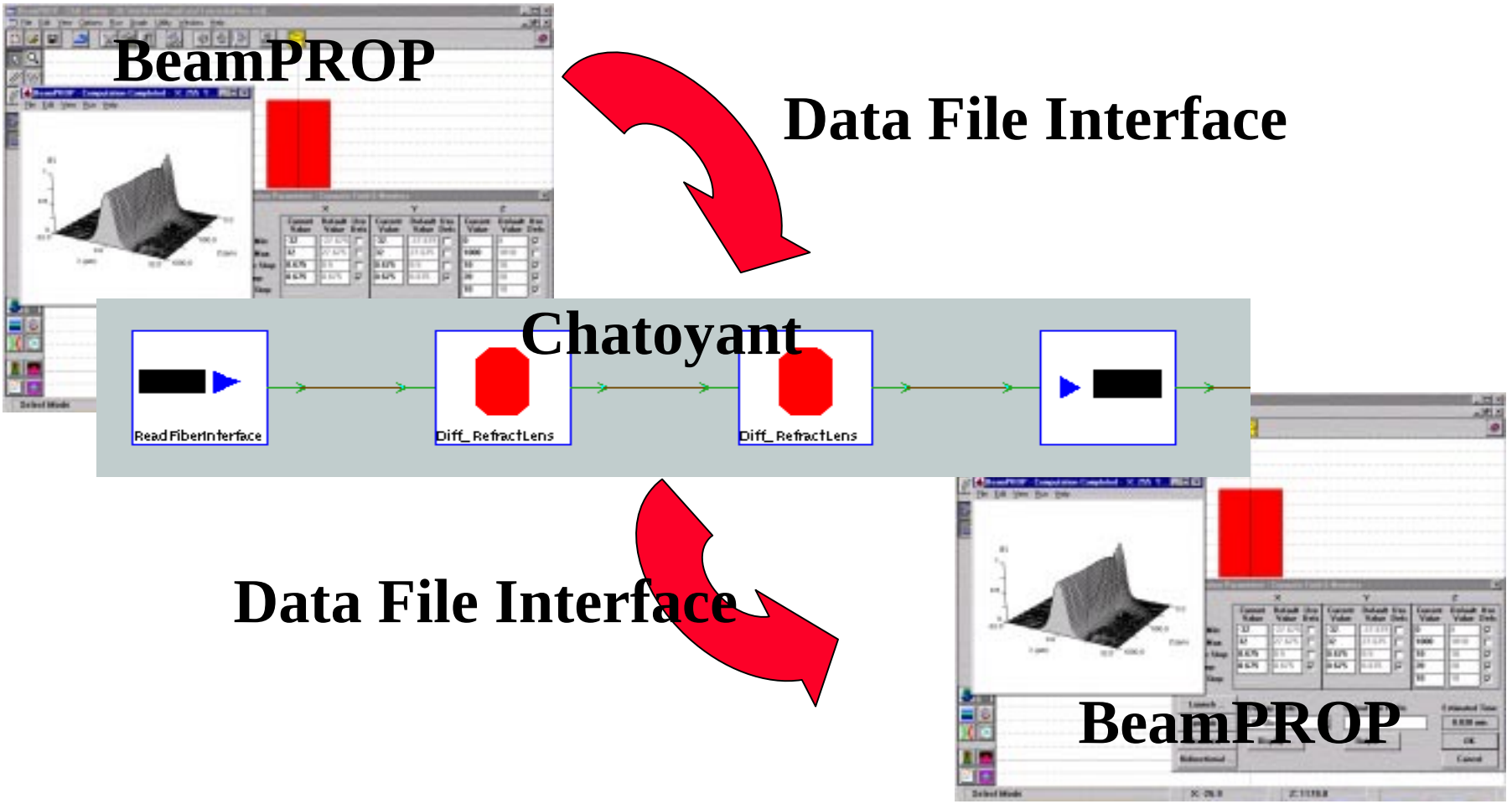
20x20

	Chatoyant		MathCAD	
	Time (min)	Difference (%)*	Time (min)	Difference (%)*
160x160	17.75	X	X	X
80x80	**4.45**	**0.637**	**120**	**0**
40x40	**1.1**	**1.67**	20	1.54
20x20	**0.29**	**3.37**	7	4.32

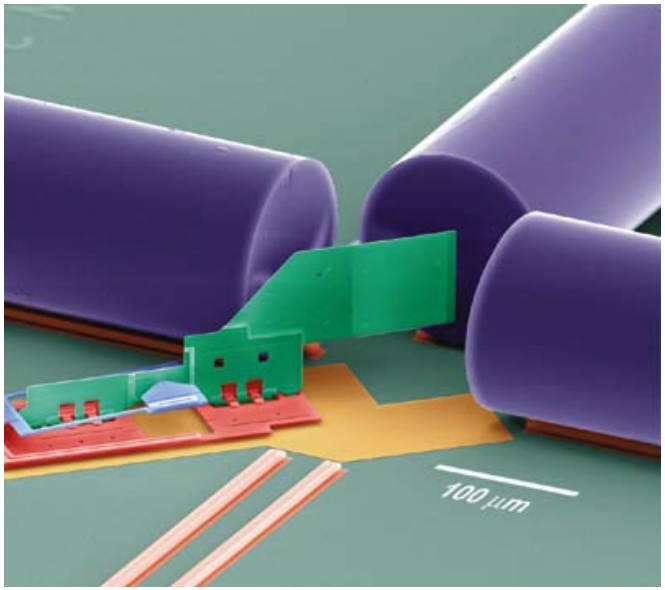
* % difference of grid cells with respect to 80x80 MathCAD

Fiber Interface

- Interface with RSoft's BeamPROP through data files representing the complex wave function

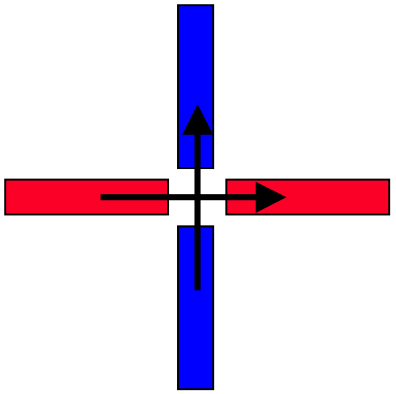


Optical MEM 2x2 Switch Simulations

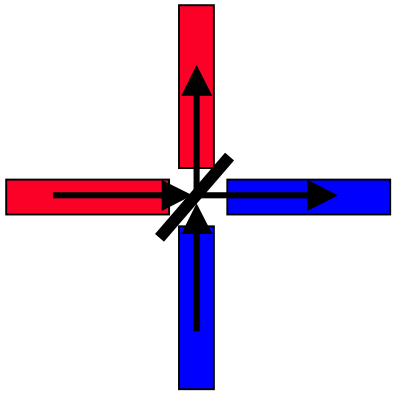


Bell Labs- http://www.bell-labs.com/

- Switching achieved by:
  - "See-saw" pivoting mirror
    - Bell-Labs
  - Scratch drive actuators
    - AT&T
    - UCLA
  - Combdrive actuator
    - University of Neuchael, Switzerland

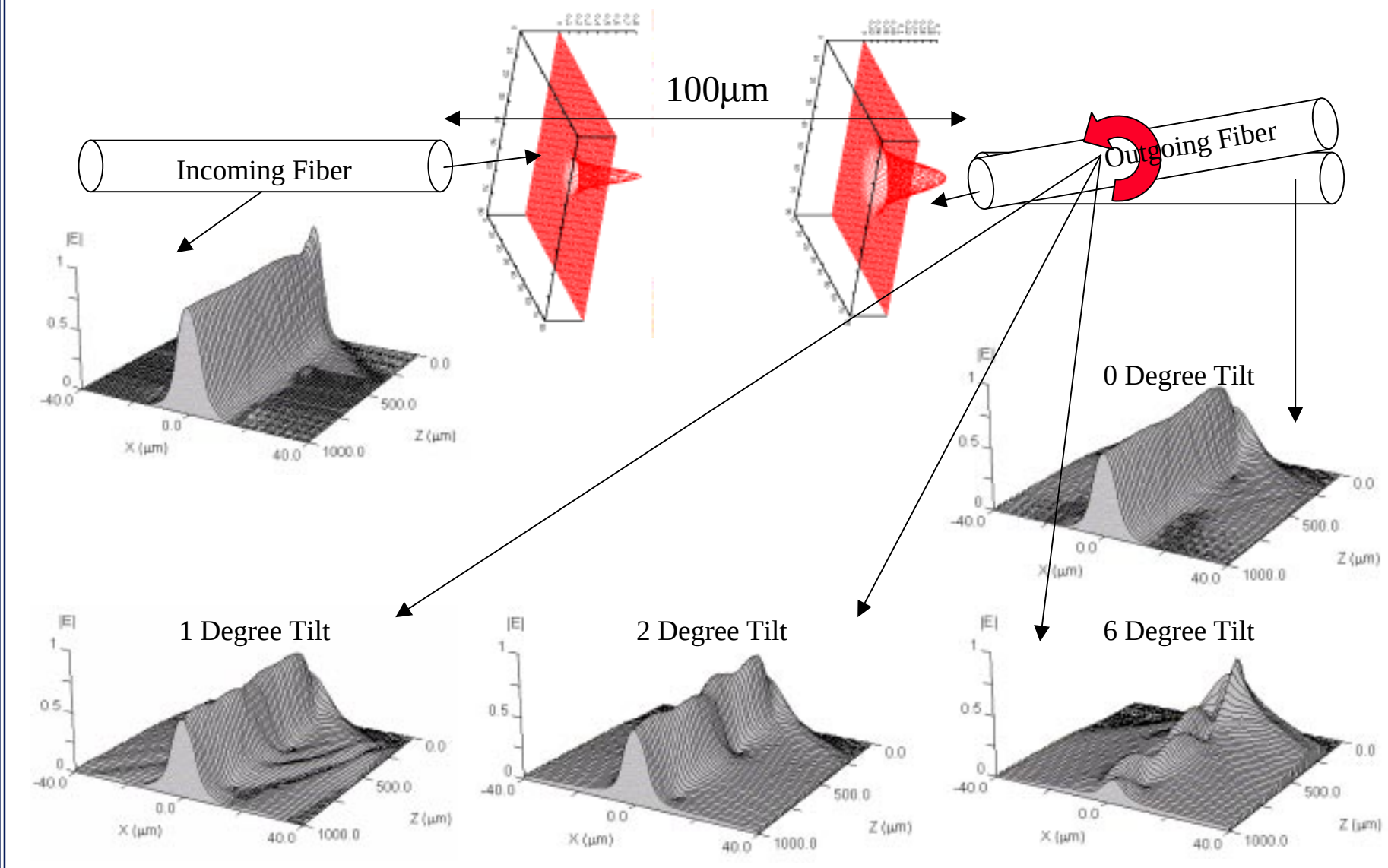


Cross State

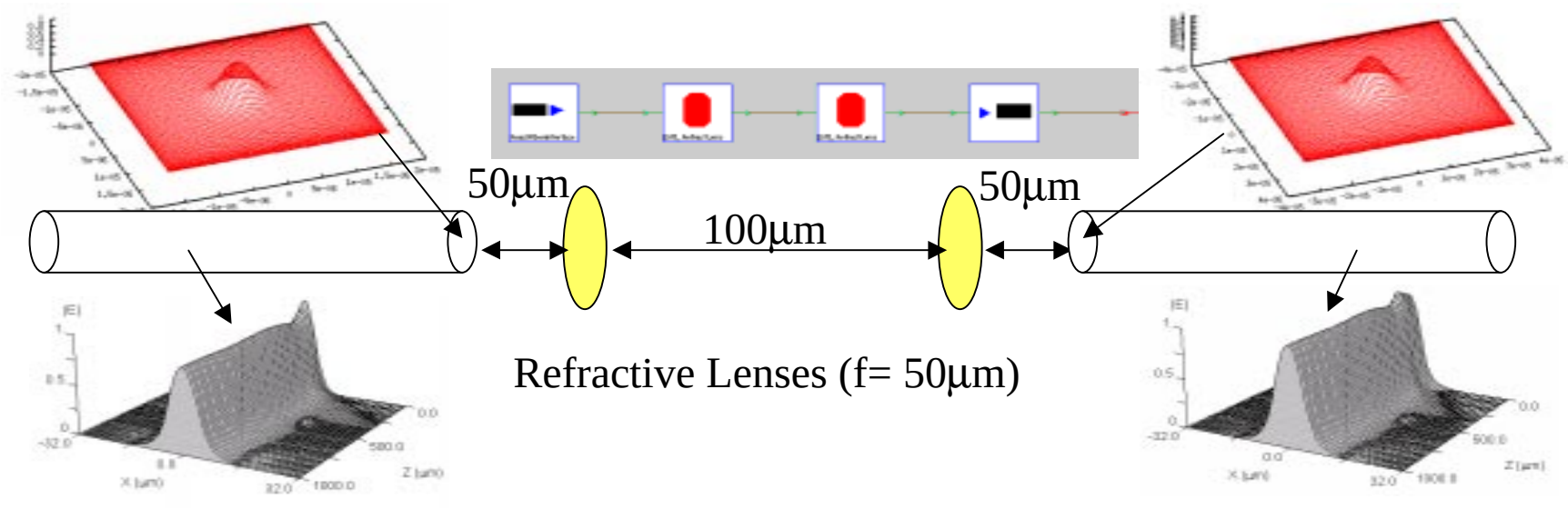


Bar State

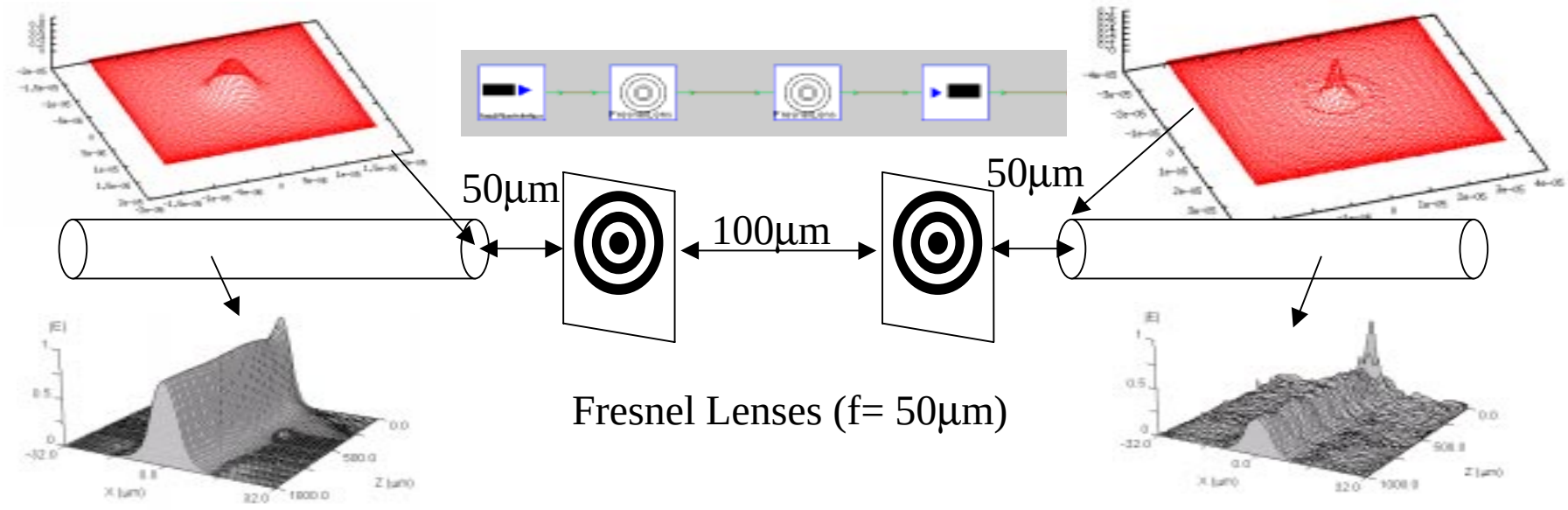
Mechanical Tolerancing of Fiber



Adding Collimating Lenses

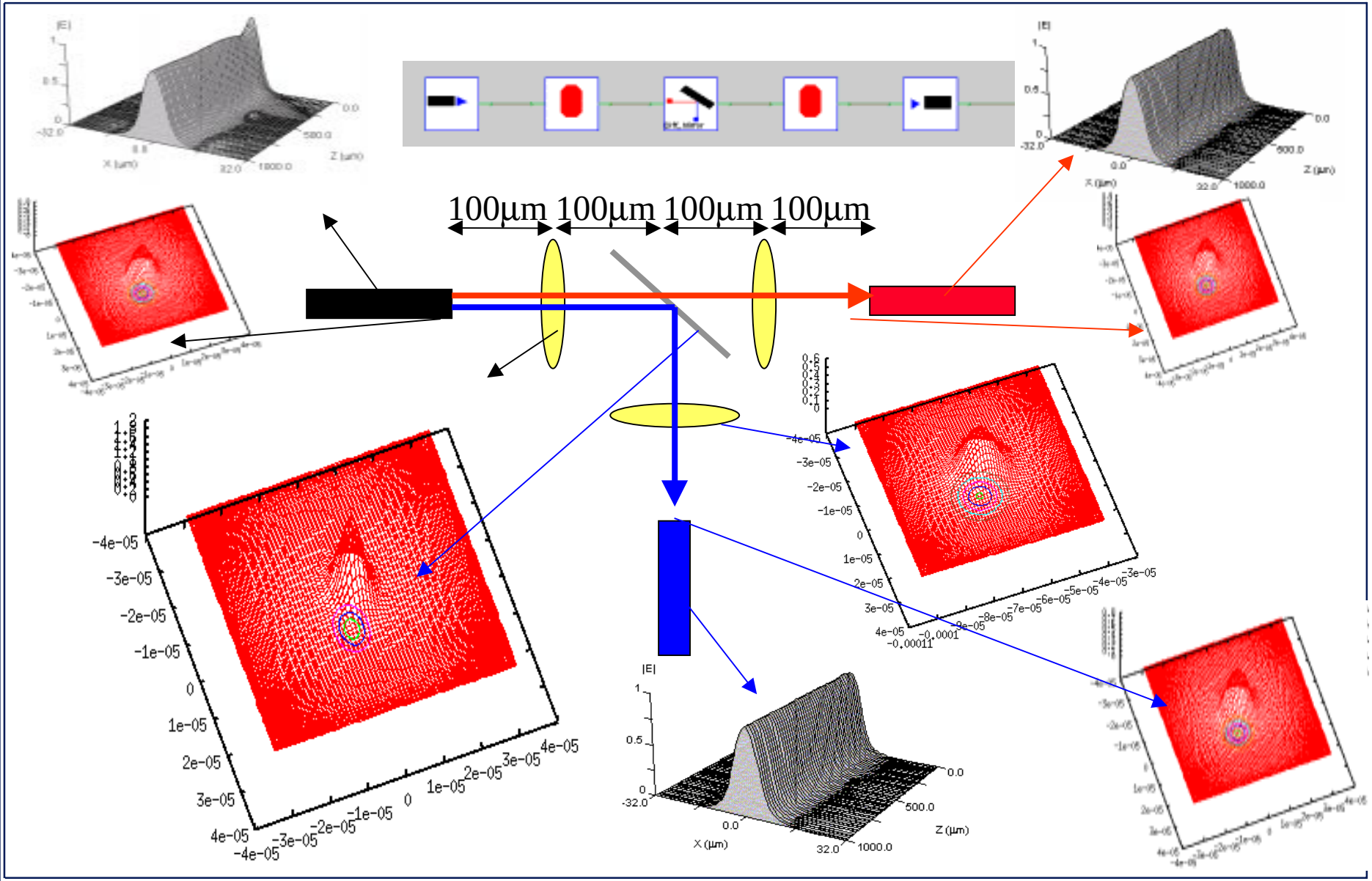


Refractive Lenses (f= 50µm)



Fresnel Lenses (f= 50µm)

Simulation of Optical Switch Link



Conclusions & Future Work

- ✓ CAD is needed for modeling optical MEMS
- ✓ Scalar wave modeling for micro-optical systems
  - Rayleigh-Sommerfeld
- ✓ Accurate and interactive
- Model fiber/free-space interface, non-uniform components, and reflective and scattering effects
- Model mechanical movement and positioning of the switching mirror
- Model and simulate WDM add/drop switching networks