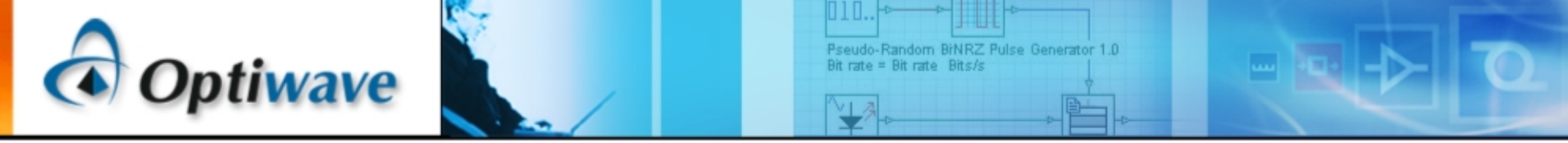
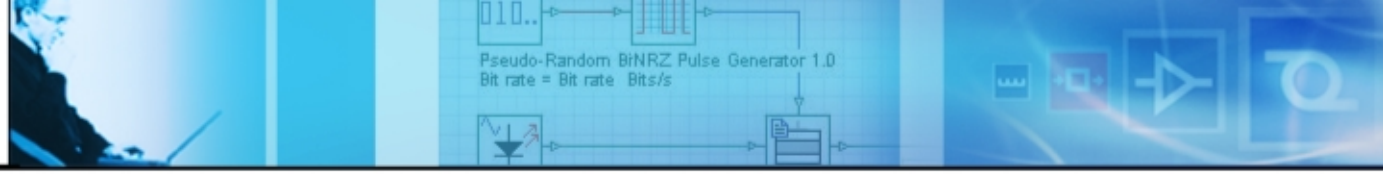
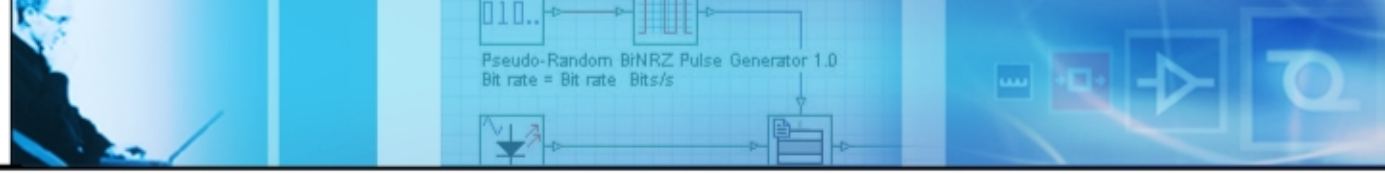


Introduction to Optical Amplifiers: Simulation, Automated Design and Analysis



Outline

- Types of Optical Amplifiers
- Typical configurations
- OptiAmplifier
- Designing Optical Amplifiers



Types of Optical Amplifiers

- Semiconductor Optical Amplifiers (SOAs)
- Erbium Doped Fiber Amplifiers (EDFAs)
- Raman Amplifiers
- Hybrid Amplifiers

Types of Optical Amplifiers

- In the early 1980s, attention was focused on Raman fiber amplifiers (RFA's) and semiconductor optical amplifiers (SOA's)
- The RFA is based on the nonlinear effect of stimulated Raman scattering - undoped glass fiber core represents the gain medium
- In the mid-1980s, a group led by D.N. Payne at the University of Southampton developed a technology of rare earth ions deposition in single-mode silica fibers and in 1987 the first EDFA was introduced

Types of Optical Amplifiers

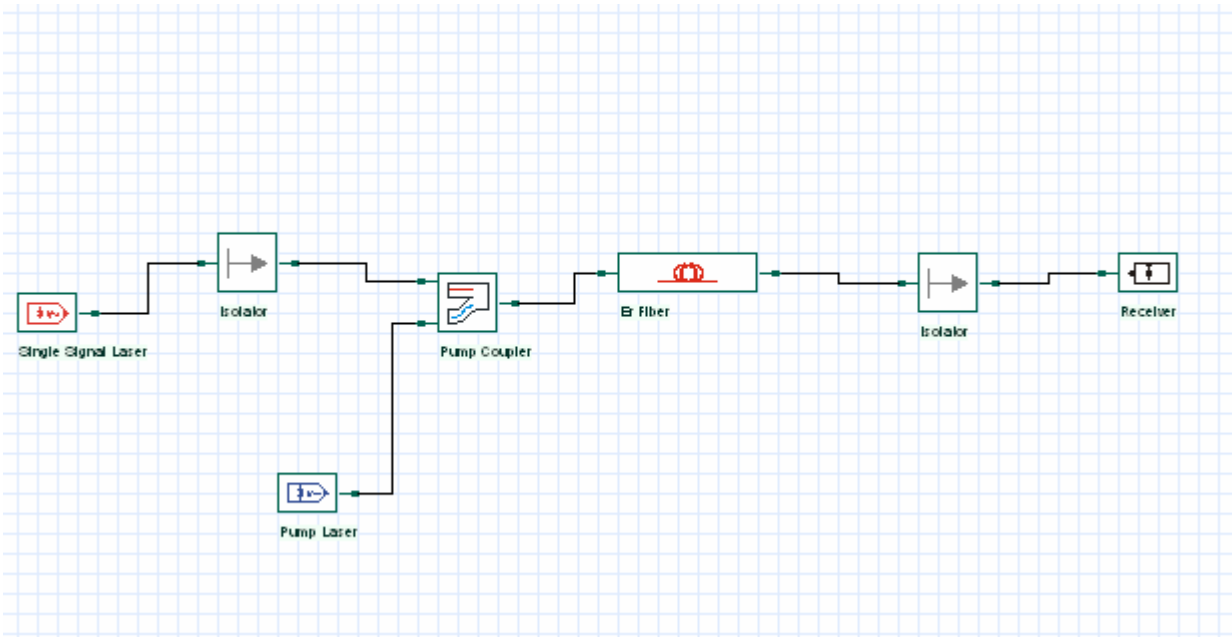
- The stimulated emission coefficient is proportional to pump power density in the core - to achieve reasonable gains with currently available pump LDs, fibers with either small core radius or large NA (not compatible with standard communication fibers) must be used .
- Gain of the SOA is polarization dependent, due to a short lifetime of charge carriers in semiconductors SOA suffer from large inter-modulation distortion and cross-talk.
- Optical amplifiers are bit rate transparent, can amplify signals at different wavelength simultaneously, in contrast to electronic regenerators they are insensitive to the type of signal modulation.

Types of Optical Amplifiers

- SOAs find new applications as wavelength converters in WDM networks.
- With the progress in the manufacture of high-power pump lasers, along with the demand for amplification bandwidth, Raman amplification is playing an important role in WDM communications.
- Hybrid amplifiers: EDFA + Raman

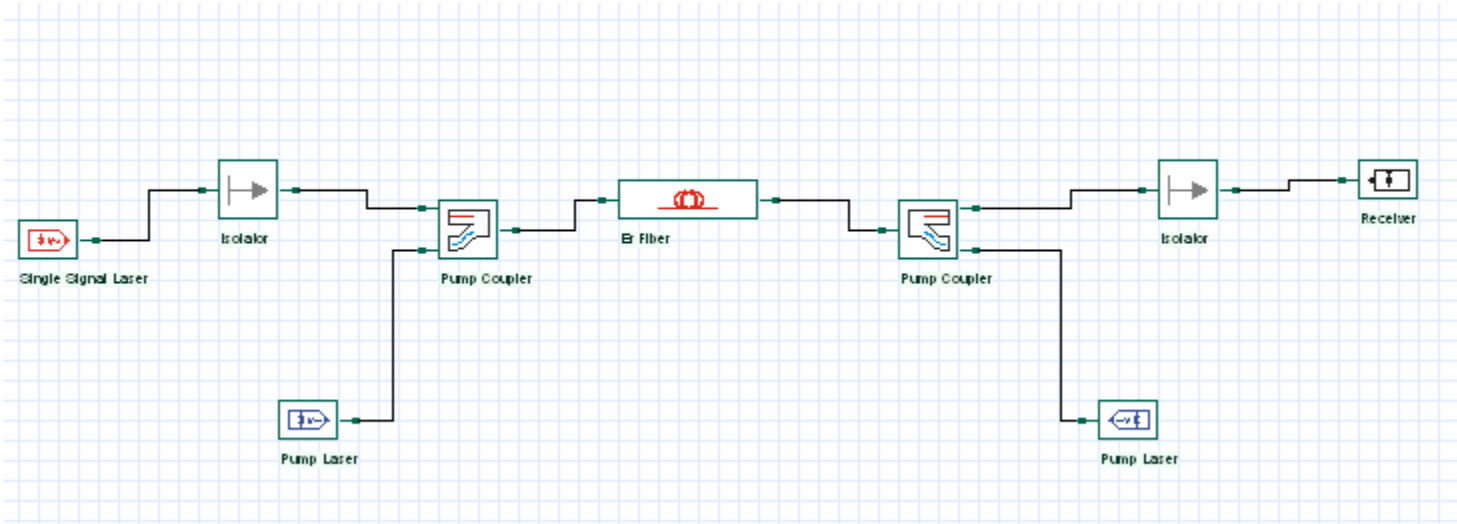
Typical Configurations

Co-propagating pump



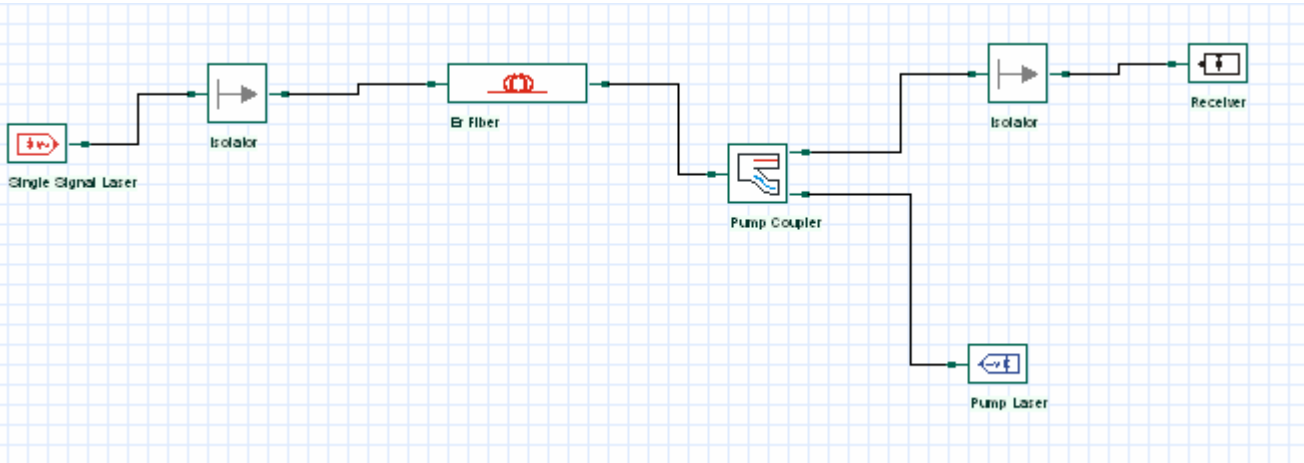
Typical Configurations

Bi-directional pump



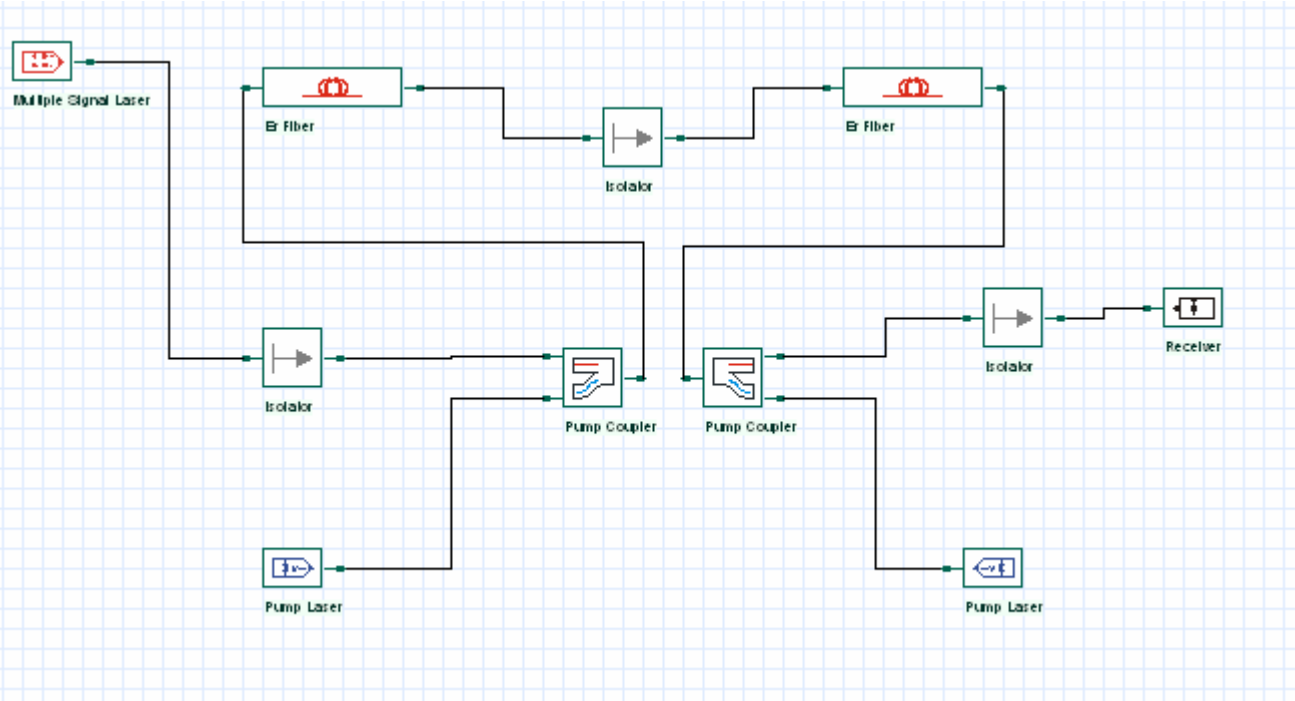
Typical Configurations

Counter-propagating pump



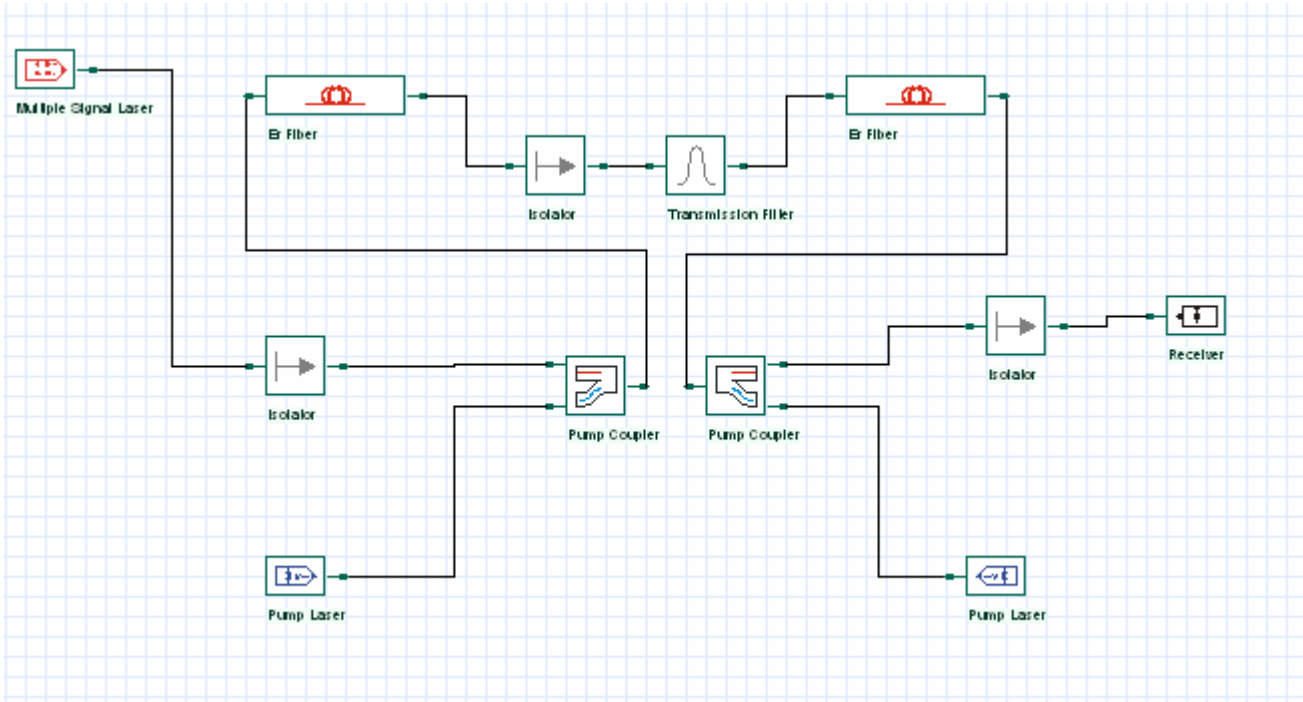
Typical Configurations

Multi stage



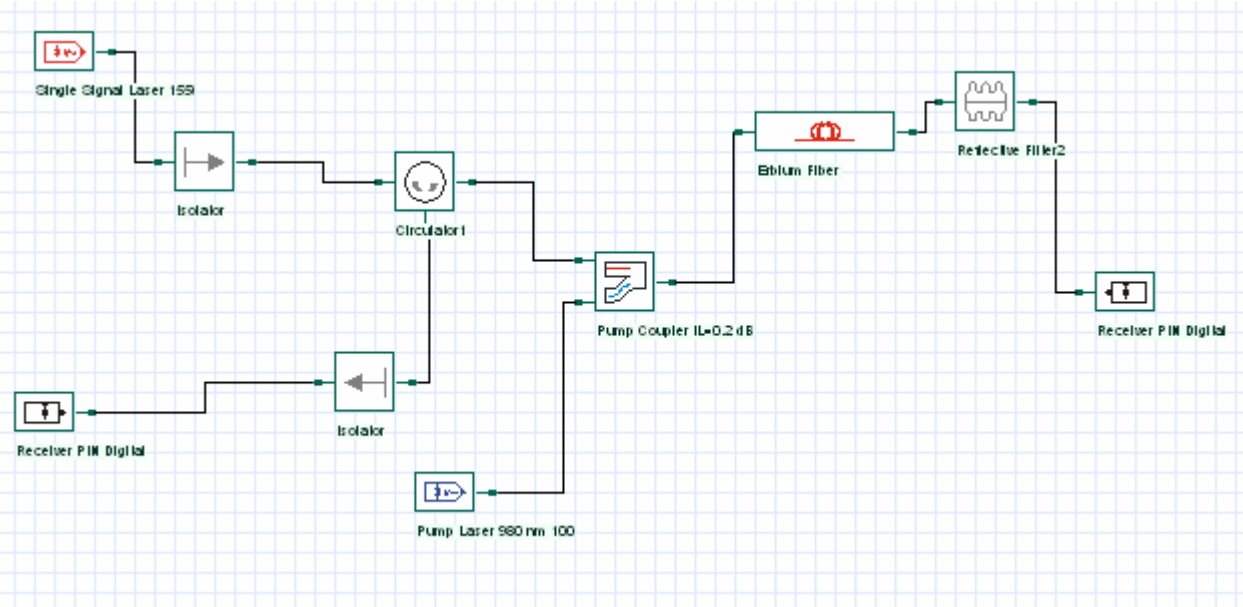
Typical Configurations

Multi stage gain flattened



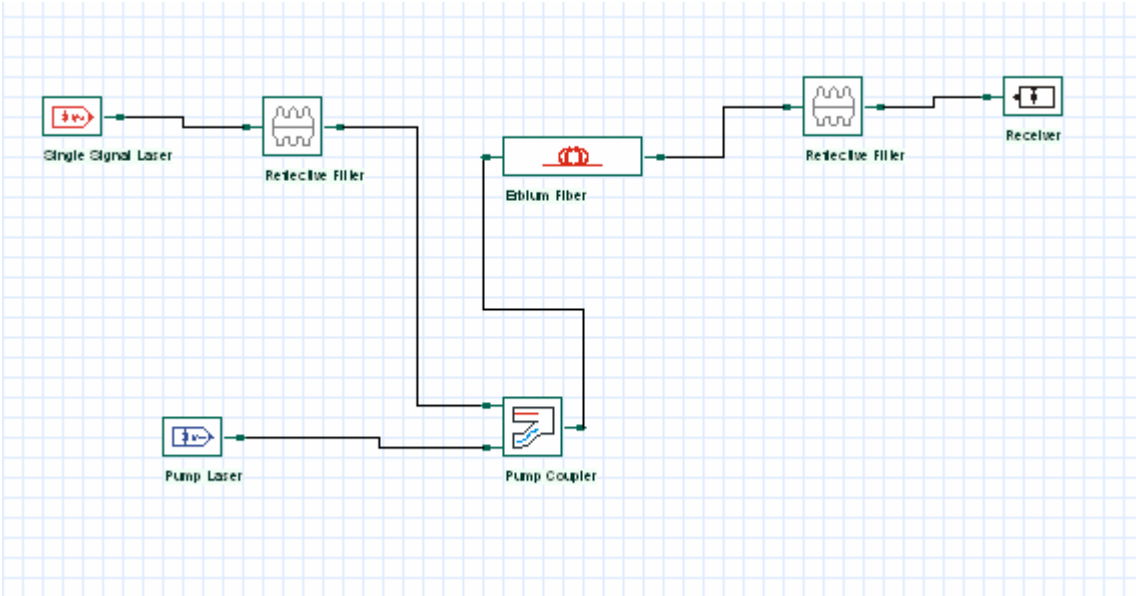
Typical Configurations

Reflective amplifier



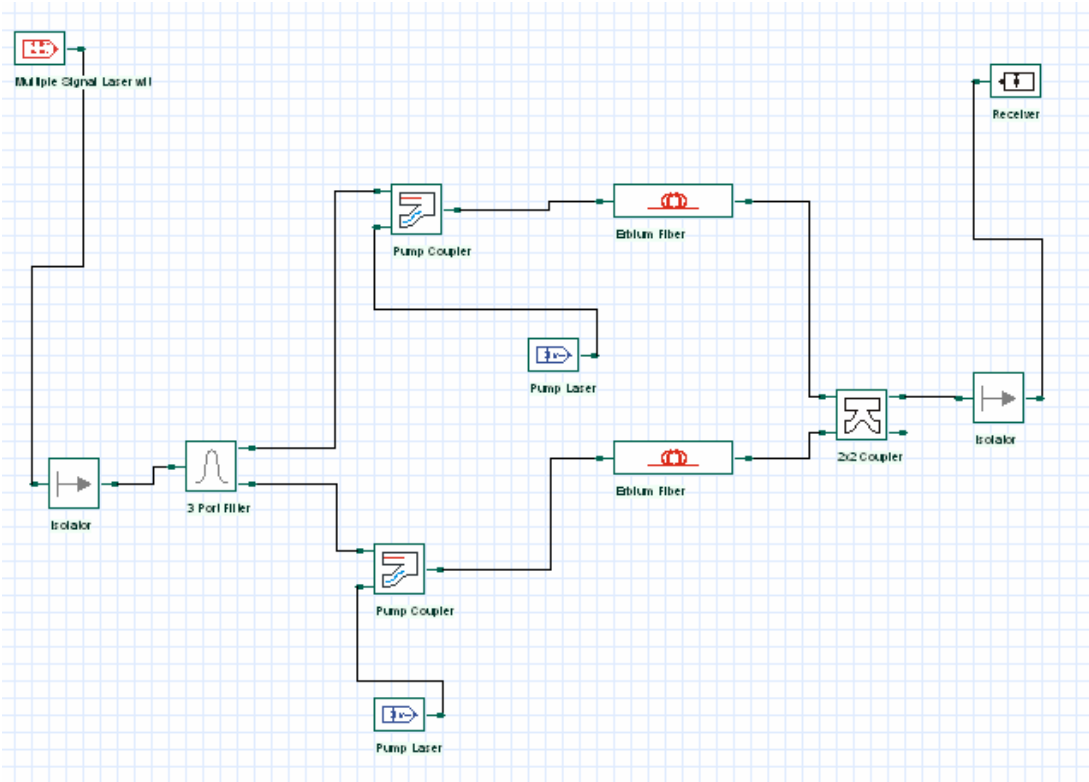
Typical Configurations

Gain clamped



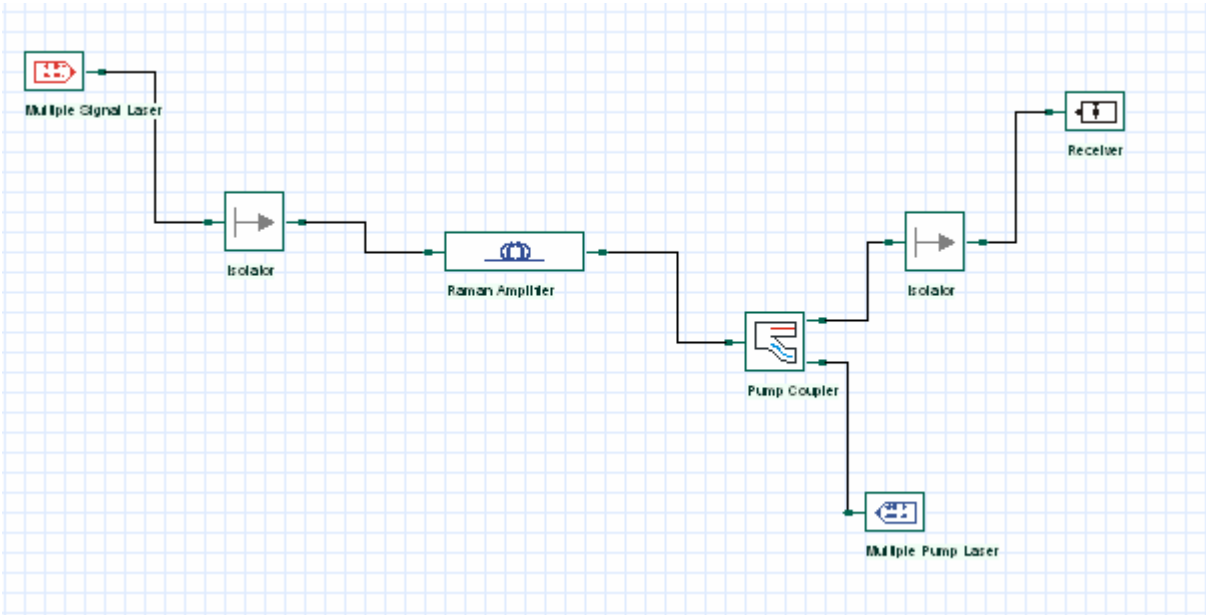
Typical Configurations

Split band



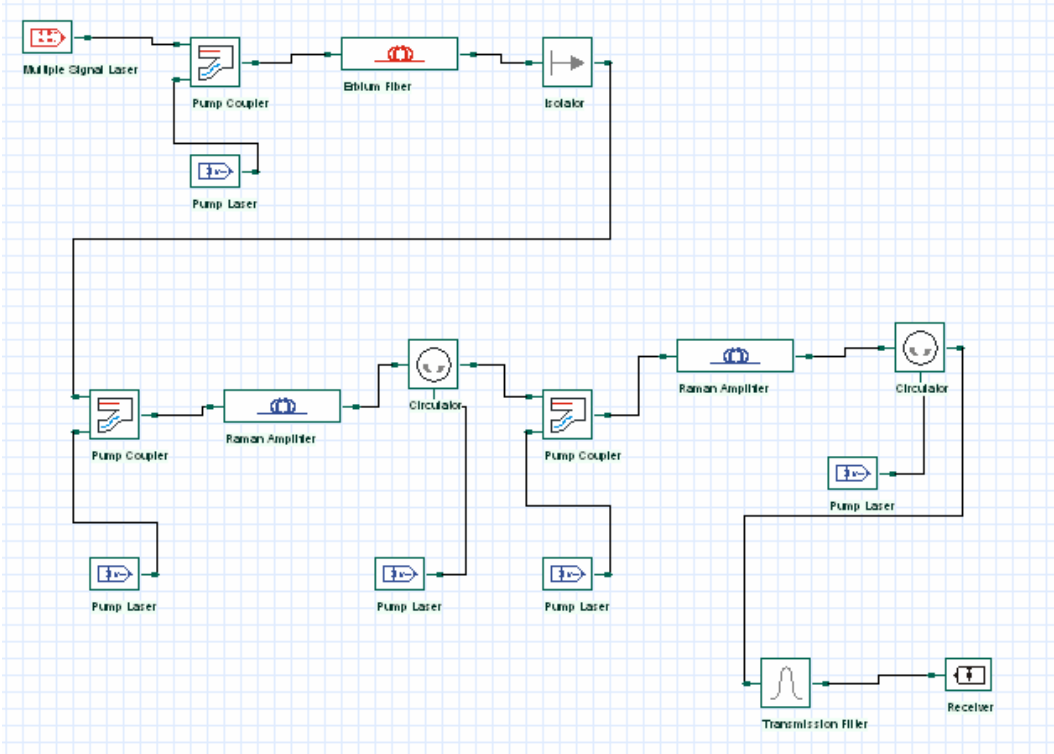
Typical Configurations

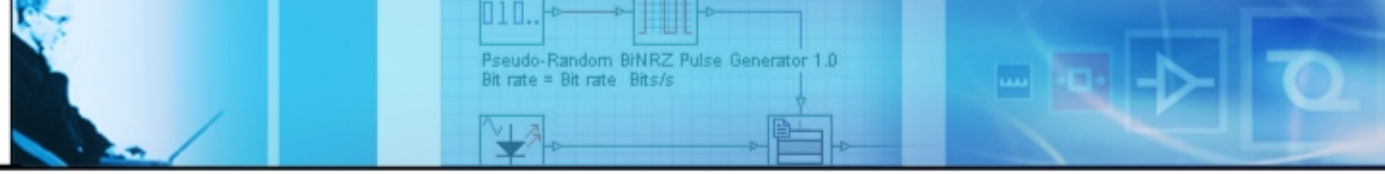
Raman counter-propagating pump



Typical Configurations

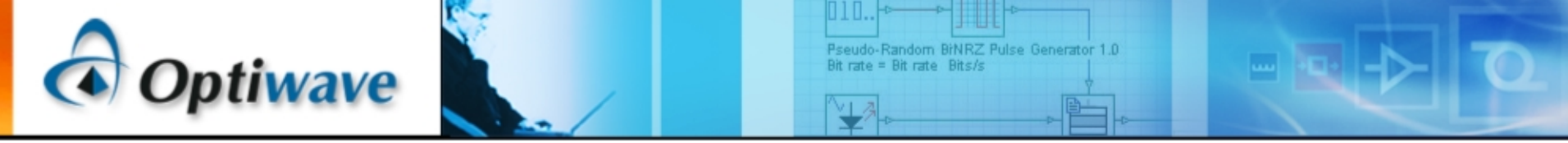
Hybrid amplifier





Designing Optical Amplifiers

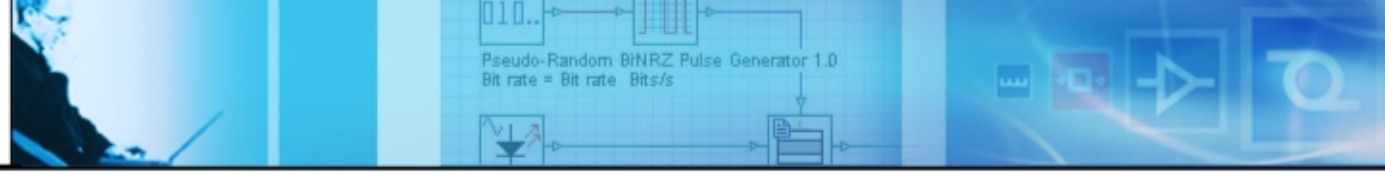
Software can assist in determining the tradeoff between optical amplifiers cost and performance by calculating how metrics such as minimum output power, maximum noise figure, maximum gain ripple, and minimum pump power depend on device specifications such as pump wavelength range, passive component losses, and component costs.



OptiAmplifier

Optical Fiber Amplifier and Laser Design Software

Innovative software for the design, simulation, and optimization of optical fiber amplifiers and lasers, thus, enabling the analysis of component performance in fiber links and systems



Typical Applications

- **Single & multi-stage,reflective & split-band amplifiers for CATV or WDM networks**
- **Optically gain-clamped hybrid amplifiers & fiber lasers**
- **ASE broadband sources**
- **Amplified system BER and link budget calculations**
- **Amplifier parameters optimizations**

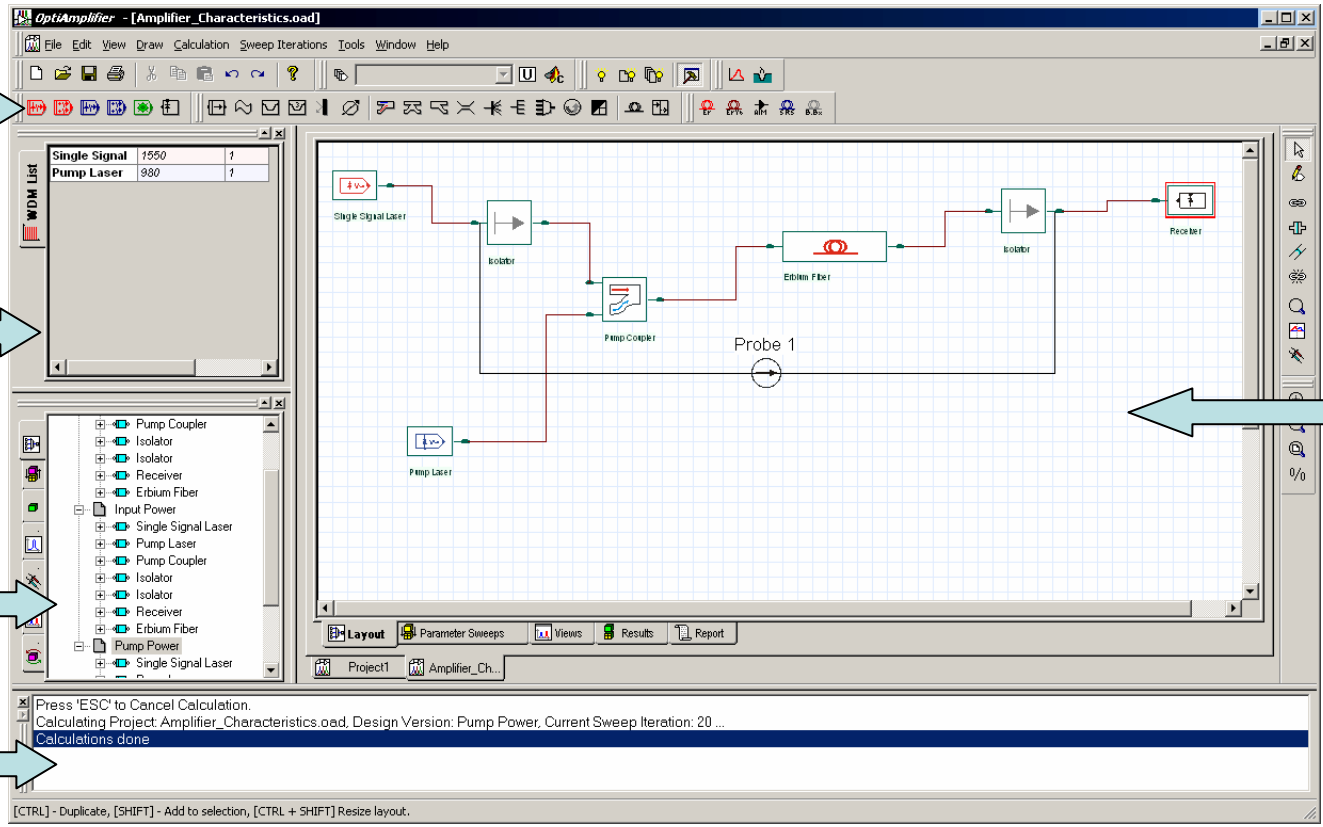
OptiAmplifier

Component Library

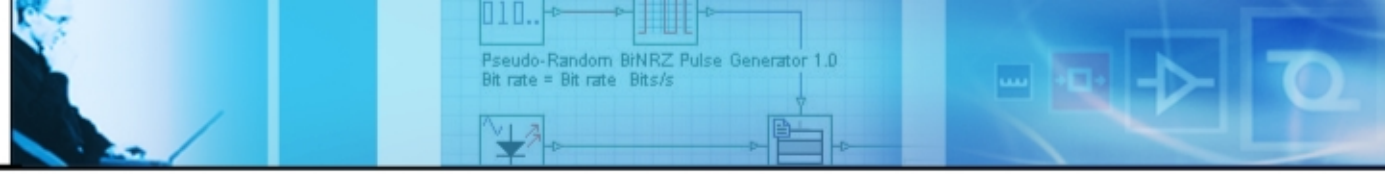
WDM List

Project Browser

Output Window



Layout Editor



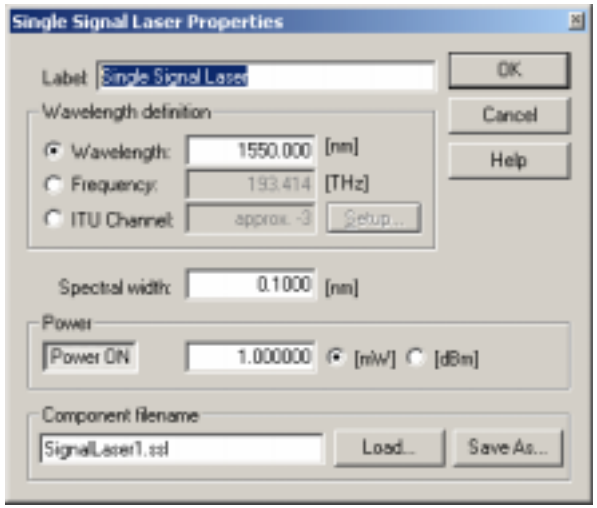
Main Elements

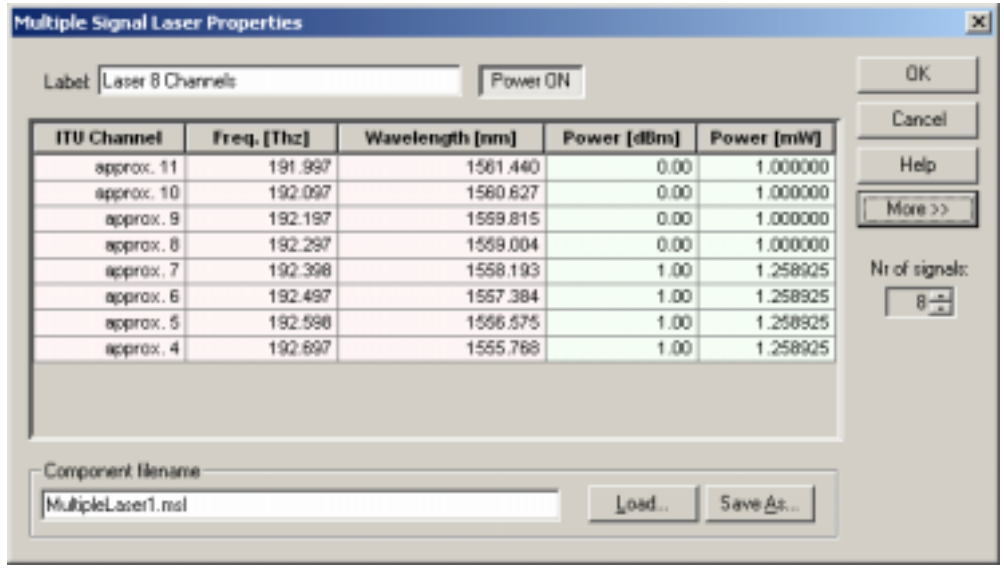
- Component Library
- Bidirectional Data Flow
- GUI (Graphical User Interface)

Component Library

- Erbium doped fibers and Black-Box EDFAs
- Erbium-Ytterbium codoped fibers
- Raman amplifier
- Pump and 1550 nm lasers
- Pump couplers and combiners
- Isolators and circulators
- APD and PIN digital and analog receivers and monitors
- Transmission and reflection filters (two and three port)
- WDM multiplexers
- Taps, splitters, connectors, splices
- Single-mode fibers
- Variable attenuators and reflectors
- 2x2 and 1xN Switches
- White light source, OSA, Power meter, BER
- Matlab and scripted components

Active Components





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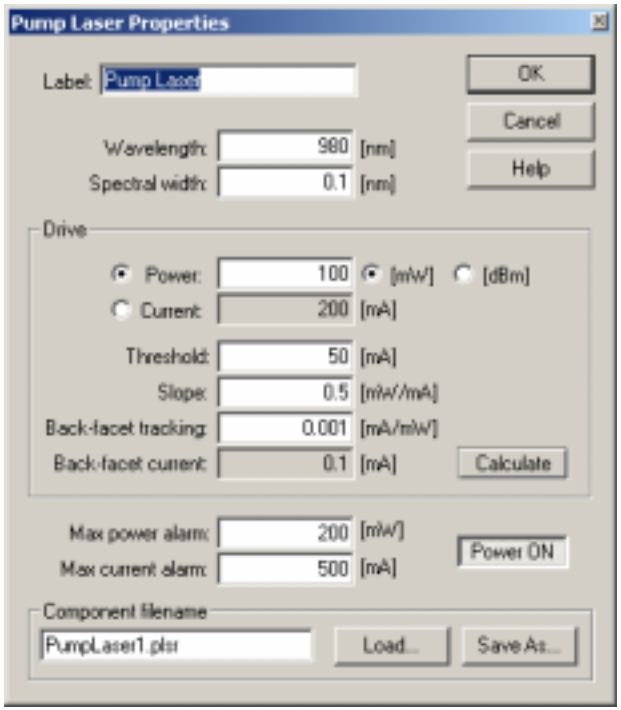

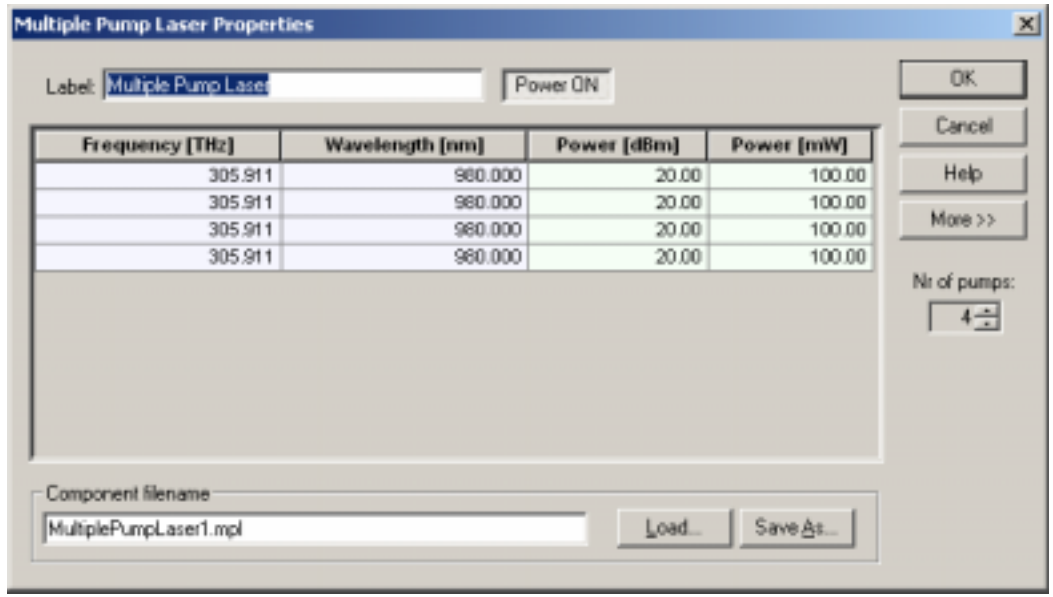

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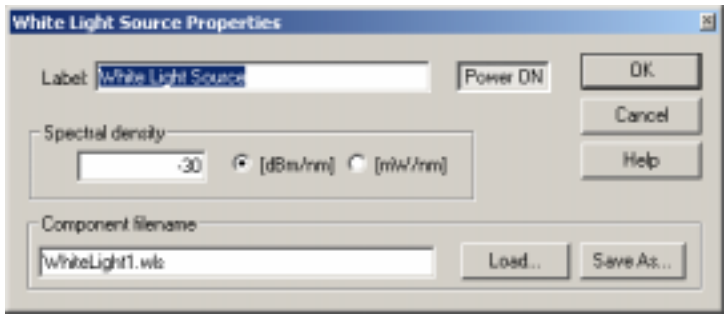

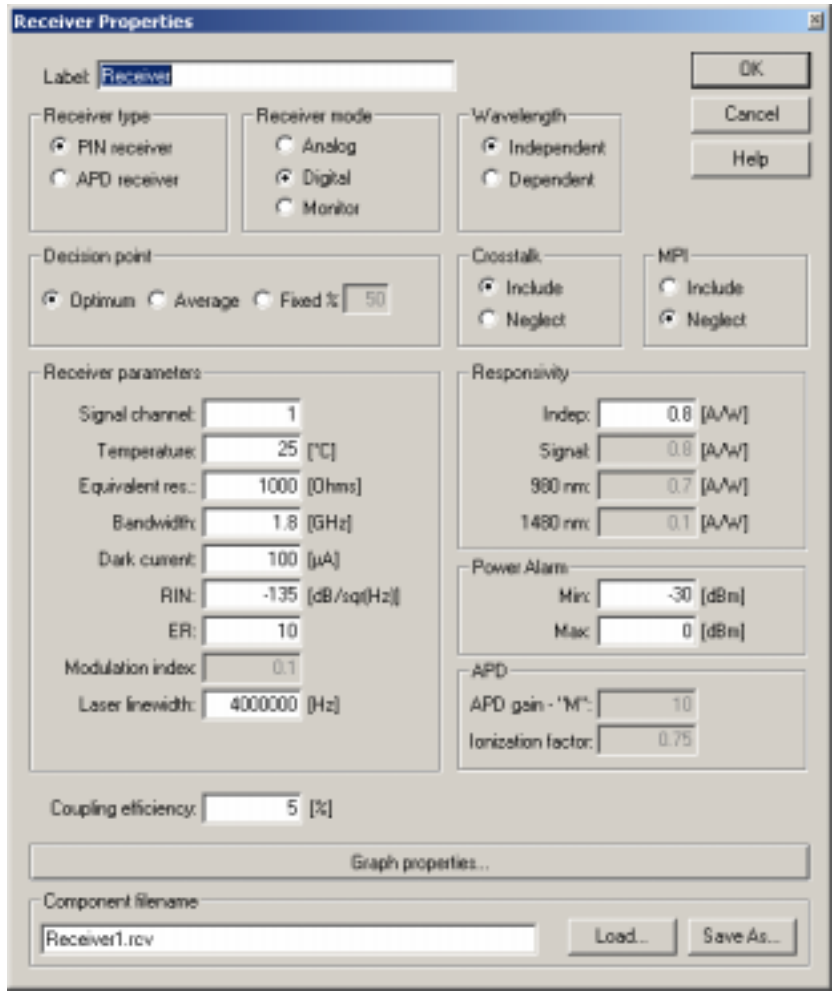

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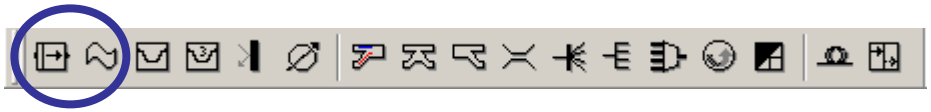

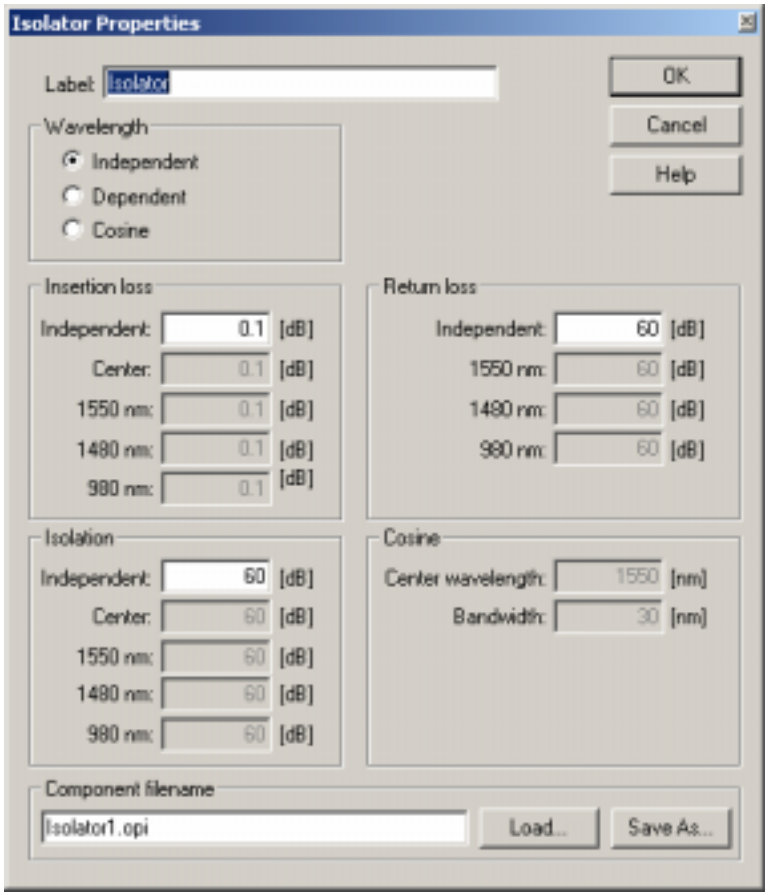

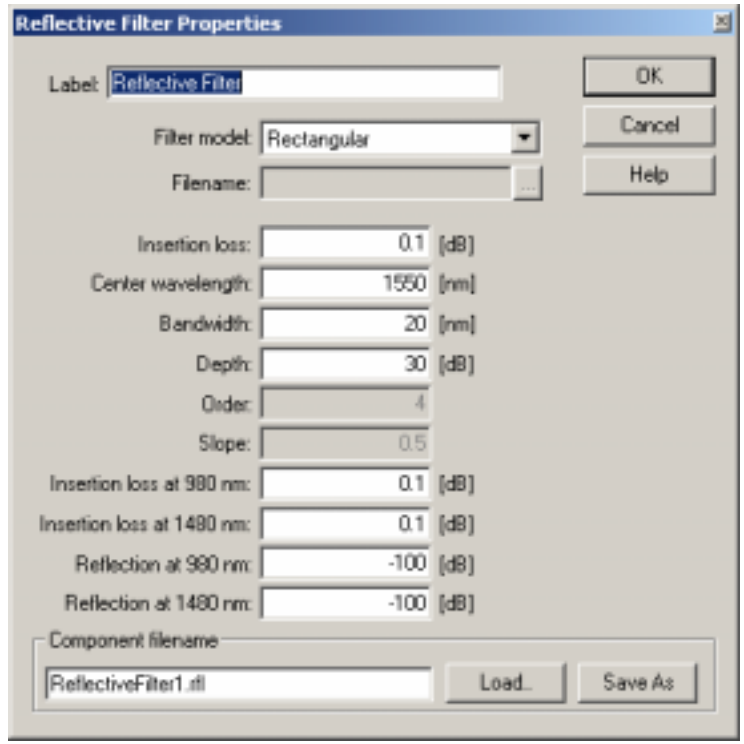

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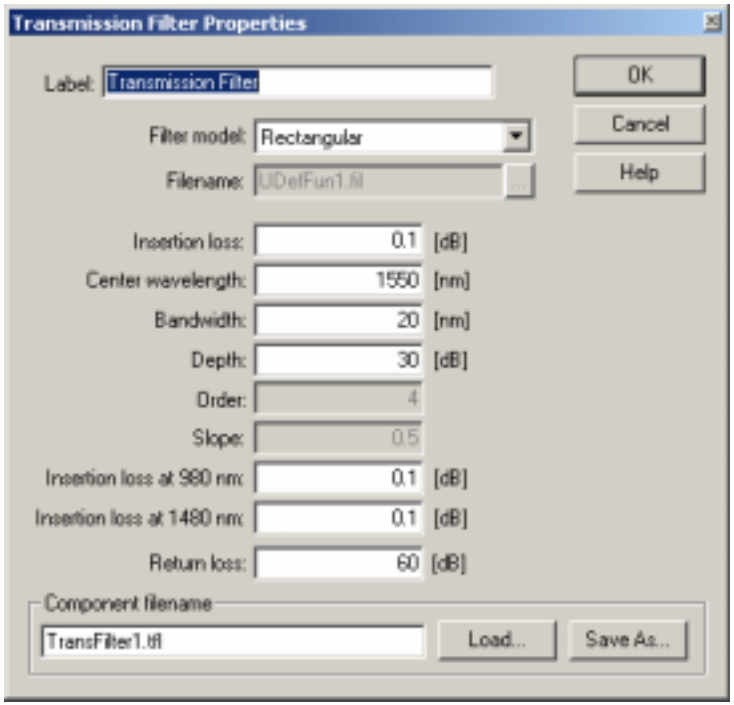

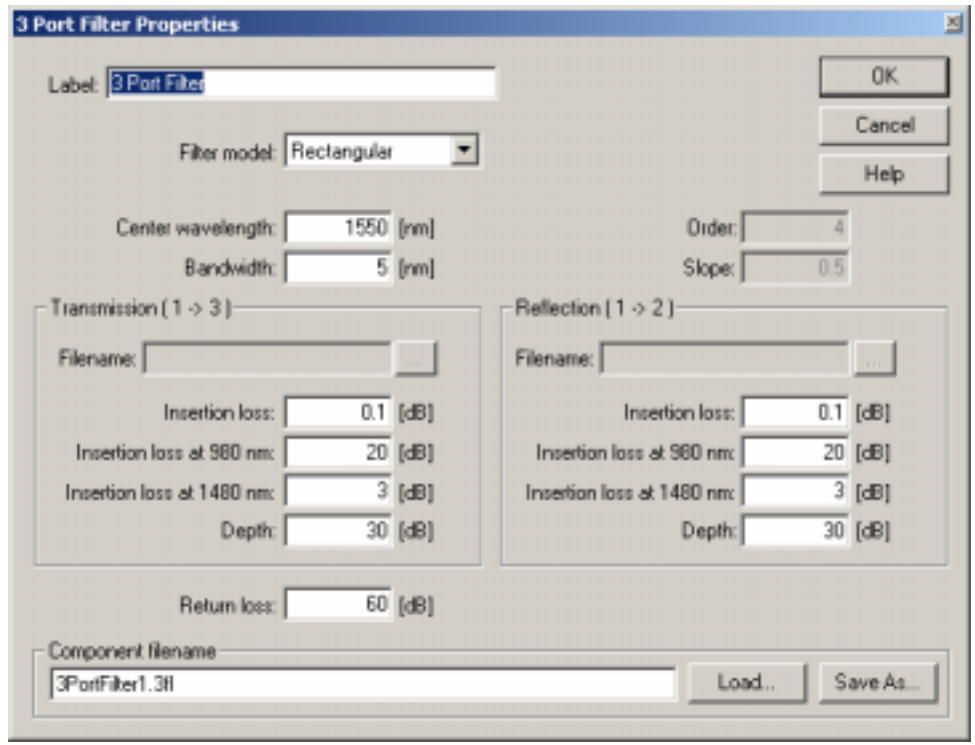

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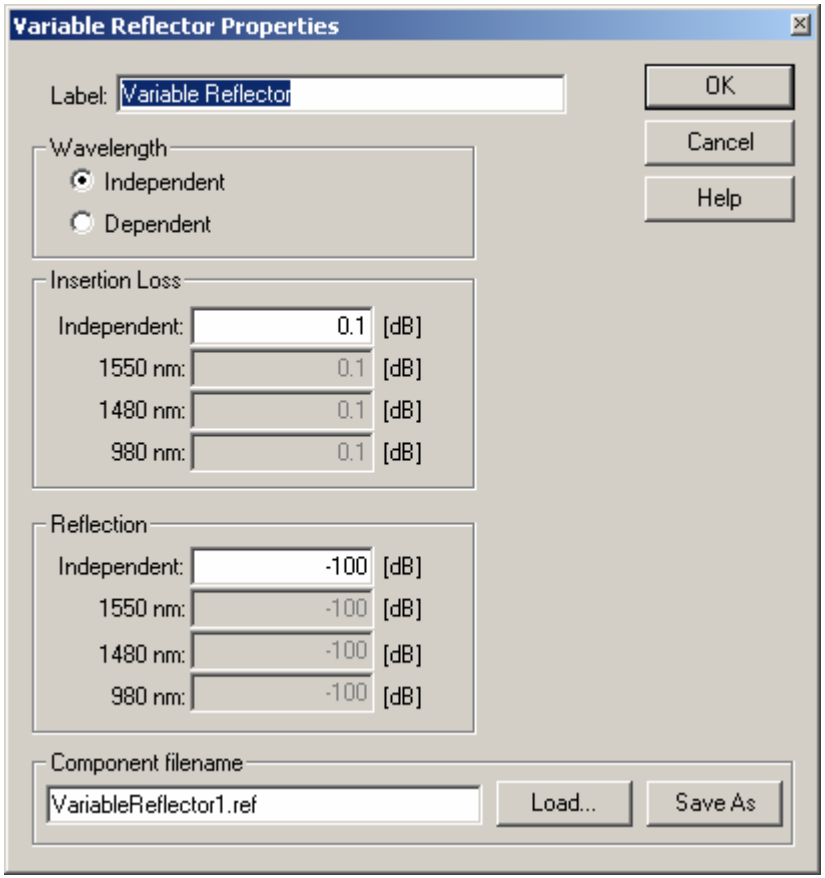

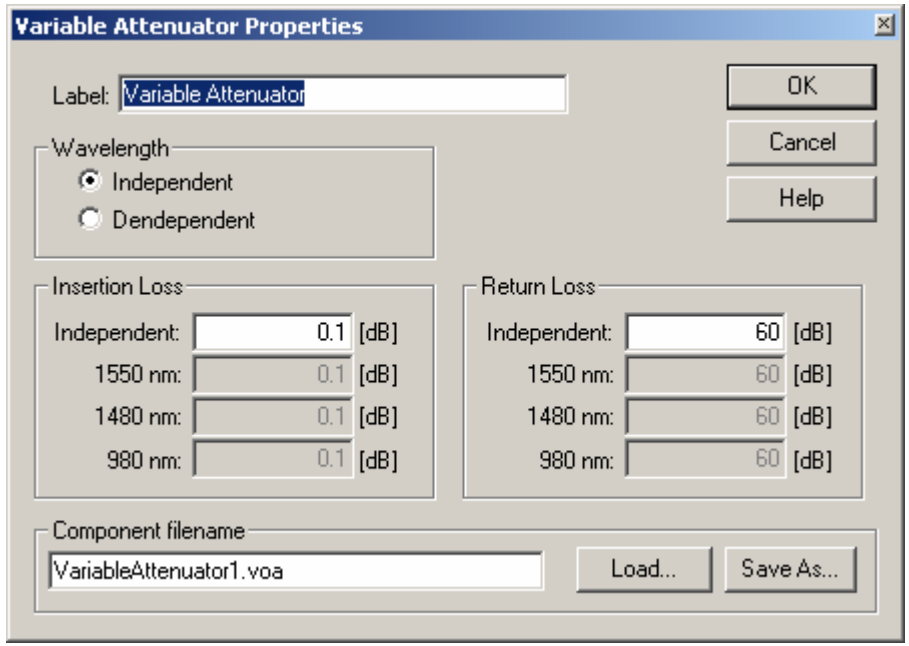

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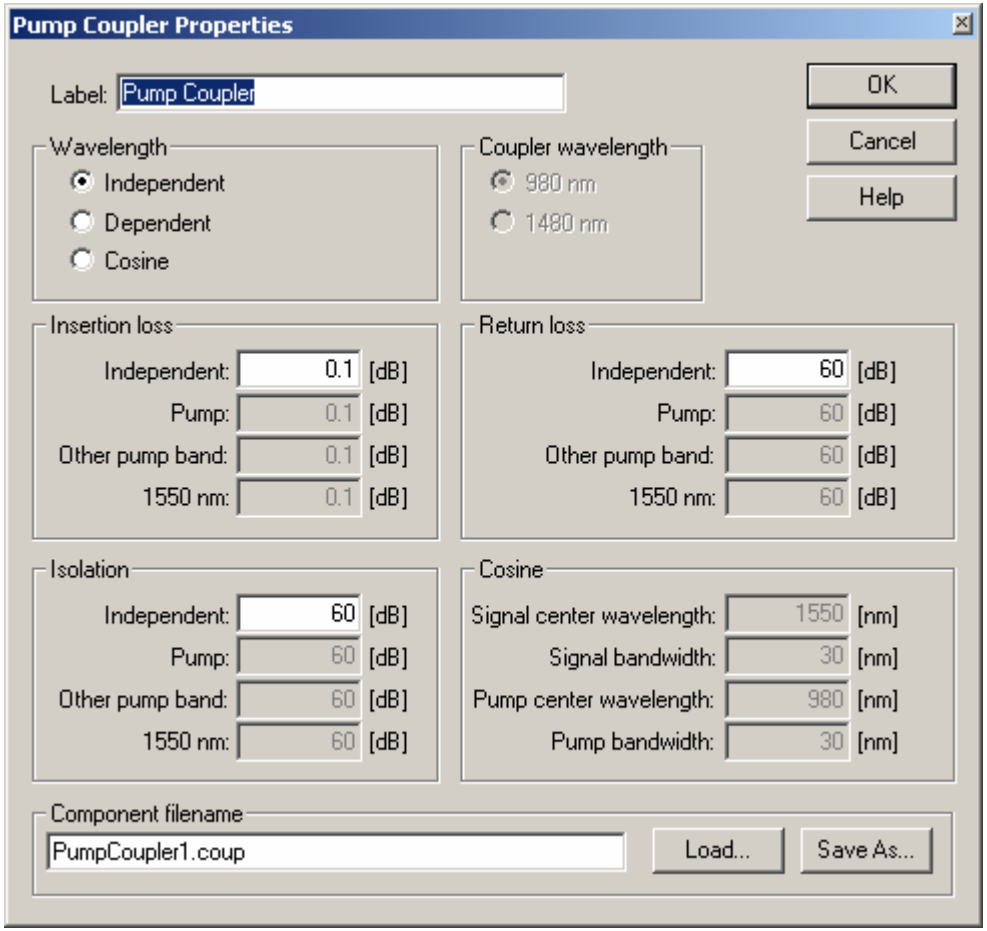

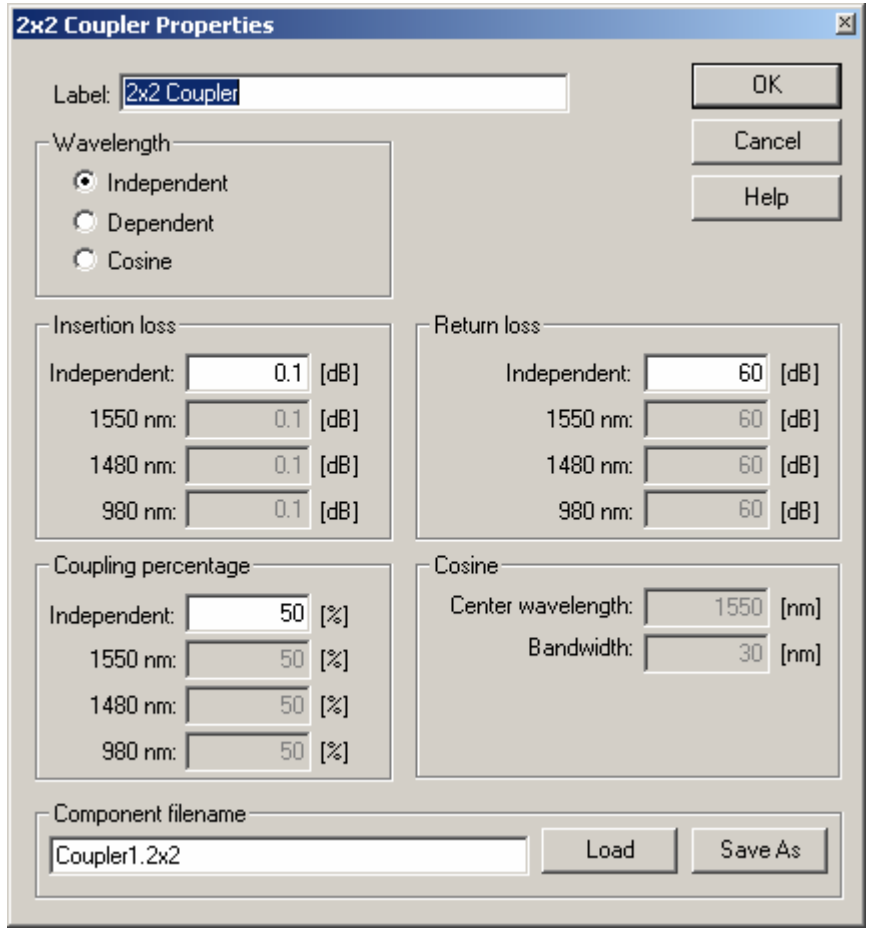

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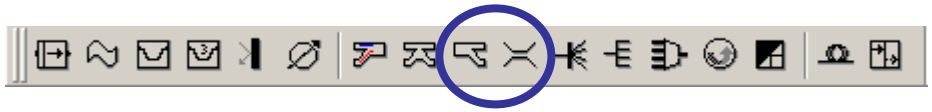

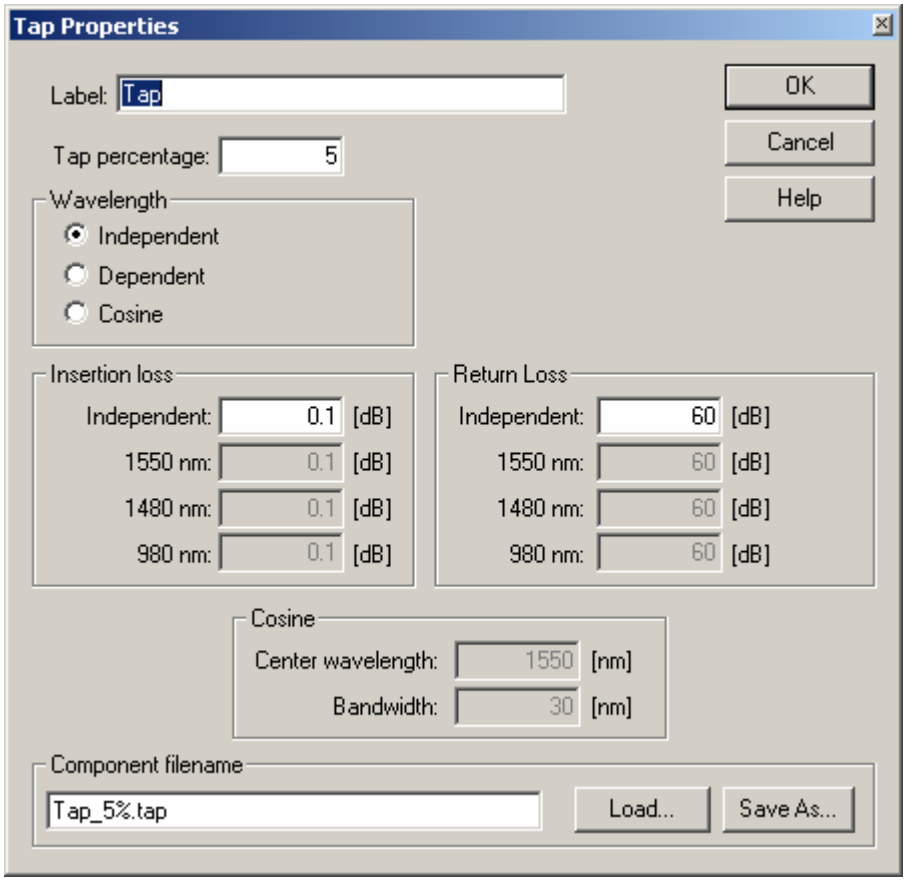

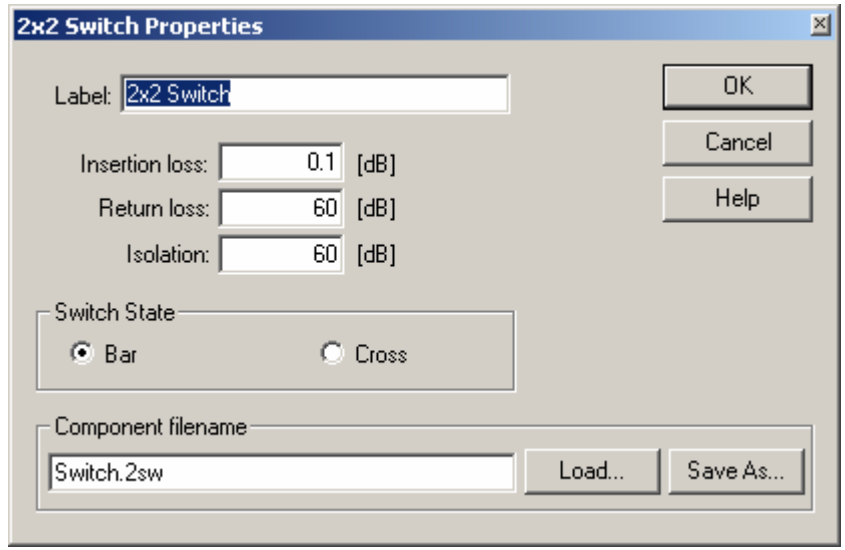

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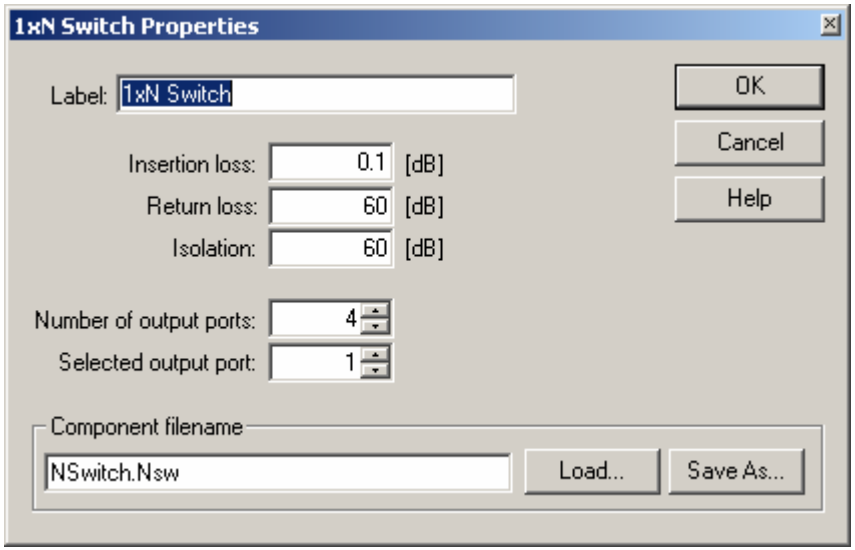

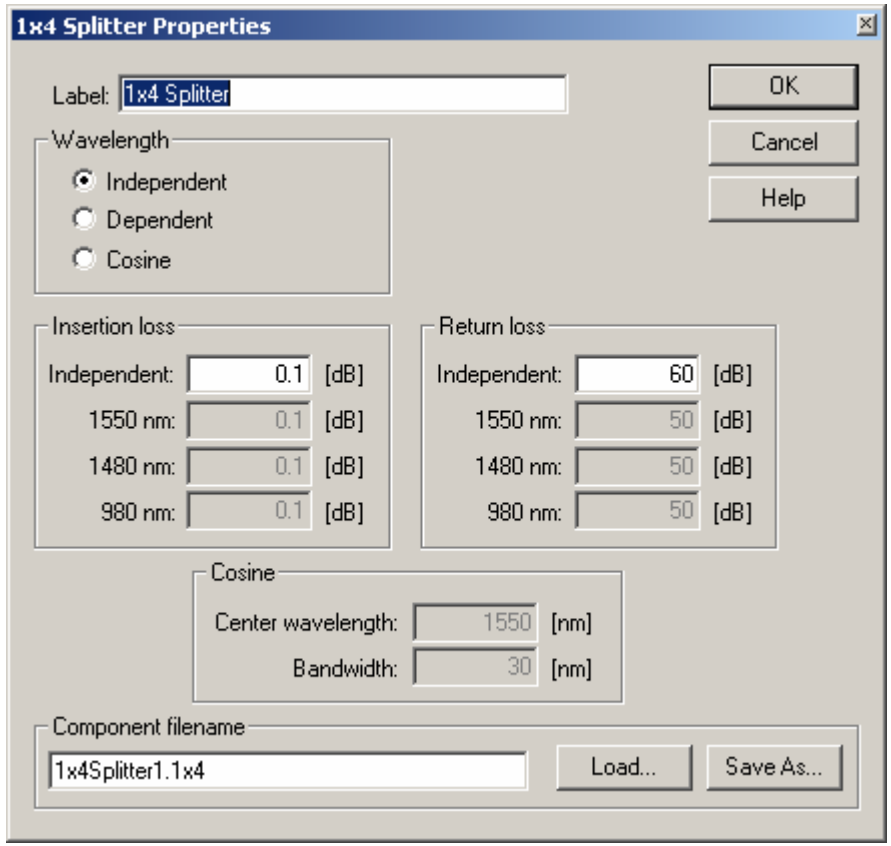

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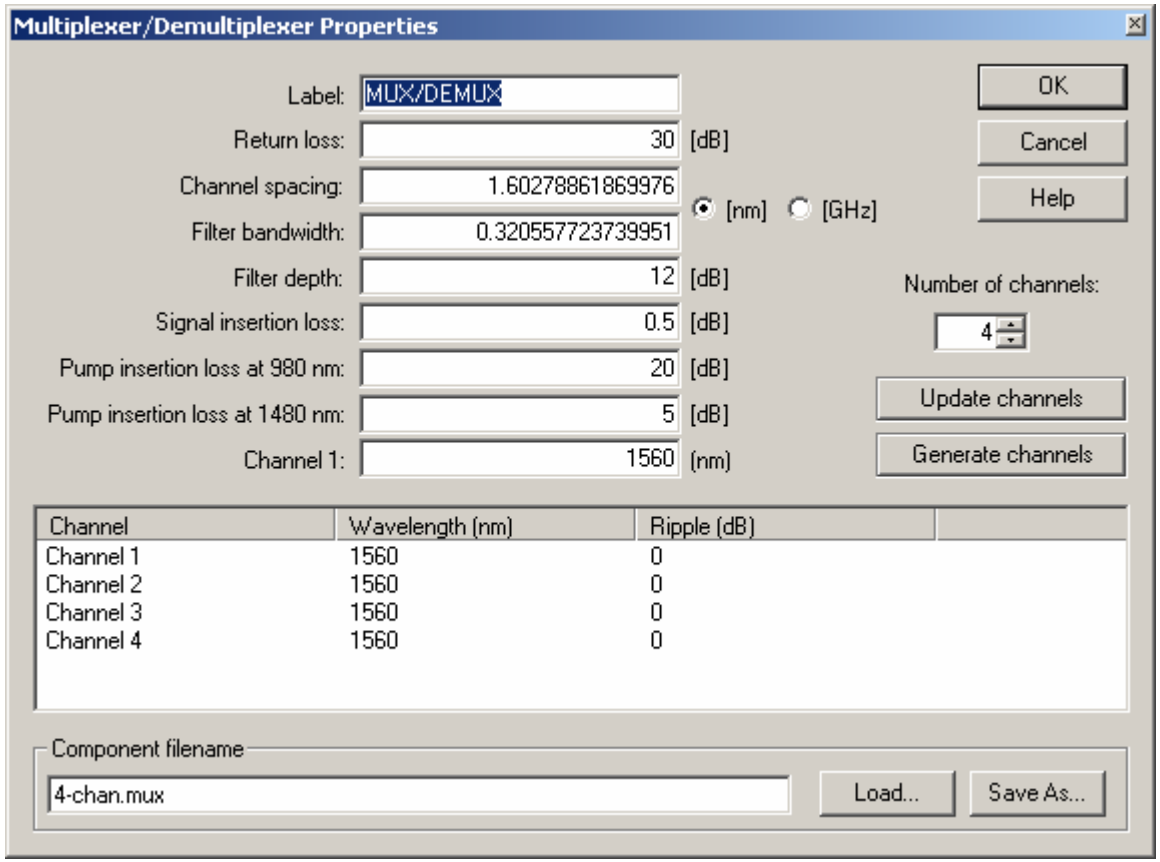

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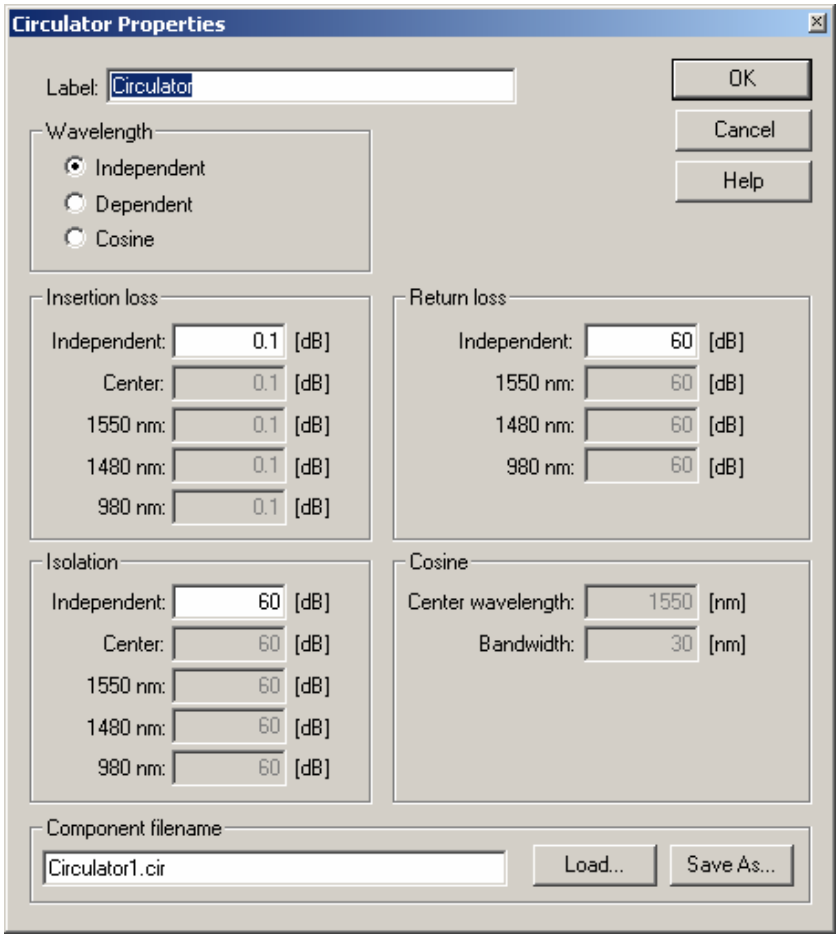

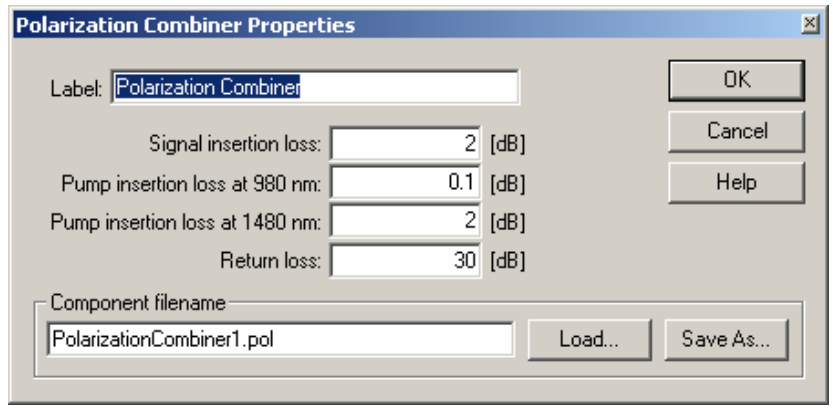

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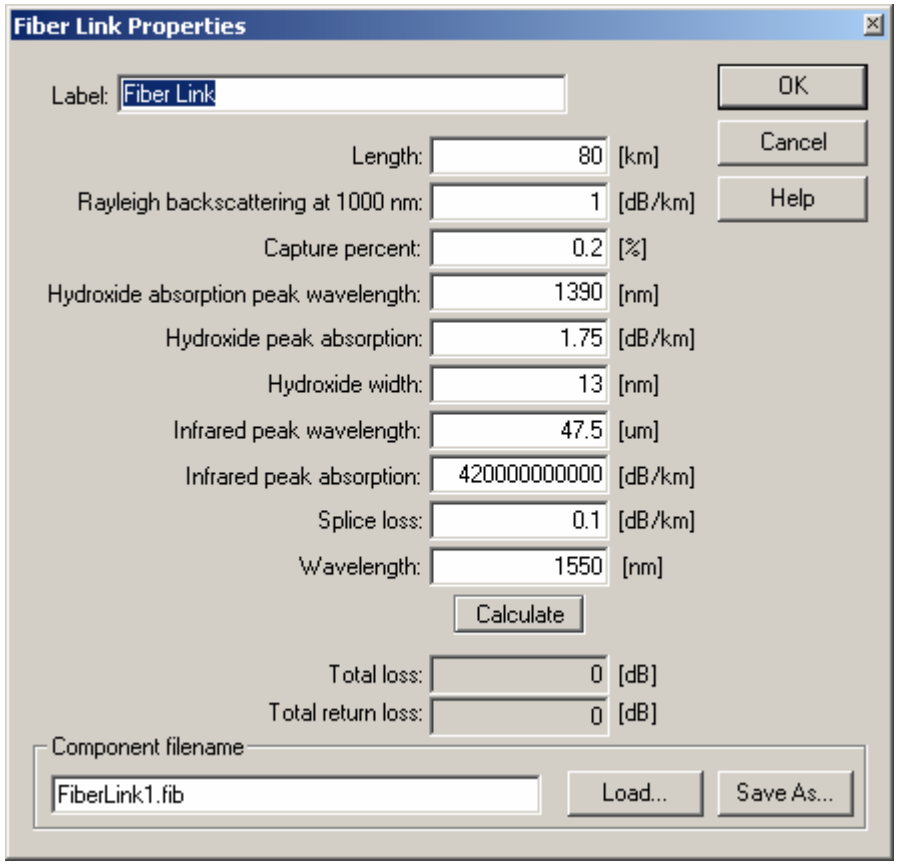
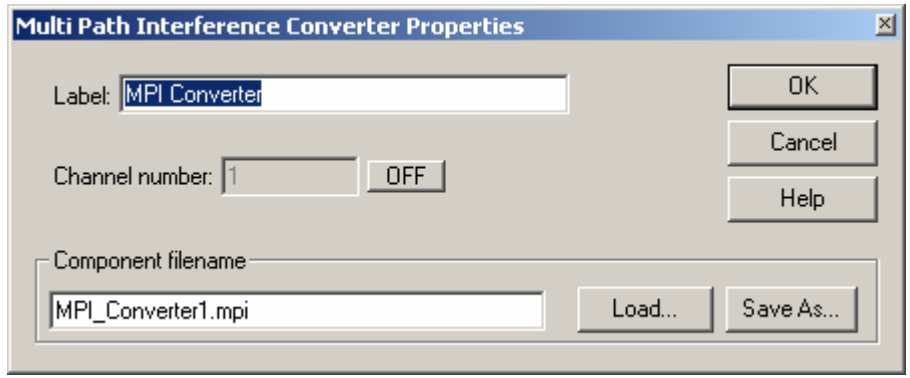
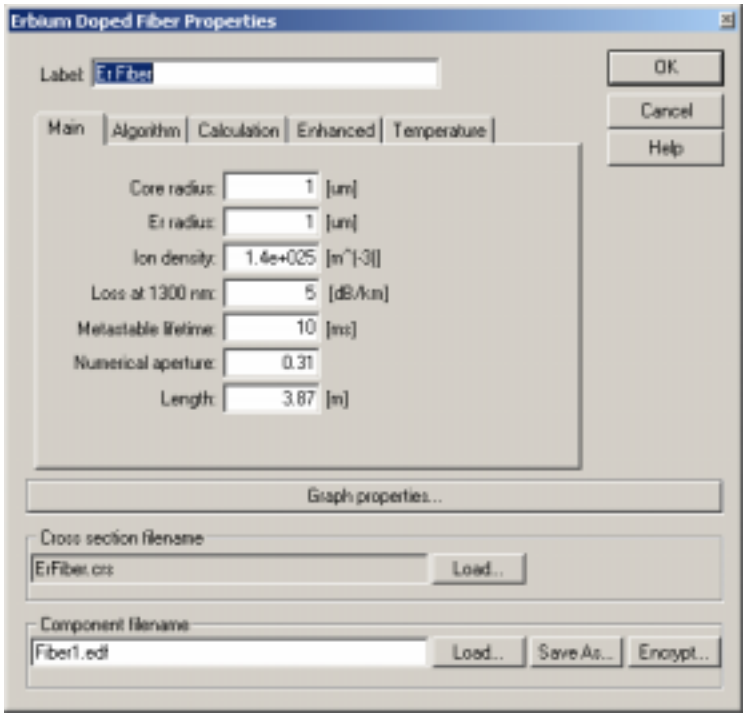
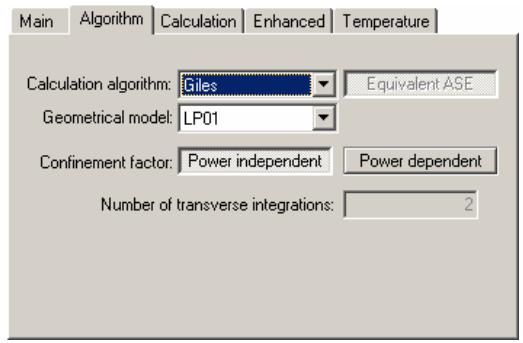
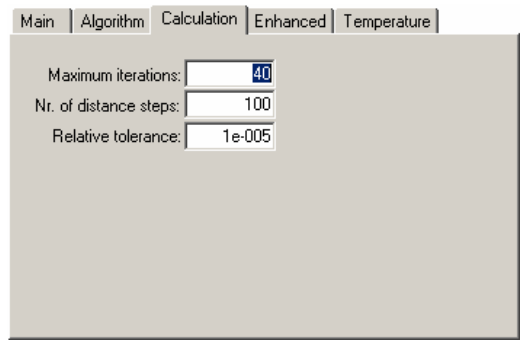


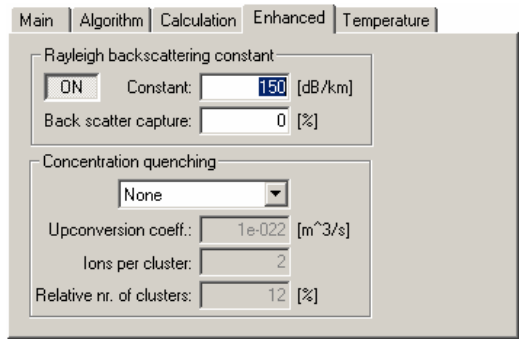


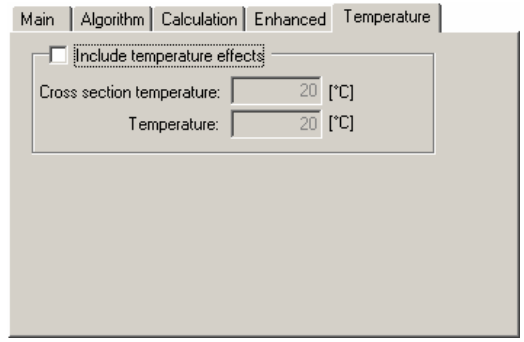
Active Fiber Models



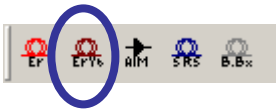


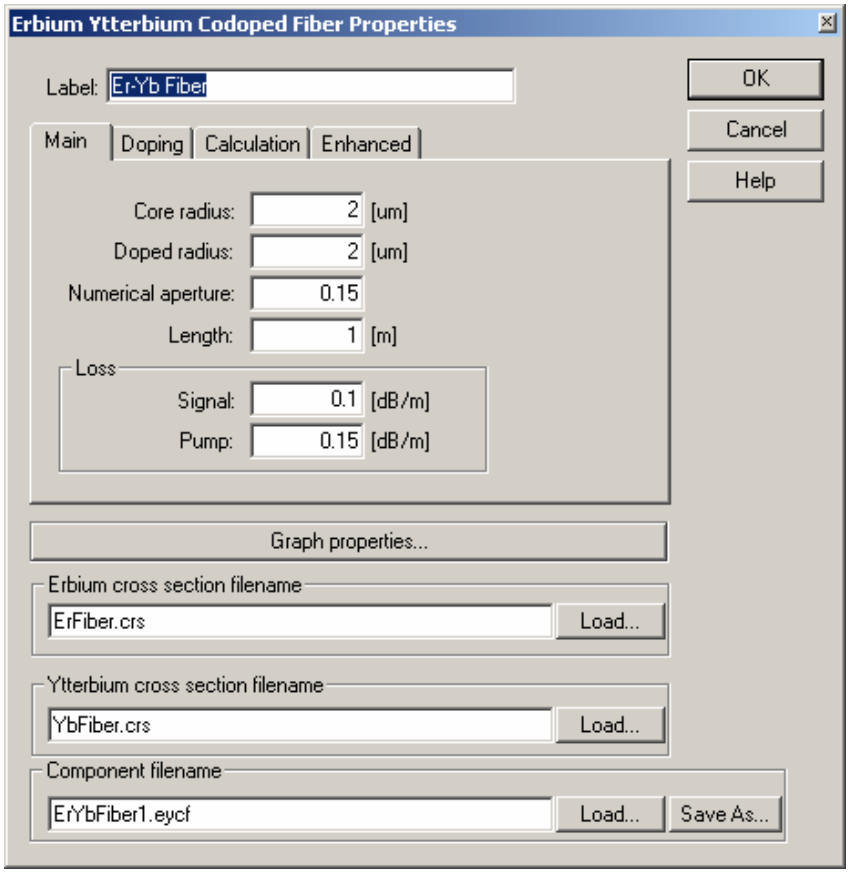


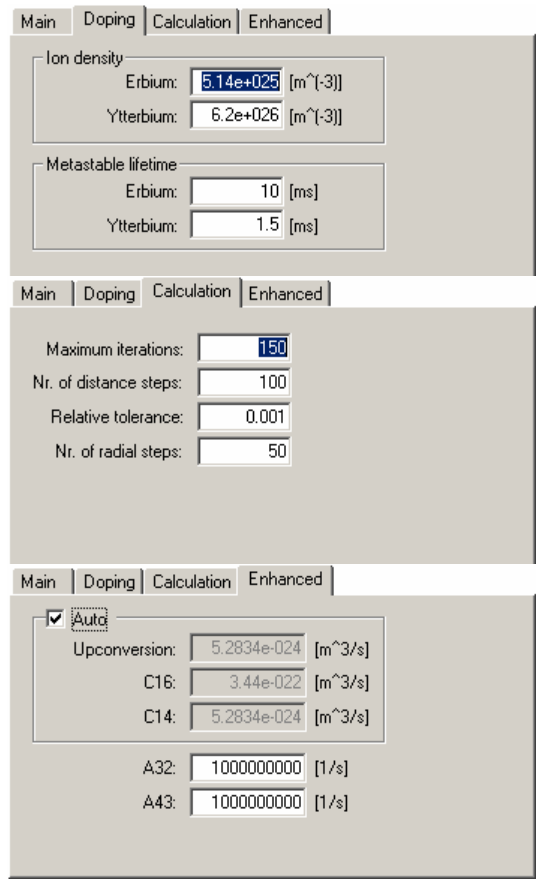




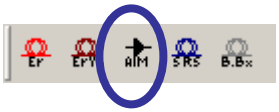
Active Fiber Models

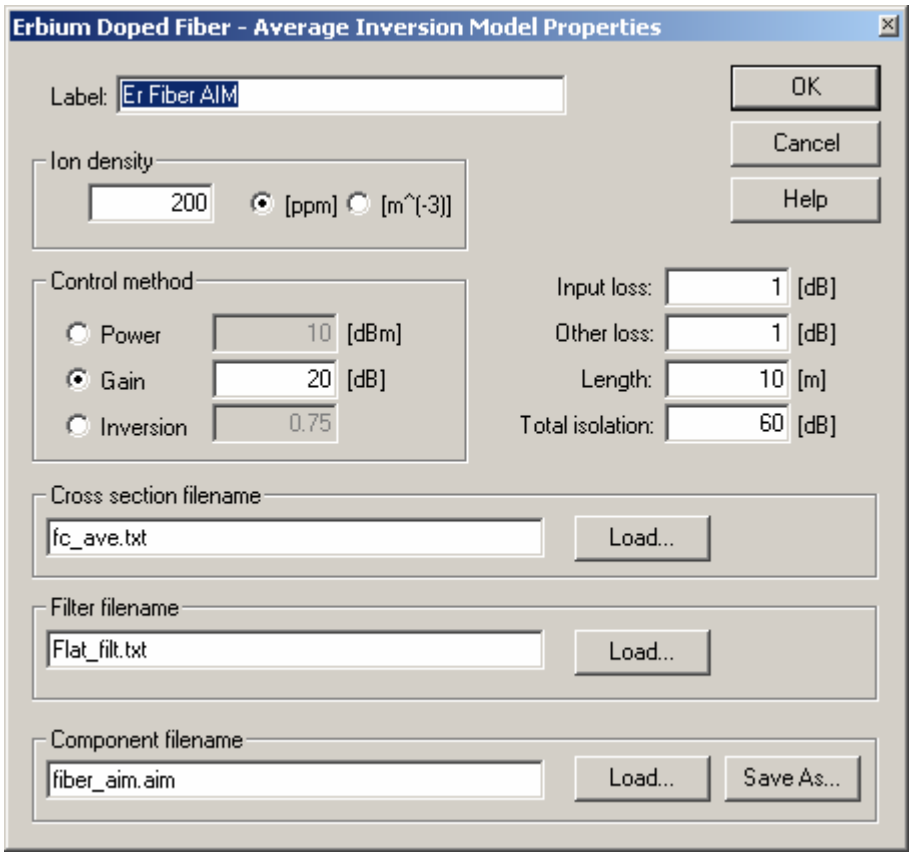




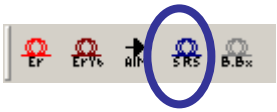


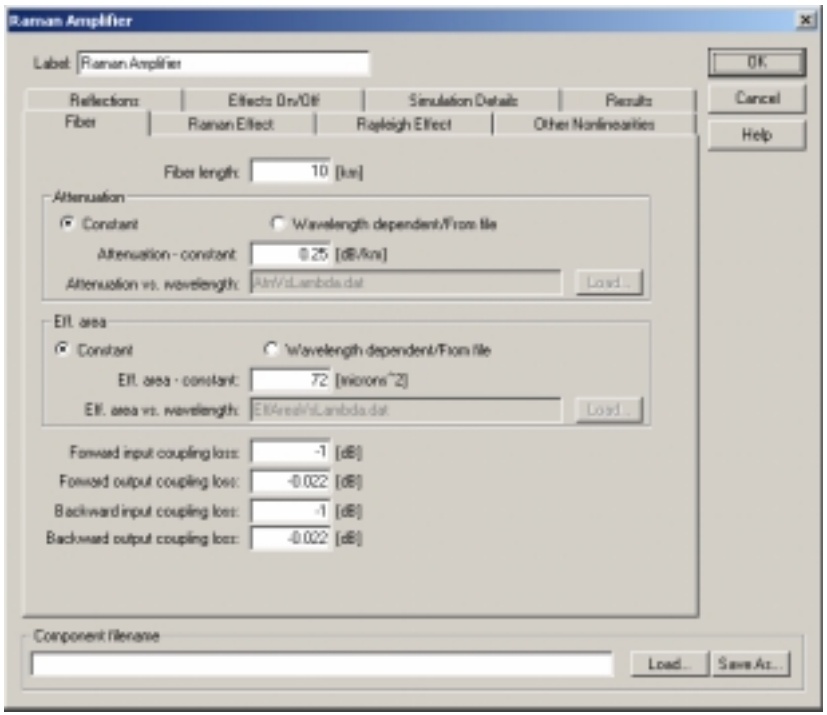
Active Fiber Models

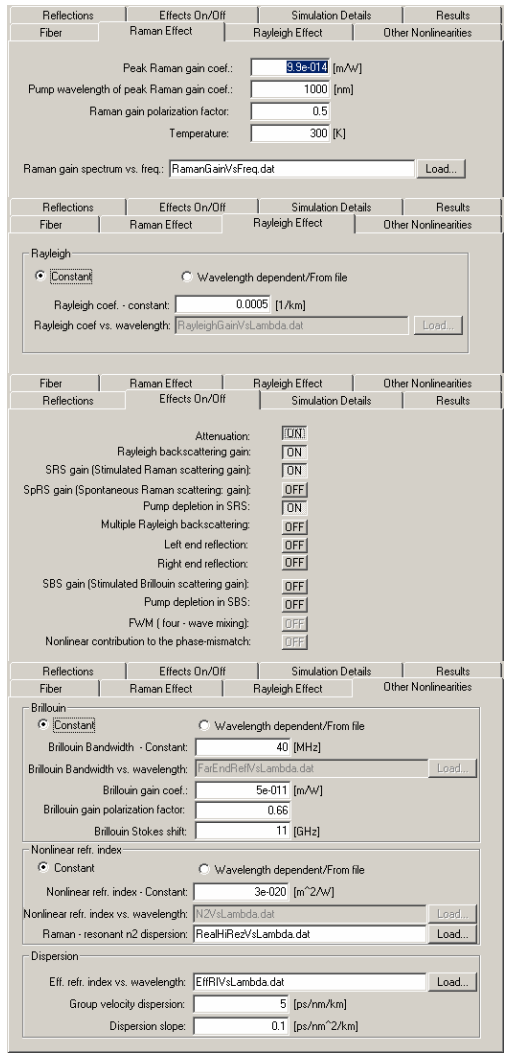


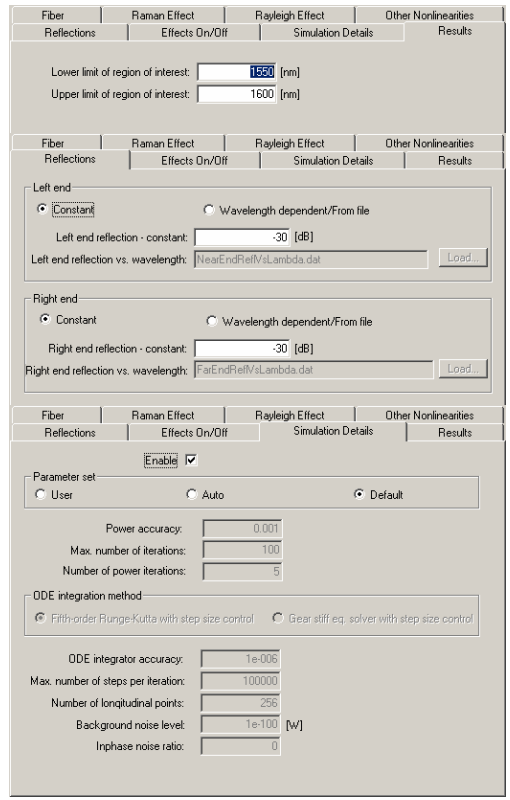


Active Fiber Models

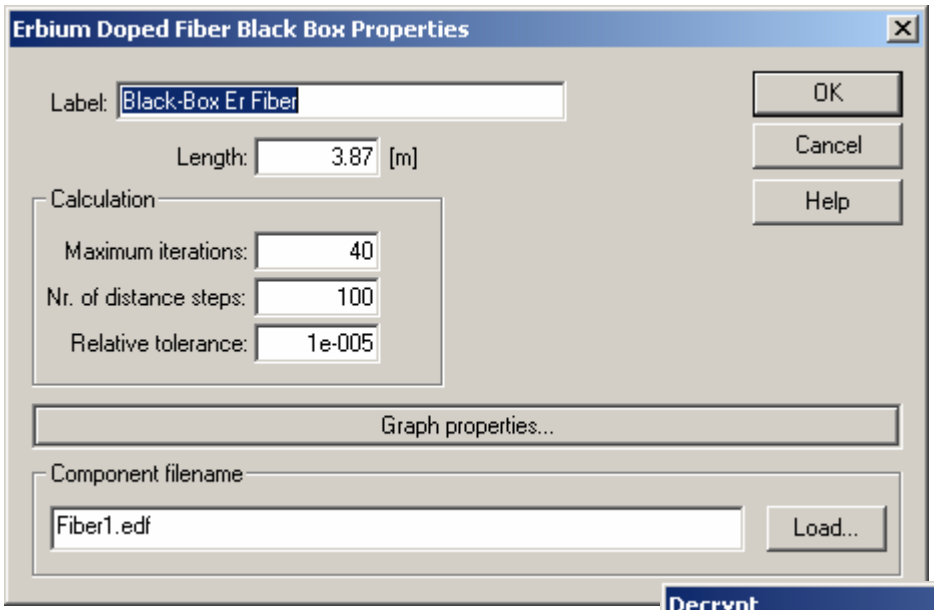


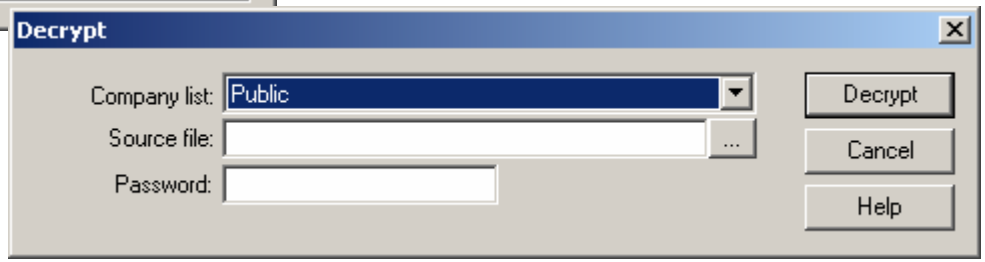


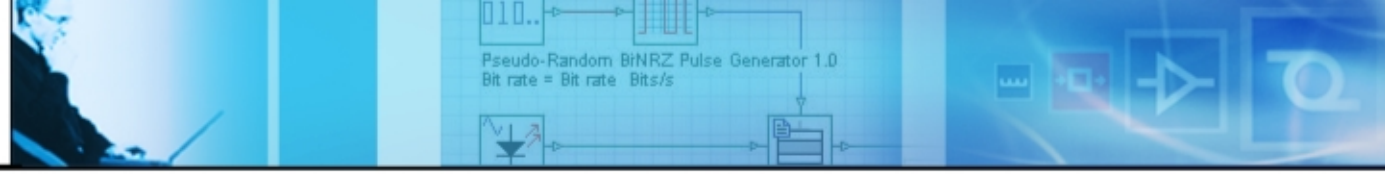




Active Fiber Models







Bidirectional Data Flow

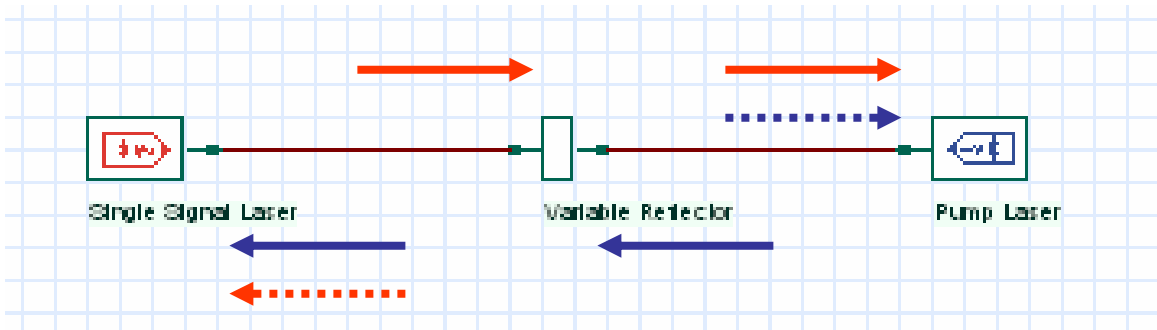
- Effects of reflections and return losses
- MPI (Multi path interference)

Signal Representation

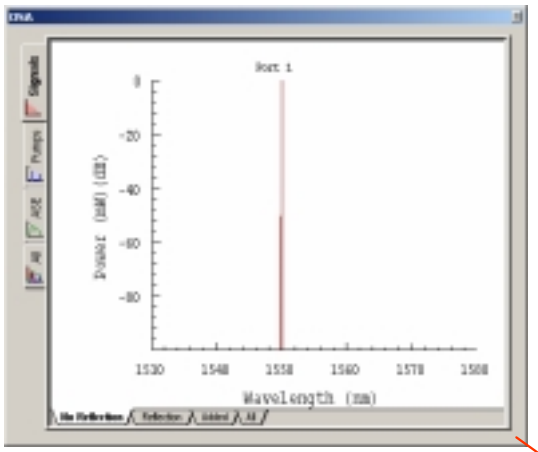
Signal without reflections

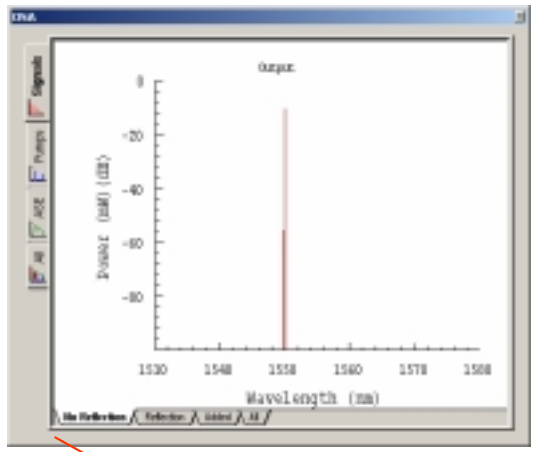
Signal from reflections

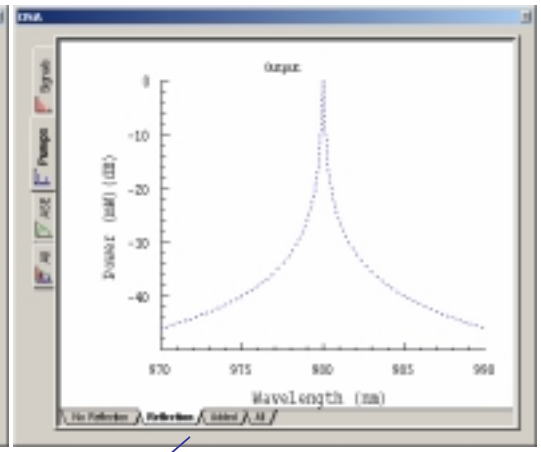
Iteration 1

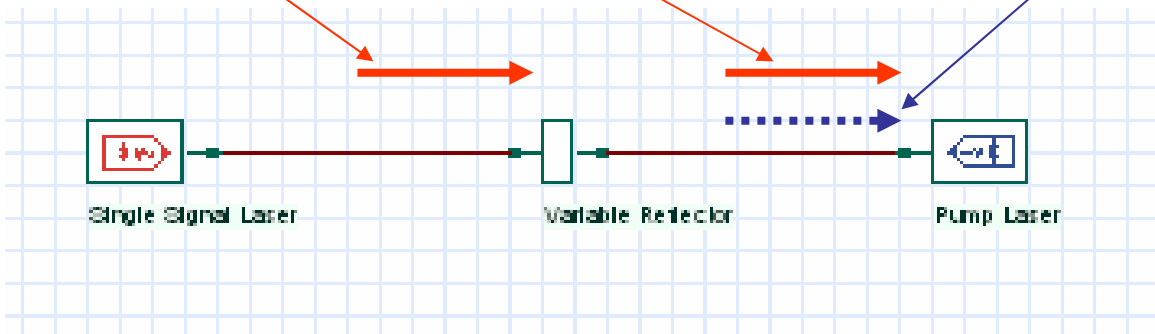


Signal Representation

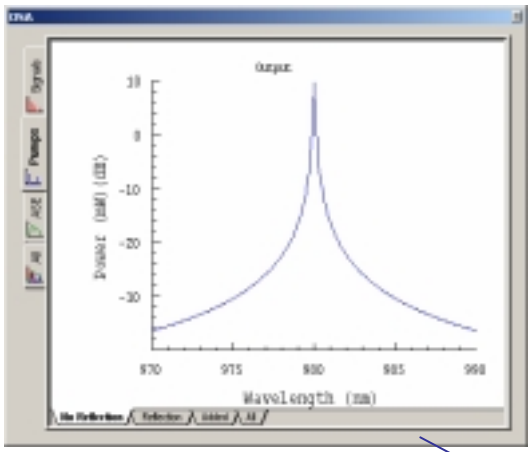


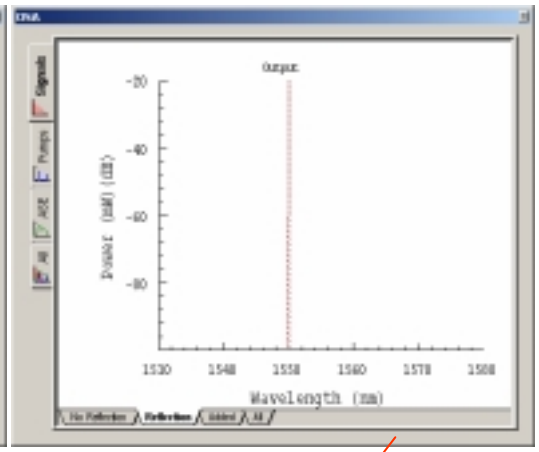


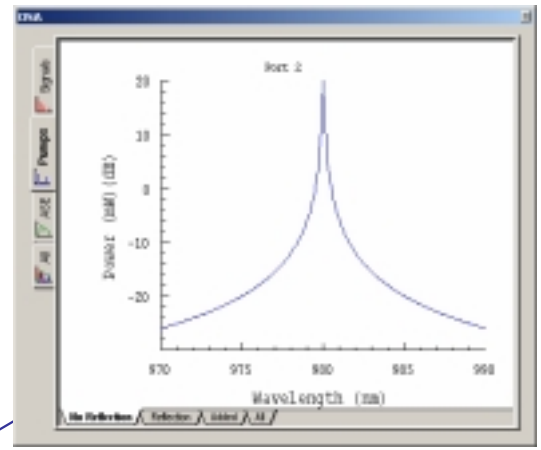


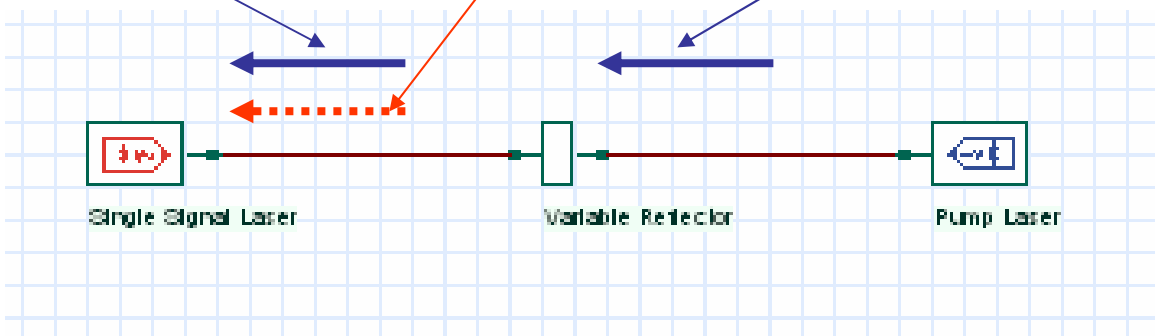


Signal Representation

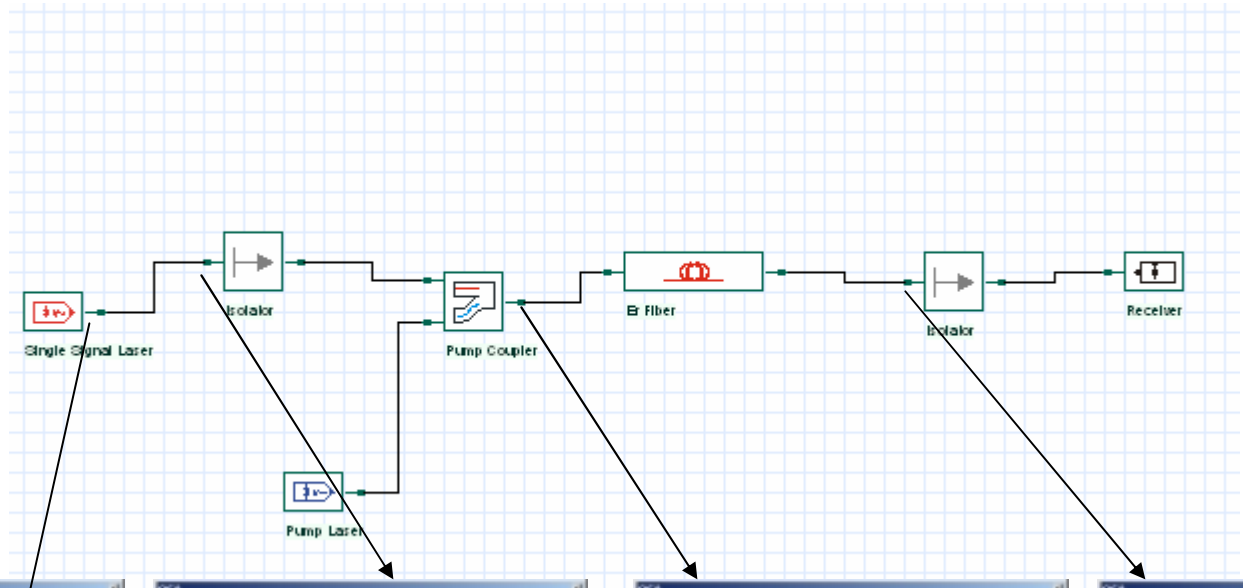


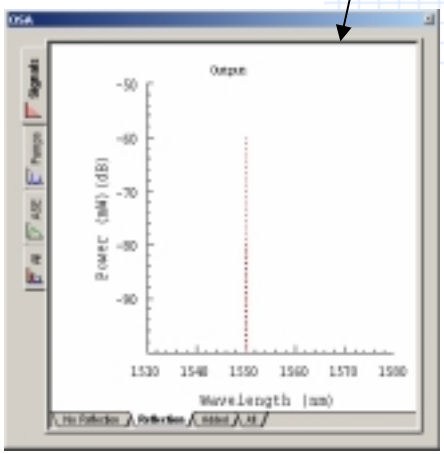


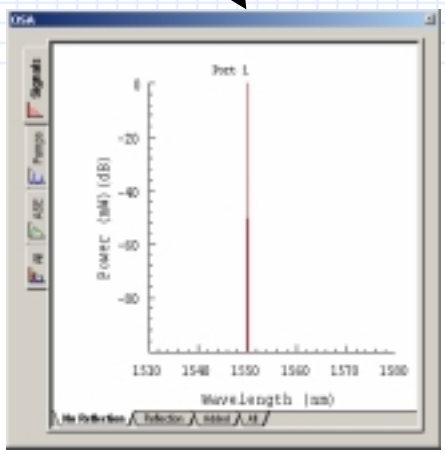


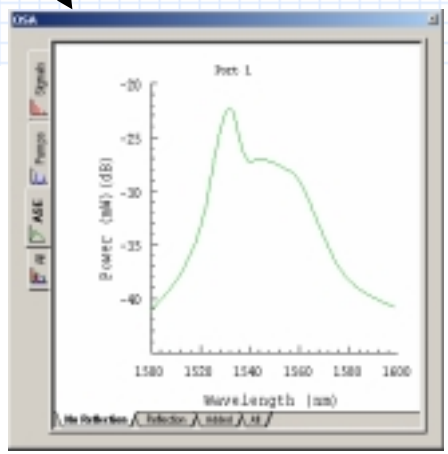


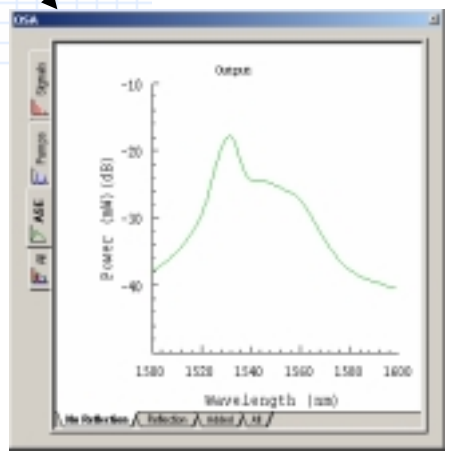
Signal Representation

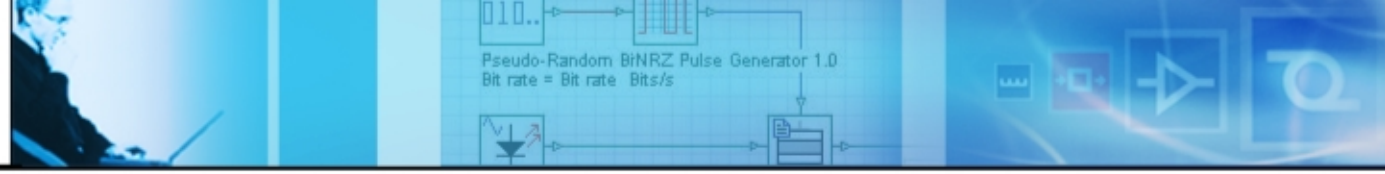










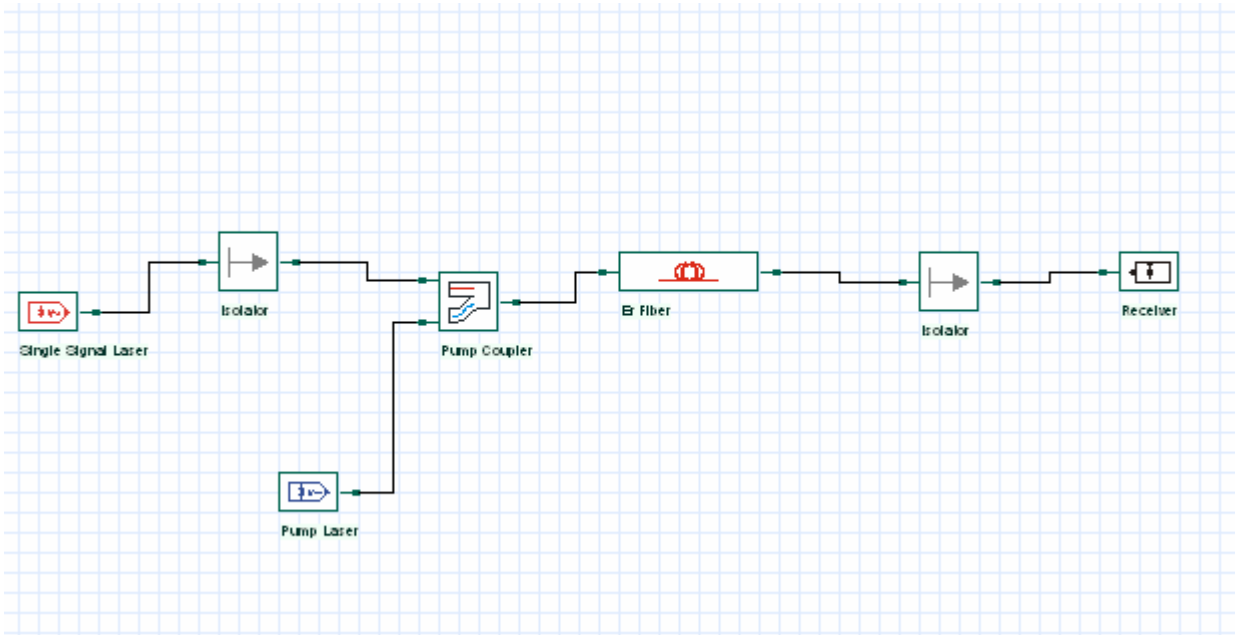


Designing Optical Amplifiers

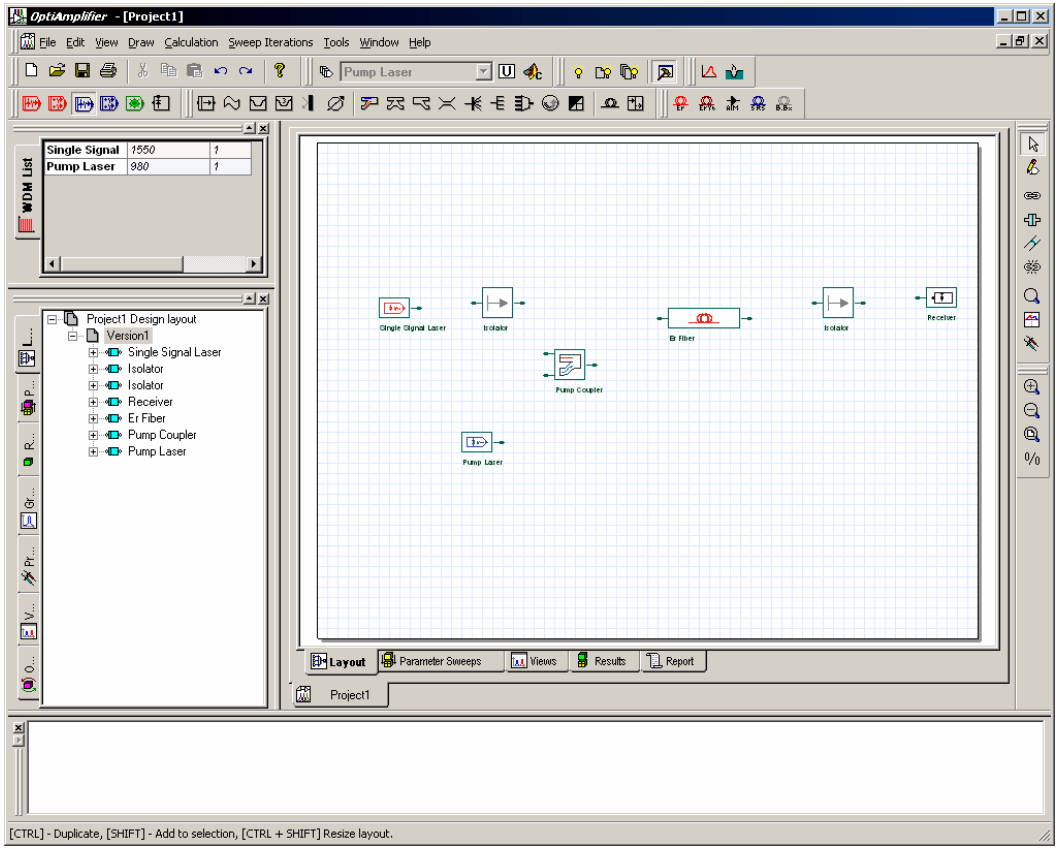
- Choose a configuration
- Draw the layout
- Set the parameters for the active and passive components
- Set the parameters for fibers
- Simulate
- Analyze results
- Optimize amplifier parameters
- Comparing Results with Measurements

Choosing a configuration

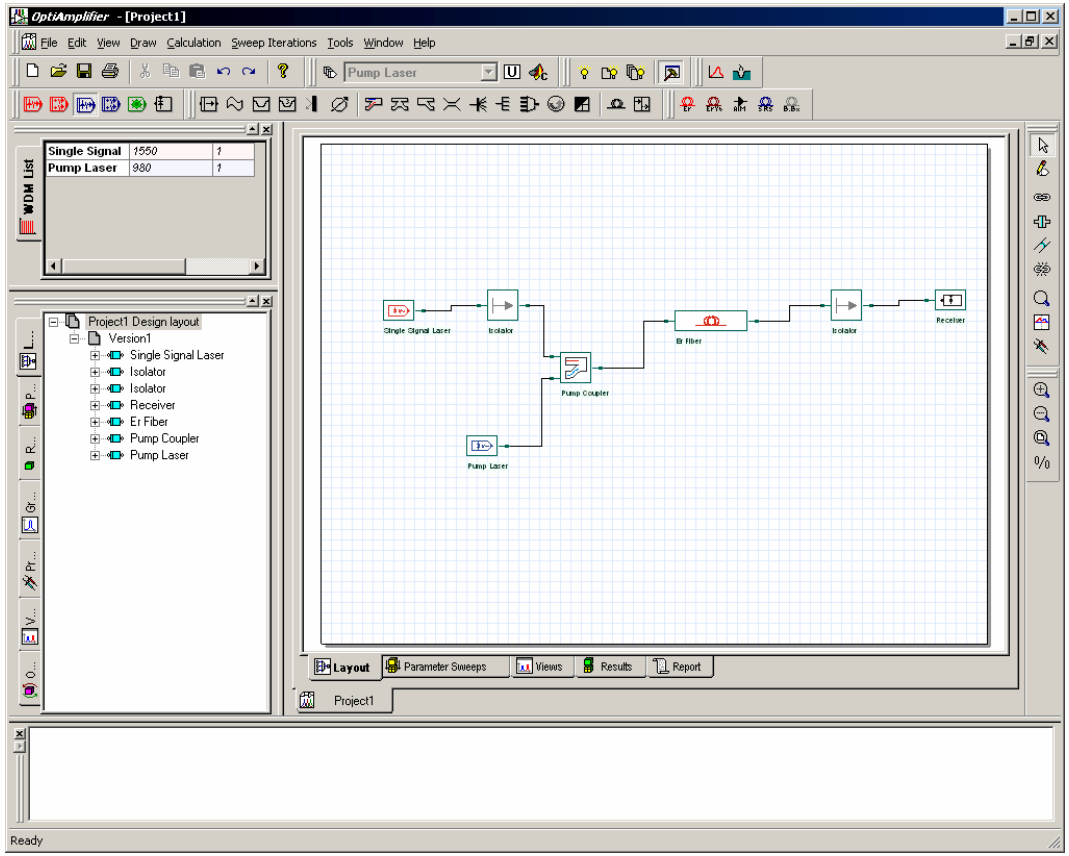
- Popular C-band configuration
- Co-propagating pump



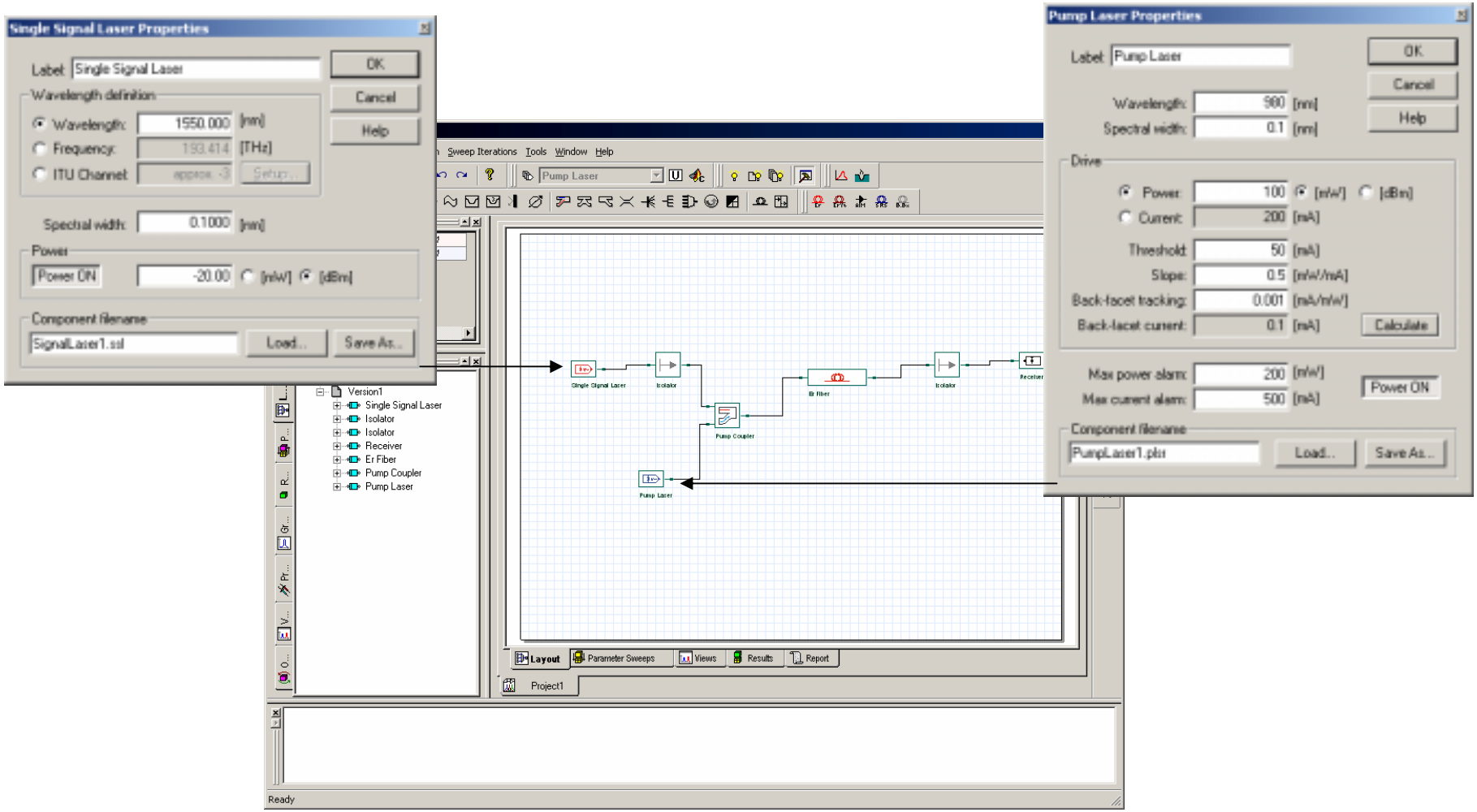
Drawing the Layout - Components



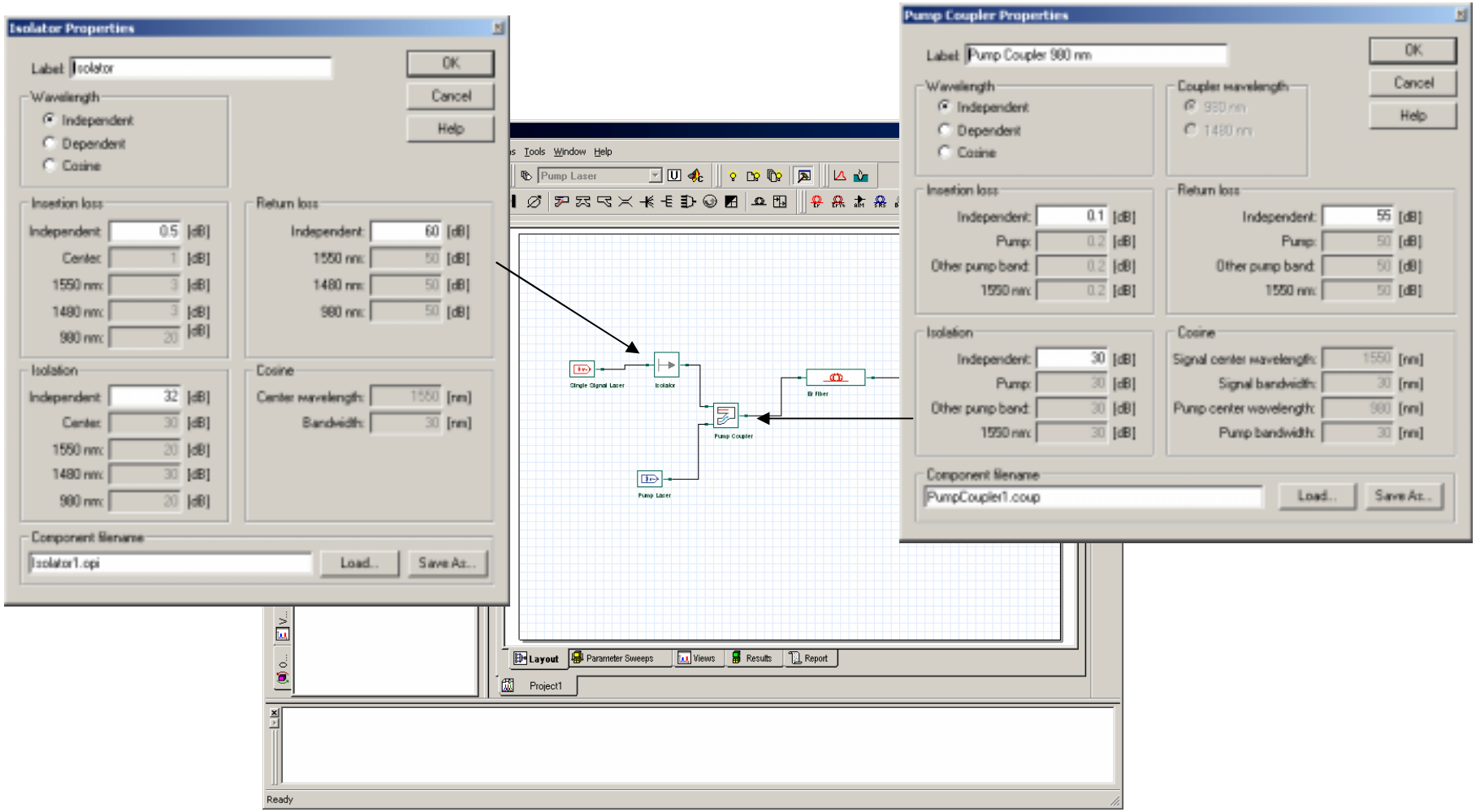
Drawing the Layout - Components



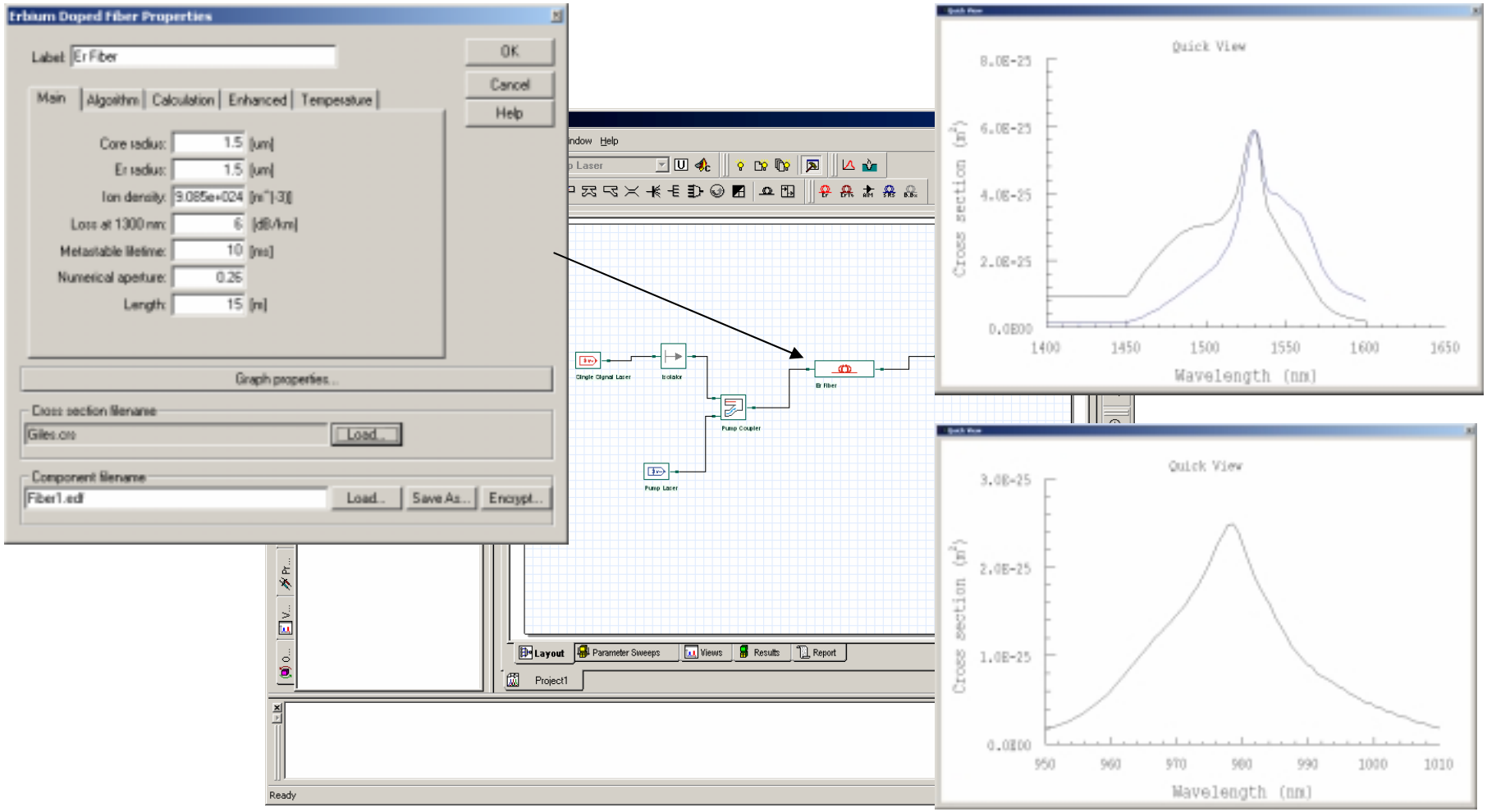
Active devices



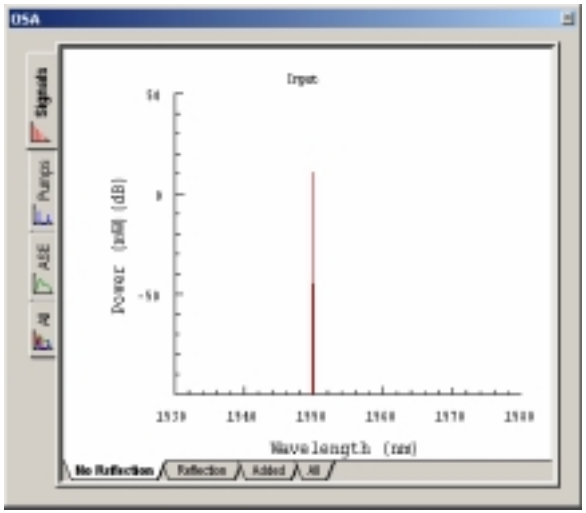
Passive devices

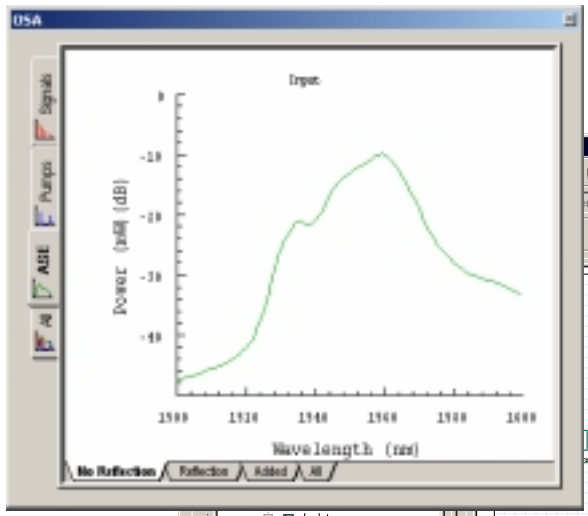


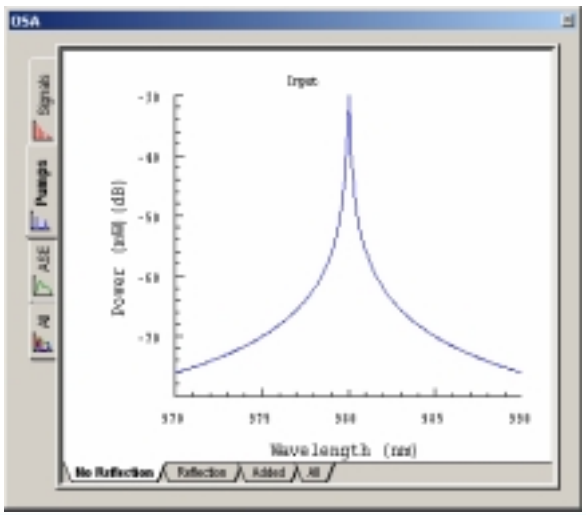
Erbium doped fiber parameters



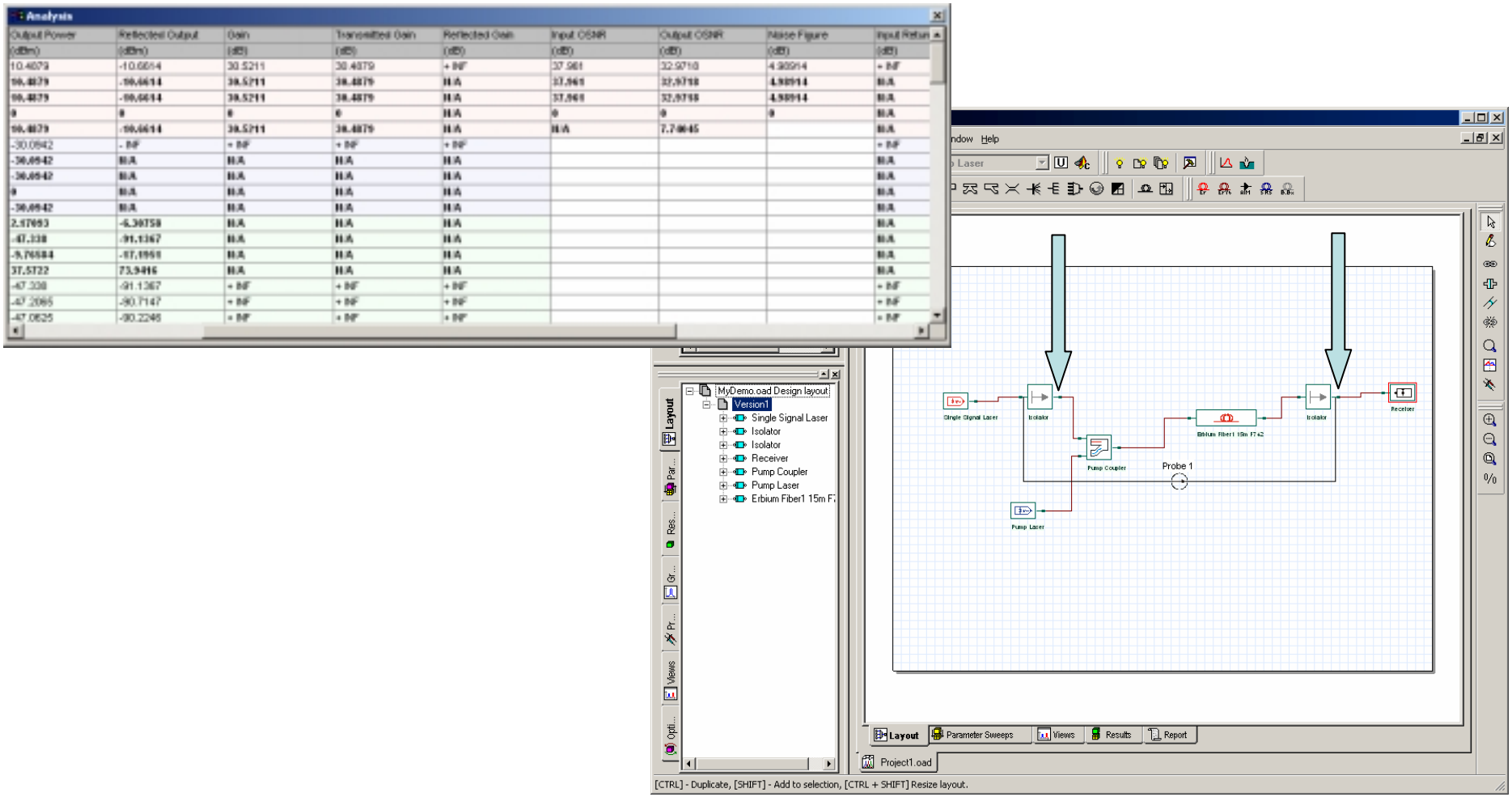
Analyze the results - OSA



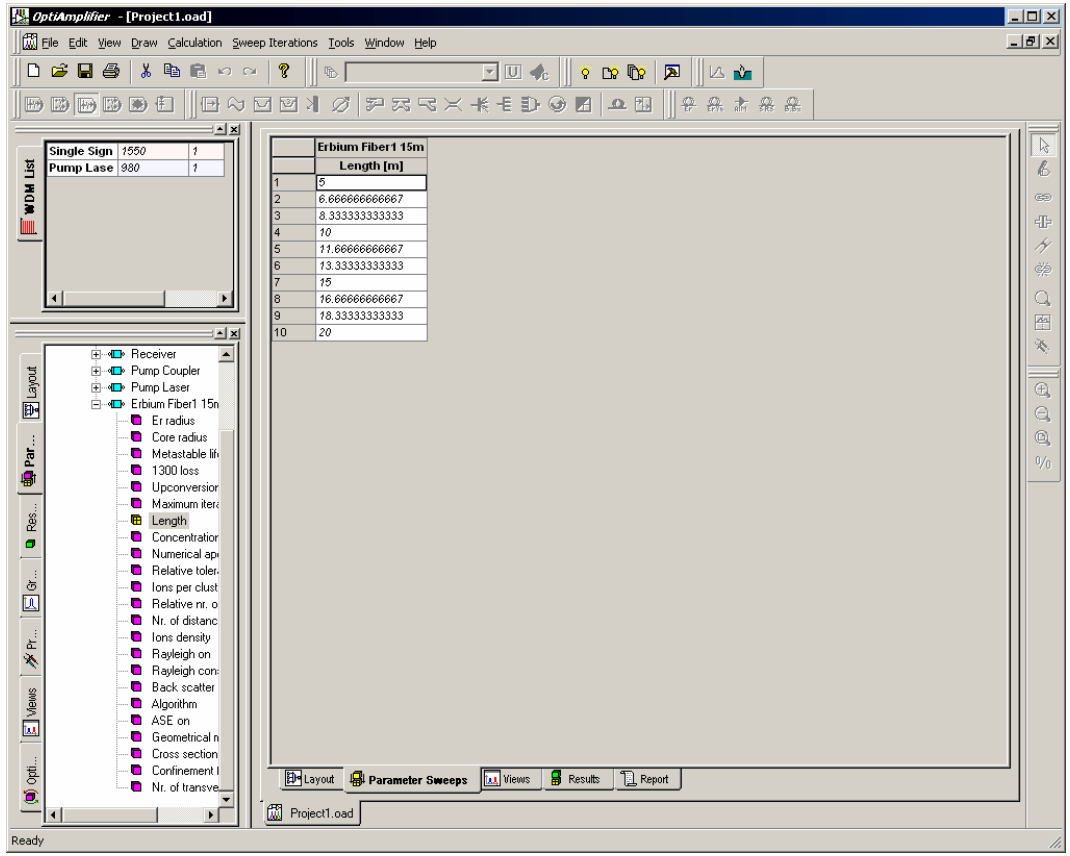




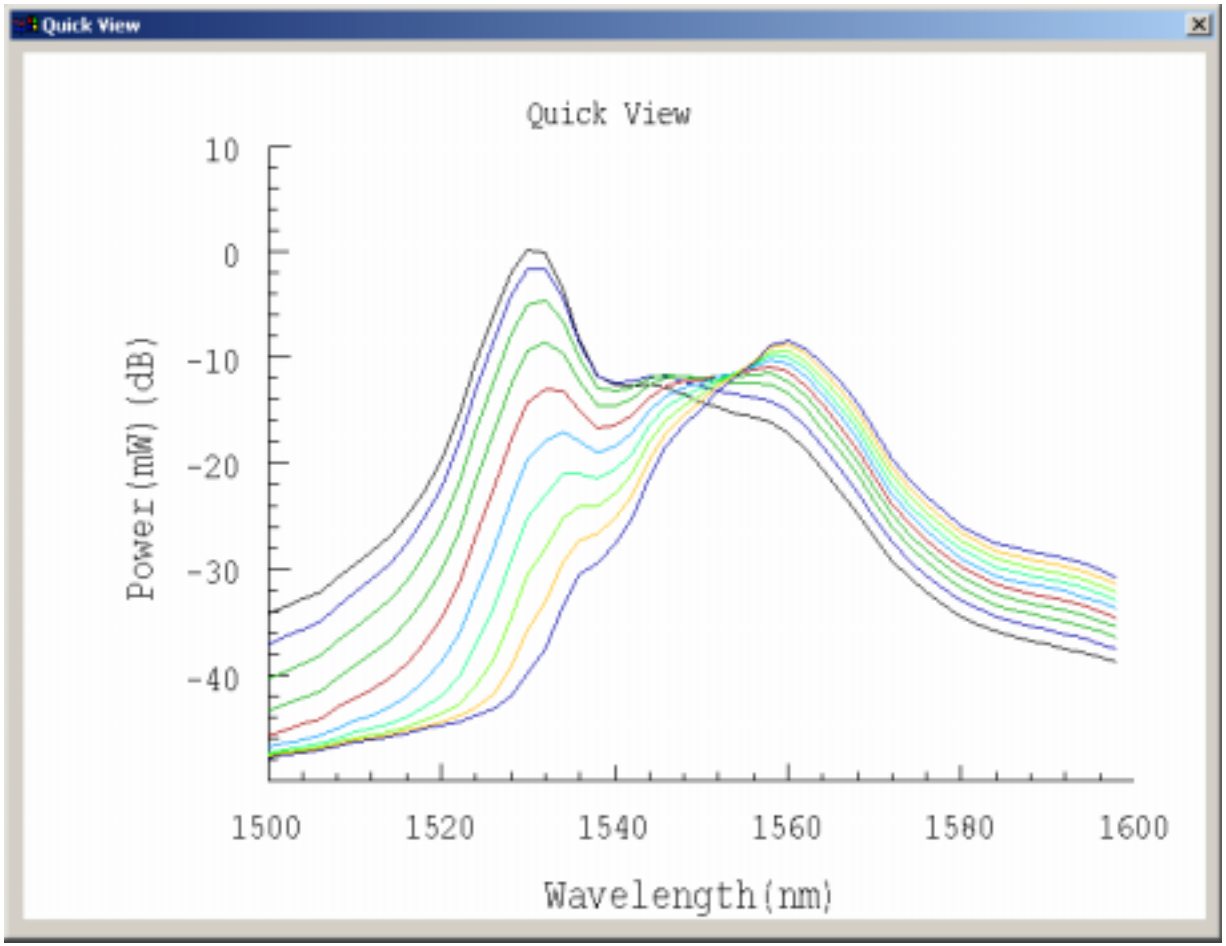
Analyze the results - Probe



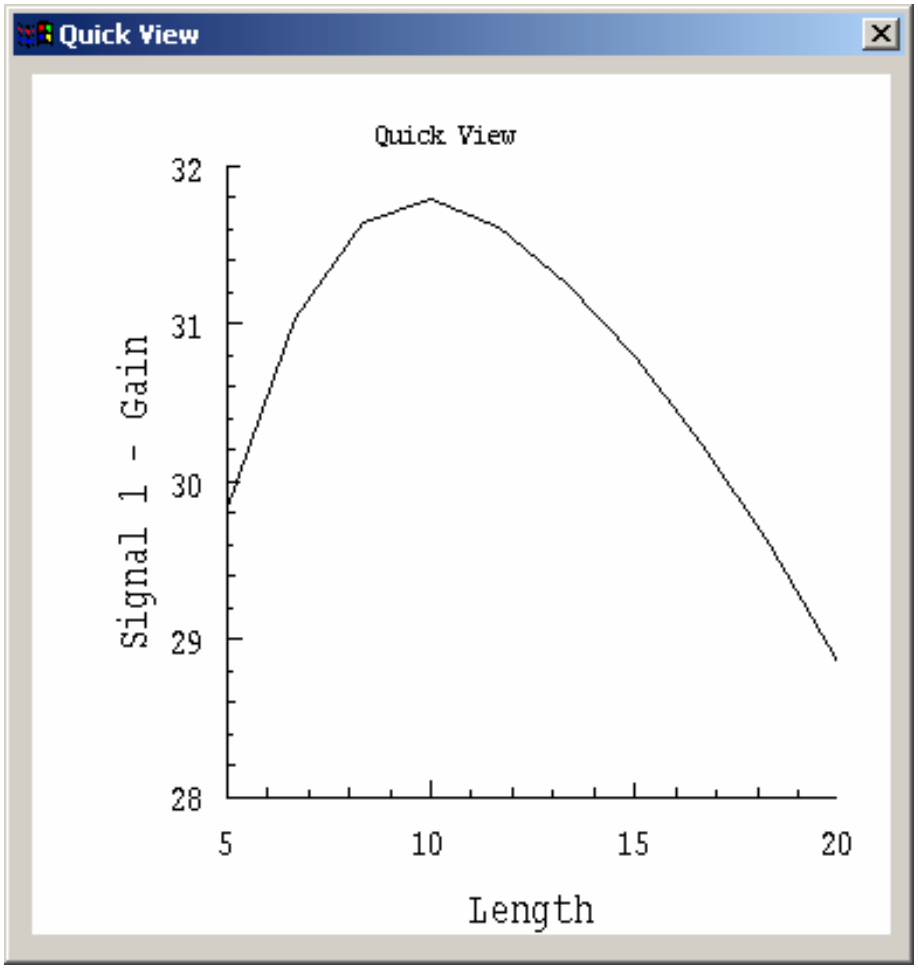
Optimize Amplifier Parameters

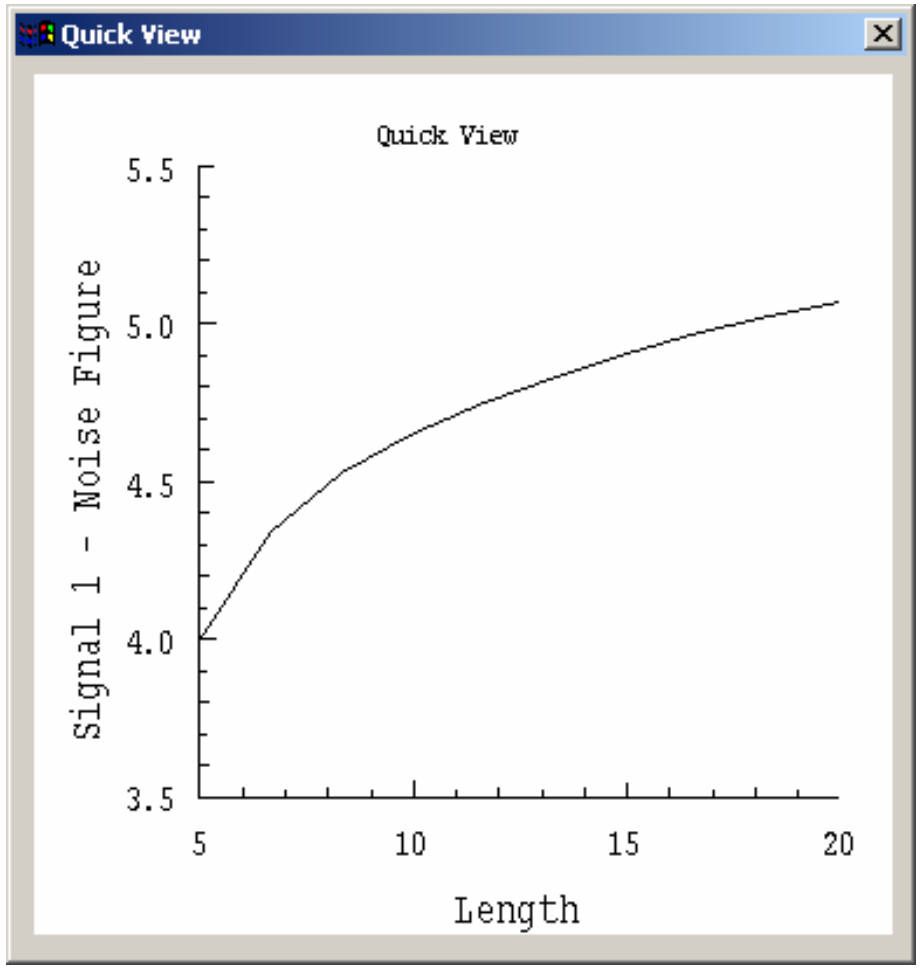


Analyze the Results

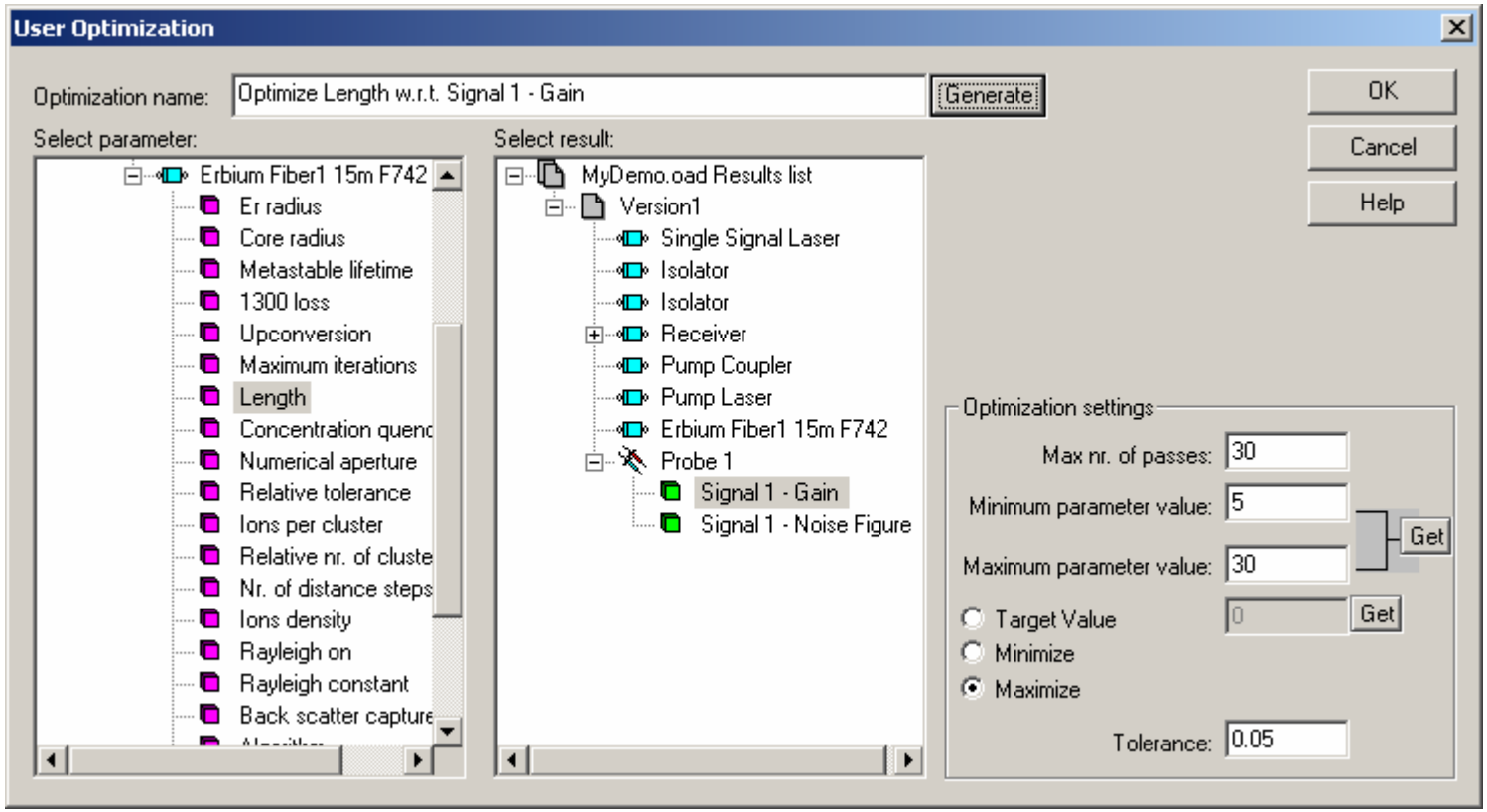


Analyze the Results

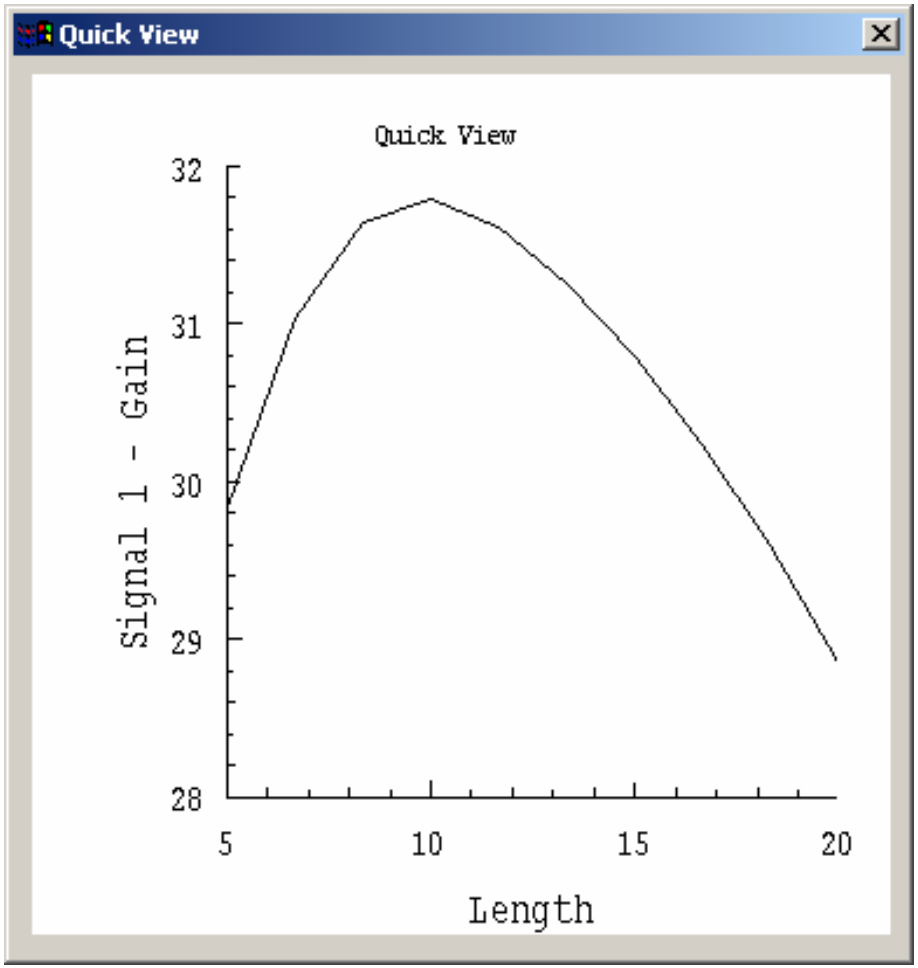




Automatic Optimizations



Automatic Optimizations



Max at 9.72 m

Comparing Results with Measurements