VIRTUAL PHOTONICS
INCORPORATED

formerly BNeD GmbH and Virtual Photonics Pty Ltd

Efficient Simulation of Optical Systems

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Outline

- *Short* notes on company and product background
- Challenges in simulating optical systems
- Software architecture
- Signal representation
- Example
- Summary

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Company and Product Background

- *Virtual Photonics Incorporated* (*VPI*) provides tools for the simulation of fiber-optical networks, systems and devices.
- VPI has been formed by
  - BNeD GmbH, a spin-off from the Heinrich-Hertz-Institute, Berlin, Germany
  - Virtual Photonics Pty. Ltd., a spin-off from the University of Melbourne, Australia
- VPI products comprise
  - *Photonic Transmission Design Suite* (*PTDS*) based on Ptolemy 0.7, aiming at providing an integrated environment for different design tasks from device to system level.
  - *Optoelectronic and Photonic Advanced Laser Simulator (OPALS)* based on LabView, aiming at device and especially laser simulation.

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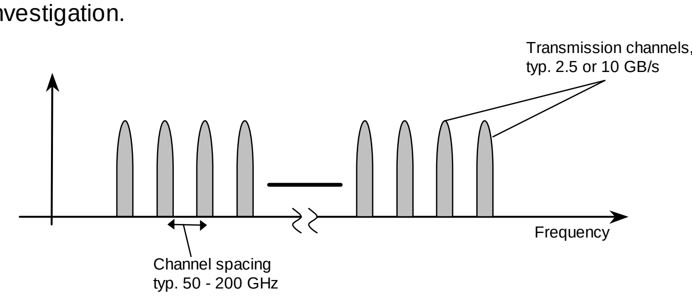
Challenges in Simulating Photonic Systems: Huge Bandwidth

- Wavelength Division Multiplexing (WDM) systems:
  - Transmit a number of modulated channels at different wavelengths.
  - Practical systems use up to 128 channels, covering bandwidth of up to 6 THz.
  - Non-linear effects (e.g. FWM, Saturation) prohibit frequency selective investigation.



⇒ Advanced models and flexible signal representation are required to focus on effects of interest.

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Challenges in Simulating Photonic Systems: Modeling Depth

- Model depth depends on effects to be investigated and on simulation approach
  - Power budget analysis
    - Signal-to-noise investigations model signals by their average power
    - Fast but very approximate
  - Simulation of physical effects
    - Consideration of various physical effects requires sampling of waveforms
    - Exact but computationally expensive
  - Semi-analytical modeling
    - Analytical computation of key signal charcteristics (e.g. average timing jitter) necessitates abstract signal description

⇒ Different, interoperable signal representations are required

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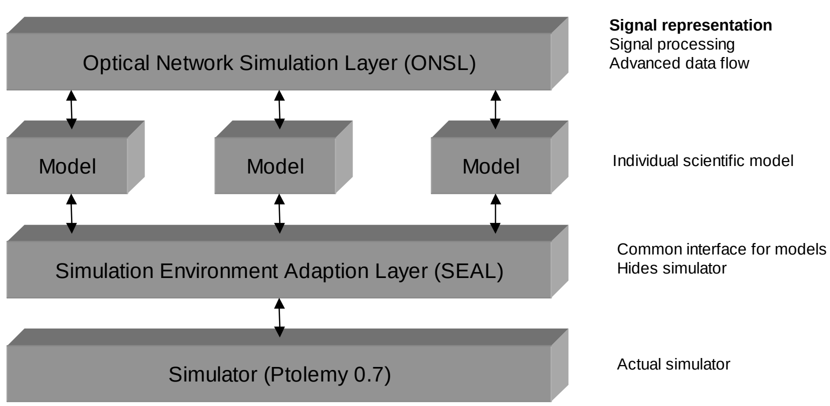
Software Architecture



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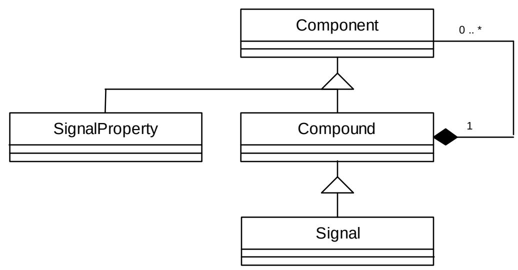
Modular Signal Representation

- OO approach to represent signals blockwise, implementation in C++
- A signal is defined by its time and frequency window and dynamically aggregated *properties*
  - *Composite* pattern
  - Provides flexibility and extensibility
  - Signal composition can be altered at run-time



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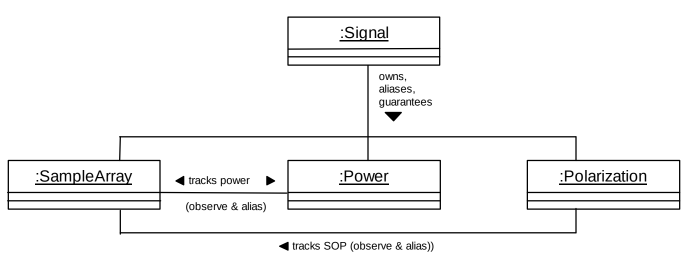
Signal / Property Interaction

- Additional functionality implemented:
  - Message passing for communication of signals and properties
  - *Observer* pattern to track dependencies between properties and signals
  - Aliasing mechanism to avoid expensive list searches
  - Mechanism to guarantee existence of properties within a signal
  - Naming of properties to allow for orthogonality
  - Nested properties



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Signal Properties

- Distinction of properties according to their contents
  - *Physical properties* contain information on a physical signal
    - Array of samples
    - Average signal power
    - State of polarization
    - Statistics of signal
  - *Logical properties* carry information on a channel of transmission
    - Modulation information
    - Pulse shape used
    - Line coding employed
    - Bit stream modulated

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Basic Signal Types

- *Logical Channel*
  - Dedicated exclusively to hold logical properties describing one channel
- *Noise Bin*
  - Serves to represent WGN in a bandwidth portion
  - Guarantees to hold properties describing power and polarization
- *Parameterized Signal*
  - Guarantees to hold properties describing signal statistically
  - May refer to a logical channel
- *Sampled Band*
  - Guarantees to hold properties providing the sampled waveform
  - May refer to a number of logical channels

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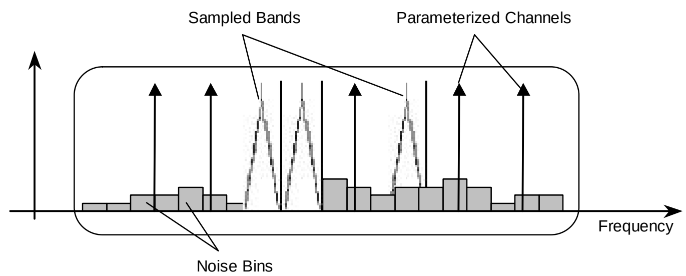
Compound Signal Representation

- To model complex signals, a compound of basic signal types is formed
  - Compound structure itself is a signal type object, handled as one entity
  - Basic signal type instances are held in according container properties



- This compound signal representation is passed between stars
- Likewise signal representation exists for electrical signals

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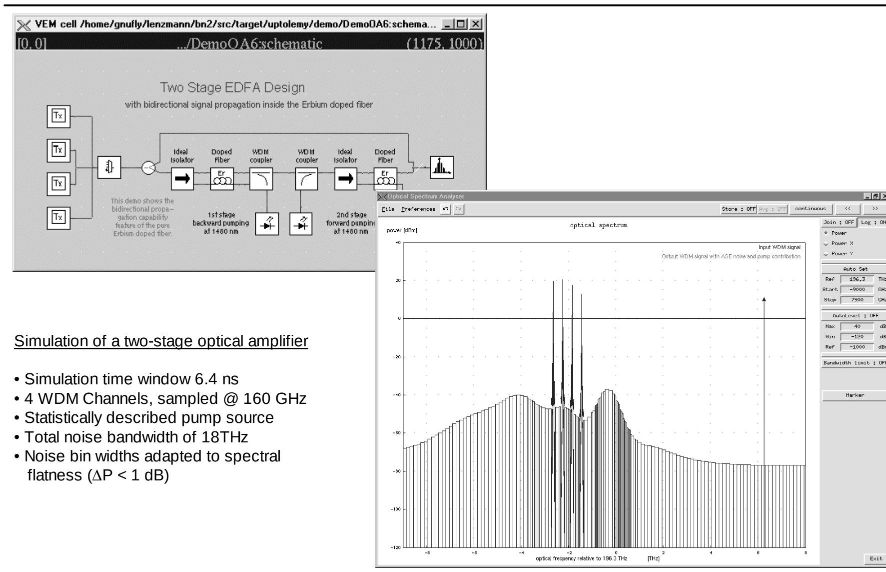
Example: Broadband Optical Amplifier



Simulation of a two-stage optical amplifier

- Simulation time window 6.4 ns
- 4 WDM Channels, sampled @ 160 GHz
- Statistically described pump source
- Total noise bandwidth of 18THz
- Noise bin widths adapted to spectral flatness ($\Delta P < 1$ dB)

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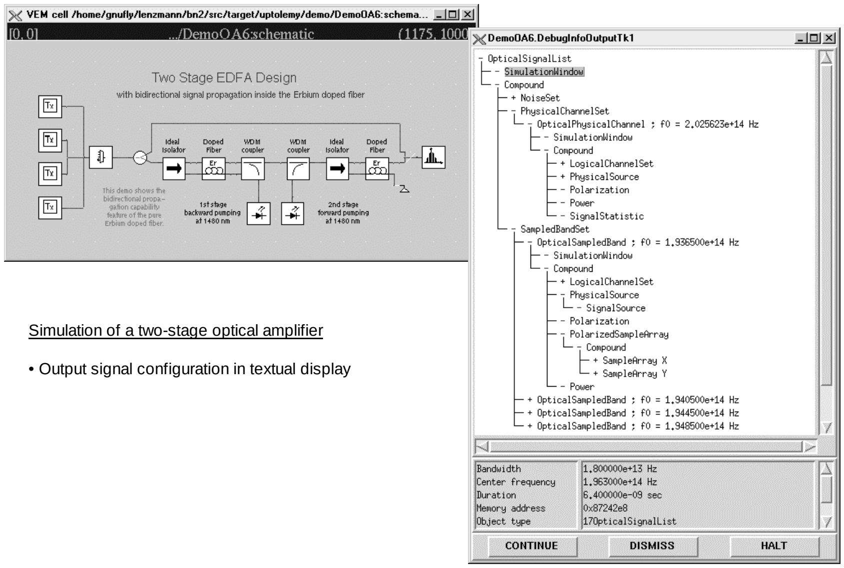
Example: Broadband Optical Amplifier



Simulation of a two-stage optical amplifier

- Output signal configuration in textual display

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Summary

- ONSL provides dynamic and open signal representation
  - Easy to extend (even by a user)
  - Allows for heterogeneous modeling requirements
  - Conveys abstract channel information associated with a physical signal
  - Rich set of common signal processing functionality provided
- Number of problems remain
  - Complex models required to handle different signal representations
  - Non-sampled signals must be assumed uncorrelated
  - Quantization of time and frequency values
  - Boundary conditions of signal blocks
- Future work
  - Investigations on parameterized ⇔ sampled signal conversions
  - Implementation of further properties to allow new analysis types

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