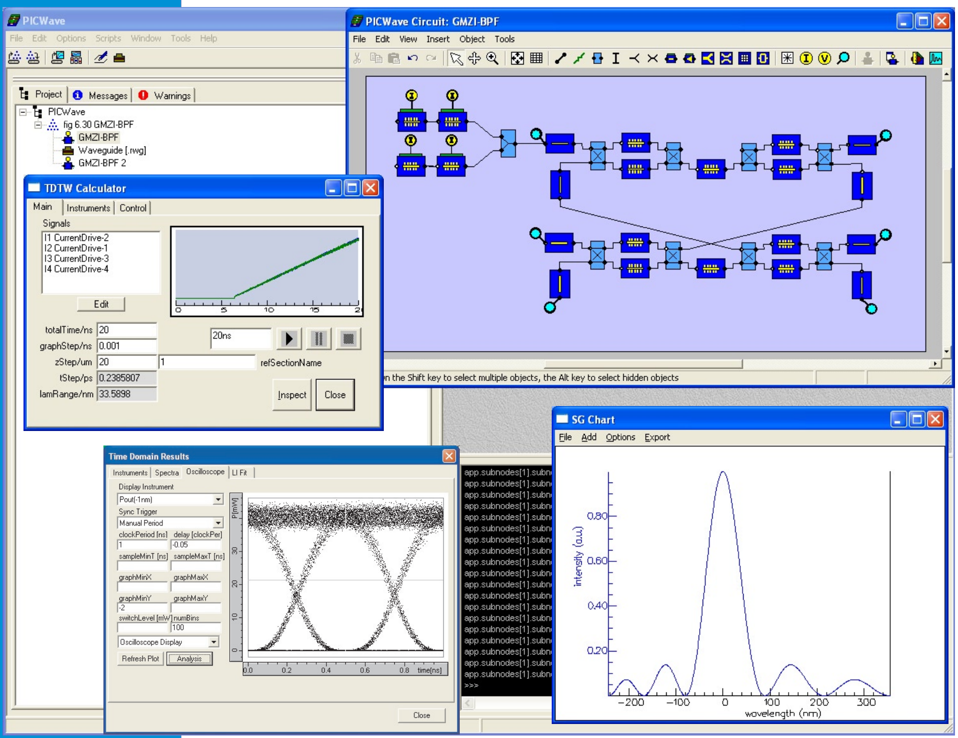
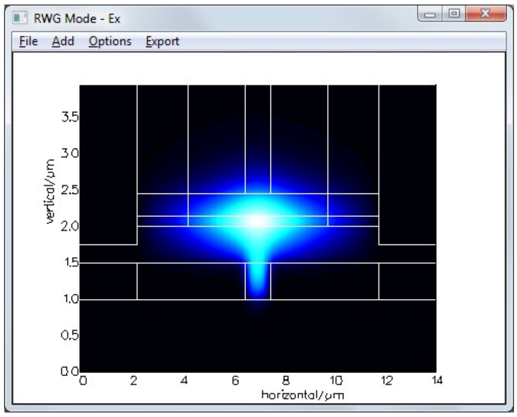
PICWave

a photonic circuit and laser diode/SOA simulator

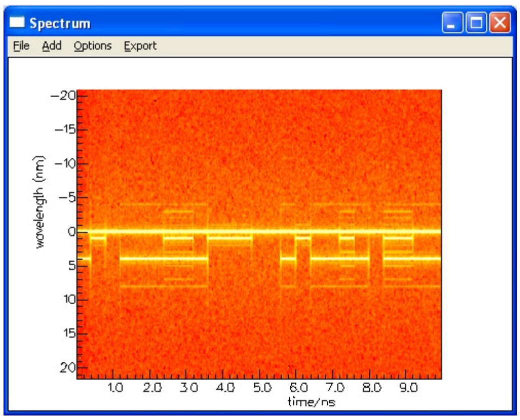


- ☑ Integrated suite of tools for both passive and active photonic IC (PIC) simulation
- ☑ Extensive laser diode and SOA physical models
- ☑ Integration with other rigorous Maxwell EM solvers
- ☑ Design kit (PDK) support
- ☑ Extensive fibre Bragg grating models



- ☑ Tuneable laser diode models
- ☑ Travelling wave SOAs
- ☑ Large ring resonators
- ☑ Mach-Zehnder modulators
- ☑ Electro-absorbtion modulators

Probably the fastest way of simulating active PICs available today



- ☑ Fast time domain engine
- ☑ Physical 2D (XY) waveguide models
- ☑ Simple drag & drop circuit builder
- ☑ Sophisticated noise models
- ☑ Static and time-evolving spectra

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What is PICWave?

PICWave is a photonic circuit (PIC) simulator including a sophisticated physical model for laser diodes and SOAs.

The simulator is ideal for developing optoelectronic devices such as tuneable lasers and modulators, then studying their interaction in a larger circuit - it can for example model a 2mm diameter ring resonator in a very short time to resolutions of a few MHz in optical frequency.

Calculation method

The calculation engine of PICWave is based on a powerful and flexible time-domain travelling wave (TDTW) model, from which almost all other results are derived.

Structure

A PICWave device can consist of any number of passive elements like waveguides, Y-junctions, directional couplers, mirrors, plus active components like an SOA or an electro-absorbtion modulator. LRC electrical circuits can then be connected to drive the circuit.

PICWave's active device model provides some of the most sophisticated features on the market today.

Design Integration

PICWave is closely integrated with other models for quantum-well modelling and with EM simulators for detailed modellign of the passive components. In addition its design kit system allows your designs to be readily exported to a compatible fab.

Requirements

PC: x86 or x64; Vista, Win-7,/8/10, 2GB+ RAM, Core-i5 2GHz or better recommended.

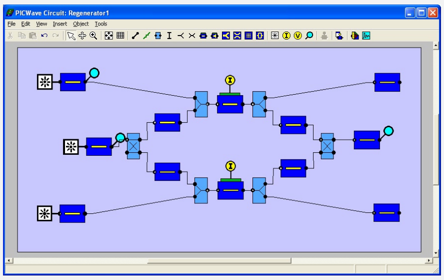
Circuit modelling, design kits and PDKs

☑ Designing active PICs: a 2R optical regenerator

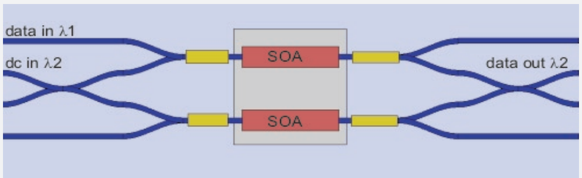
One of PICWave's strengths is it's ability to combine passive and active components. This optical regenerator consists of a large passive optical circuit totalling over 10,000um of waveguides plus two SOAs.

The regenerator is shown schematically below. A signal injected into the top-left arm at λ_1, causes non-linear interference in the SOA with a DC signal at λ_2. The result is the signal tansferred to λ_2 but with improved or "regenerated" amplitude and on-off ratio.

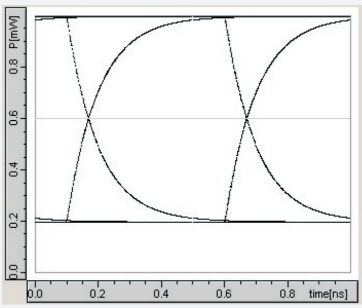
The regenerator was simulated with PICWave using an NRZ pseudo-random input bit pattern with an on/off ratio of 5:1 and a rise time of 100ns. To the right is shown eye diagrams of both the input and output signals. Notice the much higher on/off ratio of the regenerated signal and also the 20x amplification. Note however how the SOAs have added significant noise to the output. PICWave includes an extensive model for noise sources present in semiconductor devices, modelling carrier fluctuations, phase noise and intensity noise.



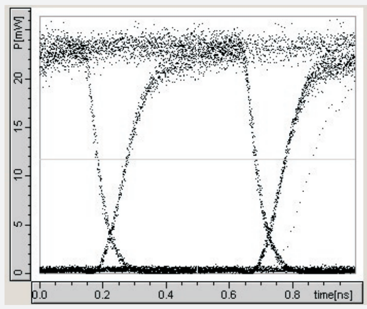
Circuit built from active and passive elements



Layout of the regenerator



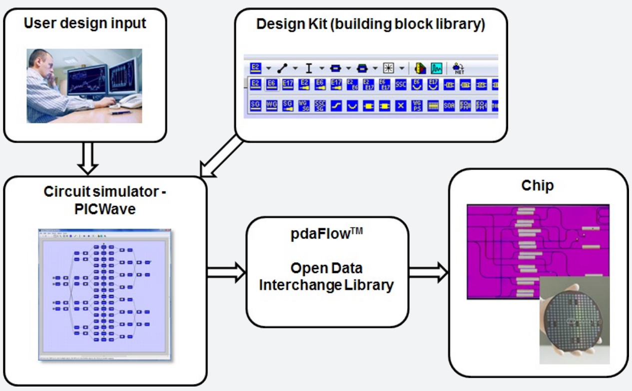
Input signal at λ1



Regenerated signal at λ2

☑ Process Design Kits (PDKs)

PICWave's design kit system enables PDK libraries of pre-made components (BBs) to be imported and used to construct circuits. At time of writing, we have PDKs for Heinrich Hertz Institut and Smart Photonics fabs under the InP JEPPIX platform. Contact us for latest availability for other fabs.



Circuit Model Features

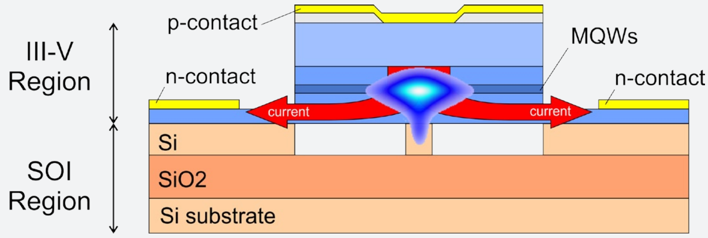
- Efficient optical circuit simulator
- Time-domain travelling wave (TDTW) optical model
- Optical response spectra
- Transient response
- Integrated XY waveguide-solver
- Arbitrary time domain input signals
- Eye diagrams
- Import component models from other EM solvers
- Nonlinear waveguides (PPLN)
- Fibre-Bragg grating models
- Material database system

Laser diode and SOA modelling

☑ Flexible laser cross-sections (XY)

The active models will support all the usual physical structures including ridge waveguides and buried heterostructures. You can even model hybrid lasers where InP is mounte din Si as below. The algorithms will model the details of the lateral current and carrier profiles, including current spreading, leakage, diffusion and spatial hole burning.

One active layer might have a gain grating in it, another might be designed as a saturable absorber.



A hybrid silicon III-V laser with current spreading

Active Model Features

- PI and PV curves
- Quantum noise
- Chirp simulation
- RIN spectra
- Travelling wave electrode model
- Non-Lorentzian gain spectra
- Carrier diffusion and spatial hole burning
- Non-linear gain / spectral hole burning
- Integrated grating solver (real and gain)
- Auger & Shockley Reed Hall processes
- Thermal effects
- Import gain tables
- Electro-absorption modulator model
- Multi-level carrier model

☑ Arbitrary geometries for laser cavities

PICWave is able to model active devices of almost arbitrary complexity with multiple sections, facets, DBR gratings, y-branches, external cavities..., allowing you to test almost any design you can think of.

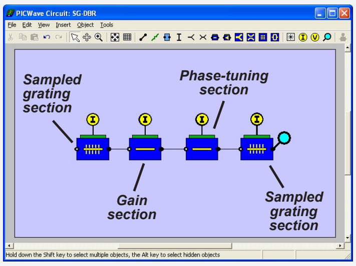
On the top right is a simulation of a **sampled grating DBR (SG-DBR) tuneable laser**, consisting of gain, tuning and grating sections.

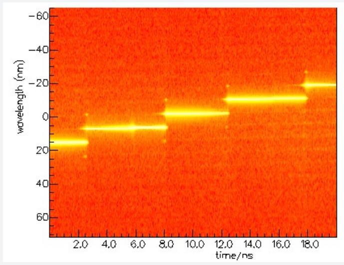
The gratings have different sampling periods so lasing only occurs at widely-spaced wavelengths where reflection resonances of the two gratings coincide.

To the bottom right is a time-evolving spectrum of the SG-DBR showing mode hops due to bad electrical control. Note also the transients and background noise.

A few examples:

- Fabry Perot
- DFB
- DBR
- Mode locked
- Tuneable DFB
- Tuneable SG-DBR
- Multiple-branch
- Ring laser
- External cavity + modulator
- External cavity with FBG
- etc.



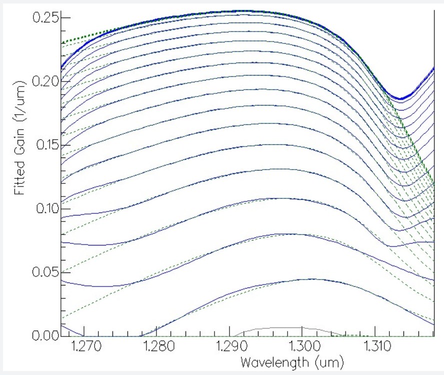


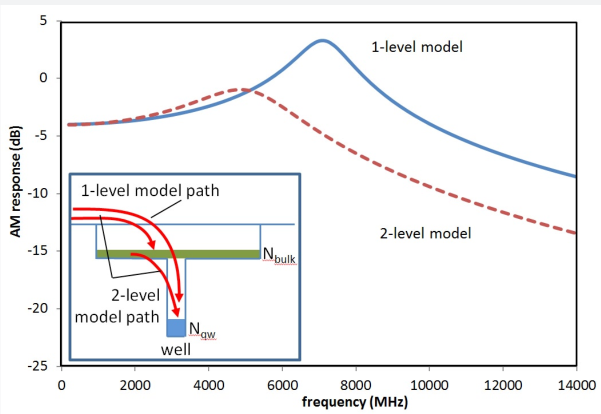
Time-evolving spectrum of output power

☑ Sophisticated active material models

Harold is a powerful quantum well hetero-structure model. PICWave is closely integrated with Harold, allowing it to accurately account for doping effects, detailed band structure, quantum well effects and sophisticated gain models while simultaneously retaining the famous speed efficiency of its device model.

To the right is shown (green) a stack of gain spectra computed by Harold at different carrier densities. PICWave will faithfully reproduce these spectra in its time-domain device model. The fit can also take account of temperature effects. Gain spectra from other sources, e.g. measurements, can be imported and fitted too.

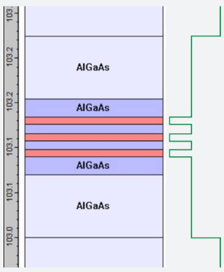




1- and 2-level carrier models:

(left) AM response vs frequency for each model

(below) epitaxial and quantum well structure



(above) Gain curves computed by Harold for a 3 QW InGaAsP epistructure are shown in green for different carrier densities. PICWave's fitted models are shown in blue. PICWave will import and fit almost all of Harold's other results, including spontaneous recombination, diffusion, refractive index data...

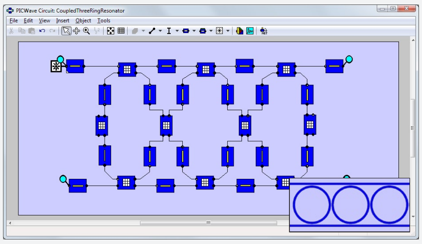
Automatically import and fit detailed material models from Harold

☑ Integration with FIMMPROP

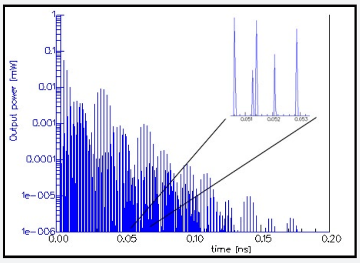
If you have a tool for detailed electro-magnetic simulation of, for example, a Y-junction, you can import the results of this simulation into PICWave in the form of a wavelength-dependent scattering matrix.

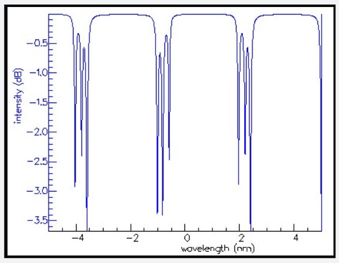
Better still: use FIMMPROP to create detailed EM models of your passive components. These can then be readily incorporated into a PICWave model at the click of a few buttons, within an integrated project management environment.

You can see here an example of PICWave and FIMMPROP co-simulating a system of three coupled ring resonators of diameter 200um. FIMMPROP is used to compute the coupling coefficient of the ring couplers and the bend losses, whilst PICWave assembles all the individual components into a circuit. The co-simulation is many orders of magnitude more efficient than e.g. FDTD for this application, allowing us to obtain a wavelength resolution of 50MHz and spectral range of 50nm in just a few minutes.



3 coupled ring resonators

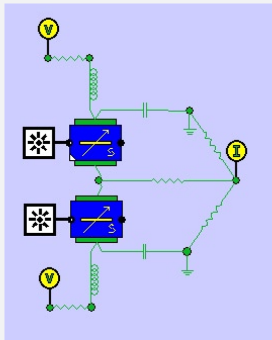




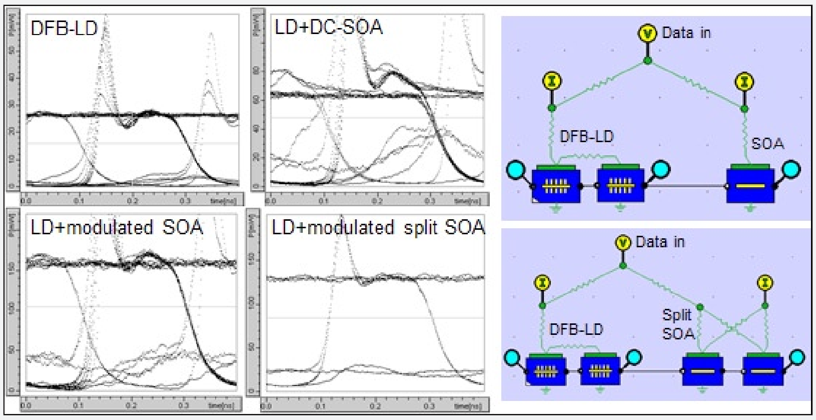
Time-domain (left) and frequency-domain (right) response

☑ High-speed Optoelectronics

As well as the current flow and leakage models working in a device cross-section, PICWave includes many features for modelling the electrical side of an optoelectronic device. PICWave's travelling wave electrode model allows simple microwave models to be created. Electrical wires, resistors, capacitors and inductors can connect electrodes together in an arbitrary electrical circuit. Together, these allow PICWave to correctly model high-speed optoelectronic components such as this high-speed modulated laser/SOA or this balanced photo-detector.



Balanced photo-detector with LRC circuit

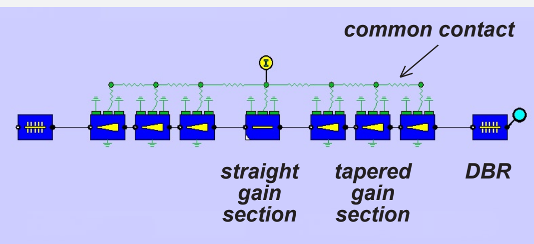


High speed directly-modulated laser/ SOA design. By adding electrical connections to co-modulate the SOA, substantial improvements in the device performance can be obtained.

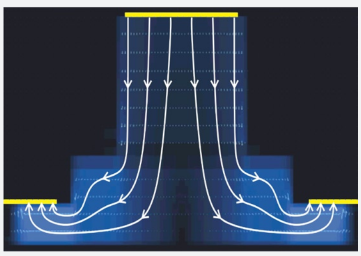
☑ Modelling a tapered hybrid III-V / SOI laser

PICWave has all the tools needed to rigorously model the complexities of a hybrid InP/SOI laser. Gain curves (from Harold) model the QW gain vs. wavelength and temperature. A current spreading model computes the detailed flows from the central p-contact, through the junction, then laterally to the n-contacts on the sides (see figure) taking into account changes in resistivity through the layers. The laser uses a tapered waveguide to move the light from the silicon to the InP active layer and back down. PICWave takes into account all the variations in the waveguide modes, current flows and carrier-diffusion as the taper cross-section changes.

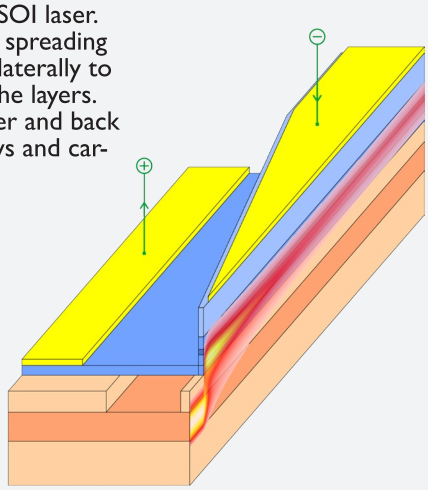
Hybrid lasers typically use a DBR grating in the silicon waveguides to provide optical feedback for lasing action. This is readily added in PICWave's circuit model. The completed PICWave layout is shown below.



Symbolic layout with DBRs and active taper



Current spreading



Tapered part of the laser, showing the optical intensity in the central cross-section