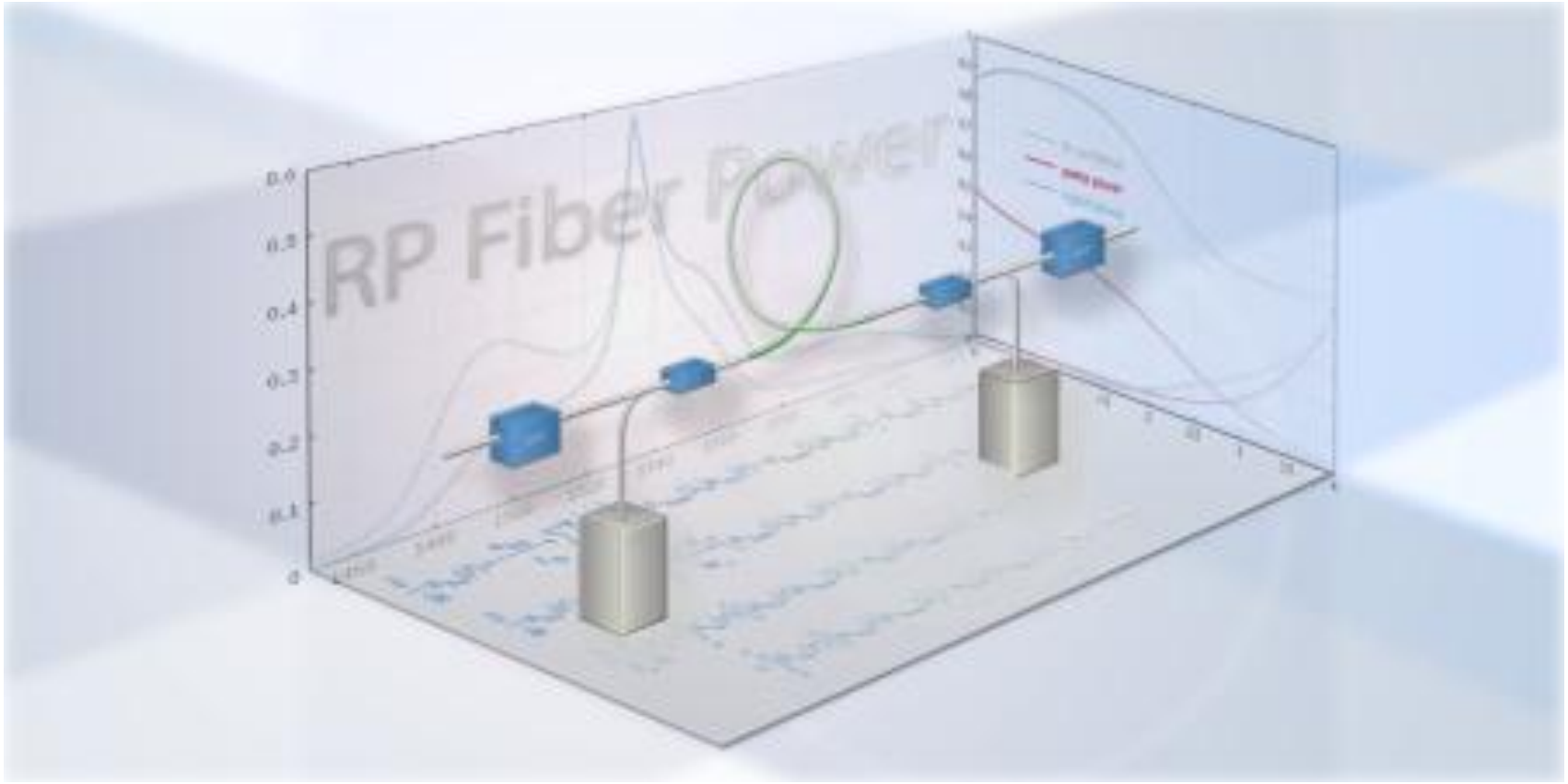
RP Fiber Power 4.0

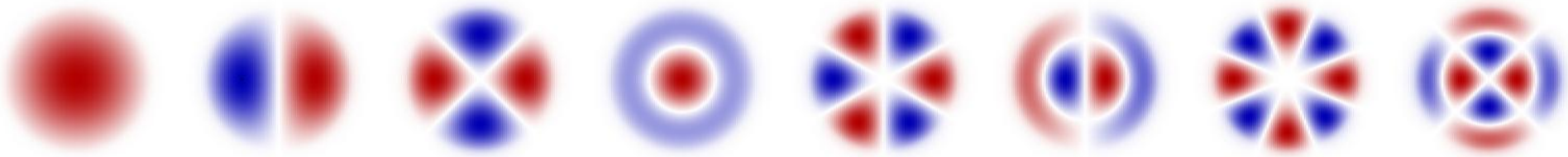


a software product of

RP Photonics Consulting GmbH

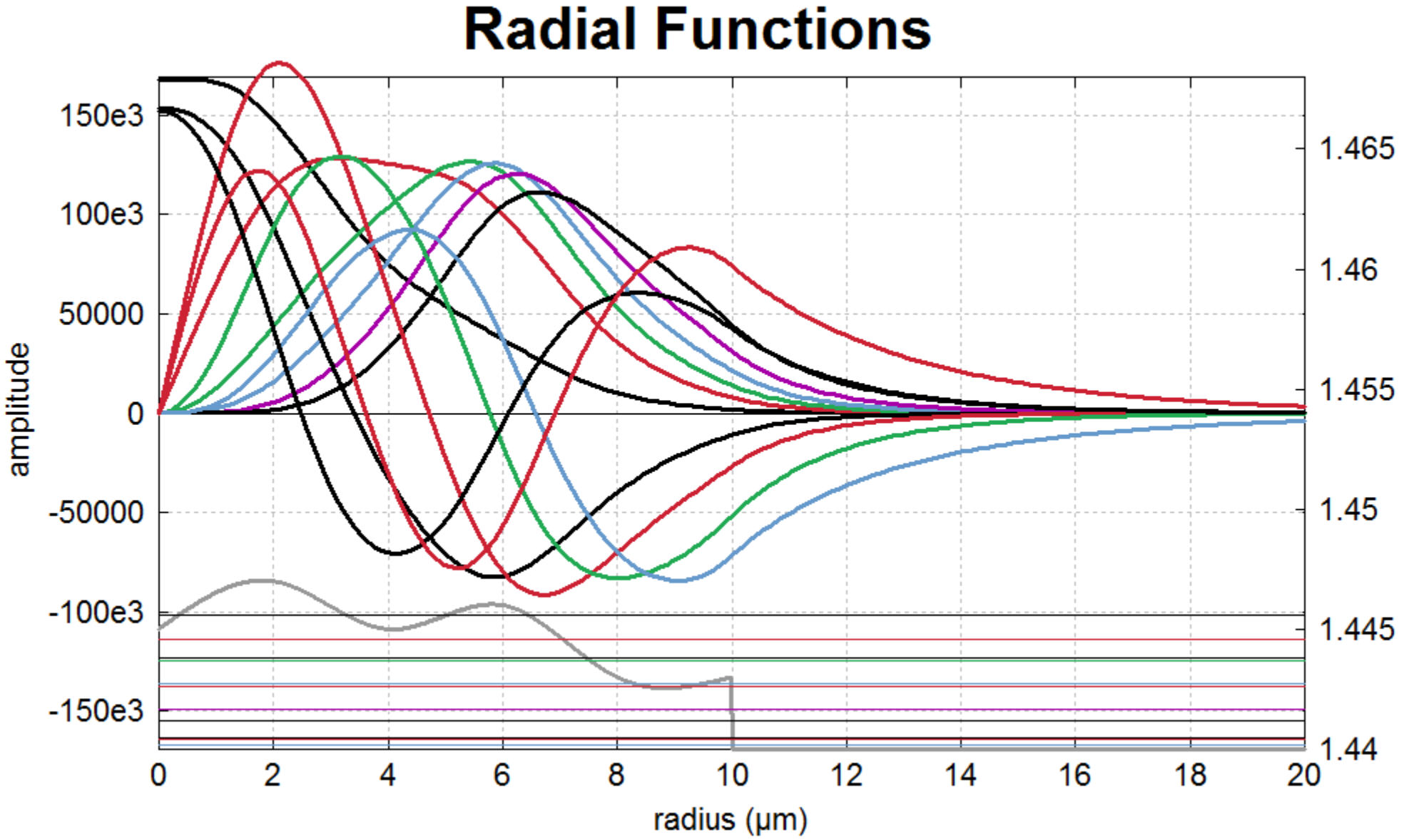
www.rp-photonics.com/fiberpower.html

Calculation of Fiber Modes (1)



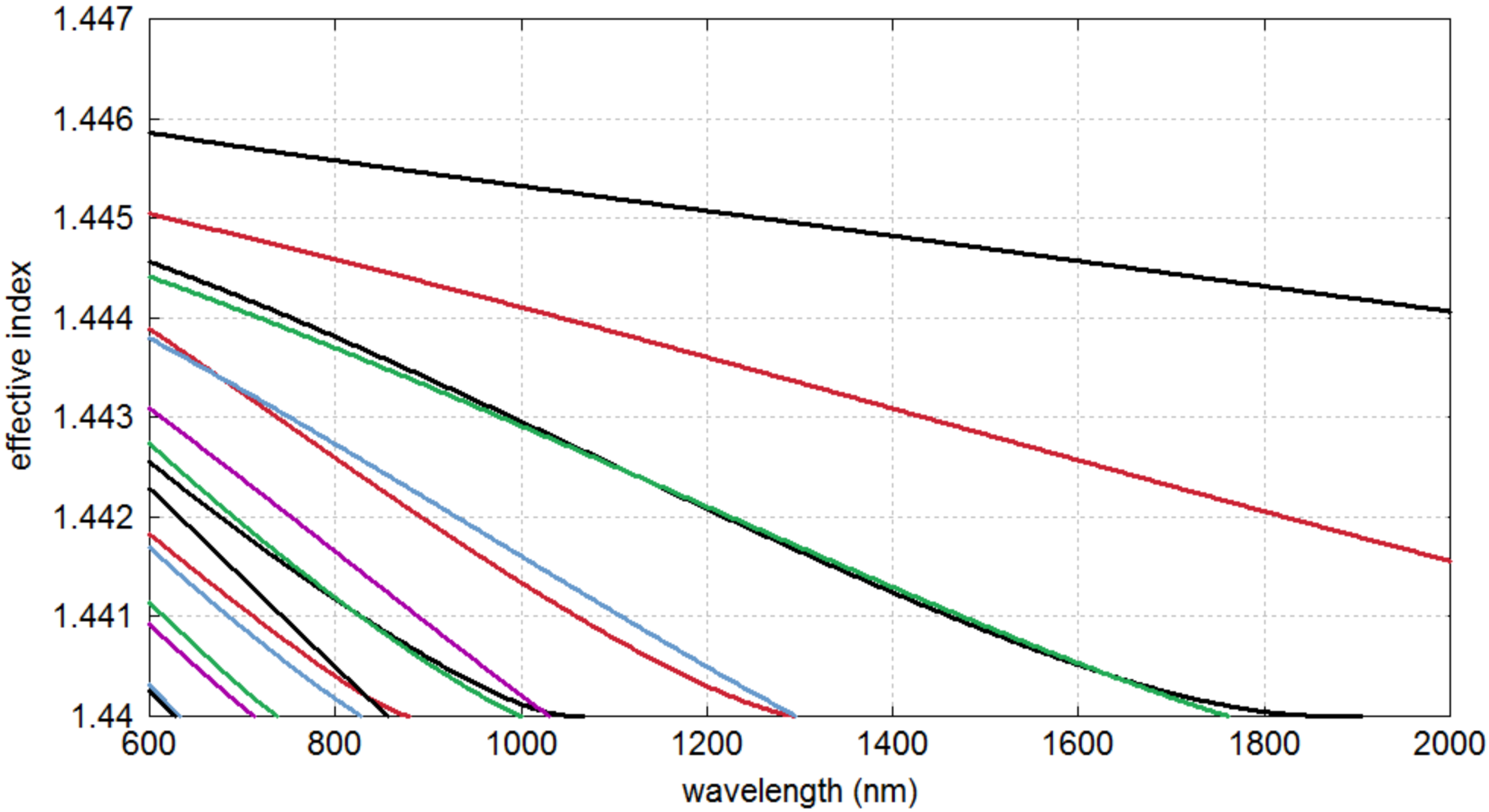
- From a given refractive index profile, the **integrated mode solver** calculates all guided modes (LP modes):
  - amplitude and intensity profiles
  - effective mode areas
  - cut-off wavelengths
  - effective refractive indices and group indices
  - chromatic dispersion
- Index profiles can have any radial dependence and wavelength dependence.

Calculation of Fiber Modes (2)

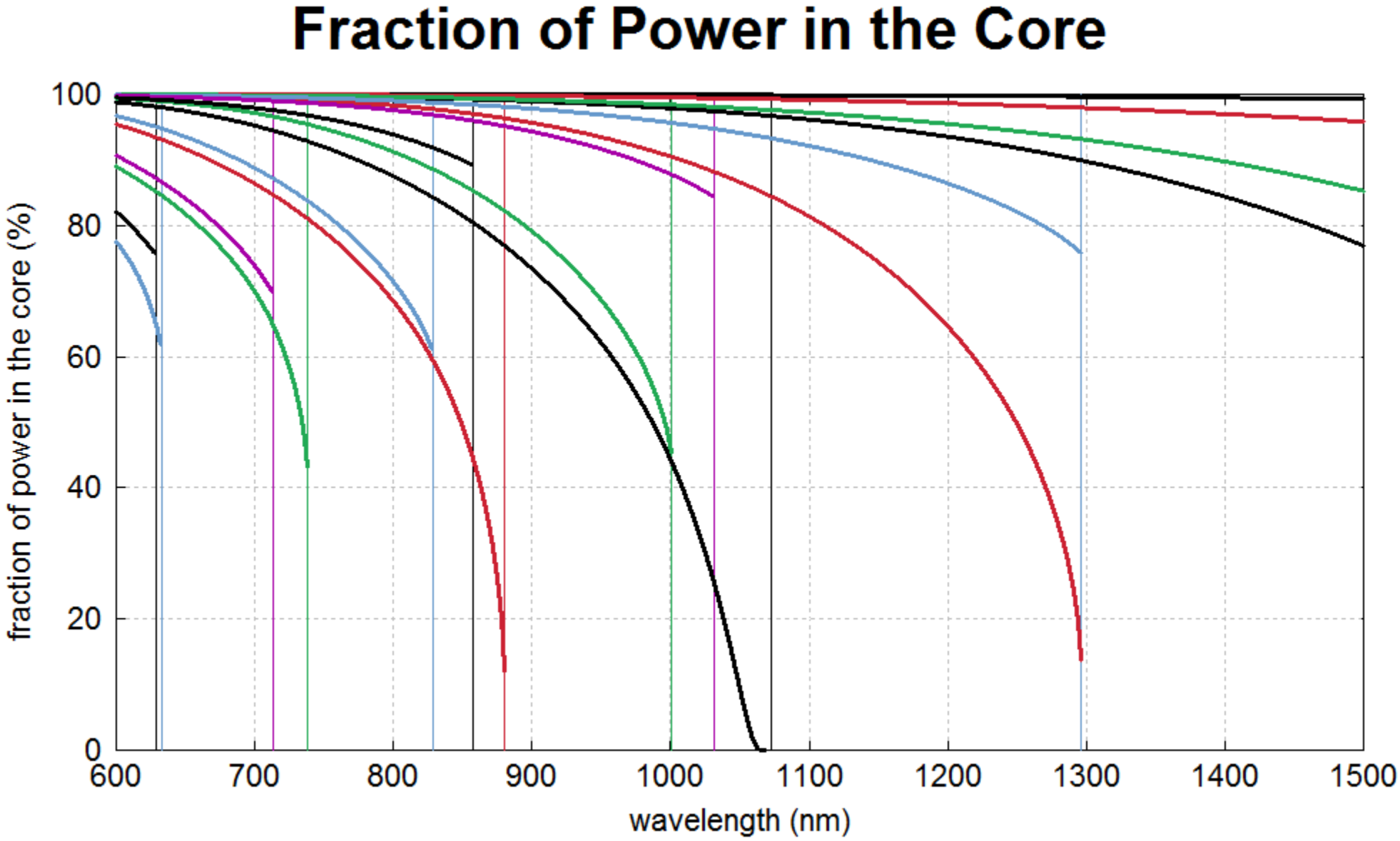


Calculation of Fiber Modes (3)

Effective Indices of Modes vs. Wavelength

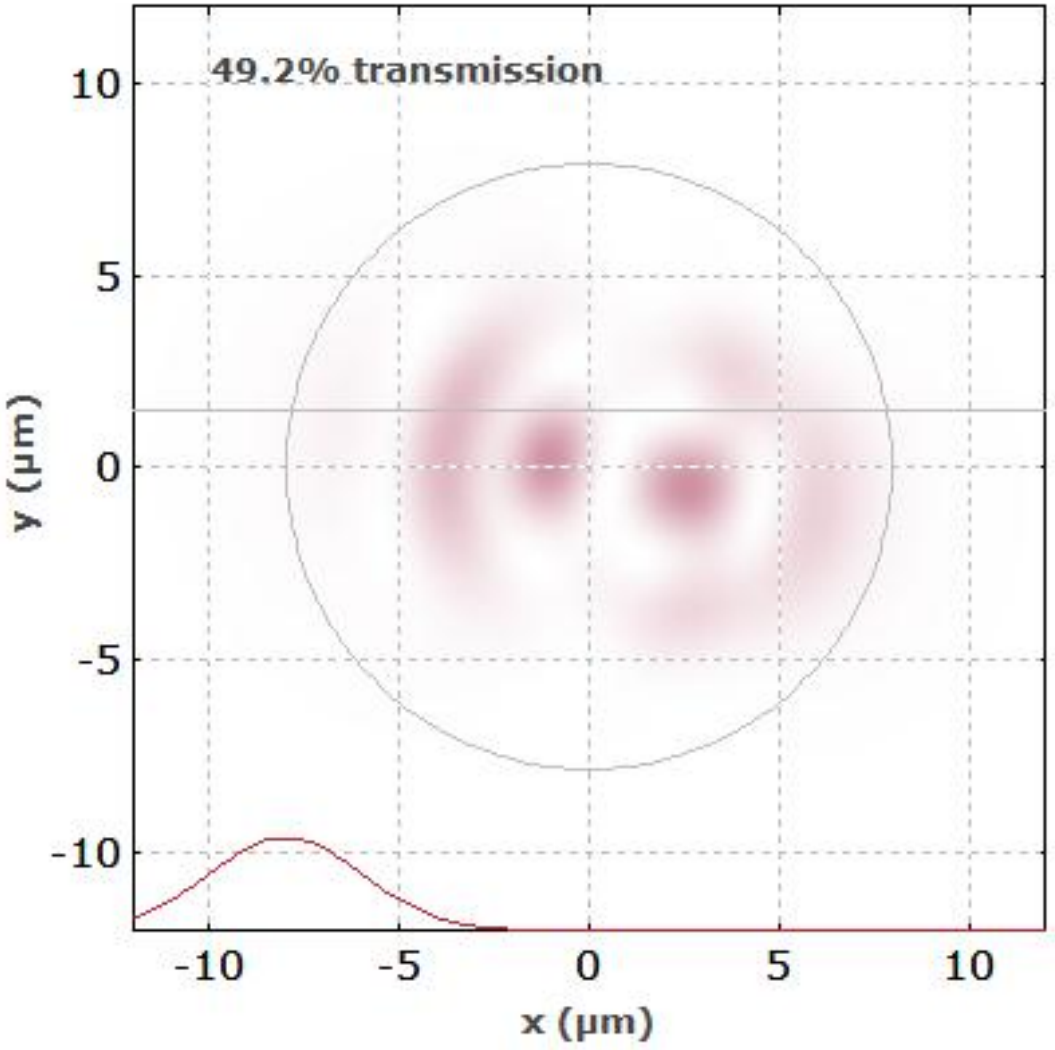


Calculation of Fiber Modes (4)



Calculation of Fiber Modes (5)

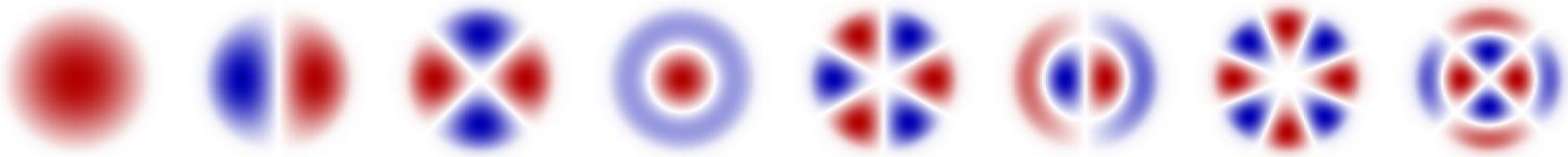
Example: Launching light into a multimode fiber



A simple script does the following:

- Fiber modes are calculated from the refractive index profile.
- Input light (here: misaligned laser beam) is decomposed into modes.
- Complex mode amplitudes change according to the different propagation constants.
- Resulting intensity profile at fiber end is displayed.

Calculation of Fiber Modes (6)



Applications:

- **Analyze** existing fibers in detail – fully understand their properties.
- **Optimize** fiber designs to obtain the needed modal properties.
- **Learn** a lot by playing with the model! For example, try out how mode properties react to changes of the index profile.

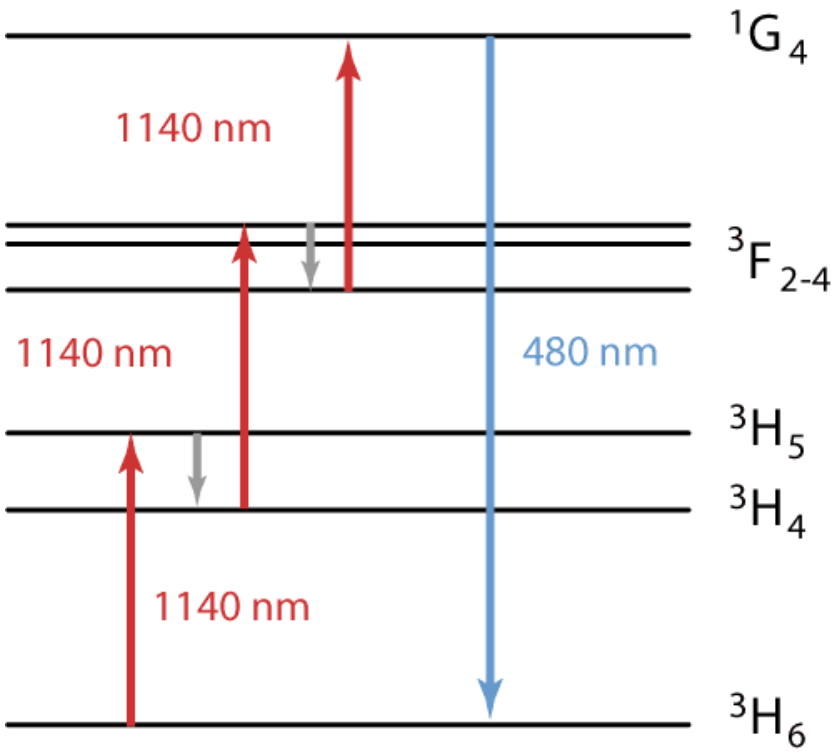
RP Fiber Power is a *must-have* if you work with fiber devices and an *excellent educational tool* for fiber optics!

Calculation of Optical Powers (1)

Models for Laser-active Ions:

- **Simple gain model:** only one metastable level, defined most easily. Applicable to Yb^{3+}, Nd^{3+}, and often for Er^{3+}, Tm^{3+}, etc.
- **Extended gain model:**
  - can have arbitrary user-defined level scheme
  - define arbitrary set of processes: spontaneous and stimulated emission, energy transfers and upconversion, …

  Example case: Tm^{3+} upconversion laser.



Calculation of Optical Powers (2)

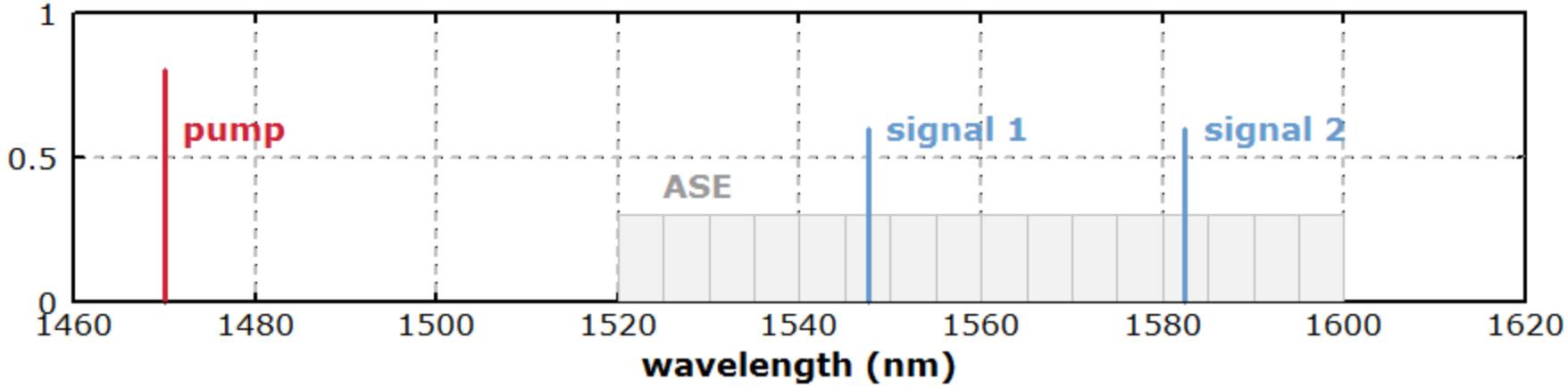
Define a transverse density profile of laser-active ions:

- **Full transverse resolution:** radial and azimuthal dependencies
- **Multiple types of laser-active ions:**
  for example, can have Yb^{3+} and Er^{3+} ions, with energy transfer between them. Each one can have its own density profile.
- Overlap with optical intensity profiles is calculated automatically.

Calculation of Optical Powers (3)

Define “optical channels”:

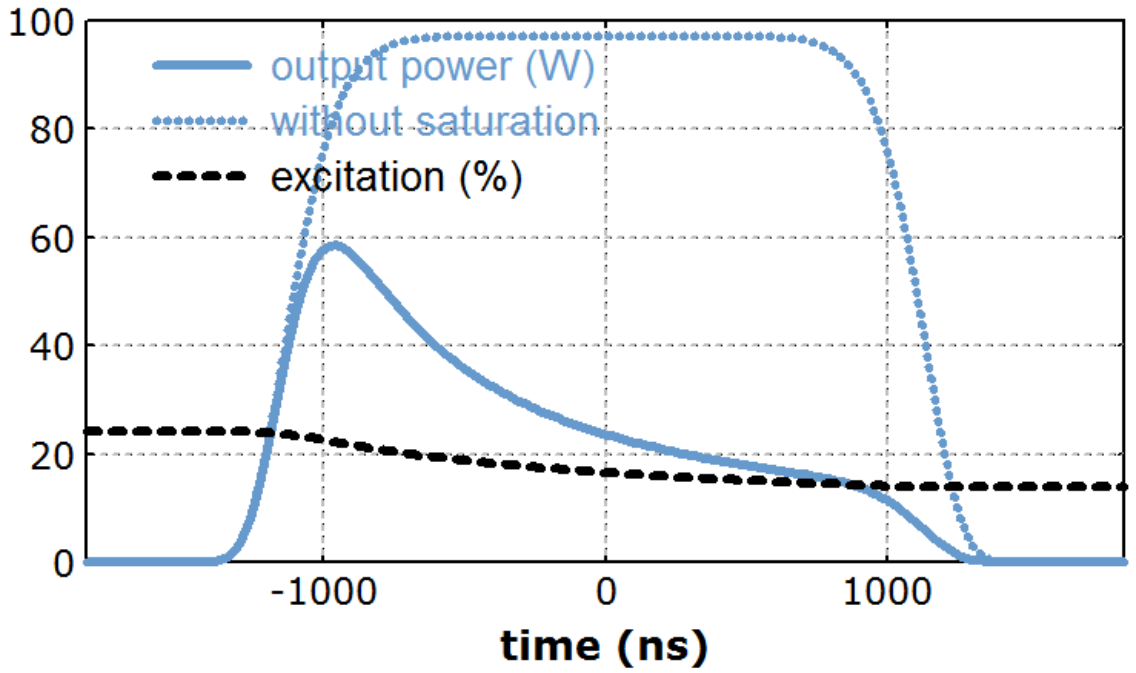
- **Input channels:** for pump or signal input waves, each with its own wavelength, input power, propagation direction, intensity profile, …
- **ASE channels:** for amplified spontaneous emission
- Can have hundreds of channels.
- Intensity profiles can be taken from the mode solver, or specified otherwise.



Calculation of Optical Powers (4)

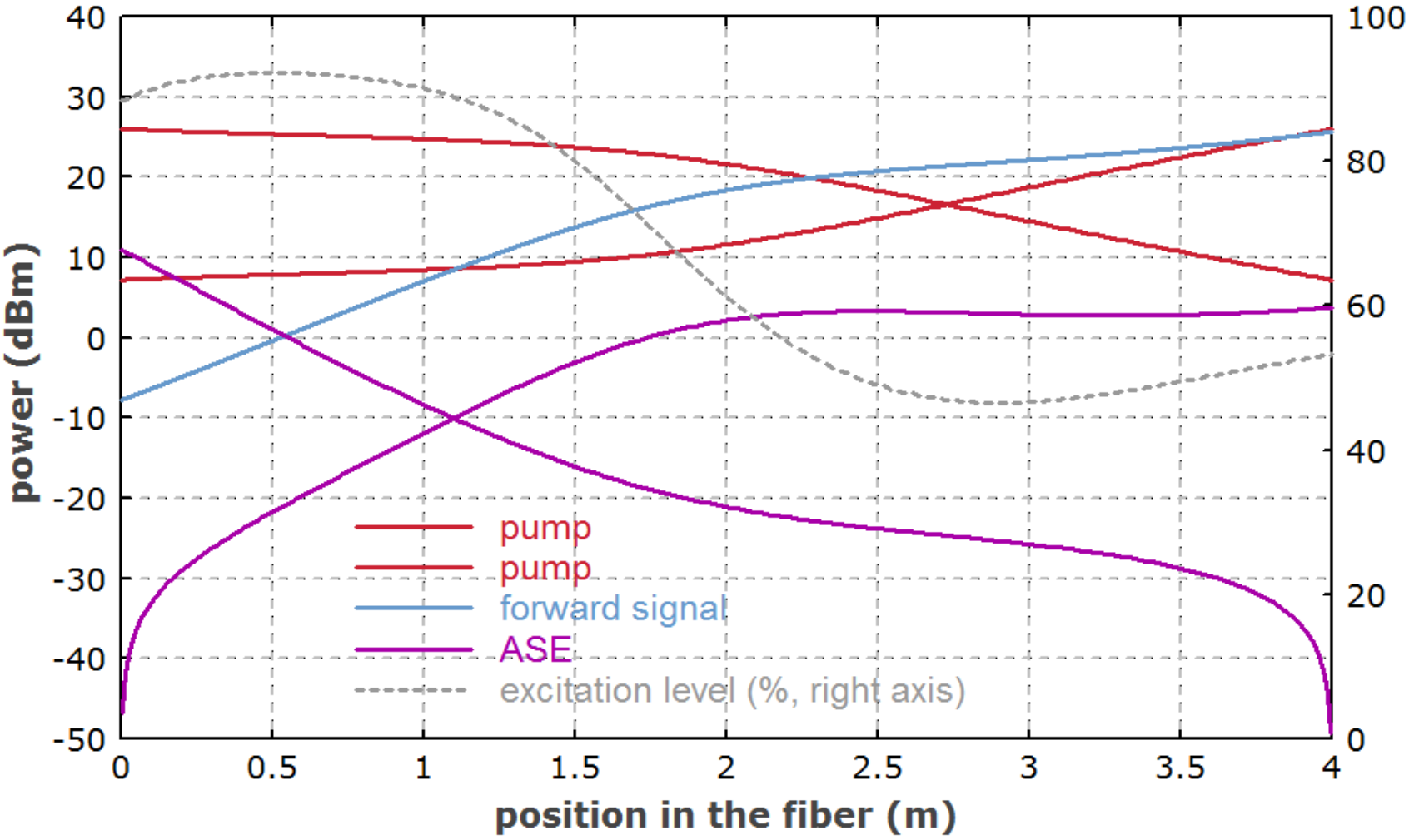
Dynamical calculations:

- The input powers of all channels can have different time dependencies. Example: amplifier for short pulses with long pump pulses.
- Time dependencies of inputs can be described with formulas. Functions are provided for accessing the calculated time-dependent output powers and excitation densities.
- Applications:
  - pulsed amplifiers
  - Q-switched fiber lasers



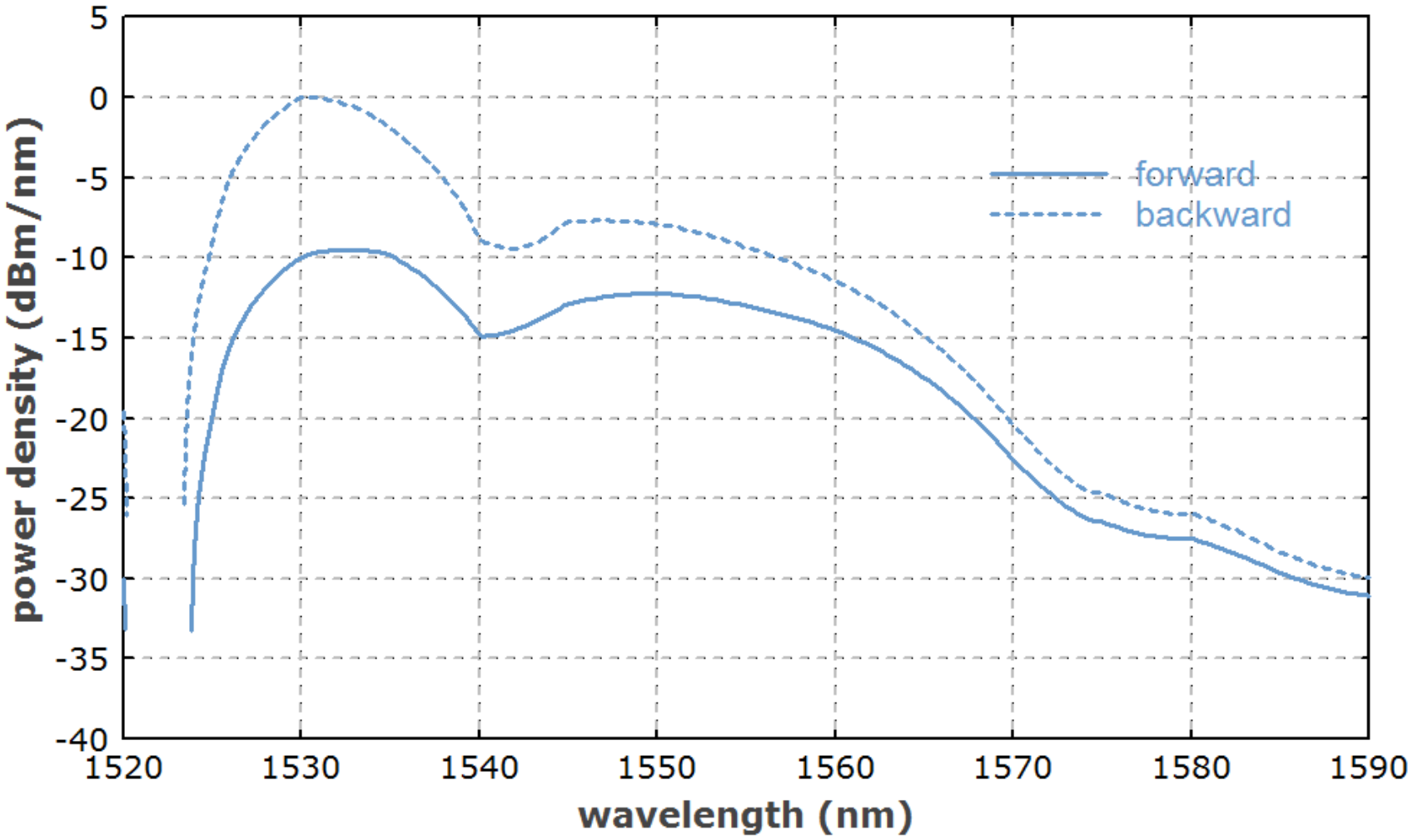
Calculation of Optical Powers (5)

Distribution of optical powers in an erbium-doped fiber amplifier



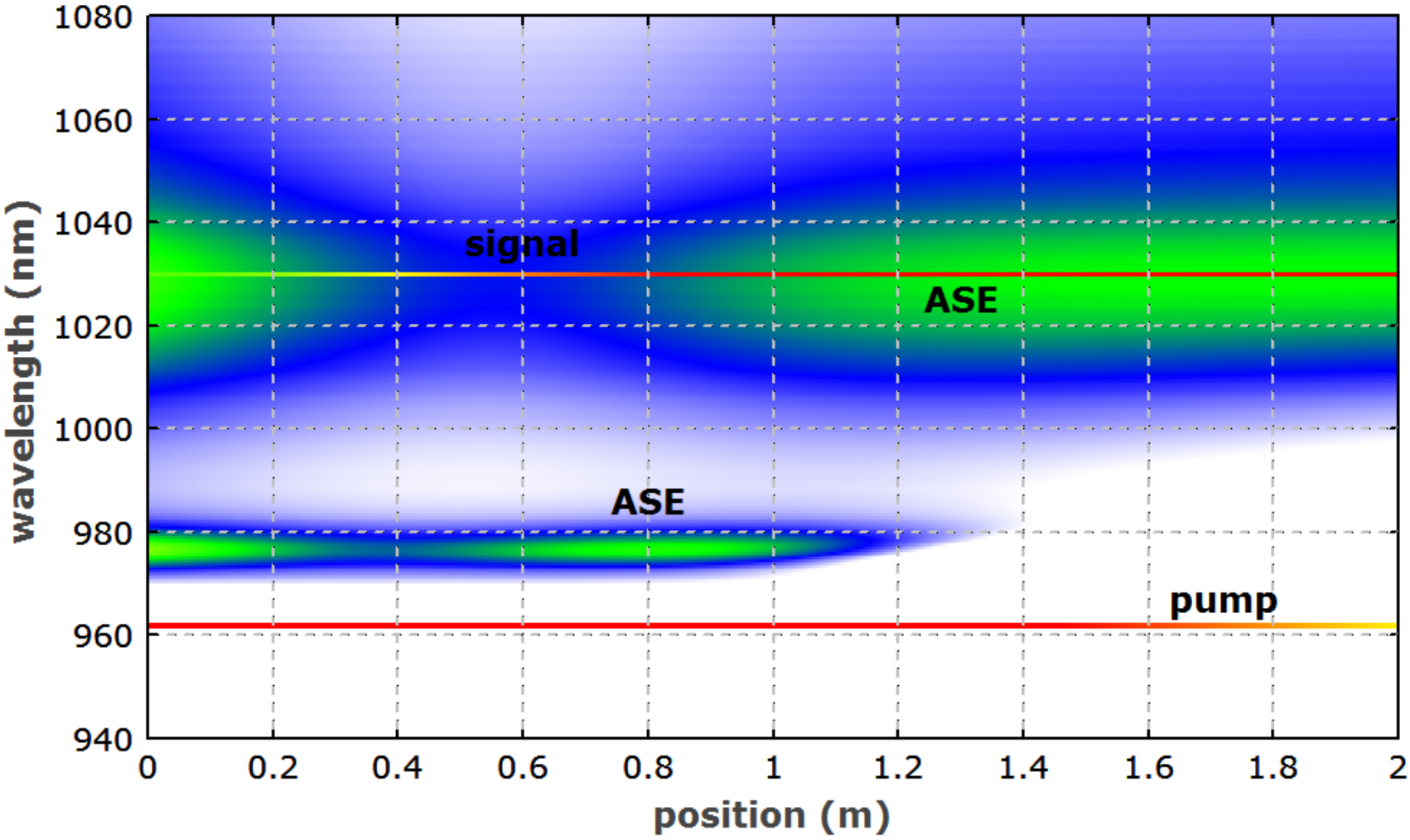
Calculation of Optical Powers (6)

ASE spectrum of an erbium-doped fiber amplifier



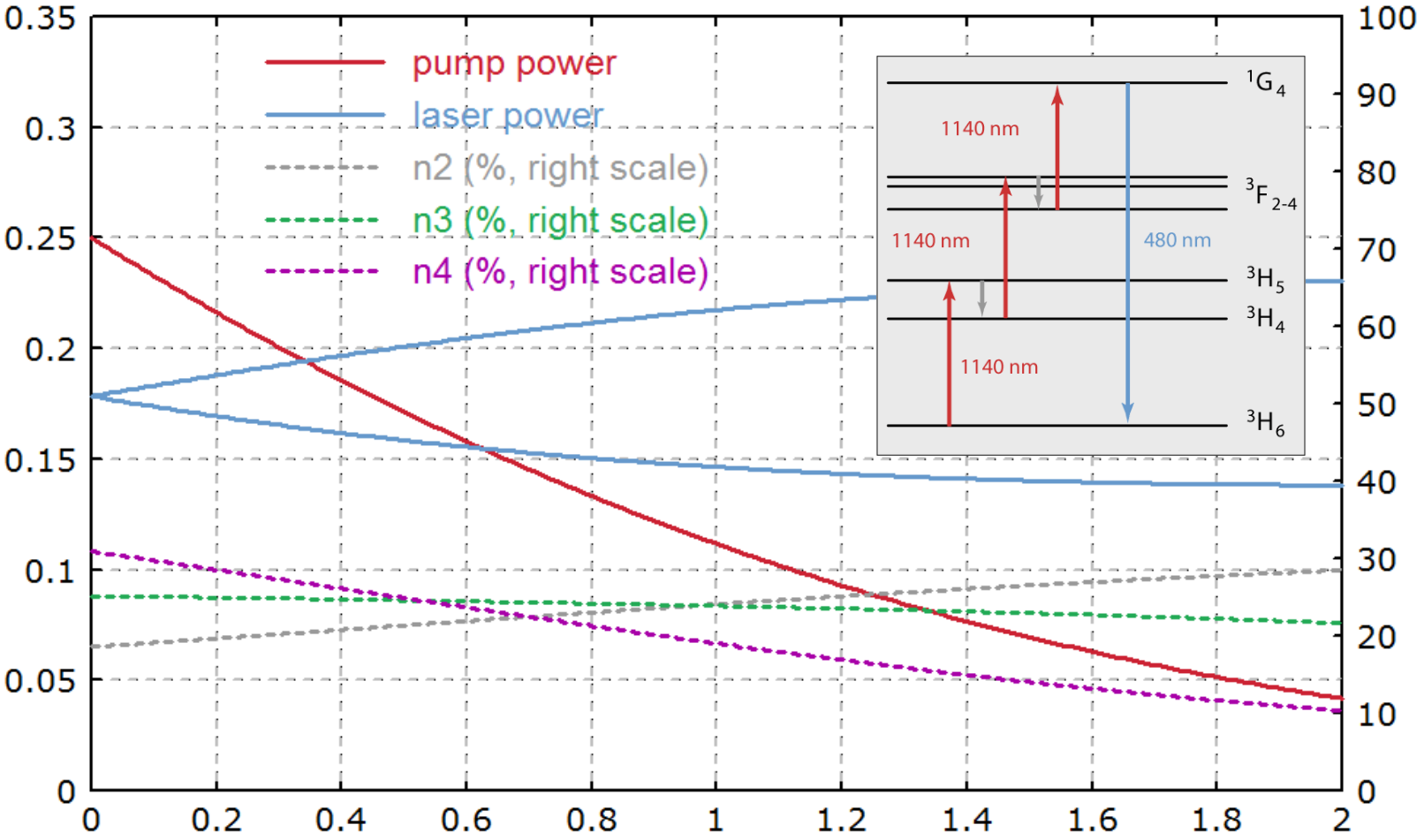
Calculation of Optical Powers (7)

ASE in ytterbium-doped amplifier



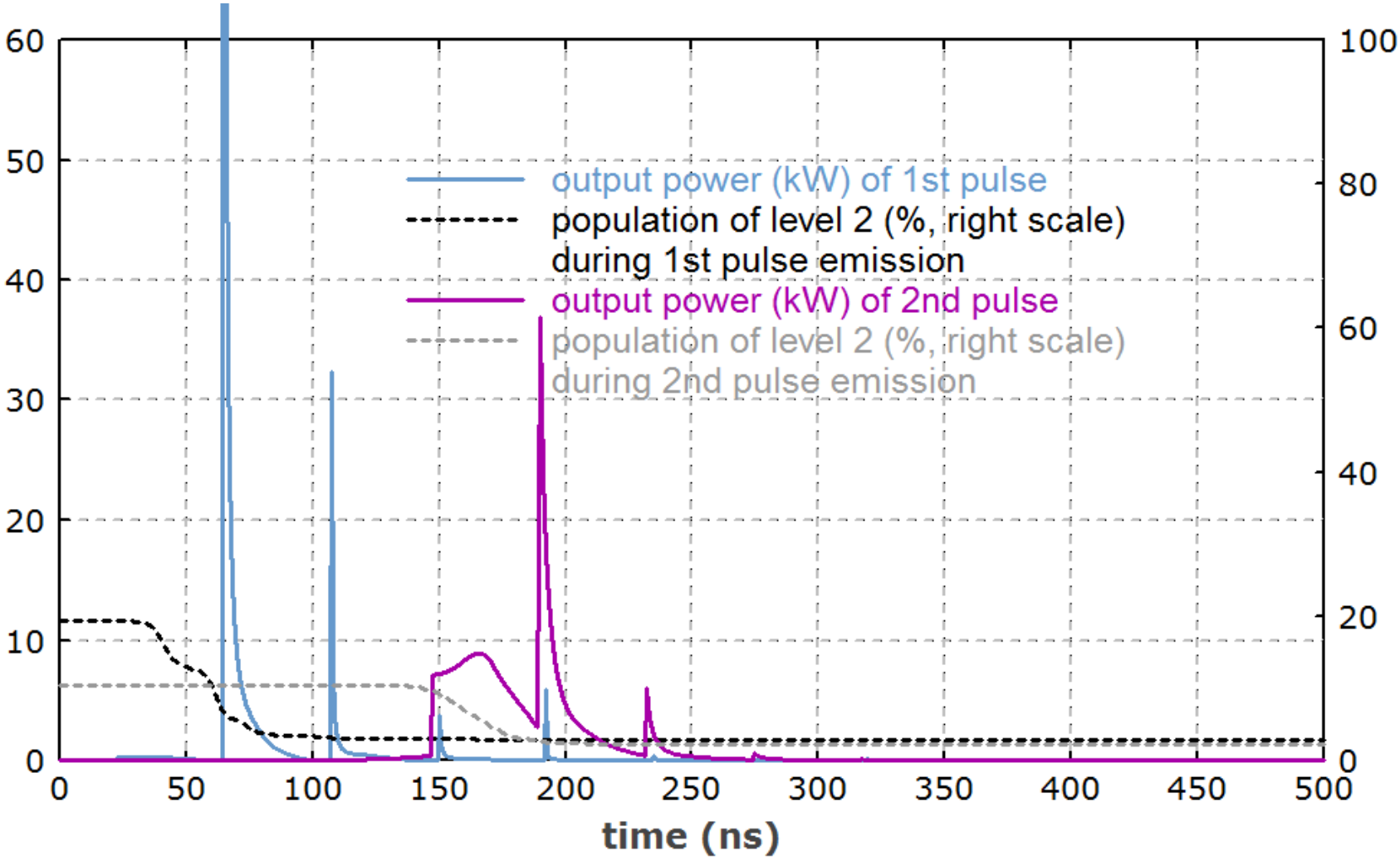
Calculation of Optical Powers (8)

Optical powers and excitation densities in a thulium-doped upconversion fiber laser



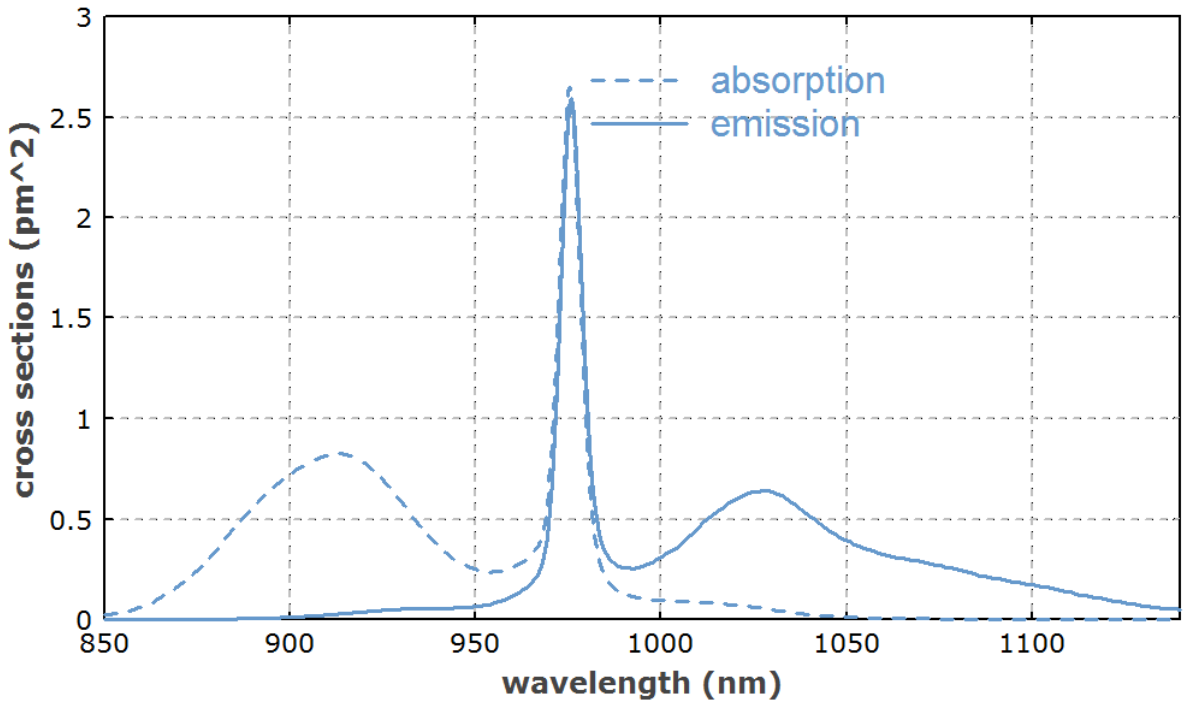
Calculation of Optical Powers (9)

Q-switched fiber laser



How to Get the Fiber Data

- **RP Fiber Power** comes with a variety of data sets for various fibers, including data of some commercial fibers from companies which teamed up with RP Photonics to facilitate calculations.
- If you have your own spectroscopic data, you can integrate them such that the software can use them in the same way as the originally provided data.
- If you first need to do spectroscopic measurements, you can obtain help from RP Photonics (within the support time), both concerning the measurements and the data processing.



Ultrashort Pulse Propagation (1)

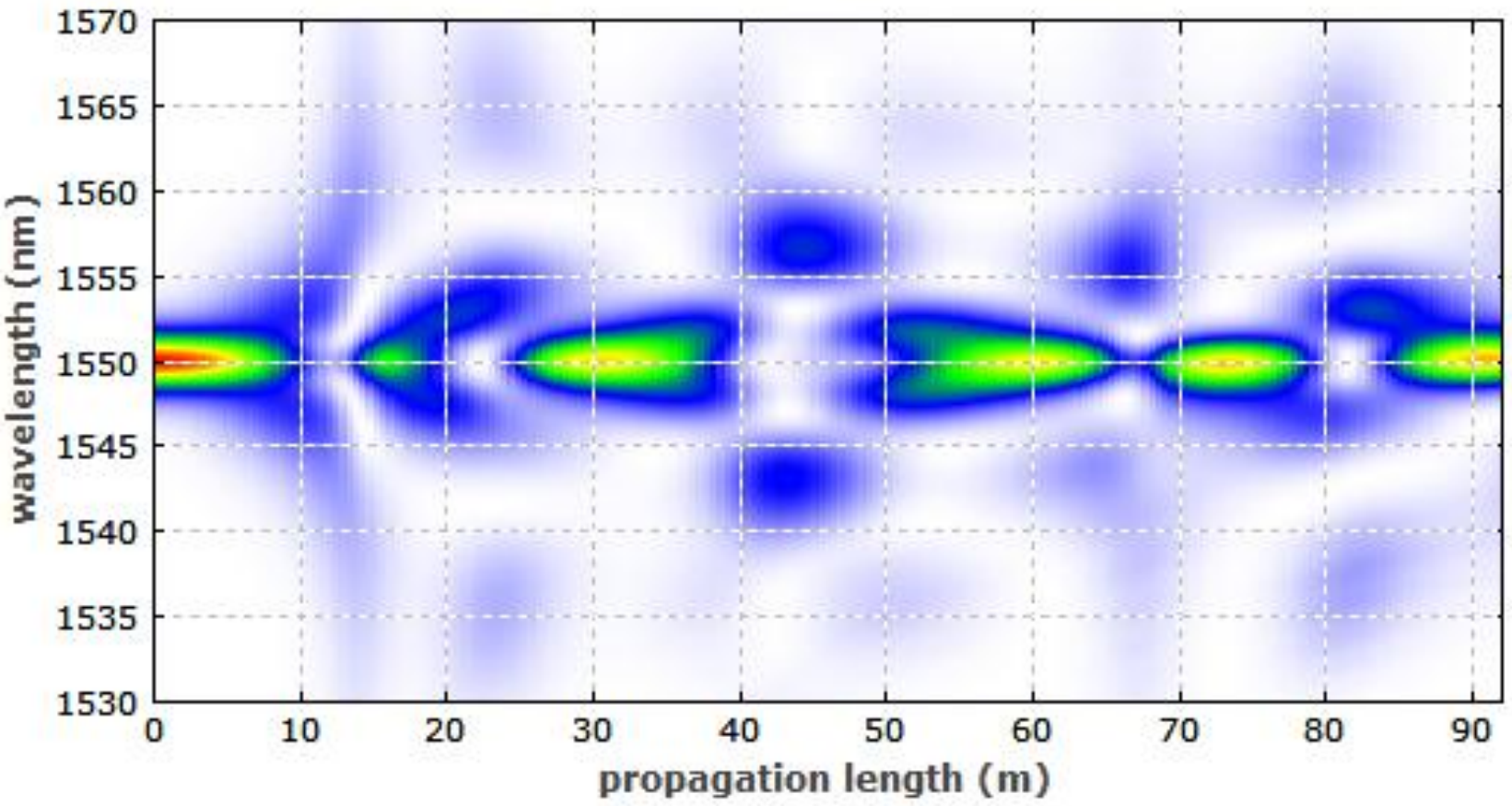
- **Take into account many fiber properties:**
  - chromatic dispersion (may be calculated with the mode solver)
  - Kerr nonlinearity and stimulated Raman scattering, both also with self-steepening
  - wavelength-dependent amplification (based on fiber state calculated with a steady-state or dynamic simulation)
- **Define a start pulse:**
  - Gaussian pulse, sech^2-shaped pulse, or arbitrary pulse shape given in time or frequency domain
  - Can also take the pulse resulting from the last simulation, or a previously stored pulse

Ultrashort Pulse Propagation (2)

- **Additional features:**
  - spectral filtering before and after the fiber, or within the fiber
- **Obtain calculated pulse properties:**
  - Script language provides many dozens of functions for retrieving all sorts of pulse properties: pulse energy, peak power, peak position, pulse duration and spectral width (based on different definitions), amplitude profiles, spectral phase, autocorrelation, etc.
  - Easy pulse inspection with the interactive pulse display window.
- **Control the simulation:**
  - Other functions can control the simulation – for example, do multiple passes through an amplifier, repeat simulation with different parameters, store pulses for later inspection, etc.

Ultrashort Pulse Propagation (3)

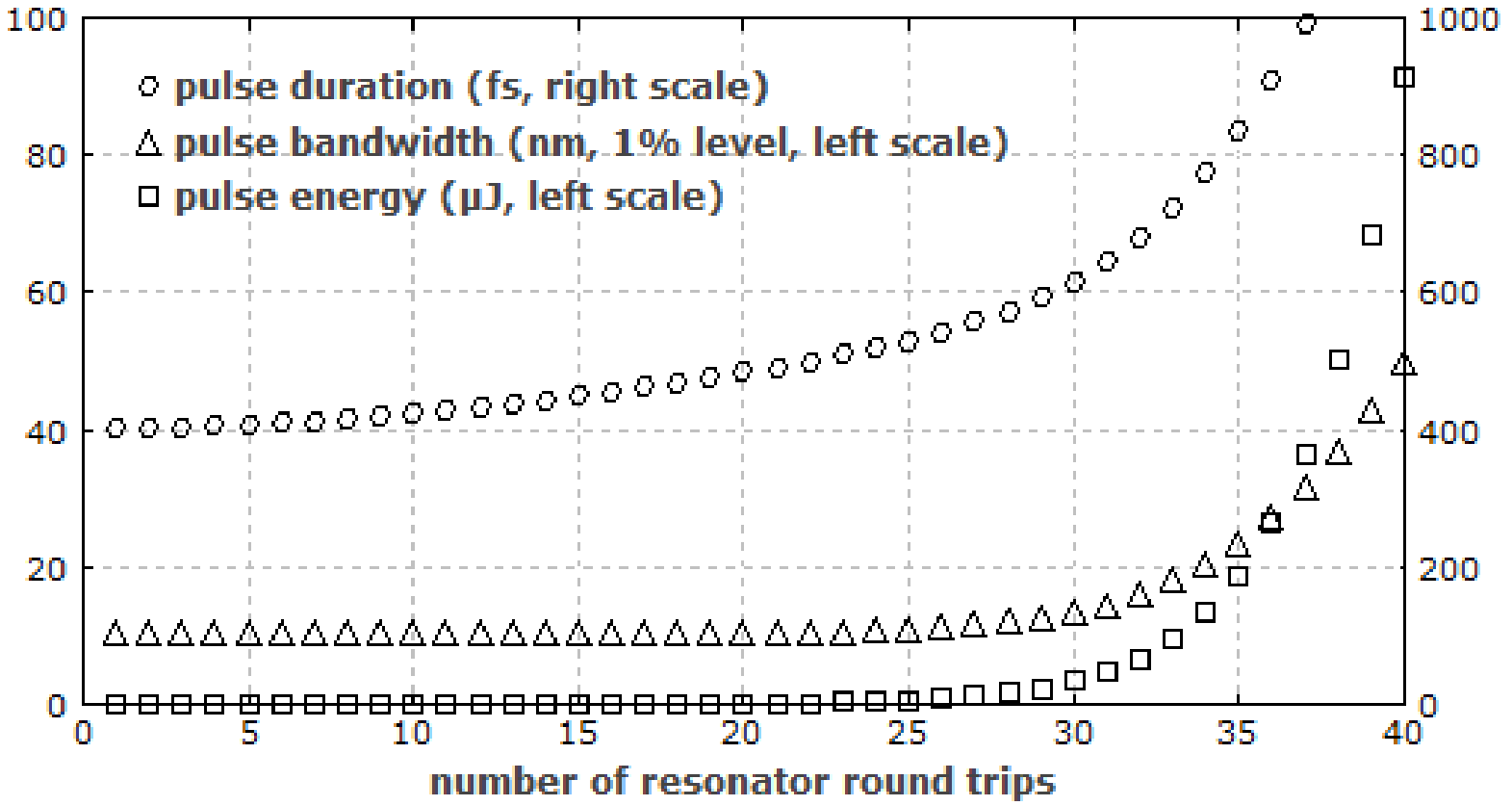
Example: higher-order soliton propagation:



(evolution is not perfectly periodic due to higher-order dispersion)

Ultrashort Pulse Propagation (4)

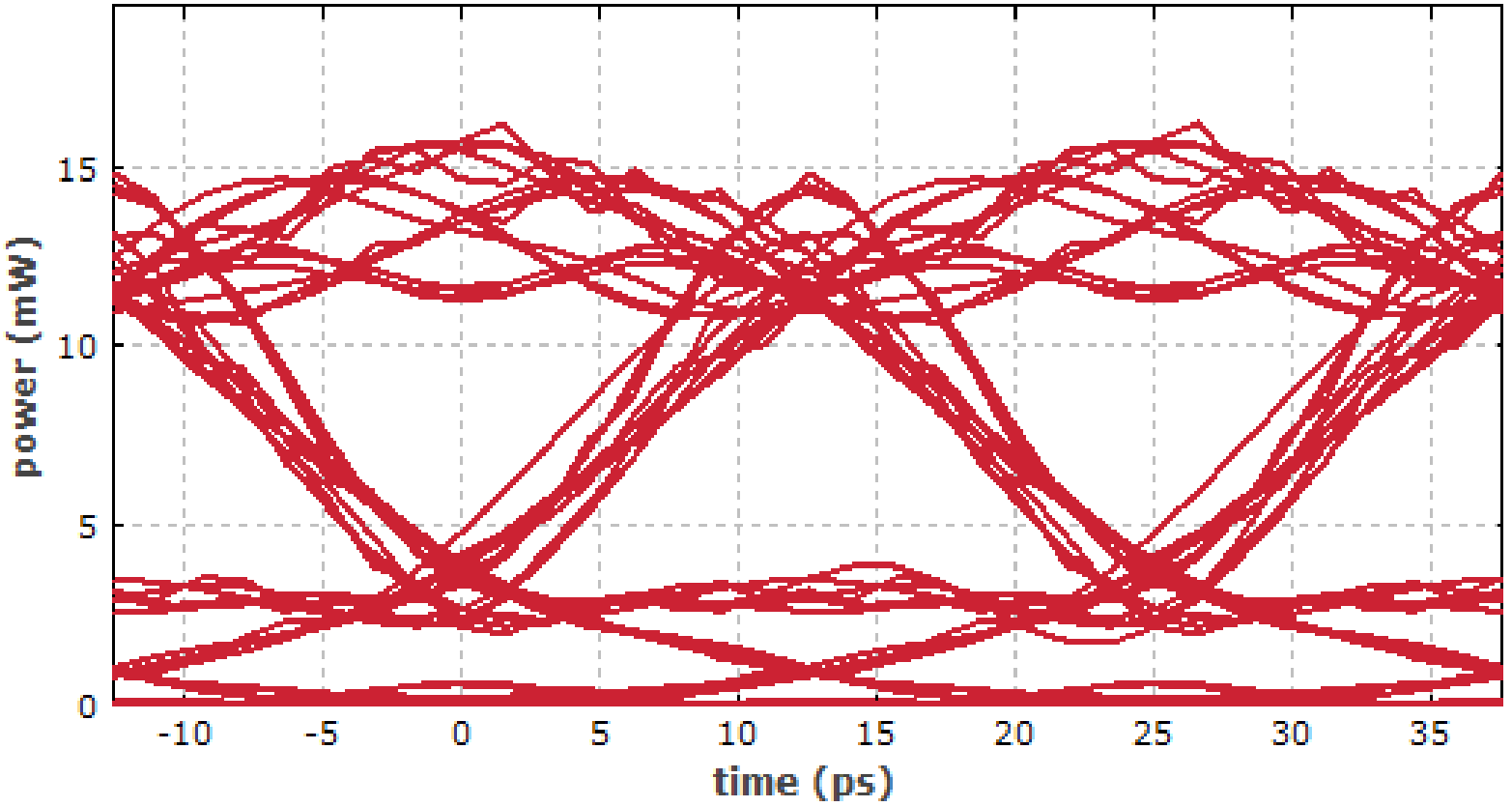
Example: regenerative bulk amplifier:



(Can easily simulate multiple amplification and pumping cycles, get steady-state values, etc.)

Ultrashort Pulse Propagation (5)

Example: optical data transmission in telecom fiber:



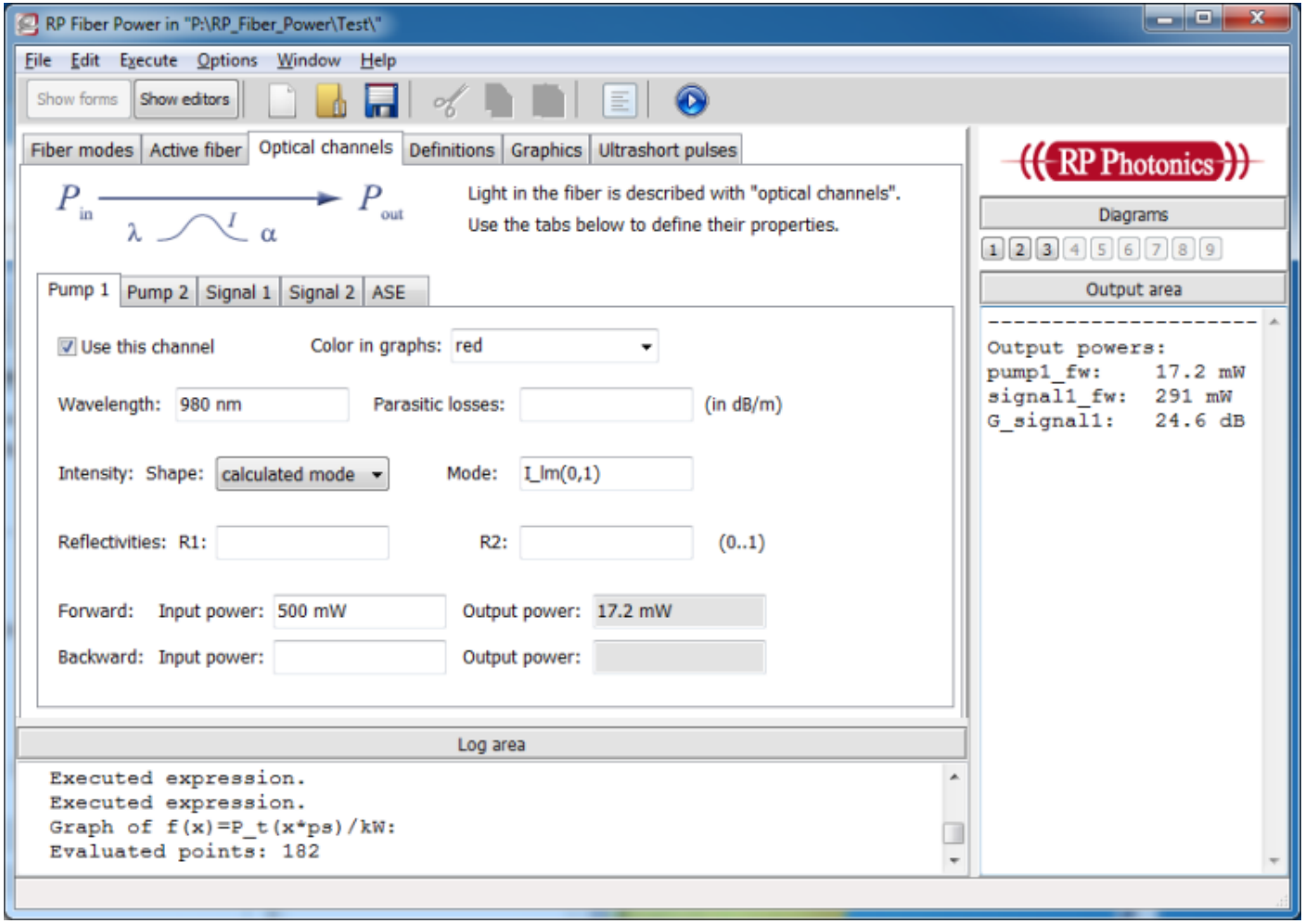
(Eye diagram generated with pseudorandom bit sequence.)

The User Interface (1)

Interactive Forms: simply enter the relevant data:

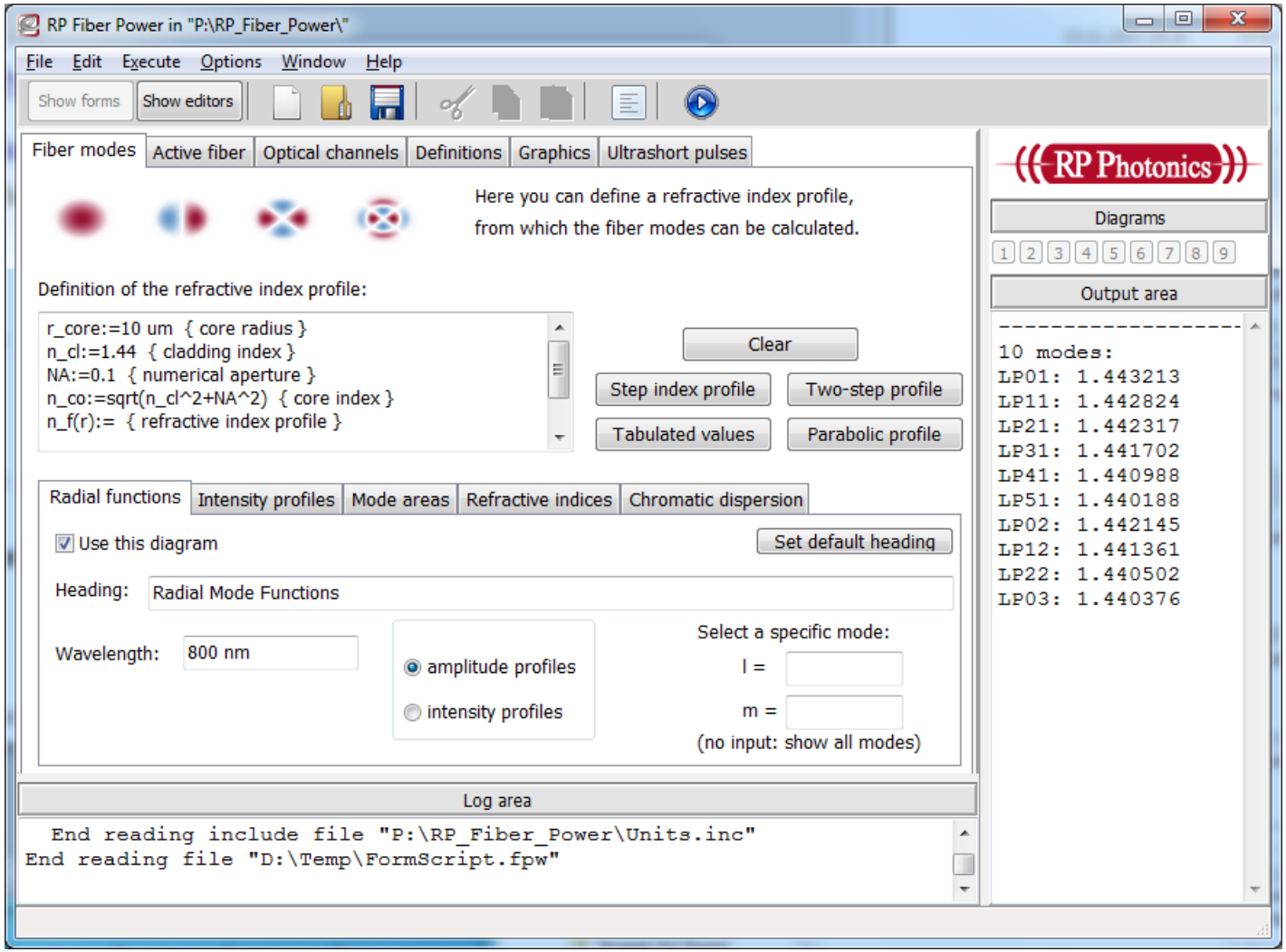
- fiber details
- optical channels (pump, signal, ASE)
- details of graphical output

Then execute this with one click to see your graphical and numerical output.



The User Interface (2)

Same for the mode solver, active fiber data, pulses, etc.



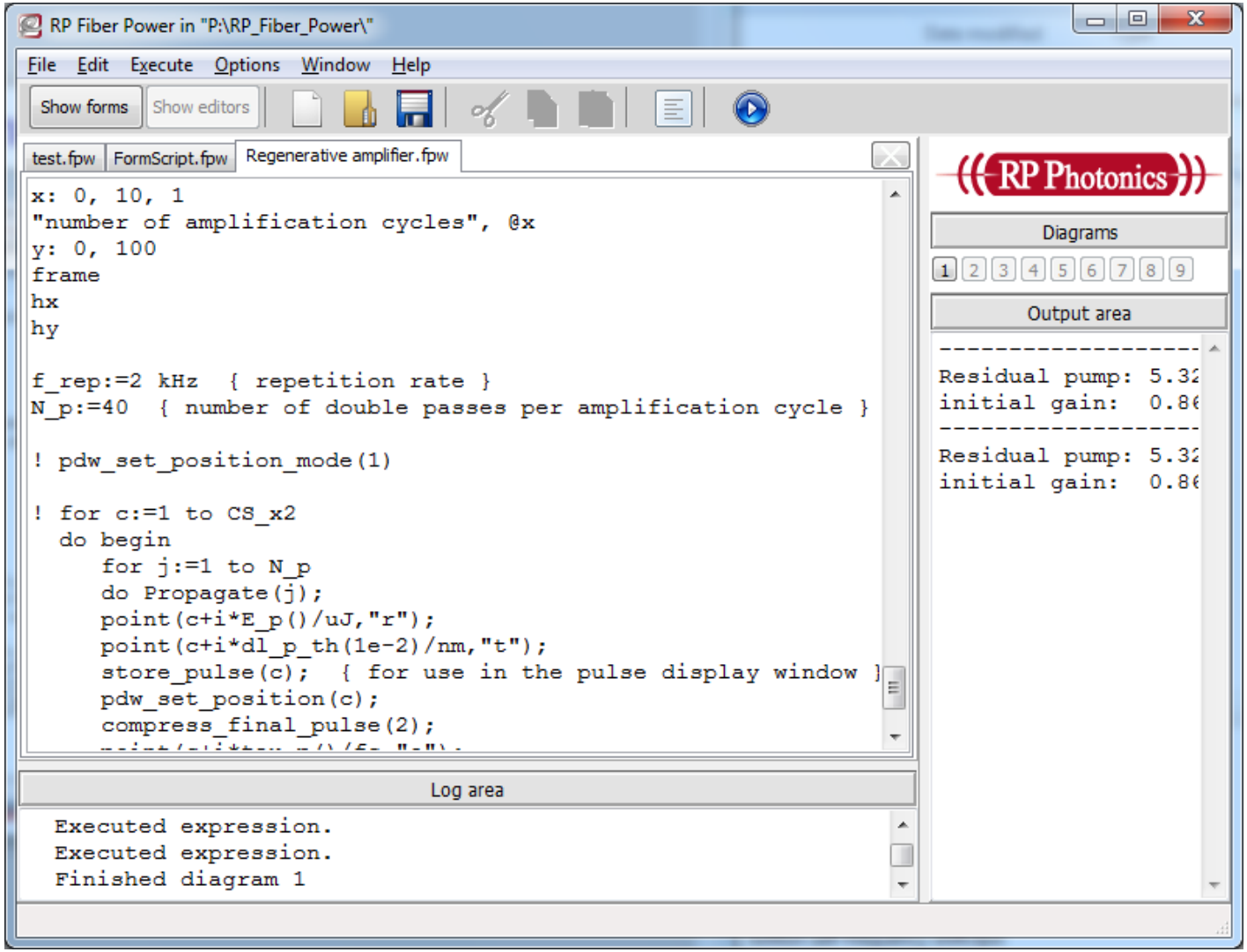
The User Interface (3)

What if the forms are too restrictive?

- From your form inputs, a script is generated automatically.
- You may edit this script, exploiting the full power of the script language.
- Example:
  - Forms give room to define a single fiber only.
  - However, can use script code to simulate multi-stage fiber amplifiers.
  - Take output of one fiber as input for the next one,
    or even consider feedback, do iterative calculations, etc.
- Result: RP Fiber Power gives you a unique **combination of an easy start with uttermost flexibility**!

The User Interface (4)

Use the script editors to program anything you like!

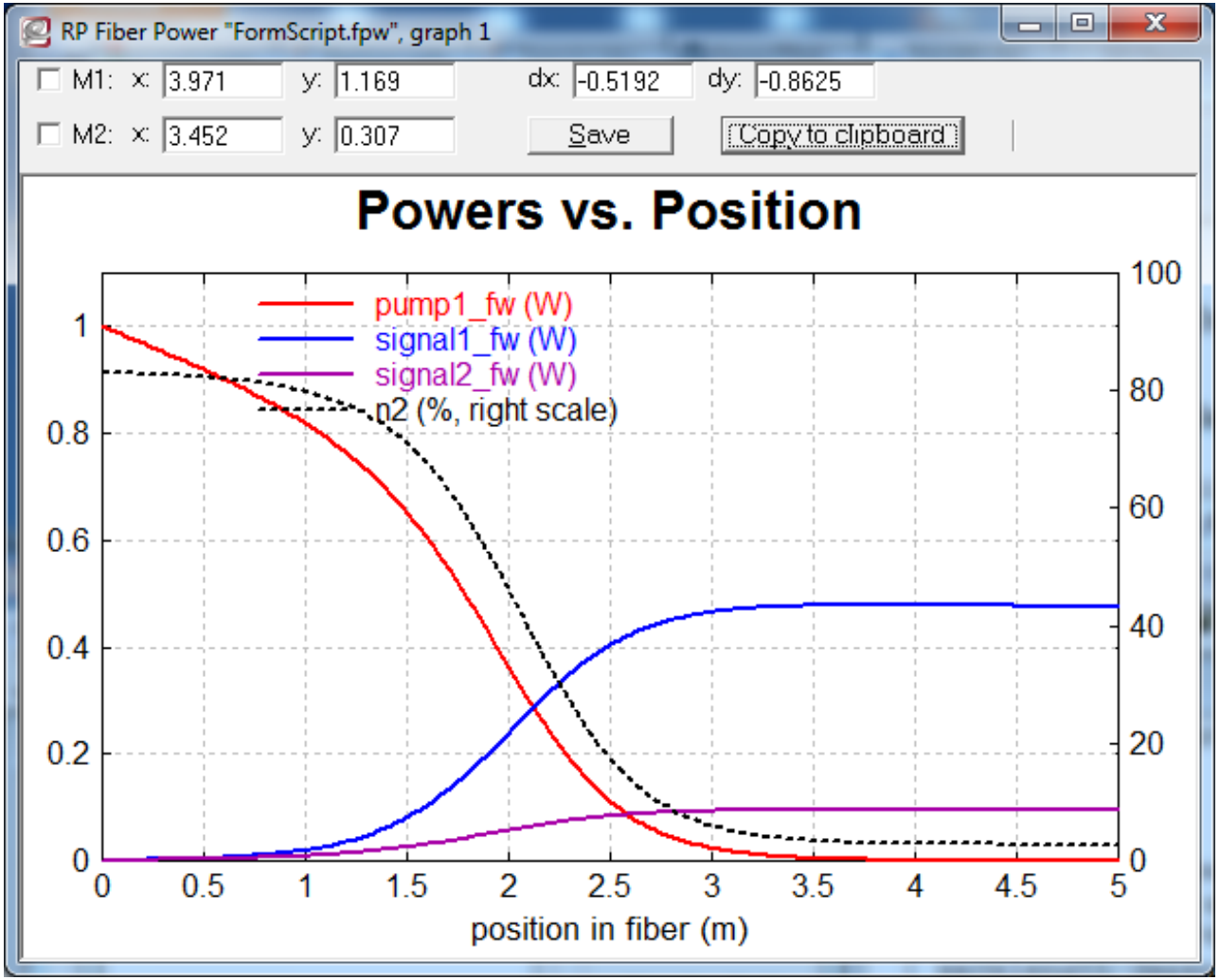


The User Interface (5)

Graphical output windows

- high-quality graphics, directly usable for publications: copy to clipboard or save to file
- can make animated graphics
- adjustable resolution
- markers for doing measurements

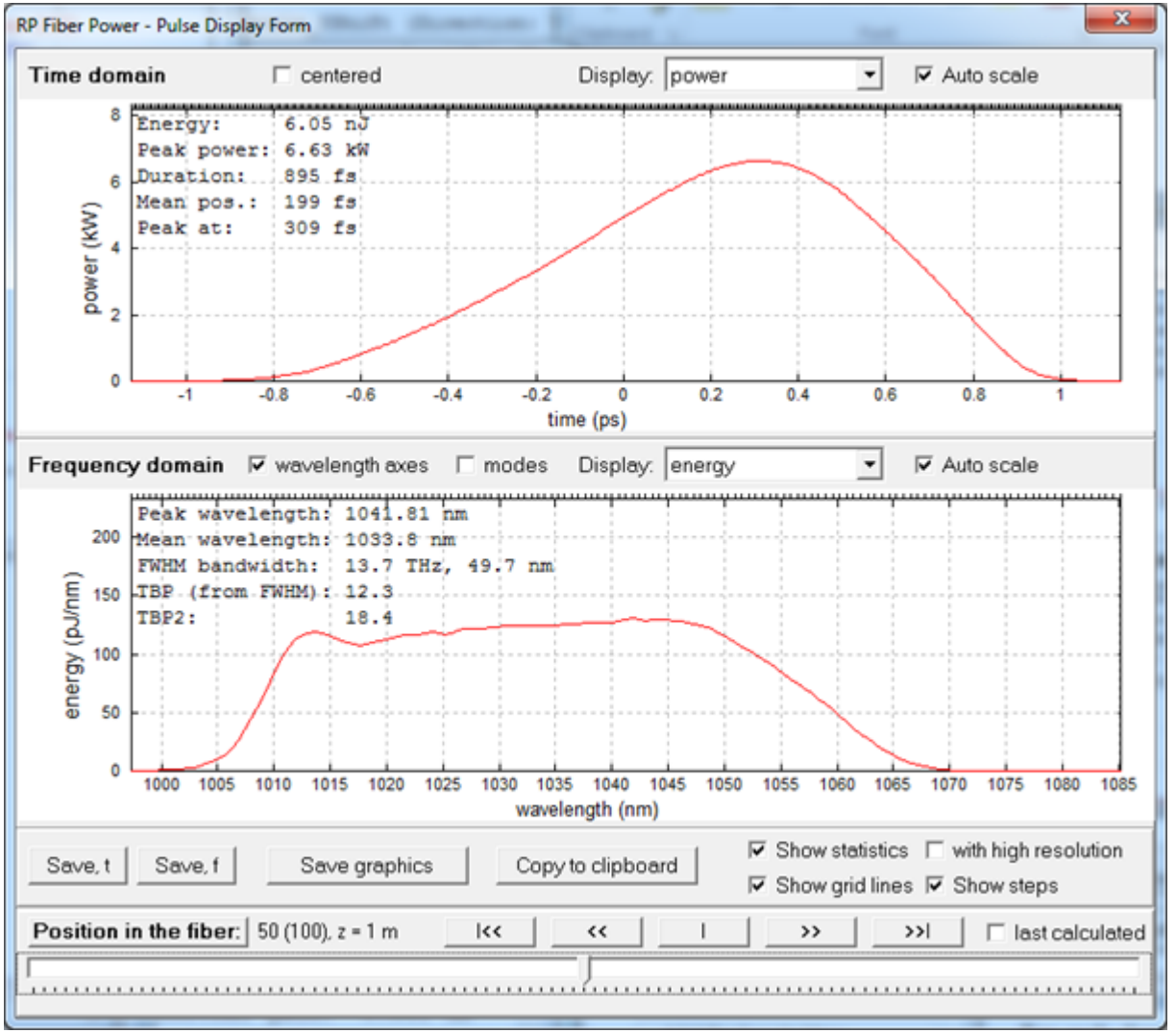
Also have flexible options for generating output in text form!



The User Interface (6)

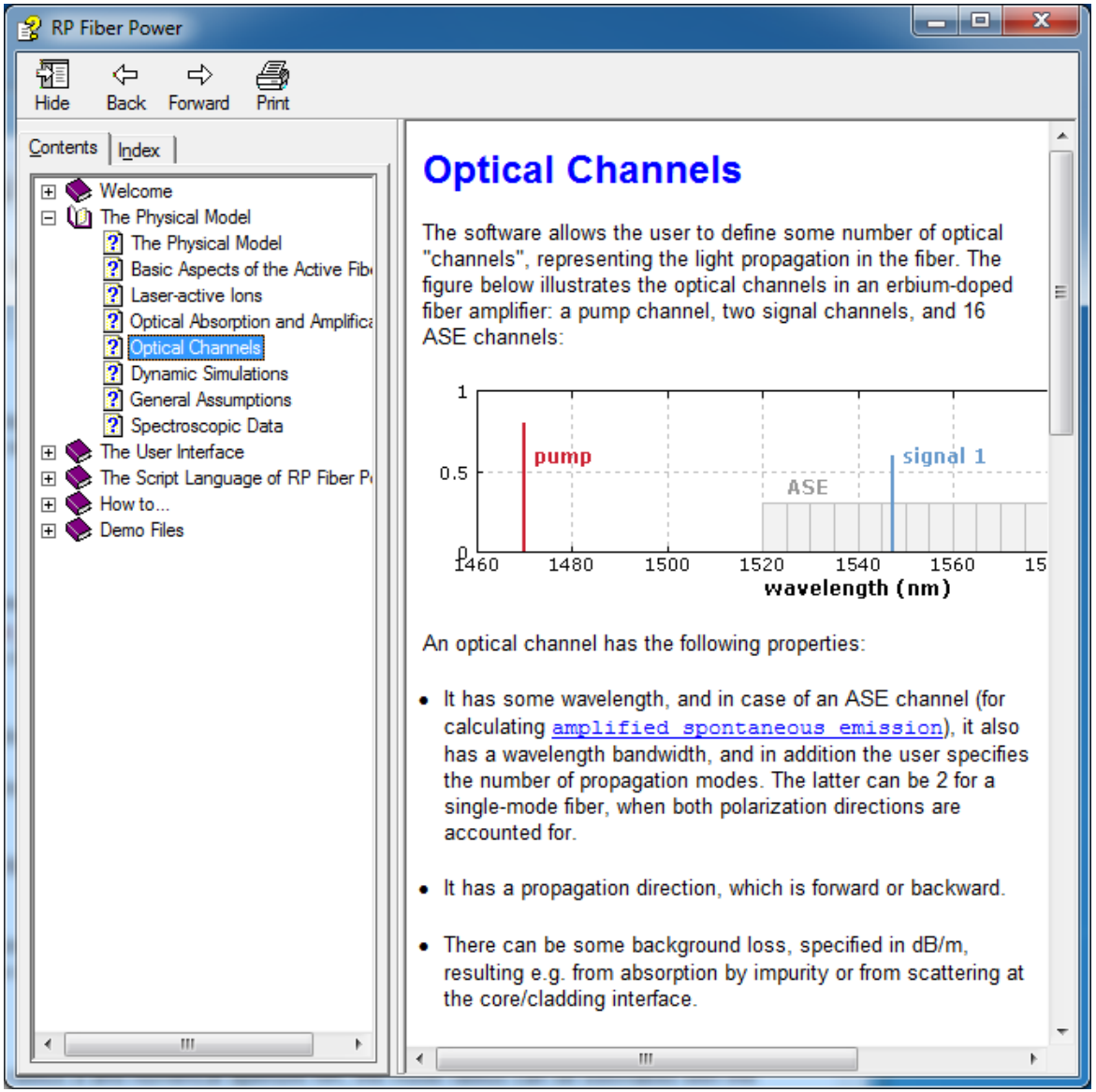
Interactive Pulse Display Window

- Browse the pulses along the fiber, or pulses stored in an array.
- Display a variety of properties in the time and frequency domain.
- Get pulse parameters such as energy, duration, peak power, bandwidth, time–bandwidth product, etc.



Documentation

- comprehensive PDF manual
- detailed online help system
- comprehensive explanations of the used physical models, under-lying assumptions, details of the script language, etc.
- over 25 demo files, demonstrating many different possibilities



Technical Support

Any remaining technical issues can be addressed with the technical support:

- The price for a commercial user license contains 8 support hours.
- For non-commercial licenses, 4 support hours are included.

The support is done by Dr. Paschotta himself, who is a distinguished expert in this area and has developed RP Fiber Power. He will make sure that you become another very satisfied user of the software!

Dr. Rüdiger Paschotta, founder and president of RP Photonics Consulting GmbH, developer of RP Fiber Power

Note that RP Photonics also offers consultancy in other technical areas!

Can I Afford This Software?

Sure, a high-quality product costs money. However, you get a fair value for your money: carefully worked out software and competent support from a top expert.

Anyway, the better question is:

Can I afford *not* to have a powerful software tool, i.e.,

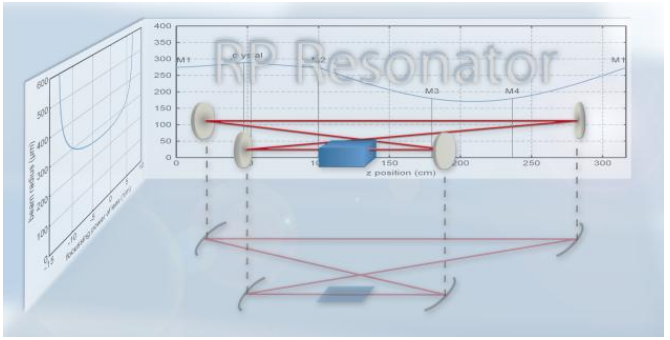
- to muddle through with insufficient tools?
- to use trial & error, wasting time and materials?
- to let customers wait while my competitors sell their products?

Whether you are fiber manufacturer, a user of passive or active fibers, or a scientist working in fiber optics: the **RP Fiber Power** software will give a boost to your productivity! Also, your employees (or students) will become productive sooner when they acquire a deep understanding by playing with this software.

Other Software from RP Photonics

RP Photonics also offers some other software products:

- **RP Resonator** can be used for the design and optimization of optical resonators, in particular of laser resonators.



- **RP ProPulse** can simulate the propagation of ultrashort pulses, in particular in the resonators of mode-locked lasers and synchronously pumped optical parametric oscillators (OPOs), and in optical fibers.