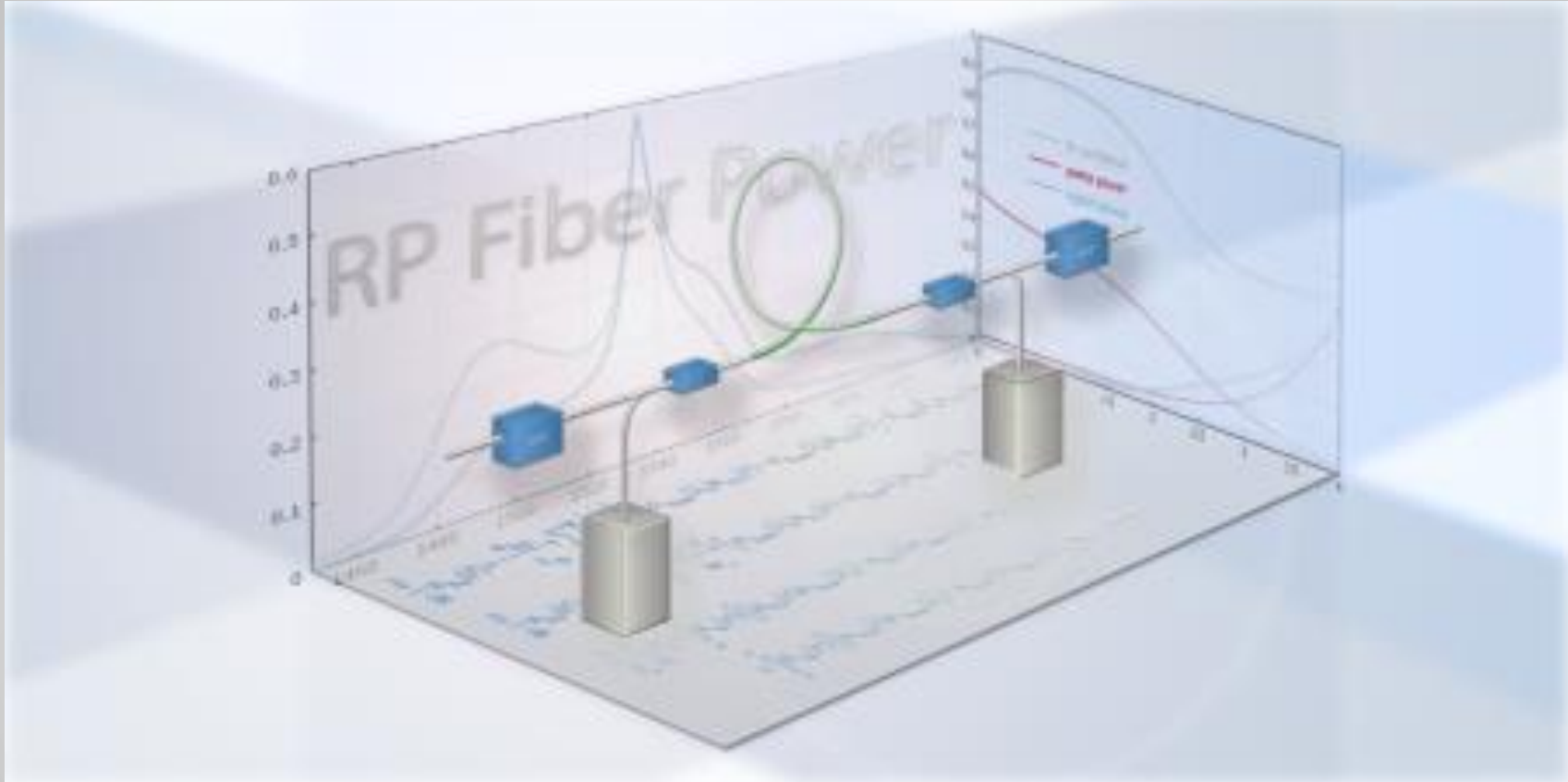


# RP Fiber Power V8



a software product of  
**RP Photonics AG**

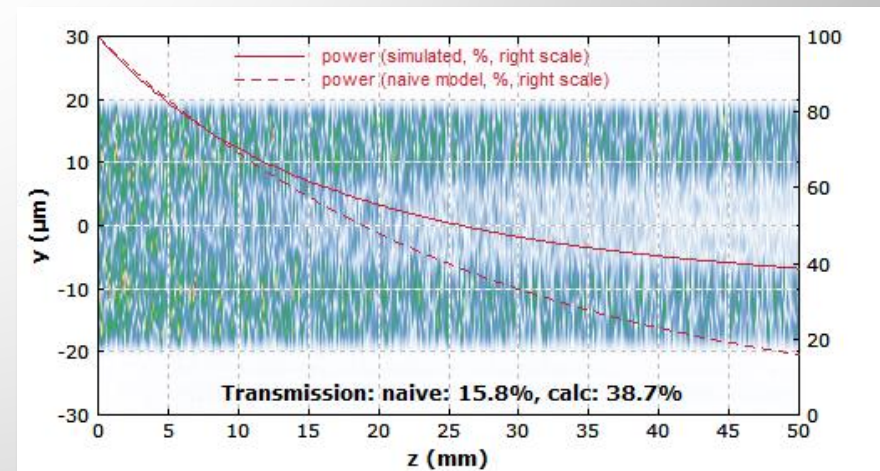
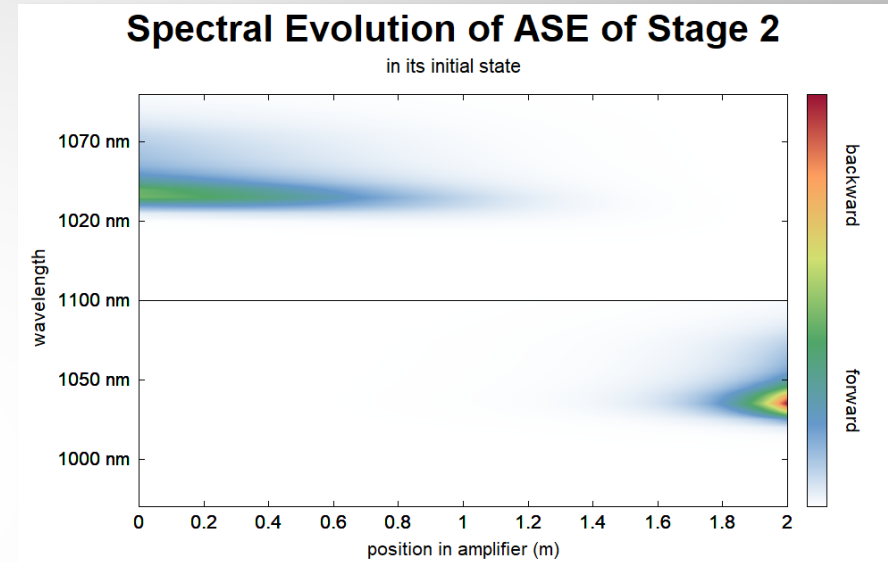
[www.rp-photonics.com/rp\\_fiber\\_power.html](http://www.rp-photonics.com/rp_fiber_power.html)

# What are Simulations in Fiber Optics Good For?

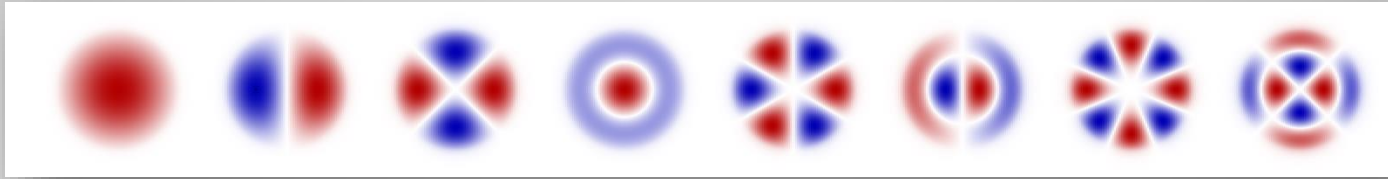
- ▶ Develop a quantitative understanding of your devices.
- ▶ Understand performance limitations and find optimized device designs.
- ▶ Thoroughly check designs before buying the parts and building a prototype or an improved version.
- ▶ Find out the cause of unexpected behavior.  
(Experiments often don't tell you *why* it doesn't work.)
- ▶ Get inspired for new ideas when playing with a model.
- ▶ **Get better results in your R&D work while speeding it up and reducing the cost.**

# Profit From Powerful Software

- ▶ Get all relevant calculations done, e.g. involving fiber modes, power propagation, full beam propagation, ultrashort pulses, laser dynamics, etc.
- ▶ Easily work with a graphical user interface, *but without being limited by a fixed set of forms!*
- ▶ Enjoy high-quality comprehensive documentation.
- ▶ Get reliable results and competent technical support from a top expert in the field.
- ▶ **RP Fiber Power offers all that. It is the industry-leading solution.**



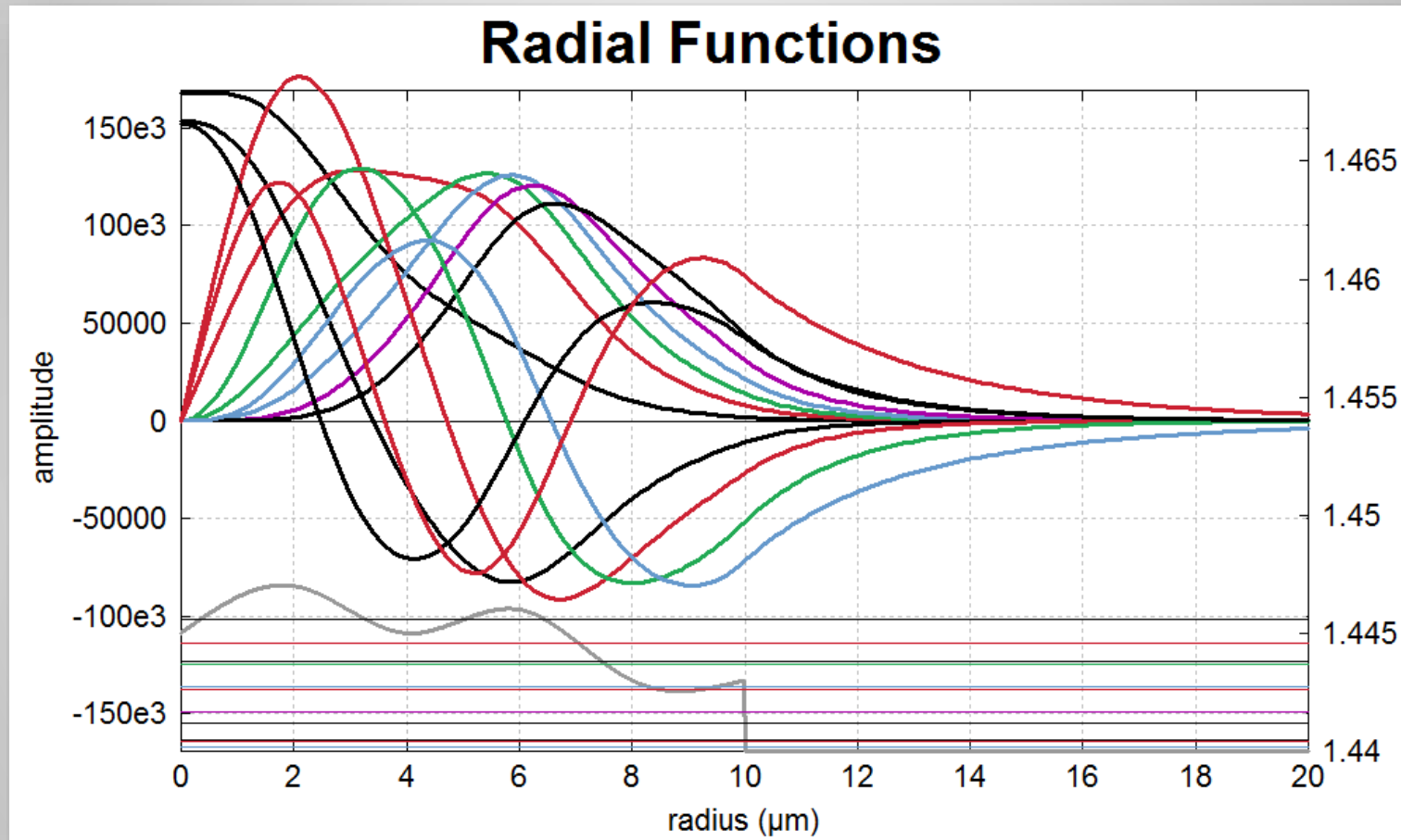
# Calculation of Fiber Modes (1)



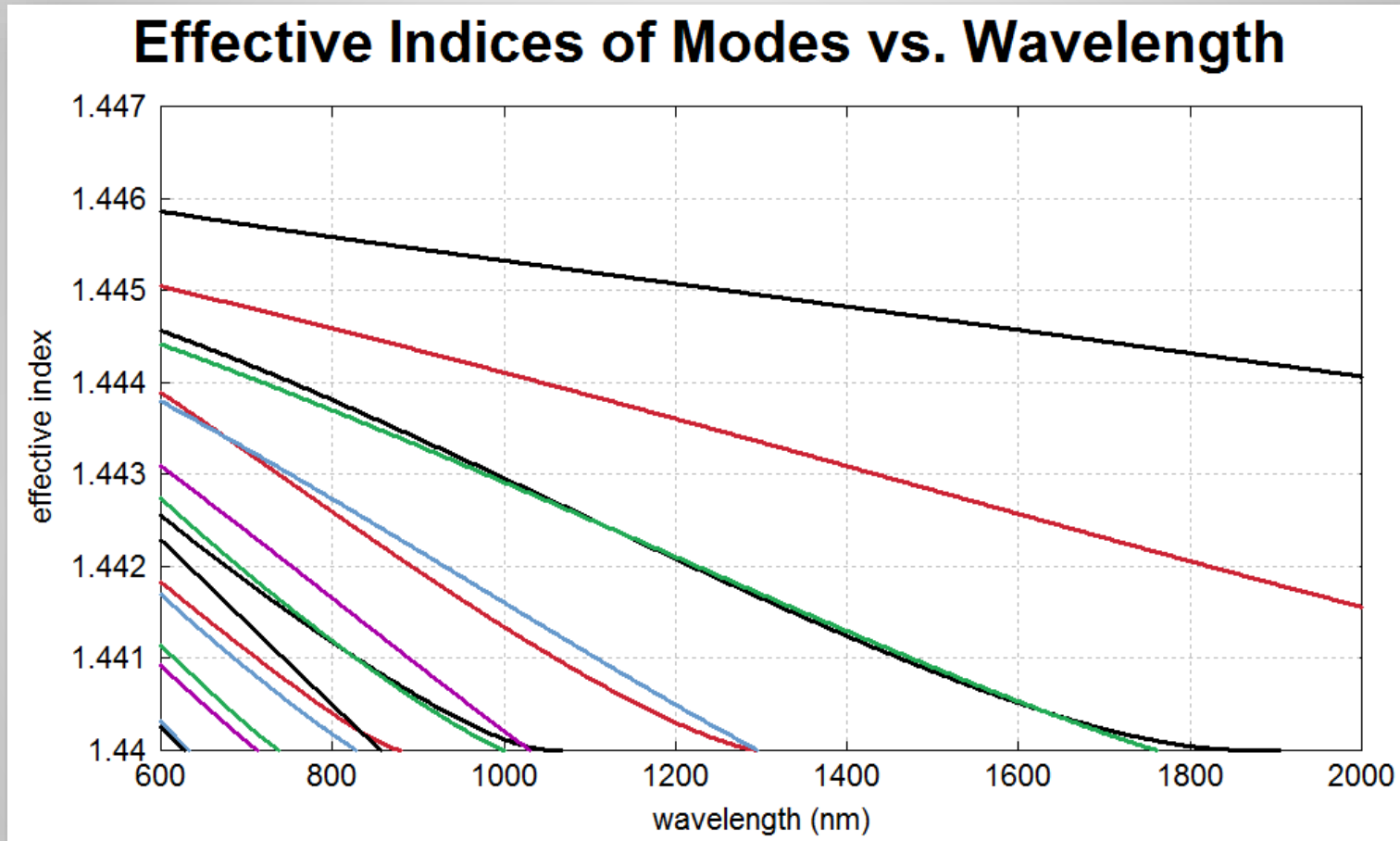
From a given refractive index profile, the integrated mode solver calculates all guided modes (LP modes):

- ▶ 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.

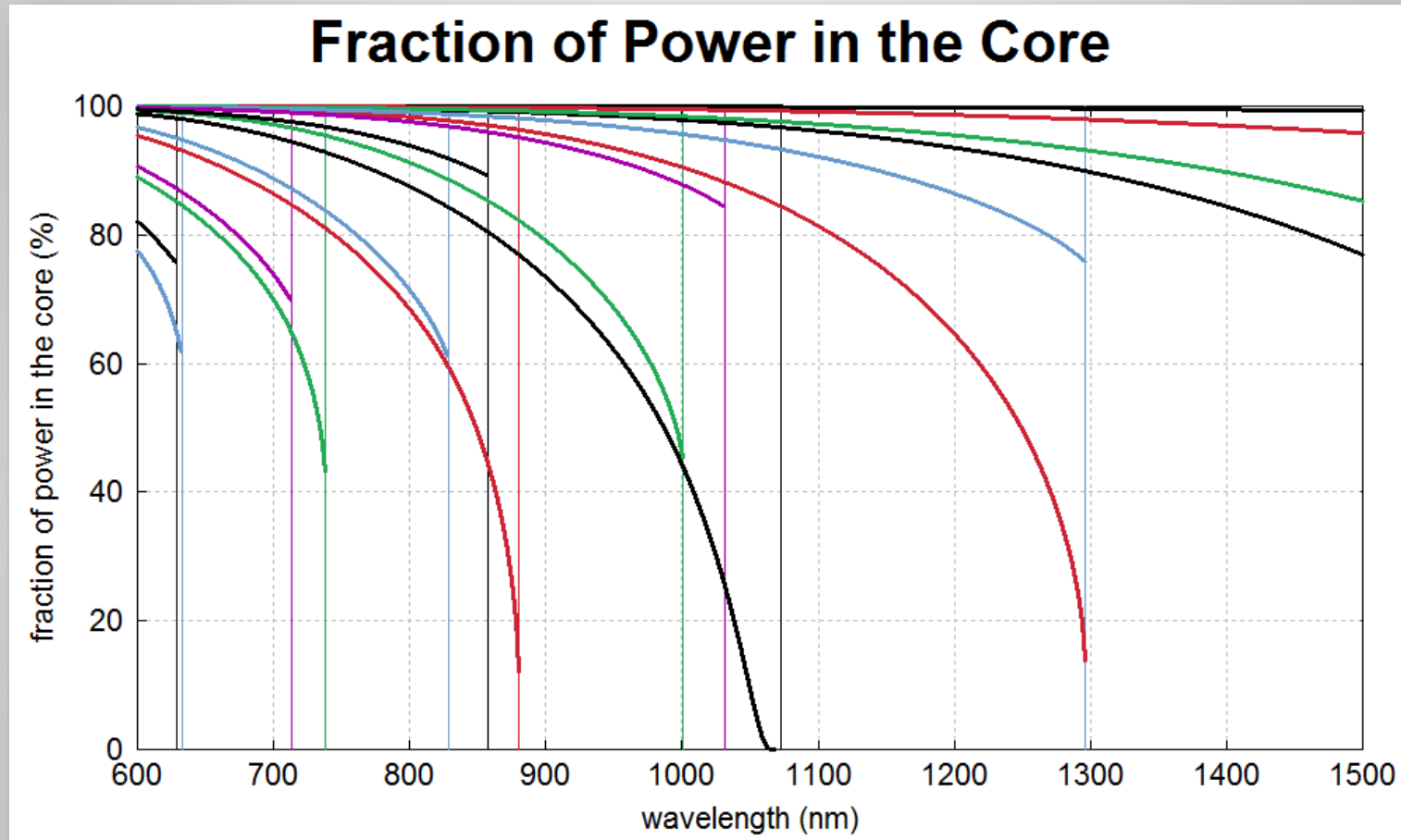
# Calculation of Fiber Modes (2)



# Calculation of Fiber Modes (3)

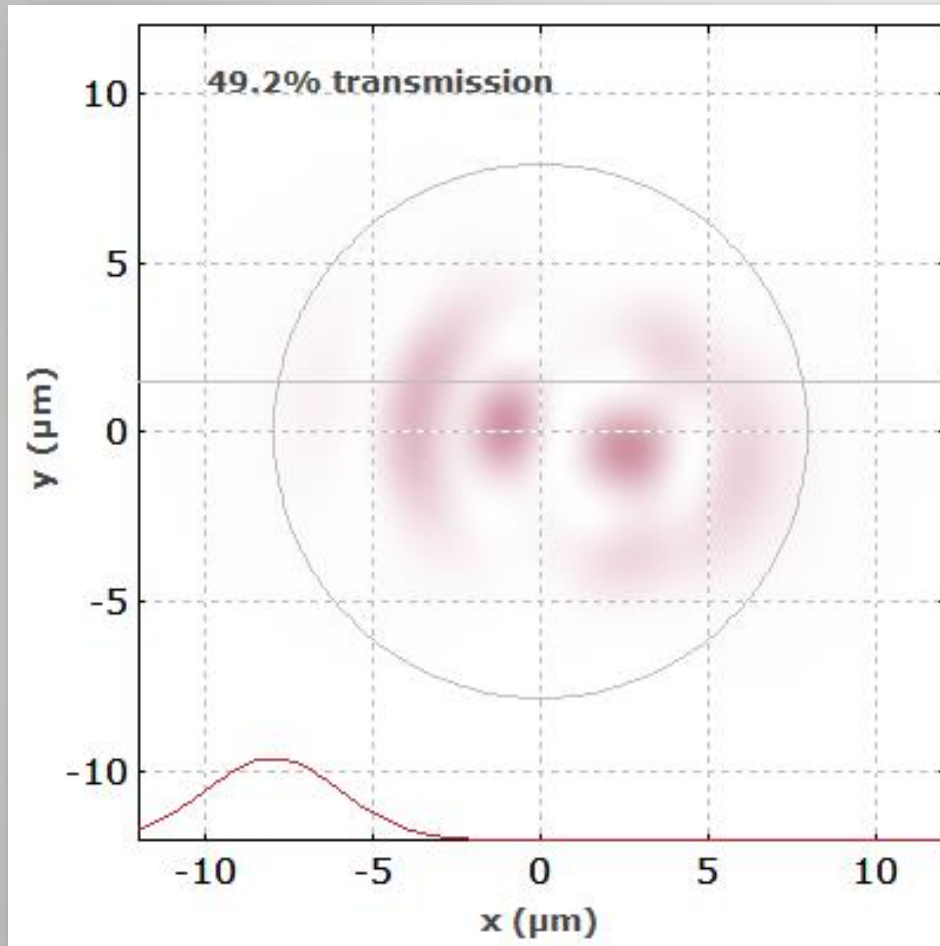


# Calculation of Fiber Modes (4)



# Calculation of Fiber Modes (5)

## Example: Launching light into a multimode fiber

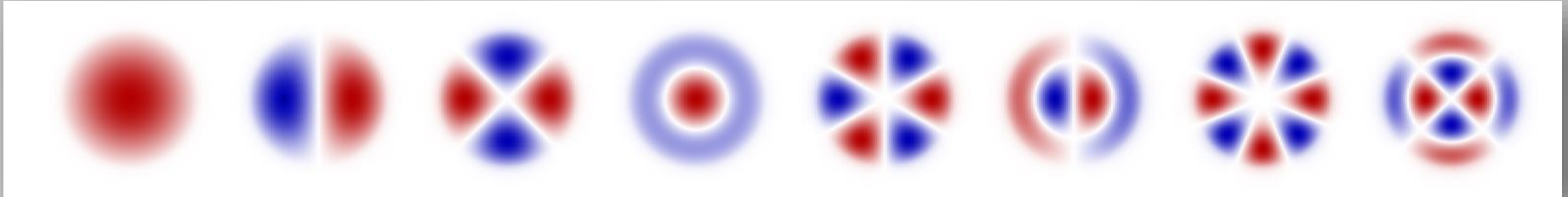


A simple script does the following:

- ▶ 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)

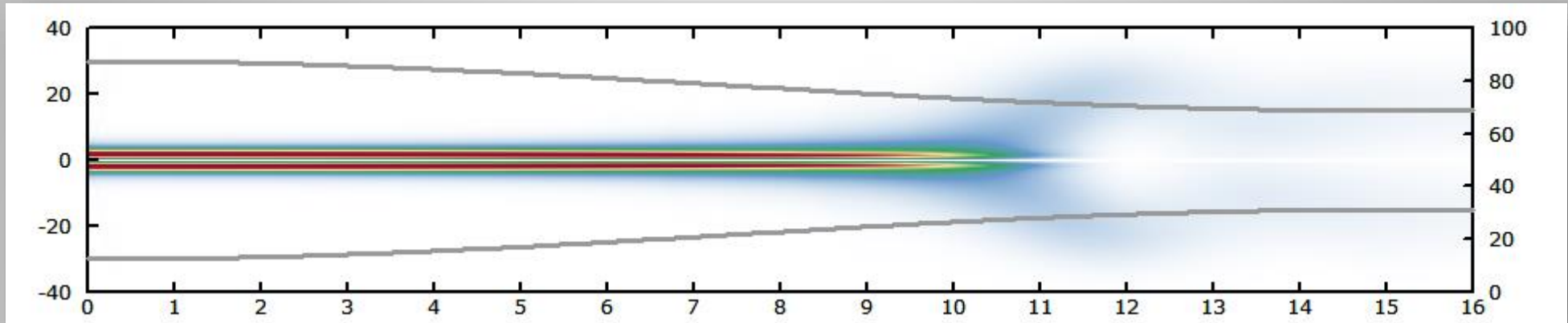


## Applications:

- ▶ **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!

# Numerical Beam Propagation (1)

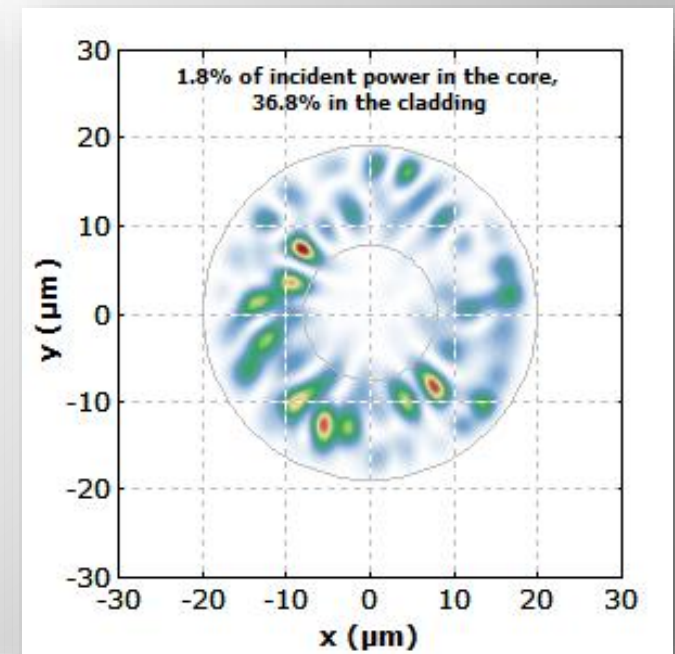
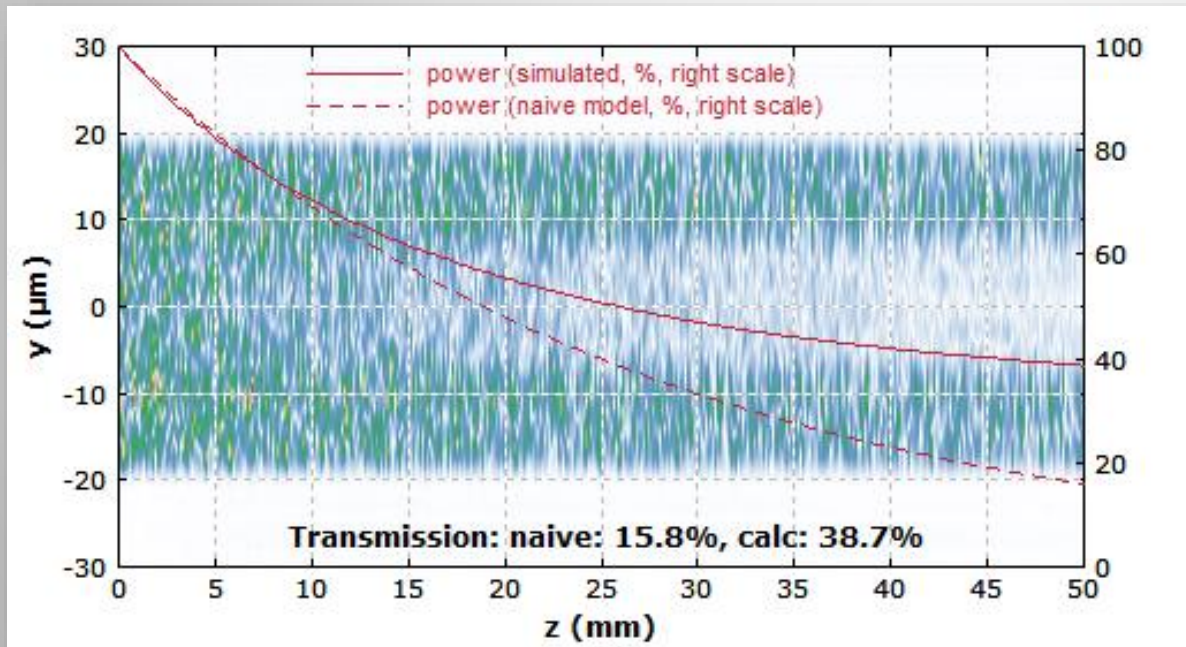


- ▶ Propagate arbitrary field distributions through fibers or other waveguides.
- ▶ Create structures as you like:  
may have tapered regions, variable bends, multiple cores, lossy regions, saturable laser gain, ...  
→ usable for double-clad fibers, fiber couplers, multi-core fibers, helical core fibers, etc.
- ▶ Optimize the designs even of very sophisticated devices.

# Numerical Beam Propagation (2)

## Example: pump absorption in a double-clad fiber

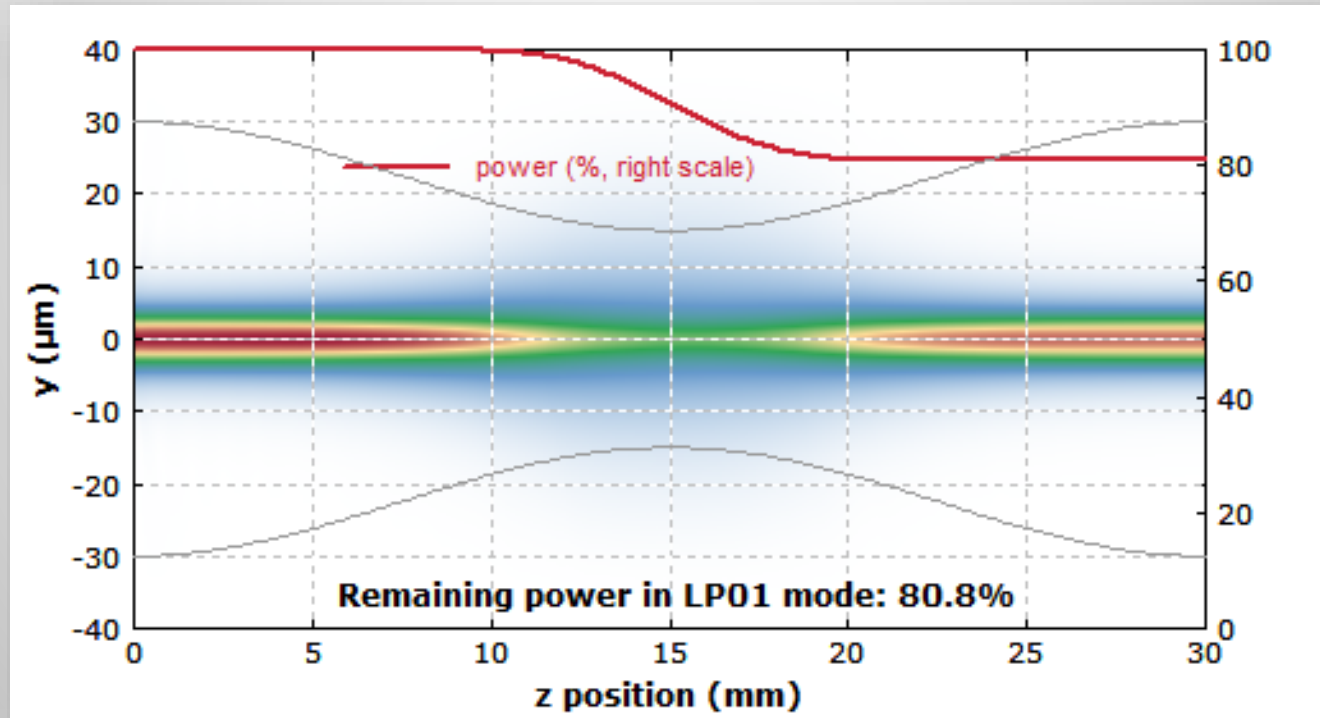
- ▶ Incomplete pump absorption due to helical cladding modes (see below).
- ▶ Can investigate how bending, an off-centered core, a D-shaped or octagonal cladding or other design modification improves the performance.



# Numerical Beam Propagation (3)

## Example: tapered fiber

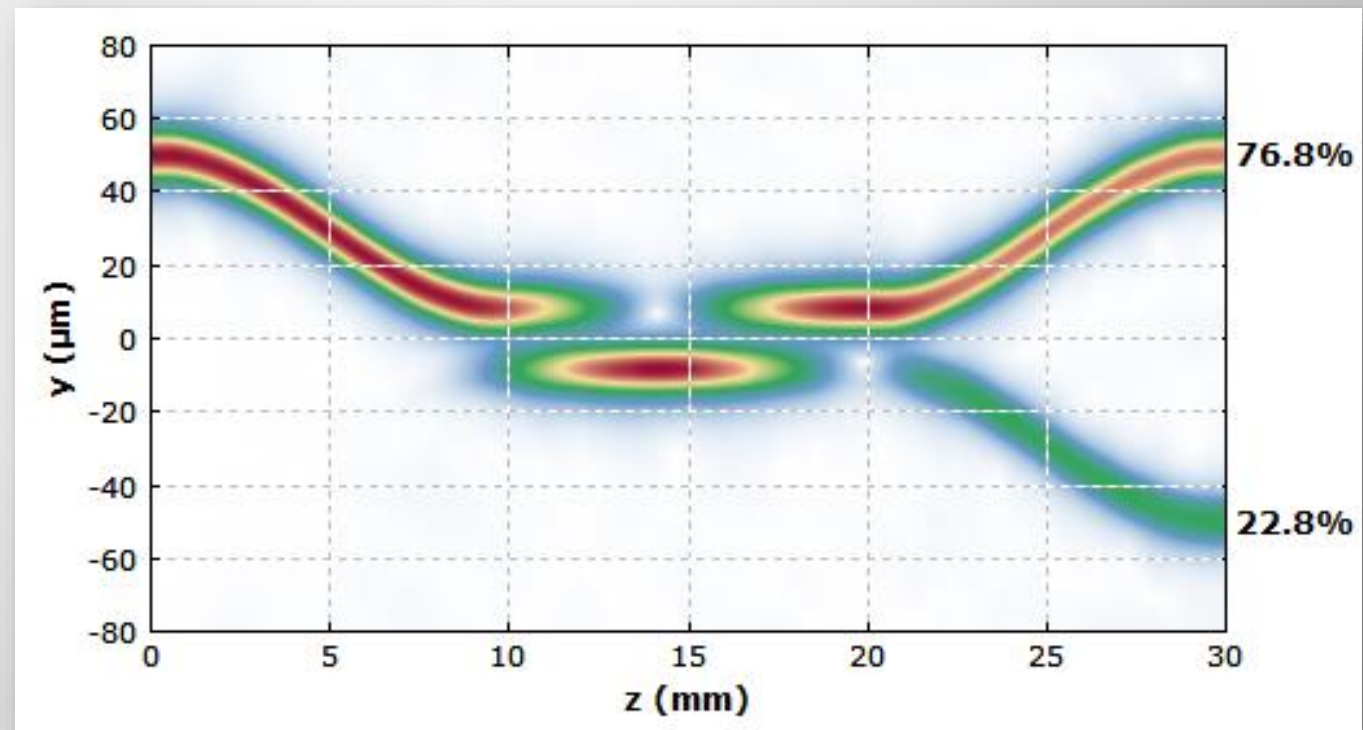
- ▶ Define a three-dimensional refractive index profile with a waveguide which gets narrower in some region.
- ▶ Study the wavelength- and mode-dependent losses.



# Numerical Beam Propagation (4)

## Example: fiber coupler

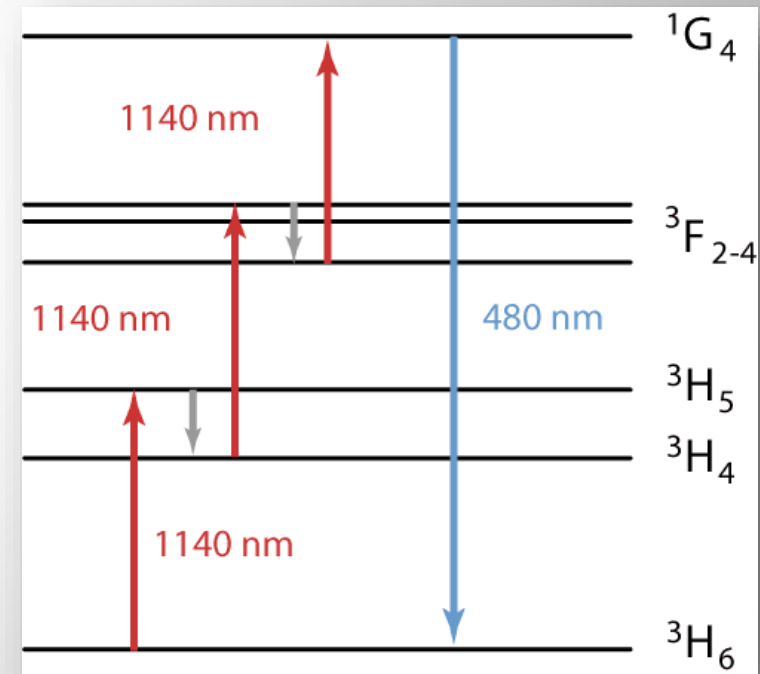
- ▶ Define a three-dimensional refractive index profile with two waveguides.
- ▶ Study evanescent field coupling. At long wavelengths, also get bend losses.



# Calculation of Optical Powers (1)

## Models for laser-active ions:

- ▶ **Simple gain model:** only one metastable level, defined most easily. Applicable to  $\text{Yb}^{3+}$ ,  $\text{Nd}^{3+}$ , and often for  $\text{Er}^{3+}$ ,  $\text{Tm}^{3+}$ , 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:  $\text{Tm}^{3+}$  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  $\text{Yb}^{3+}$  and  $\text{Er}^{3+}$  ions, with energy transfer between them. Each one can have its own density profile.
- ▶ Overlap with optical intensity profiles is calculated automatically.

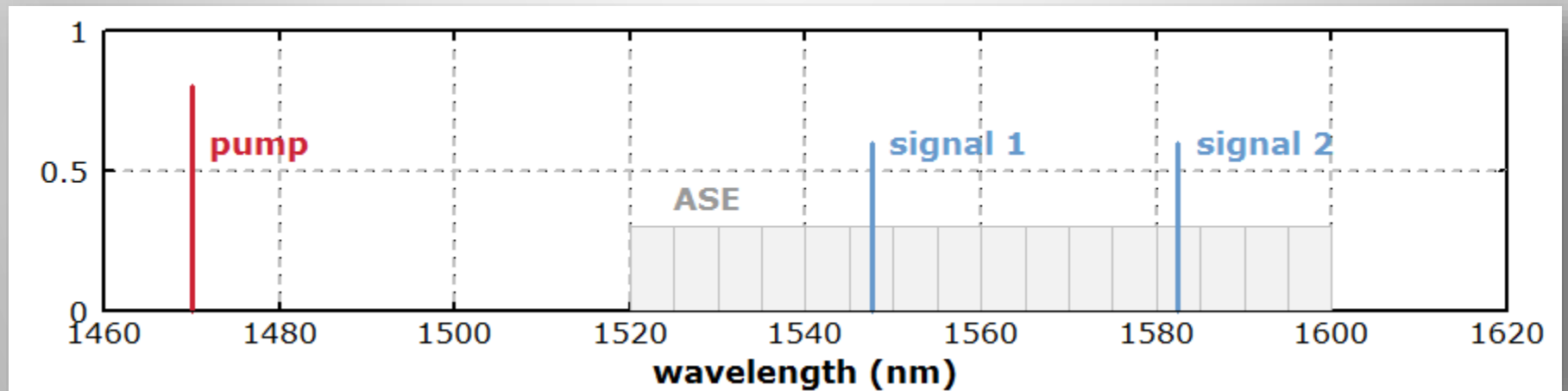
# Calculation of Optical Powers (3)

Define “**optical channels**”:

- ▶ **Input channels**: for pump or signal waves, each with its own wavelength, 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.





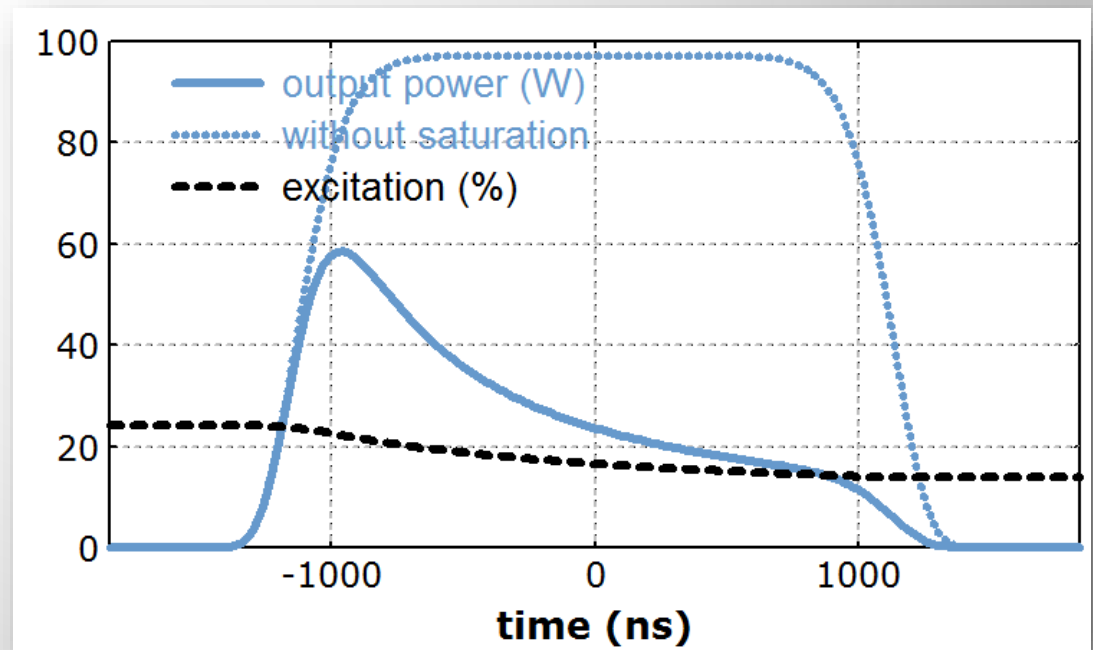
# Calculation of Optical Powers (4)

## Dynamical calculations:

- ▶ The input powers of all channels can have different time dependencies. Example: amplifier for short pulses with long pump pulses.
- ▶ Describe time dependencies with formulas. Functions are provided for accessing the calculated time-dependent output powers and excitation densities.

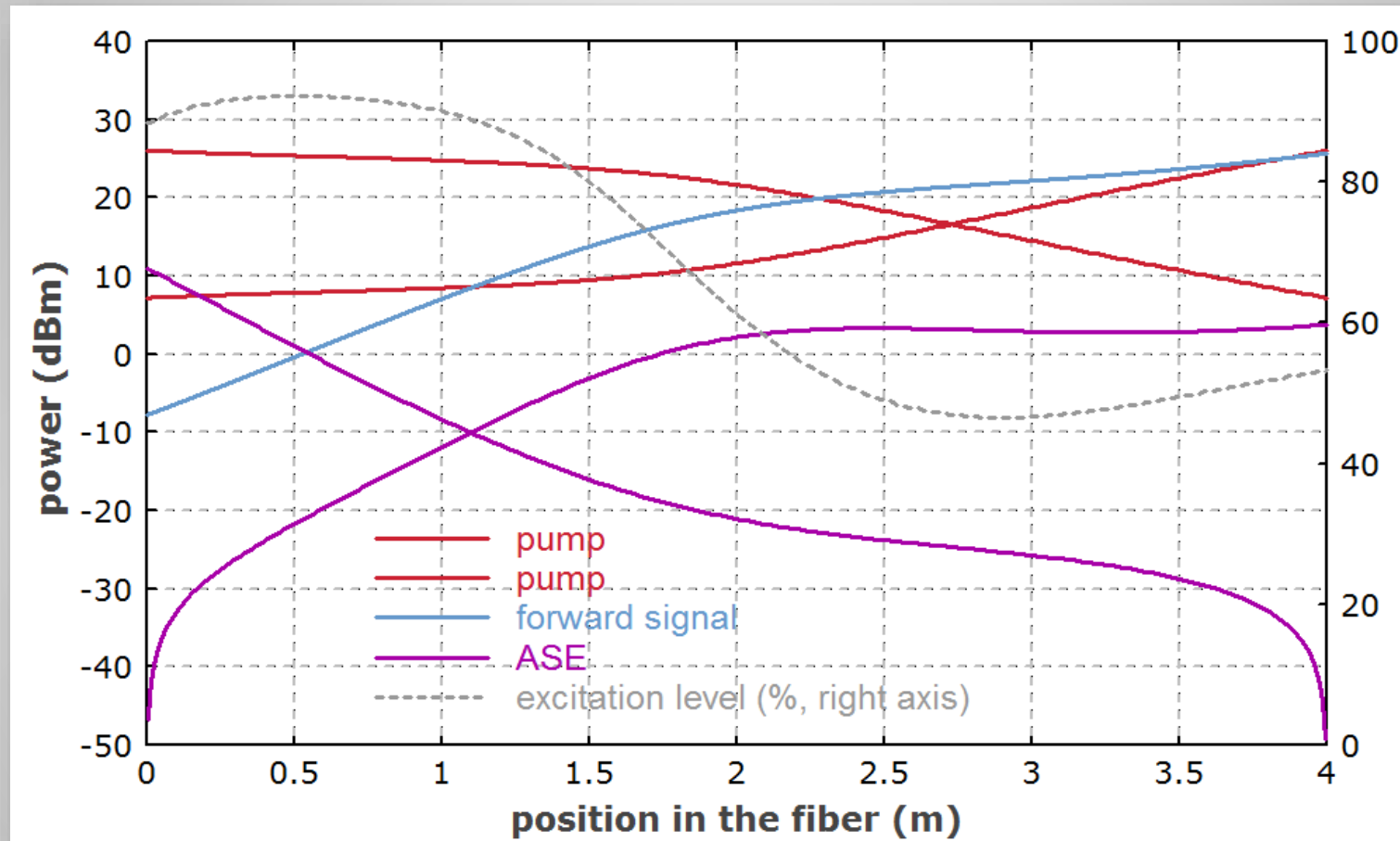
## Applications:

- ▶ pulsed amplifiers
- ▶ Q-switched fiber lasers



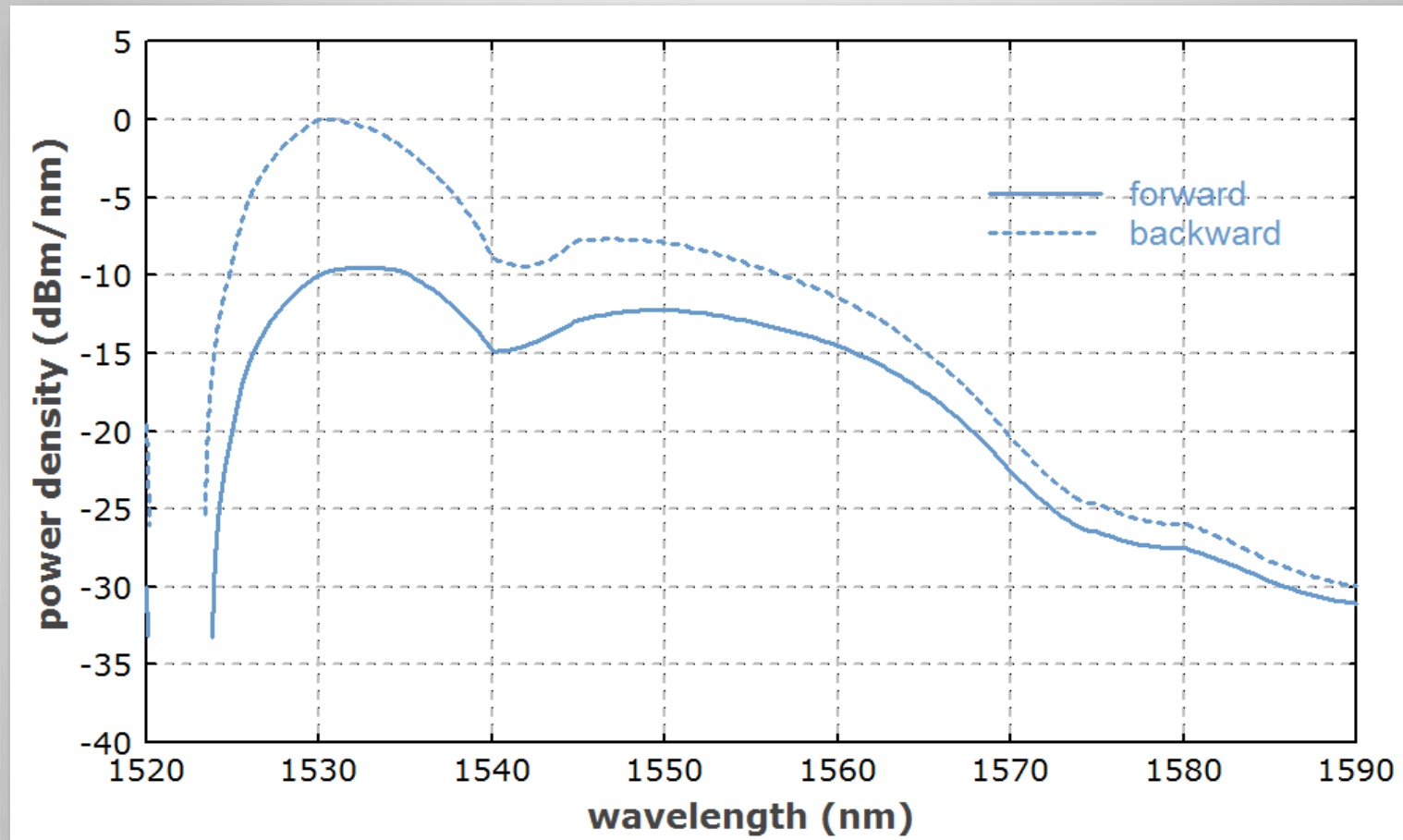
# Calculation of Optical Powers (5)

## Distribution of optical powers in an erbium-doped fiber amplifier



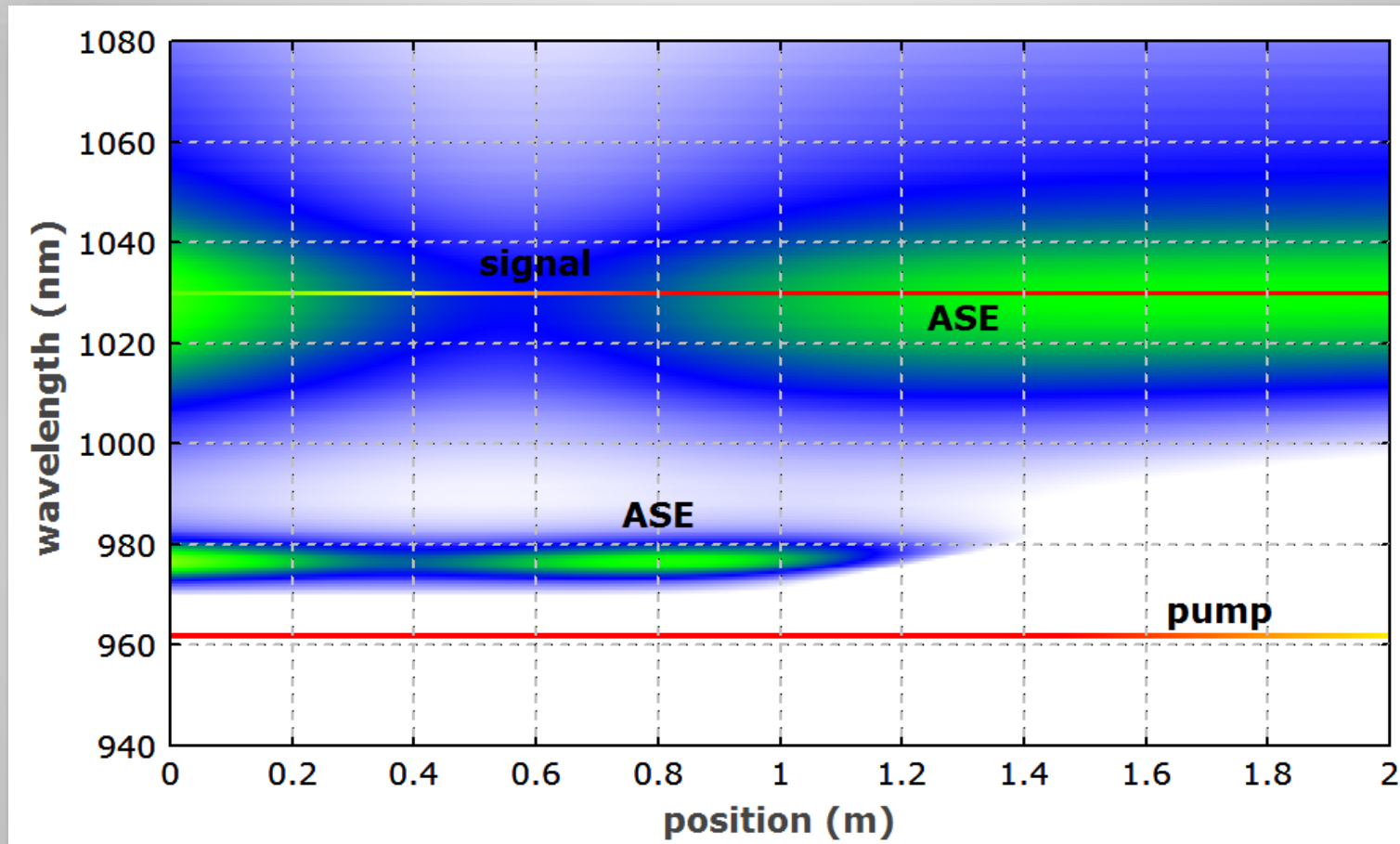
# Calculation of Optical Powers (6)

## ASE spectrum of an erbium-doped fiber amplifier



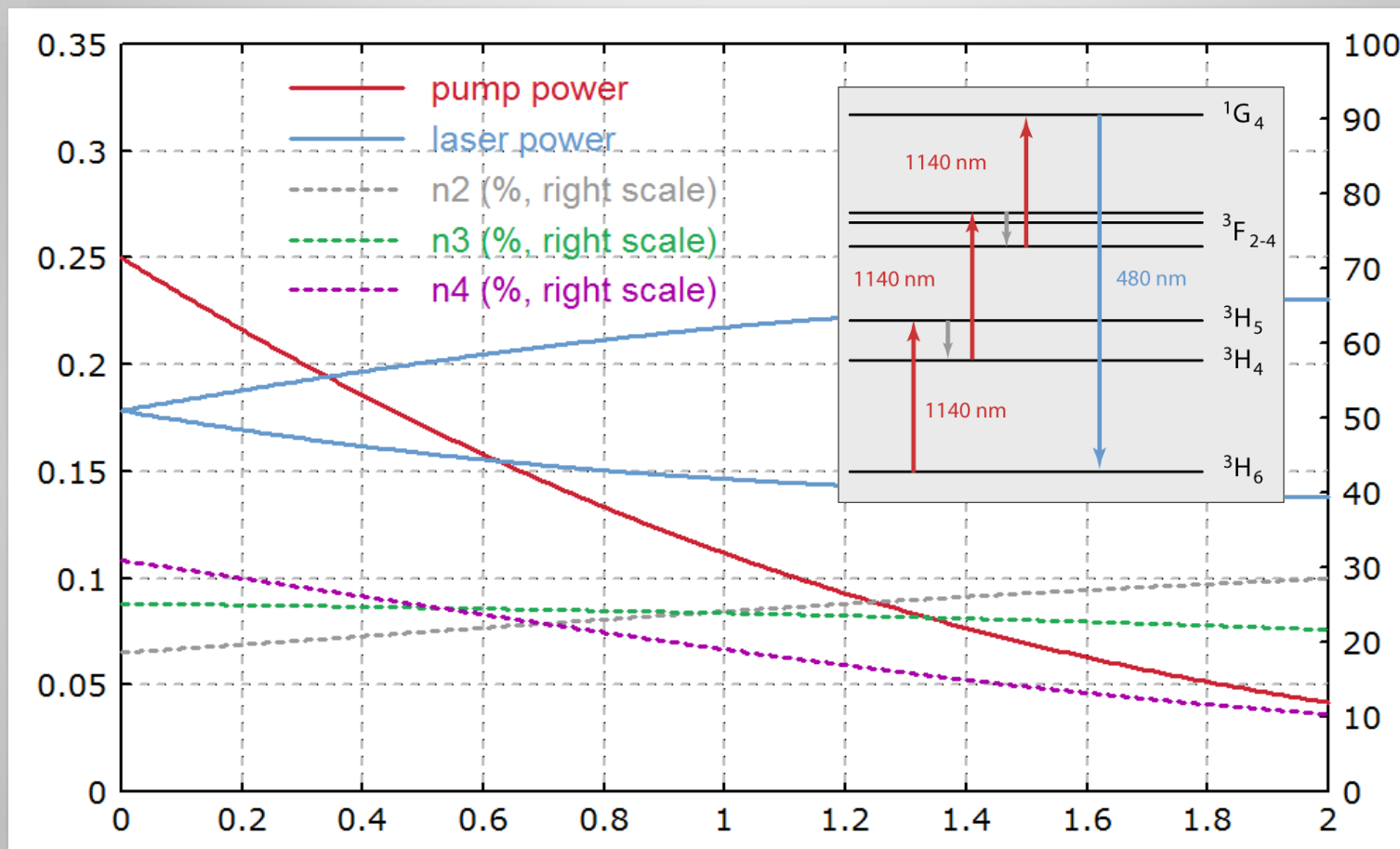
# Calculation of Optical Powers (7)

## ASE in ytterbium-doped amplifier



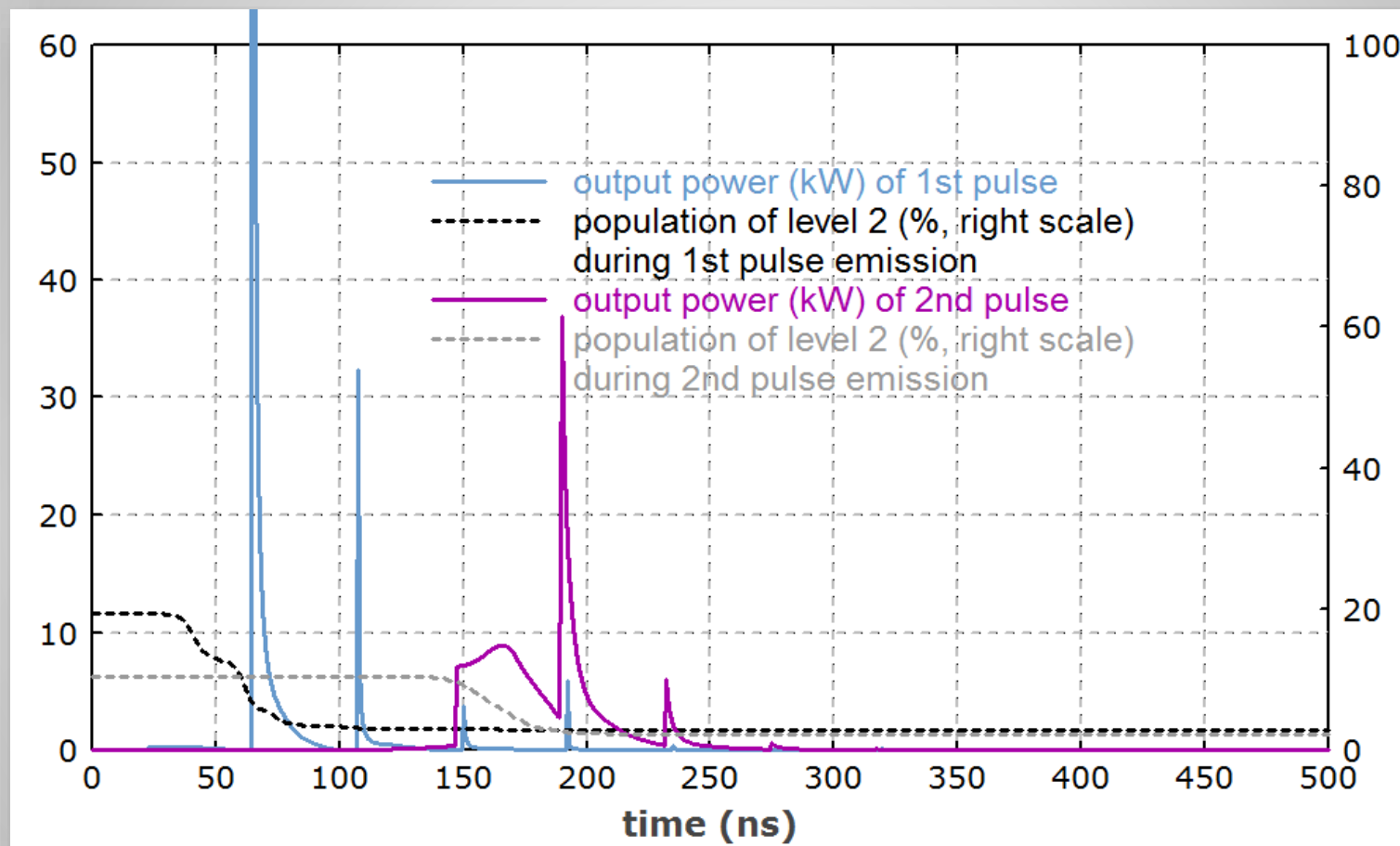
# Calculation of Optical Powers (8)

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



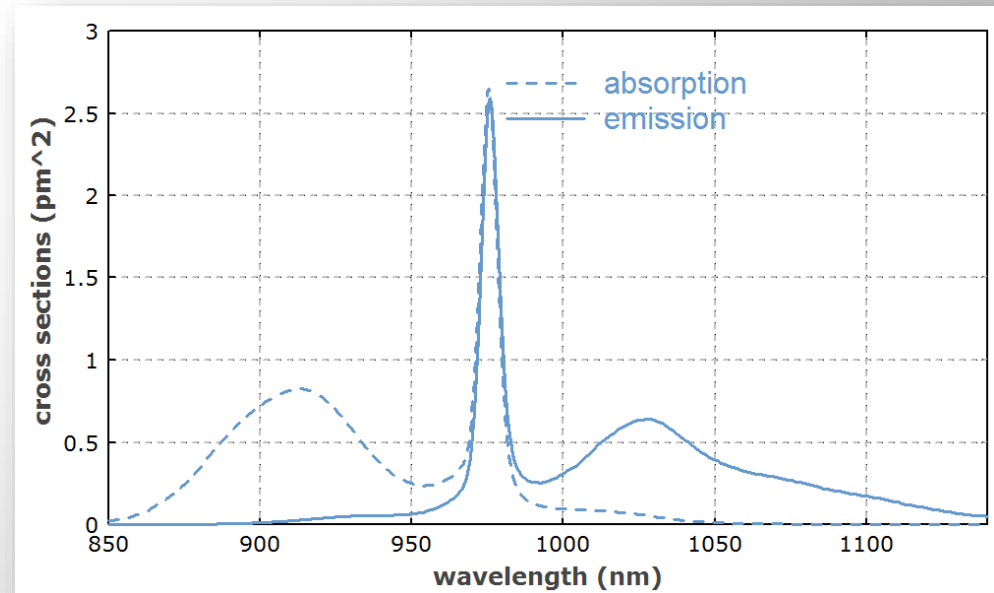
# Calculation of Optical Powers (9)

## 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** (this is support!), 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<sup>2</sup>-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:

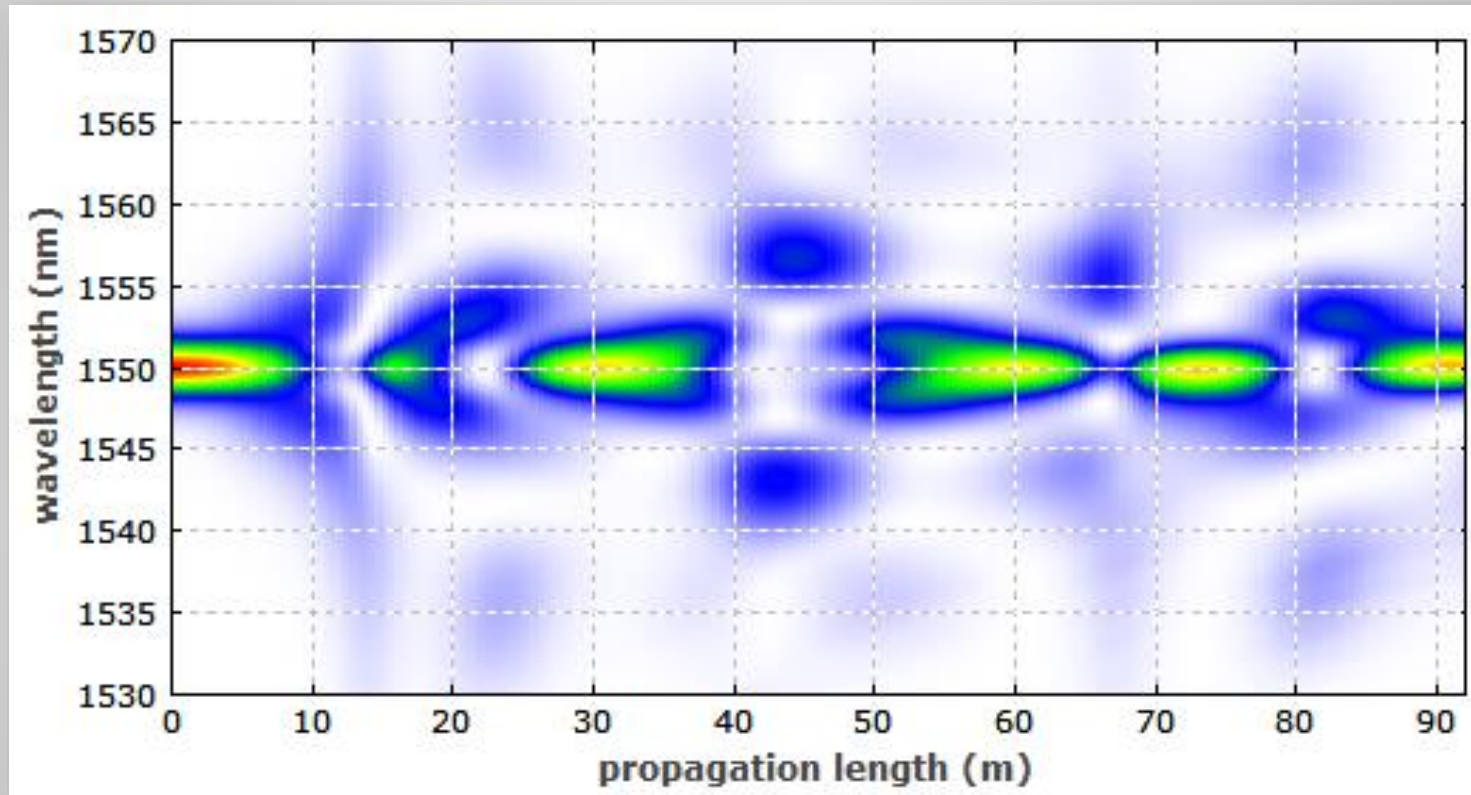
- ▶ Script language provides many dozens of **functions for retrieving all sorts of pulse properties**: pulse energy, peak power, peak position, pulse duration and spectral width (based on different definitions), amplitude profiles, spectral phase, autocorrelation, etc.
- ▶ Easy pulse inspection with 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)

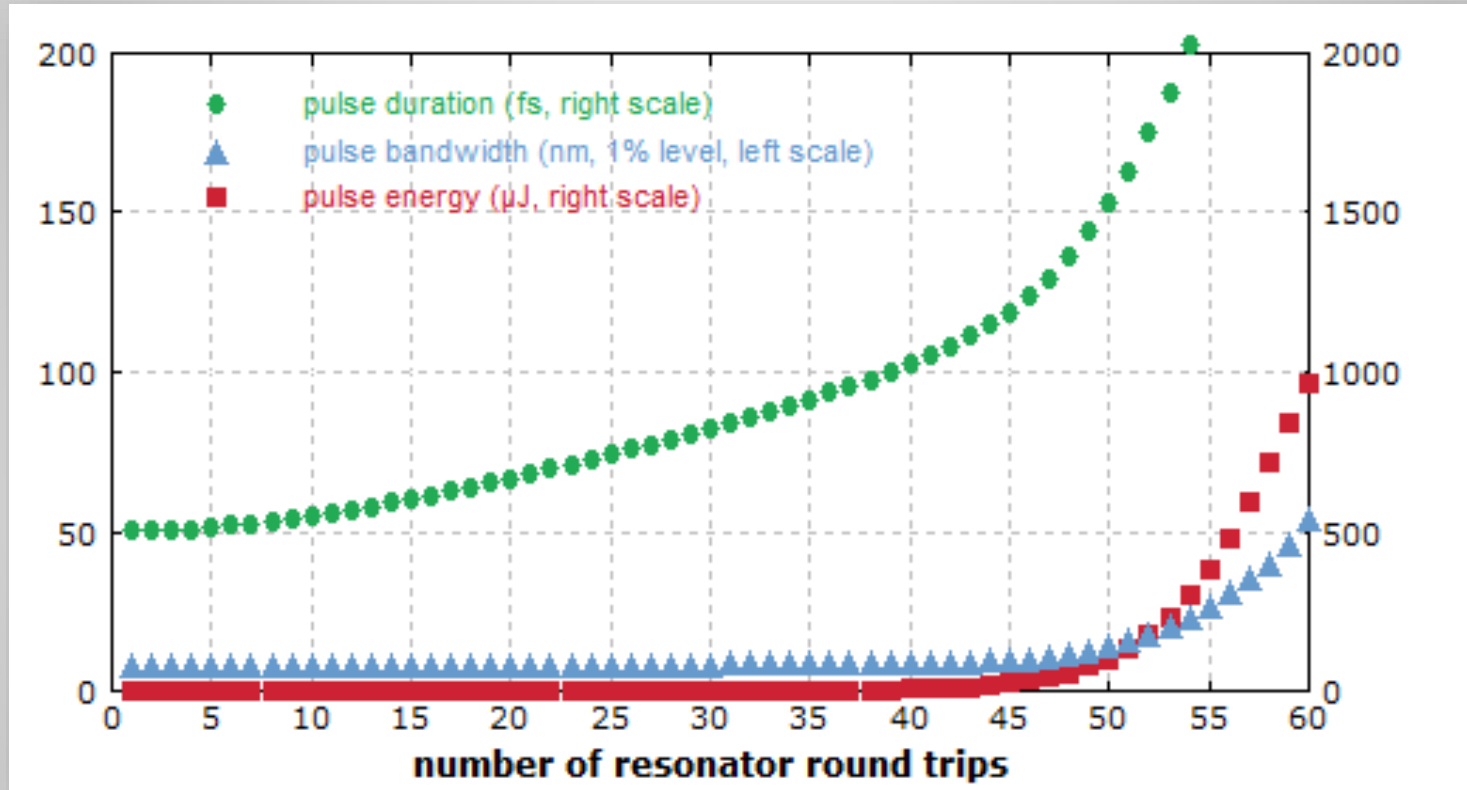
**Example: higher-order soliton propagation:**



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

# Ultrashort Pulse Propagation (4)

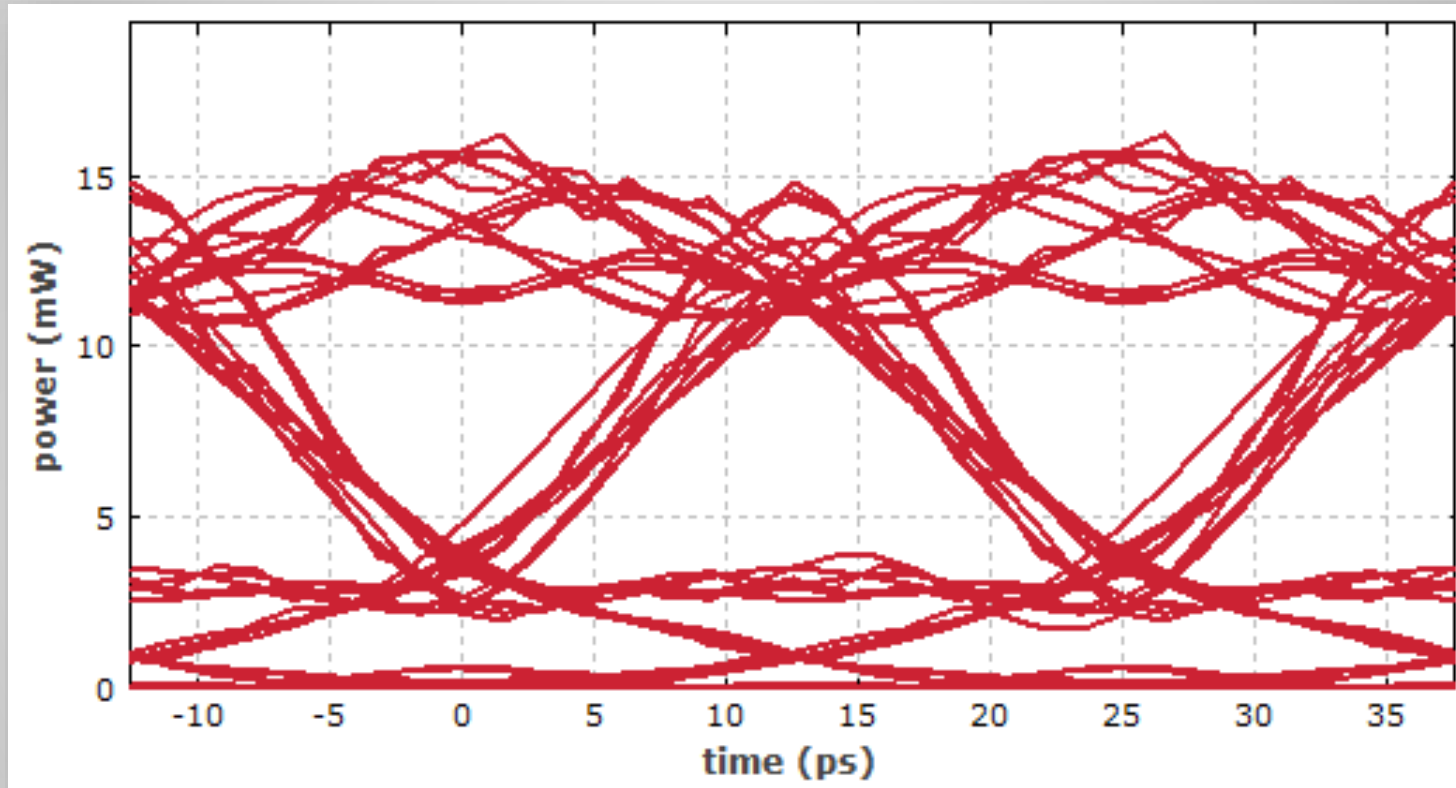
**Example: regenerative bulk amplifier:**



(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)

## New in RP Fiber Power V8: **Power Forms!**

- ▶ The software comes with several such forms, offering easy-to-use and very powerful simulation models for things like
  - ▶ fiber amplifiers for multiple continuous-wave (possibly broadband) signals, or with multiple short or ultrashort pulse signals
  - ▶ offering up to 5 fiber amplifier stages, with wavelength-dependent losses between them
  - ▶ flexible pumping options, including multiple bidirectional broadband pumps
- ▶ Just fill in your input parameters, select and configure the wanted diagrams, and execute!
- ▶ Get numerical outputs in the form as well as informative and nice diagrams.

# The User Interface (2)

- Simply pick the suitable Power Form. Example:

## Fiber Amplifier for Ultrashort Pulses

Input parameter set:

**Input pulses**

Pulse 1 | Pulse 2 | Pulse 3 | Pulse 4 | Pulse 5 | Pulse 6 | Pulse 7 | Pulse 8 | Pulse 9 | Pulse 10

Activate this pulse

Pulse energy:  Central wavelength:

**Pulse shape**

Pulse shape:

Duration:  Chirp:

Coupling loss:  %

**Time trace**

Width of pulse grid:  Number of amplitudes:  Resolution:

**Simulation cycles**

Repetitive operation

Repetition rate:  Repetition period:

Preparatory cycles

Number of cycles:  Step size:

Stop if steady state is reached Allowed change:  (of pulse energies)

Number of cycles:

Pumping resolution:

(This is only the beginning of the form; there is more, e.g. for defining details of the amplifier stages and for configuring diagrams.)

- The input data may be stored either in some standard folder or in your work folder.

**Power Forms**  
These power forms provide easy access to powerful simulation models out of the box.

**Fiber lasers and amplifiers** (Version: 2023-08-02)

**Fiber amplifier for continuous-wave signals** (Version: 2023-08-02)

Diagram: A signal path through two amplifier stages (amplifier 1 and amplifier n). Each stage receives multiple pumps (1..5) and produces signals plus ASE. Features: continuous-wave operation, up to 5 stages, broadband signals/pumps, double pass amplifiers.

**Fiber laser and amplifiers** (Version: 2023-08-03)

Diagram: A signal path starting with a Laser, followed by amplifier 1 and amplifier n. Each stage receives multiple pumps (1..5) and produces signals plus ASE. Features: continuous-wave operation, laser stage, up to 5 amplification stages, double pass amplifiers.

**Fiber amplifier for pulses** (Version: 2023-08-03)

Diagram: A signal path through two amplifier stages (amplifier 1 and amplifier n). Each stage receives multiple pumps (1..5) and produces signals plus ASE. Features: pulsed signals, up to 5 stages, broadband, time-dependent signals/pumps, find steady state.

**Fiber amplifier for ultrashort pulses** (Version: 2023-08-02)

Diagram: A signal path through two amplifier stages (amplifier 1 and amplifier n). Each stage receives multiple pumps (1..5) and produces signals plus ASE.

# The User Interface (3)

## Combining power, flexibility and easy of use with **Power Forms**

- ▶ You can very easily set up simple fiber laser or amplifier models, for example, but can also utilize many sophisticated features, such as multiple stages, multiple broadband pumps and signals, wavelength filtering, many diagrams, etc.
- ▶ In case that some needed special feature is still missing: just add it!  
How does that work?
  - ▶ Power Forms are not “hard-wired” in the software, but rather defined in script files.
  - ▶ For making a modified version, let the software copy the script file to your work folder and edit it there – for example, adding a diagram, some input and output fields, etc.
  - ▶ If you meet any obstacles, contact our technical support.  
We can quickly provide modified Power Form versions for you.
- ▶ In that way, we managed to **combine ease of use with great flexibility**.

# The User Interface (4)

## Custom forms: make any tailored forms you need!

- ▶ Before we introduced the Power Forms, we had **Custom Forms**. In fact, Power Forms are basically sophisticated Custom Forms which we deliver with the software.
- ▶ Basic idea: a Custom Form contains
  - ▶ (a) code to define a form (defining input and output fields, buttons, tab controls, radio boxes etc.
  - ▶ (b) code for calculations and generating outputs (numerical or diagrams)
- ▶ You can make such forms yourself (with our support) for any new application of the software!

```
6 Custom form:
7 -----
8 $font: "Arial", bold, size = 20
9 Step-index Fiber
10 $image ((var r; r := if abs(y - 30 / 2) < 4 then 0.8 else 0.9; rgb(
11 $font: "Courier New", size = 11, space = 2.1
12 $box "Fiber details", size = (600, 0)
13 Core diameter: ##### Clad index: #####
14 $input d_co:d6:"m", min = 0, max = 1e-3
15 $input n_cl:d6, min = 1, max = 2
16 Numerical aperture: ##### Core index: #####
17 $input NA:d6, min = 0, max = 1
18 $output n_co:f6
19 Super-Gauss index: ##### (0 = step index)
20 $input sg_index, min = 0, max = 1000, default = 0, hint = "use a va
21 $box end
22 $box "Fiber modes", size = (600, 0)
23 Wavelength: #####
24 $input lambda:d6:"(n)m"
```



# The User Interface (5)

Simple example for a **custom form:**

fiber amplifier model, calculating the spatial distribution of powers, output powers etc., also generating various plots

This is a delivered demo file. No problem if you need e.g. three signals instead of one – just modify the script!

But for that specific use, an existing Power Form is far more powerful.

The screenshot displays the RP Fiber Power V8 software interface. The main window title is "RP Fiber Power V8 in 'P:\RP\_Fiber\_Power\Demo\'". The interface is divided into several sections:

- Menu Bar:** File, Edit, View, Execute, Help.
- Toolbar:** Forms, Editors, Custom form (selected), Power forms, and various utility icons.
- Yb-doped Fiber Amplifier:** The main title of the custom form.
- Fiber details / Operation parameters:** A table of input parameters:

Core material:	Yb-germanosilicate		
Yb concentration:	15e24 /m <sup>3</sup>	Core diameter:	5 μm
Pump mode radius:	4.8 μm	Fiber length:	3 m
Signal mode radius:	5 μm		
- Outputs:** A table of calculated results with corresponding progress bars:

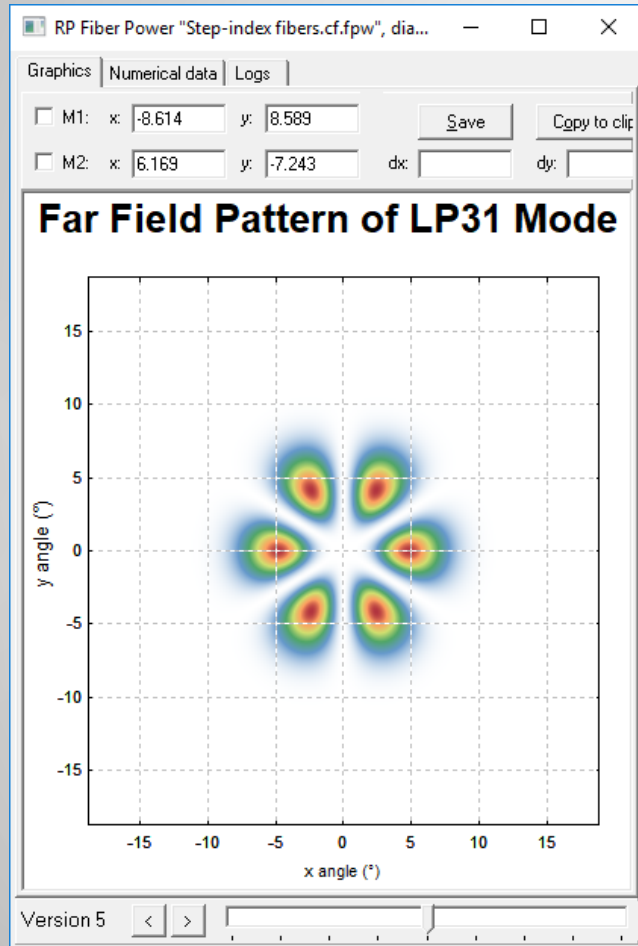
Residual pump power:	32.3 mW
Signal output power:	335 mW
Signal gain:	19.2 dB
Gain at 975 nm:	-4.4 dB
ASE power: forward:	595 μW
backward:	47.4 mW
total:	47.9 mW
Heat:	44 mW
Yb excitation:	51.1%
- Spatial distributions along the fiber:** Three horizontal color-coded bars for Pump, Signal, and Exc.
- Diagrams:** A list of checkboxes for visualization options:
  - Powers vs. position
  - gain spectrum
  - ASE spectrum
  - Transverse profiles
  - Variation of the pump power
  - Variation of the signal power
  - Variation of the fiber length
- Log area:** A text area showing execution logs:

```
End reading include file "P:\RP_Fiber_Power\Units.inc"
Start reading include file "P:\RP_Fiber_Power\Spectroscopic data\Yb-germa
End reading include file "P:\RP_Fiber_Power\Spectroscopic data\Yb-german
End reading "Yb amplifier with ASE.cf.fpw"
```
- RP PHOTONICS:** Logo in the top right corner.
- Diagrams / Output area:** A panel on the right showing calculated values:

pump: 32.3 mW  
signal: 335 mW  
heat: 44 mW  
G\_signal: 19.2 dB
- Evaluate expression:** A dropdown menu at the bottom right.

# The User Interface (6)

Another example: step-index fibers



RP Fiber Power V8 in "P:\RP\_Fiber\_Power\Demo\"

File Edit View Execute Help

Forms Editors Custom form Power forms

## Step-index Fiber

Fiber details

Core diameter: 25  $\mu\text{m}$  Clad index: 1.44

Numerical aperture: 0.2 Core index: 1.453823

Super-Gauss index: 10 (0 = step index)

Fiber modes

Wavelength: 1550 nm

Number of modes: 13 (23)

Select a mode: l = 1 m = 2

Mode radius: 9.79  $\mu\text{m}$

Mode area: 205.8  $\mu\text{m}^2$

Effective n: 1.447339

Power in core: 99.7%

Max intensity: 6.63 GW /  $\text{m}^2$  (for 1 W) LP12

Diagrams

- Radial functions
- Mode intensity profiles
- Far field profiles
- All near field mode profiles
- All far field mode profiles
- Number of modes vs. wavelength
- Fraction of power in the core

Log area

```
end reading include file P:\RP_Fiber_Power\units.inc
End reading "Step-index fibers.cf.fpw"
```

Execution time: 589 ms  
Finished successfully.

RP PHOTONICS

Diagrams

Output area

pump: 32.3 mW  
signal: 335 mW  
heat: 44 mW  
G\_signal: 19.2 dB

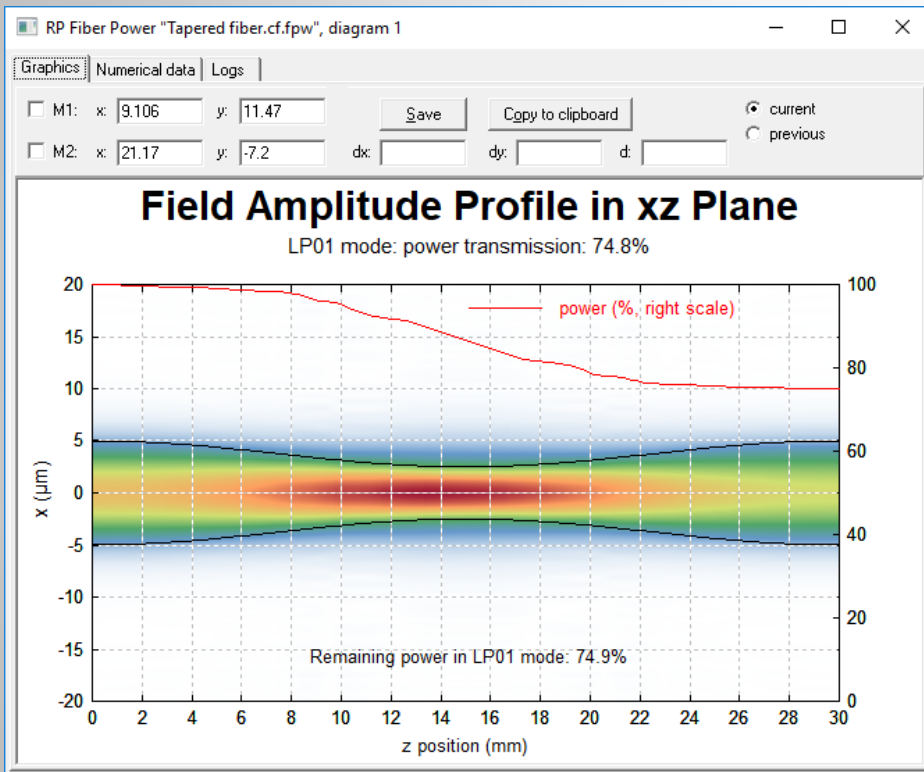
13 modes:

- LP01: 5.88986 /  $\mu\text{m}$
- LP11: 5.88474 /  $\mu\text{m}$
- LP21: 5.87825 /  $\mu\text{m}$
- LP31: 5.87057 /  $\mu\text{m}$
- LP41: 5.86184 /  $\mu\text{m}$
- LP51: 5.85219 /  $\mu\text{m}$
- LP61: 5.84174 /  $\mu\text{m}$
- LP02: 5.87633 /  $\mu\text{m}$
- LP12: 5.87070 /  $\mu\text{m}$
- LP22: 5.85703 /  $\mu\text{m}$
- LP32: 5.84661 /  $\mu\text{m}$
- LP03: 5.85569 /  $\mu\text{m}$
- LP13: 5.84459 /  $\mu\text{m}$

Evaluate expression:

# The User Interface (7)

Another example: simulating light propagation in tapered fibers



RP Fiber Power V8 in "P:\RP\_Fiber\_Power\Demo"

File Edit View Execute Help

Forms Editors Custom form Power forms

## Tapered Fiber

Fiber details

Cladding index: 1.45 NA: 0.2  
Core radius: 5  $\mu\text{m}$  Length: 30 mm  
Tapering factor: 25%  get back to original core size

Fiber Shape

Operation parameters

Wavelength: 1550 nm  
Mode: 1: 0 m: 1

Numerical grid

Max. x / y coordinates: 20  $\mu\text{m}$   
Number of grid points: (2^6) (in x and y direction)  
Longitudinal resolution: 10  $\mu\text{m}$  Sub-steps: 20

Results

Number of modes: 2 Transmission:

Diagrams

Field amplitude profile in xz plane  
 Evolution of beam parameters

Log area

End reading include file P:\RP\_Fiber\_Power\units.inc  
End reading "Tapered fiber.cf.fpw"

Execution time: 372 ms  
Finished successfully.

RP PHOTONICS

Diagrams

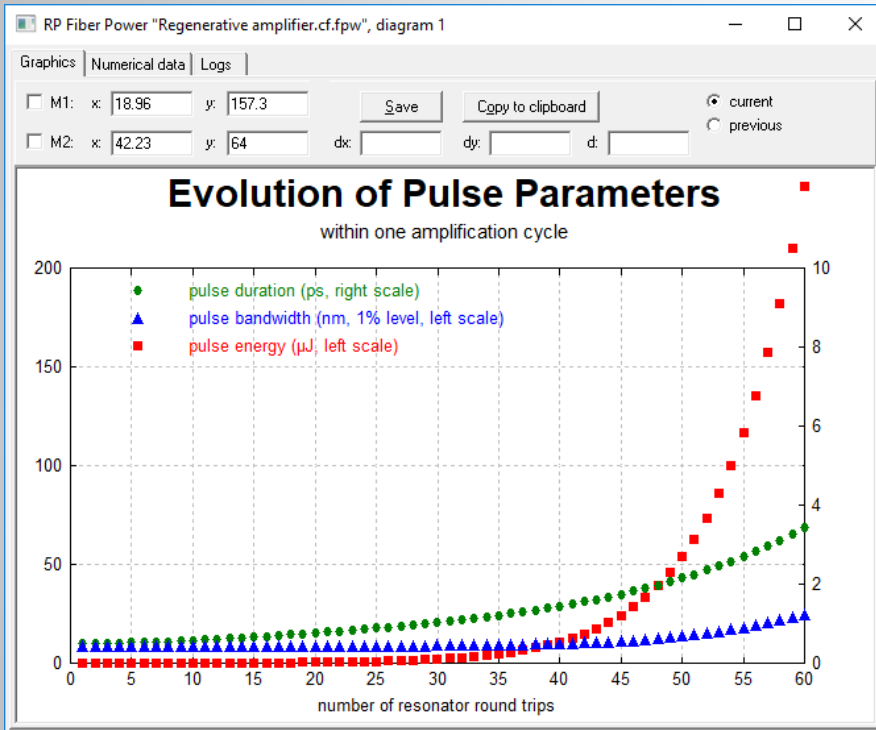
Output area

Modes: 2  
r\_max: 20  $\mu\text{m}$   
dr: 625 nm  
dr\_min: 1.23  $\mu\text{m}$

Evaluate expression:

# The User Interface (8)

Another example:  
regenerative amplifier



RP Fiber Power V8 in "P:\RP\_Fiber\_Power\Demo"

File Edit View Execute Help

Forms Editors Custom form Power forms

## Regenerative Amplifier

Gain medium Pump and signal Resonator

Material: Yb-germanosilicate  
 Length: 6 mm  
 Yb concentration: 500e24 /m<sup>3</sup>

Input pulses Numerical parameters Amplification cycles

Pulse energy: 15 nJ  
 Pulse duration: 500 fs Chirp: 0 Hz/ps

Outputs

	1	2	3	3
Cycles:	1	2	3	3
Energy:	194 μJ	98.3 μJ	67.2 μJ	67.2 μJ
Peak power:	147 MW	25.4 MW	14.8 MW	14.8 MW
Av. power:	1.94 W	983 mW	672 mW	672 mW
Duration:	42.1 fs	4.53 ps	4.88 ps	4.88 ps

Additional results

Net gain: 0.516 dB Residual pump power: 2.97 W

Diagrams

- Evolution of pulse parameters
- Final pulse in time domain
- Final pulse in frequency domain
- Parameters of compressed pulse vs. GDD

Pulse display for initial pulse final pulse

Log area

Execution time: 1.88 s  
 Finished successfully.

Evaluate expression:

# The User Interface (9)

## In a script, you can define the following:

- ▶ any model (e.g. a sophisticated multi-stage fiber amplifier model)
- ▶ any further calculations
- ▶ generation of multiple graphical diagrams
- ▶ output or input to/from text or binary files
- ▶ a custom form for easy handling

```
156 DoCycle(N_rt, T_p) :=
157   { Do one amplification phase with N_rt round trips
158     and one pumping phase with duration T_p. }
159   begin
160     global E0, tau0, chirp0, N_rt, T_p;
161     startpulse_G(E0, tau0, chirp0);
162     { Amplification }
163     for j := 0 to N_rt do
164       begin
165         if j > 0 then
166           begin
167             DoRoundTrip();
168             describe_pulse("pulse after " + str(j) + " round trips");
169           end;
170           store_pulse(j);
171         end;
172       { Pumping }
173       calc_dyn(0, T_p, minr(100 us, T_p));
174     end
```

# The User Interface (10)

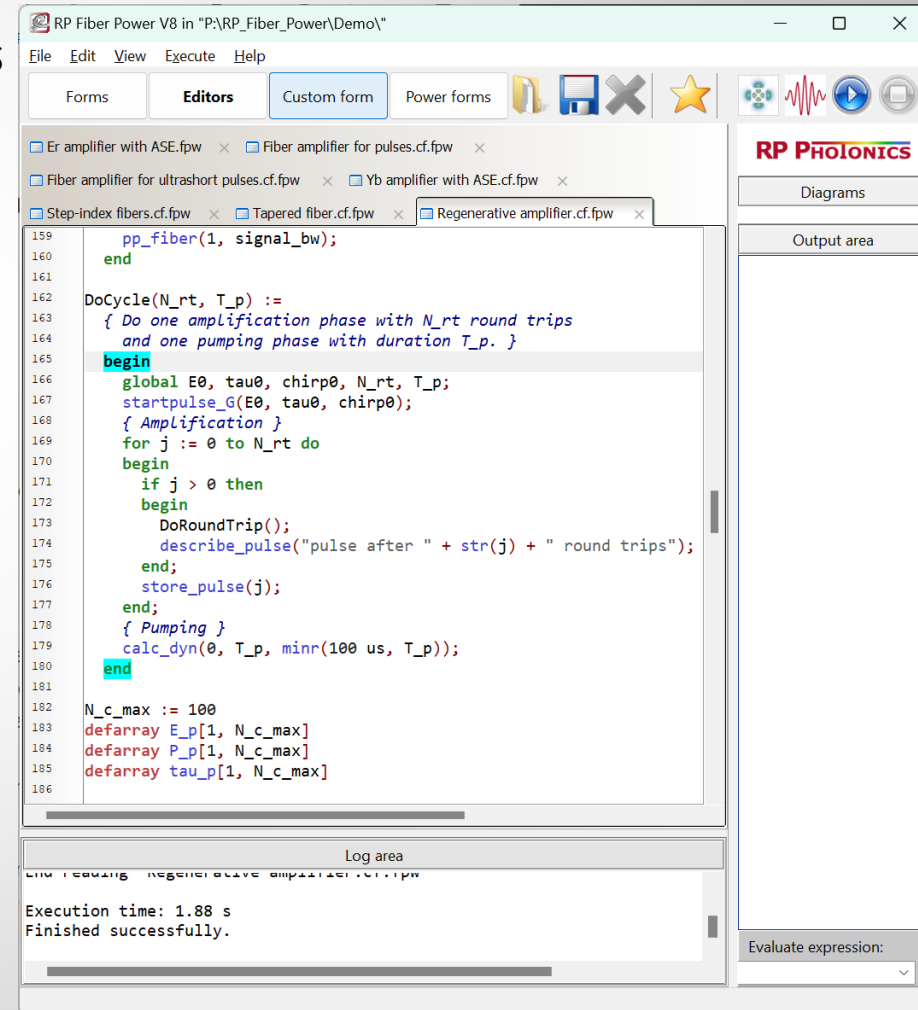
## Where to get a script from?

- ▶ Take one of the many demo scripts coming with the software and adapt it to your specific needs.  
The user interface will support you in many ways.
- ▶ For a sophisticated model, may also start from a Power Form.
- ▶ Get help within the technical support – get even complete scripts developed for you!

# The User Interface (11)

## Powerful script editors and editing tools:

- ▶ **Code snippet library** for inserting frequently used parts of code
- ▶ **Parameter hints** for hundreds of functions
- ▶ **Multilevel undo/redo functionality**
- ▶ **Syntax highlighting** for good readability of code
- ▶ **Integrated syntax checker**
- ▶ Conveniently modify indentation of code blocks
- ▶ **Automatic code formatting** for consistent formats
- ▶ Setting of **breakpoints** for easy debugging



The screenshot displays the RP Fiber Power V8 software interface. The main window is titled "RP Fiber Power V8 in 'P:\RP\_Fiber\_Power\Demo'". The interface includes a menu bar (File, Edit, View, Execute, Help), a toolbar with icons for forms, editors, custom forms, power forms, and other functions, and a sidebar with "RP PHOTONICS" branding and sections for "Diagrams" and "Output area".

The central editor shows a script for a regenerative amplifier. The code is as follows:

```
159 pp_fiber(1, signal_bw);
160 end
161
162 DoCycle(N_rt, T_p) :=
163 { Do one amplification phase with N_rt round trips
164   and one pumping phase with duration T_p. }
165 begin
166   global E0, tau0, chirp0, N_rt, T_p;
167   startpulse_g(E0, tau0, chirp0);
168   { Amplification }
169   for j := 0 to N_rt do
170     begin
171       if j > 0 then
172         begin
173           DoRoundTrip();
174           describe_pulse("pulse after " + str(j) + " round trips");
175         end;
176         store_pulse(j);
177       end;
178       { Pumping }
179       calc_dyn(0, T_p, minr(100 us, T_p));
180     end
181
182   N_c_max := 100
183   defarray E_p[1, N_c_max]
184   defarray P_p[1, N_c_max]
185   defarray tau_p[1, N_c_max]
186
```

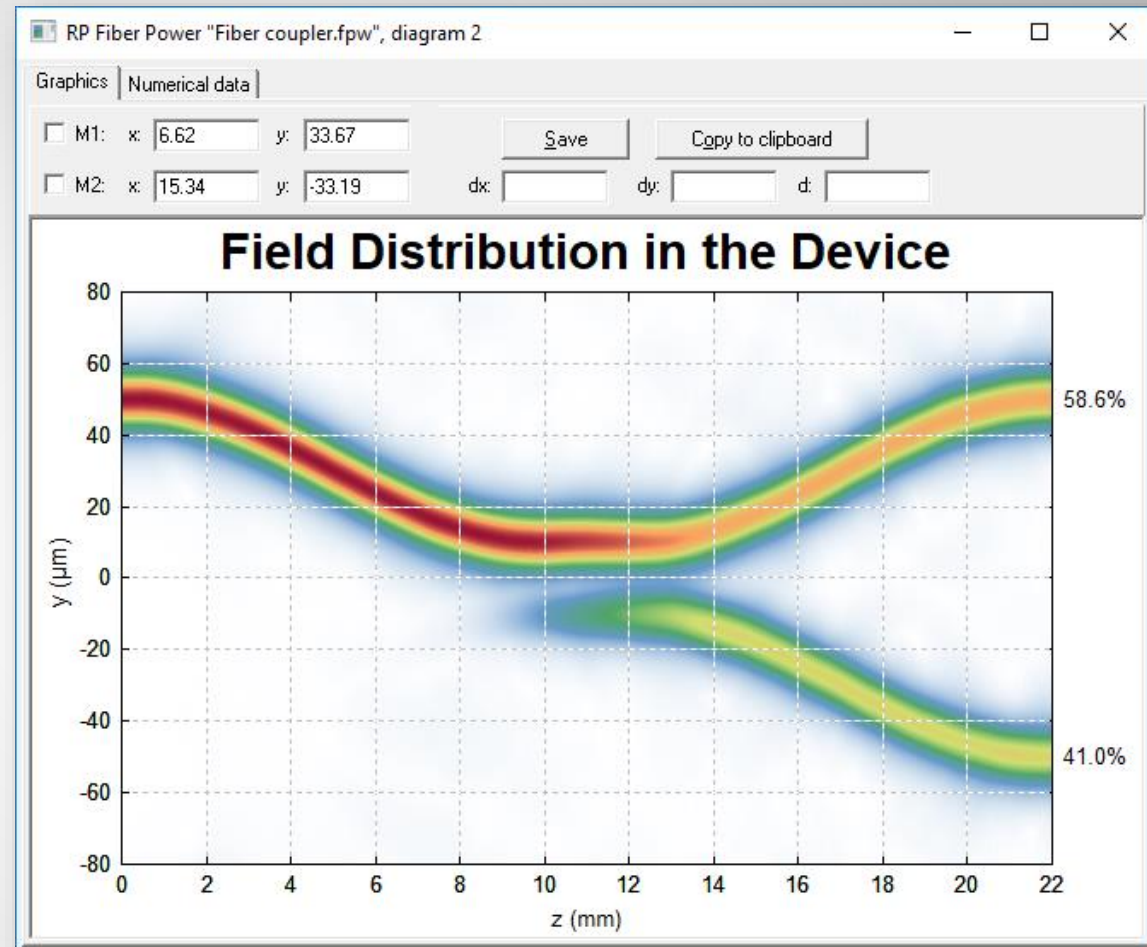
At the bottom of the window, there is a "Log area" showing the execution results:

```
Log area
Execution time: 1.88 s
Finished successfully.
```

# The User Interface (12)

## 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
- ▶ export of numerical data



Also have flexible options for generating output in text form!

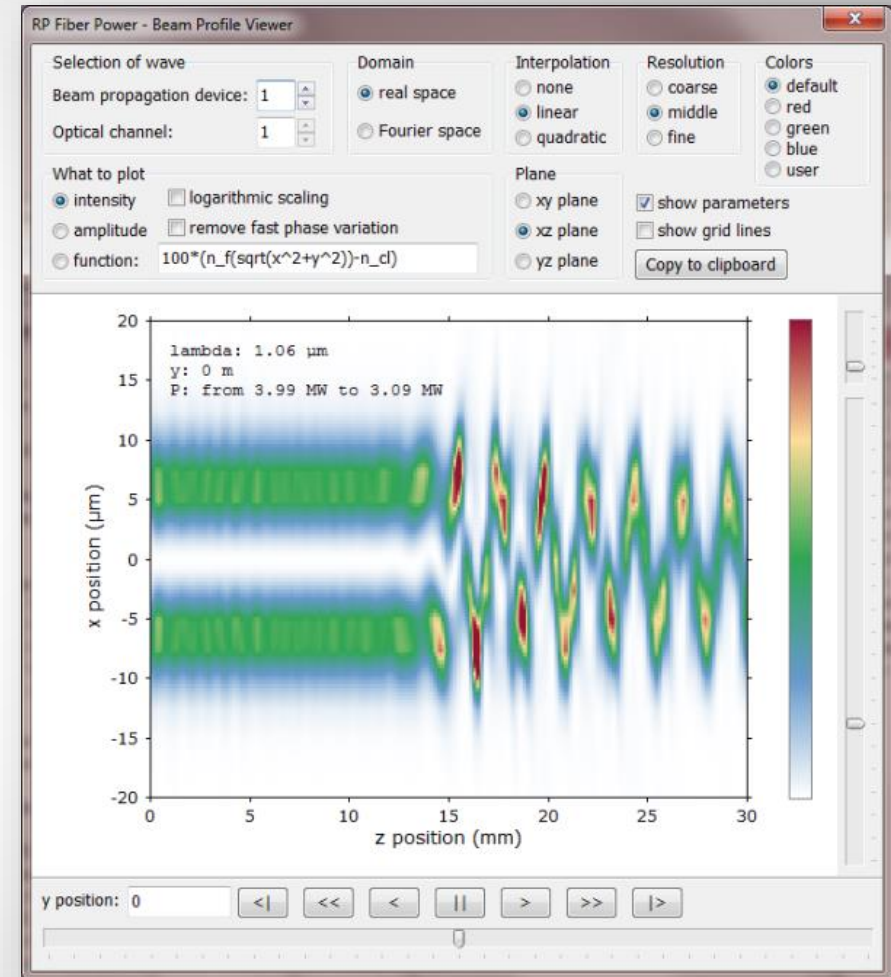
Put that into diagrams or files as you like.



# The User Interface (13)

## Interactive beam profile viewer

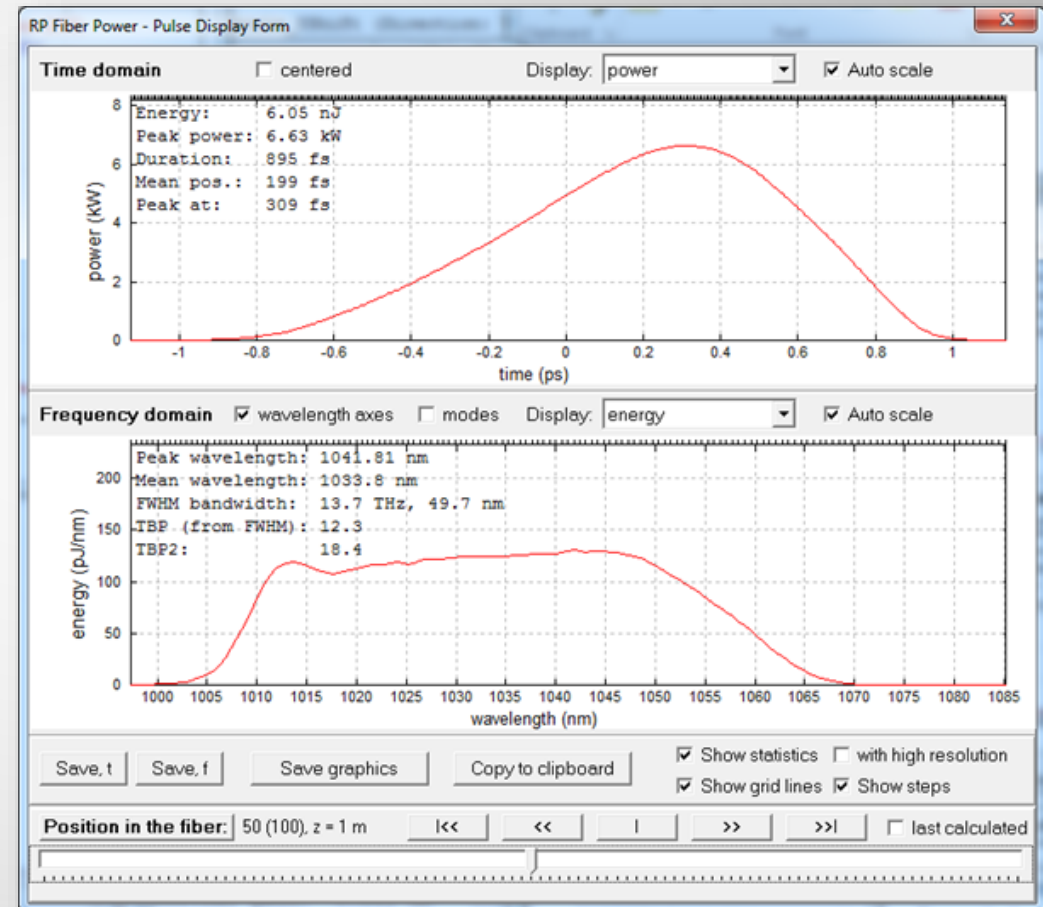
- ▶ Inspect calculated beam profiles.
- ▶ Switch between different wavelength components, displayed with different colors.
- ▶ Show profiles in xy, xz or yz plane.
- ▶ Change scaling or use logarithmic display in order to reveal weak satellites.
- ▶ Get parameters like center position and beam width displayed.



# The User Interface (14)

## 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.



# The Debugger

- ▶ In **debug mode**, inspect the detailed state of the system: global and local variables, arrays, functions, fiber definitions etc.
- ▶ Can evaluate any expression for monitoring further details.
- ▶ Can set **breakpoints** even within mathematical expressions! Also can use temporary and conditional breakpoints.
- ▶ Decide how to go forward: evaluate another step, continue executing normally, or abort the execution.

The screenshot shows the 'RP Fiber Power - inspector for debugging' window. It features a top bar with an 'Update' button and a message field containing 'resonator round-trips'. Below this is a navigation bar with tabs for 'Debug expression', 'Variables', 'Arrays', 'User-defined functions', 'Fibers', and 'Beam propagation'. The main area is divided into three sections: 'Code', 'Local variables', and 'Expression to evaluate'. The 'Code' section displays a script with line numbers 01 to 14. Line 11, 'describe\_pulse('pulse after ' + str(j) + ' r...', is highlighted in blue, indicating a breakpoint. The 'Local variables' section shows three variables: 'j = 1', 'N\_rt = 60', and 'T\_p = 0.0001'. The 'Expression to evaluate' section has a dropdown menu and a button labeled 'Click here or press the Enter key to evaluate'. At the bottom, there are three buttons: 'Next expression', 'End debug mode', and 'Abort'.

```
01 Function DoCycle(N_rt, T_p):
02 begin
03   global E0, tau0, chirp0, N_rt, T_p;
04   startpulse_G(E0, tau0, chirp0);
05   debug('resonator round-trips');
06   for j := 0 to N_rt do
07     begin
08       if j > 0 then
09         begin
10           DoRoundTrip();
11           describe_pulse('pulse after ' + str(j) + ' r...
12         end;
13       store_pulse(j);
14     end;
```

Last value: 0

Local variables

01	j = 1
02	N_rt = 60
03	T_p = 0.0001

Expression to evaluate:

Click here or press the Enter key to evaluate

Value of expression:

Next expression End debug mode Abort

# Documentation

- ▶ comprehensive **PDF manual**
- ▶ detailed **interactive help system** (displaying content in your web browser)
- ▶ comprehensive explanations of the used physical models, underlying assumptions, details of the script language, etc.
- ▶ dozens of **demo files**, demonstrating many different possibilities
- ▶ detailed explanations also for each Power Form

The screenshot shows a web browser window displaying the RP Photonics documentation. The page title is 'Optical channels'. The main content area features a 'Contents' section with a list of links to various documentation topics. Below the contents is a 'Tags' section with '#fiber model'. The main heading is 'Optical channels', followed by a paragraph explaining that the software allows users to define optical channels for light propagation in a fiber. A graph shows the power distribution of these channels, with a 'pump' channel at approximately 1470 nm, an 'ASE' channel between 1520 nm and 1560 nm, and two 'signal' channels at approximately 1550 nm and 1580 nm. The x-axis is labeled 'wavelength (nm)' and ranges from 1460 to 1620. The y-axis represents power, ranging from 0 to 1. Below the graph, the text states: 'An optical channel has the following properties:' followed by a list of properties including wavelength, bandwidth, propagation modes, direction, background loss, reflectances, parasitic losses, and transverse intensity distribution.

RP PHOTONICS

You are reading the documentation of the RP Fiber Power software.

## Optical channels

The software allows the user to define some number of optical "channels", representing the light propagation in the fiber. The figure below illustrates the optical channels in an erbium-doped fiber amplifier: a pump channel, two signal channels, and 16 ASE channels:

An optical channel has the following properties:

- It has some wavelength, and in the case of an ASE channel (for calculating **amplified spontaneous emission**), it also has a wavelength bandwidth, and in addition the user specifies the number of propagation modes. The latter can be 2 for a single-mode fiber, when both **polarization** directions are accounted for.
- It has a propagation direction, which is forward or backward.
- There can be some **background loss**, specified in dB/m, resulting e.g. from absorption by impurity or from scattering at the core/cladding interface.
- There can be **reflectances** for some channel and both fiber ends, which couple this channel to a channel with the opposite propagation direction. (This is particularly used for fiber lasers.) See the page on **reflections and laser resonators**.
- There can be additional parasitic losses at both ends, inside and/or outside the reflector.
- There is a transverse intensity distribution, characterized with a function. (The software automatically normalizes that function.) For single-mode fibers, the intensity distribution can normally be well approximated with a Gaussian mode function:

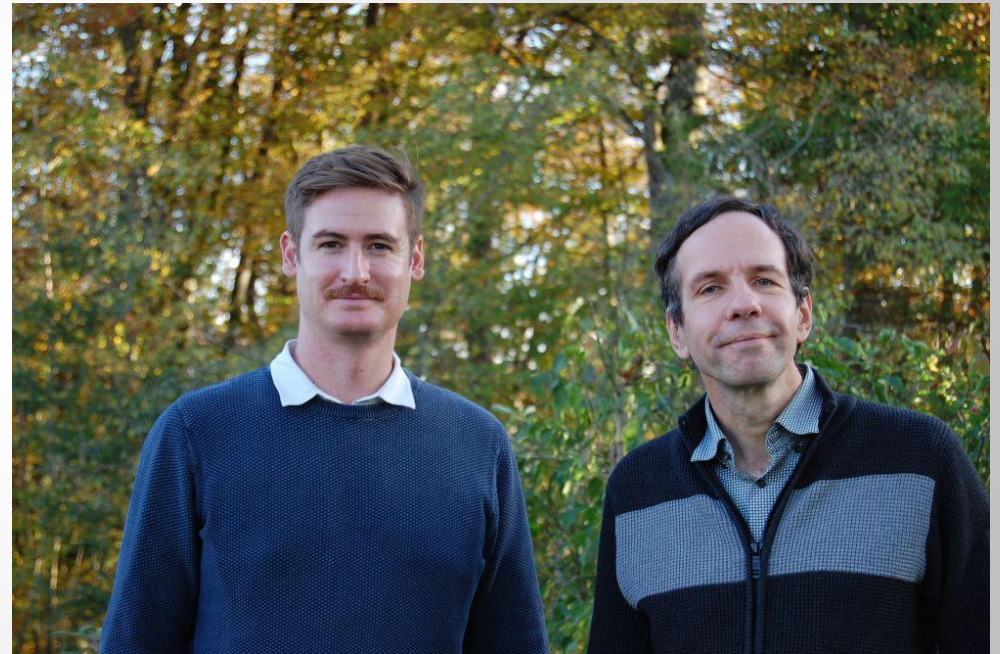
$$\Psi(r) = \exp\left(-2\frac{r^2}{w^2}\right)$$

# Technical Support

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

The price for a **commercial user license** contains **8 support hours** (non-commercial licenses: 4 hours).

The support is done by Dr. Paschotta, who is a distinguished expert in this area and has originally developed the software, and by Dr. Gareth Moore. They will make sure that you become another very satisfied user of the software!



Note that RP Photonics also offers technical consultancy.

# Can I Afford This Software?

Sure, a high-quality software product including competent support from a top expert costs some money.

Anyway, the better question is:

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

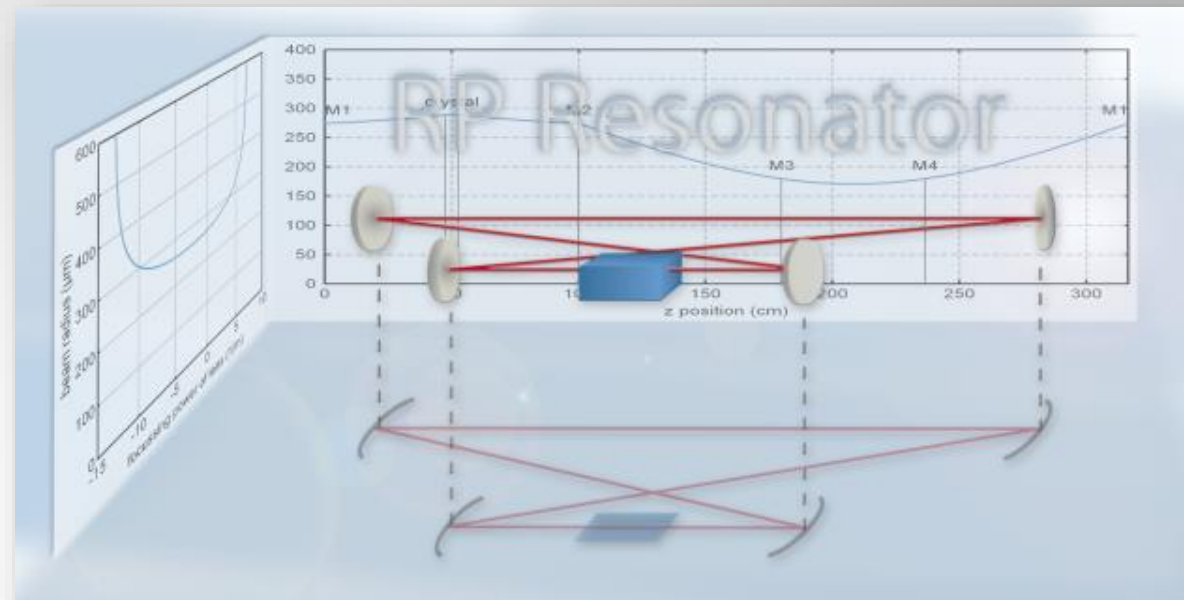
- ▶ to muddle through with insufficient tools?
- ▶ to use trial & error, wasting time and materials?
- ▶ to let customers wait while my competitors sell their products?

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 Resonator:

- ▶ design of optical resonators for lasers, OPOs, filters, etc.
- ▶ can fully parameterize the designs
- ▶ powerful script language for an enormous flexibility
- ▶ can do most sophisticated analysis and optimizations

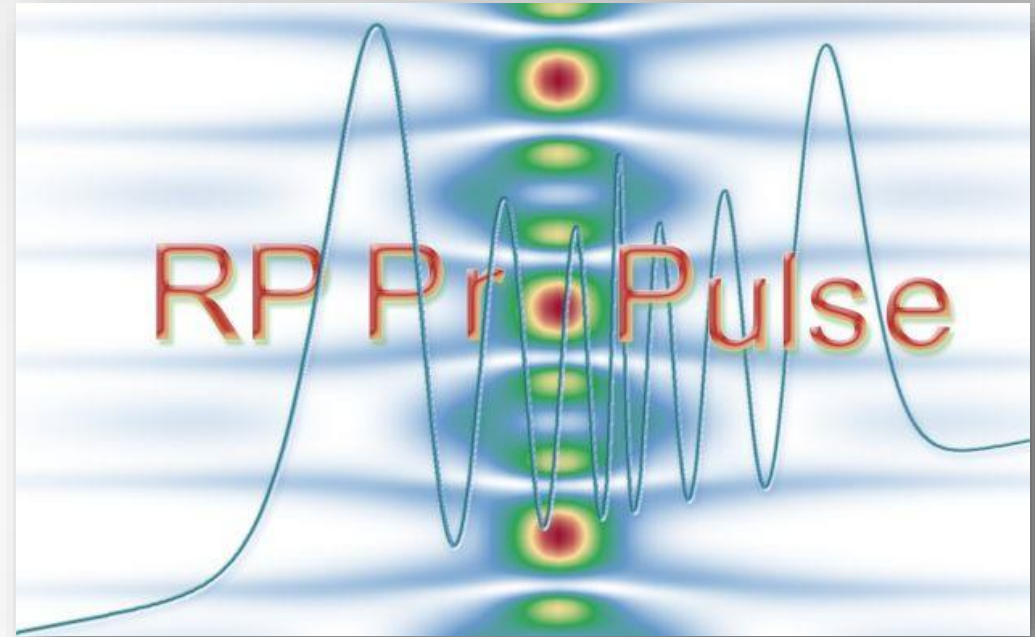


See a detailed description: [www.rp-photonics.com/rp-resonator.html](http://www.rp-photonics.com/rp-resonator.html)

# Other Software from RP Photonics

## RP ProPulse:

- ▶ simulates the propagation of ultrashort pulses e.g. in mode-locked lasers or sync-pumped OPOs
- ▶ can include laser gain, parametric gain, SHG, Kerr and Raman effect, chromatic dispersion, etc.
- ▶ pulse display window
- ▶ can do most sophisticated analysis and optimizations



See a detailed description: [www.rp-photonics.com/rp\\_propulse.html](http://www.rp-photonics.com/rp_propulse.html)



# Other Software from RP Photonics

## RP Coating:

- ▶ analysis of multilayer thin-film devices: laser mirrors, filters, anti-reflection coatings, dispersive mirrors, polarizers, SESAMs, VECSELs, ...
- ▶ can fully parameterize designs
- ▶ read / write data from or to text files or binary files with arbitrary formats:  
read transmission spectra from a spectrometer, control a coating machine, etc.
- ▶ can do most sophisticated analysis and optimizations

See a detailed description: [www.rp-photonics.com/rp\\_coating.html](http://www.rp-photonics.com/rp_coating.html)

