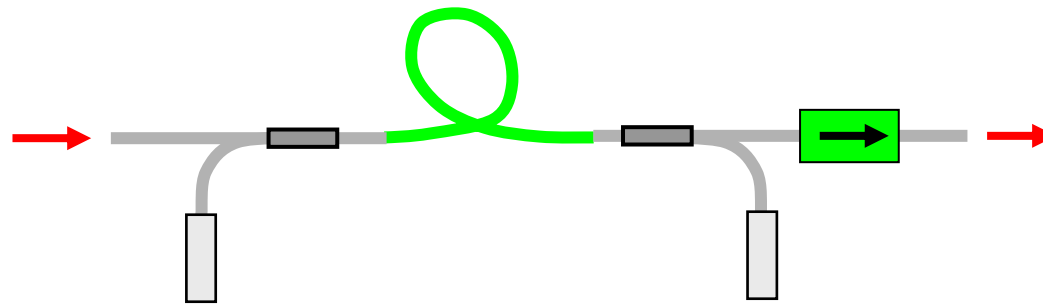


**Dr. Rüdiger Paschotta
RP Photonics Consulting GmbH**



**Competence Area:
Fiber Devices**

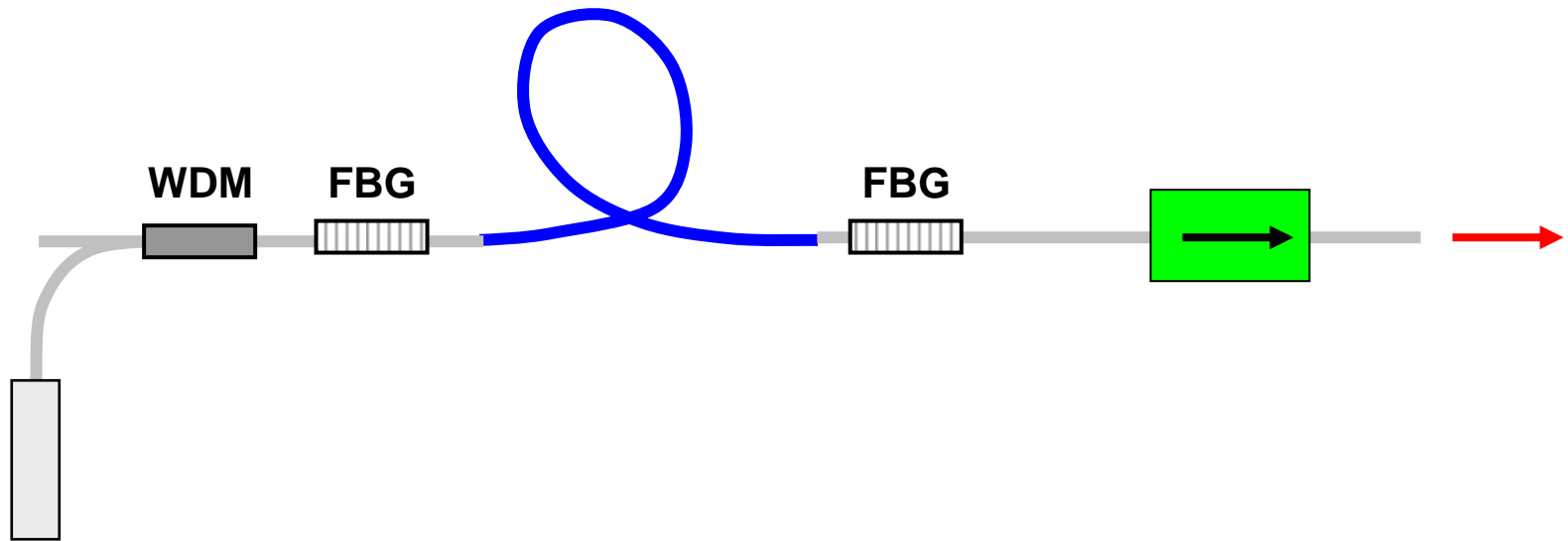
Topics in this Area

- Fiber lasers, including “exotic” types
- Fiber amplifiers, including telecom-type devices and high power devices
- Q switching of fiber lasers
- Mode locking of fiber lasers
- Pulse propagation in fibers
- Noise in fiber devices

Note: for more details (with references to publications) on the scientific achievements of R. Paschotta, see

http://www.rp-photonics.com/Science_Paschotta.ppt

Fiber Lasers



Fiber Lasers

- Fiber lasers occur in a great variety of forms, serving very different applications, e.g.:
 - Lasers generating outputs at special wavelengths, e.g. in the visible or in the infrared spectral region
(tracking lasers, displays, pumping of solid-state lasers)
 - Lasers for very high output power (many watts or even kilowatts) with good beam quality
(material processing, various industrial processes, military applications)
 - Q-switched and mode-locked lasers for short or ultrashort pulses
(distance measurements, time & frequency metrology, material processing)
- Fiber technology creates a huge amount of attractive technical options, but also comes with a bunch of technical difficulties

Fiber Lasers

Examples for previous activities of R. Paschotta:

- Developed numerical computer models for optimizing various kinds of fiber lasers, e.g. blue upconversion lasers with three-step excitation; this lead to the powerful commercial software package [RP Fiber Power](#).
- Discovered unexpected quenching effects in Yb-doped fibers
- Worked out design guidelines for various devices
- Contributions to the invention of ring-doped fiber designs
- Identification and demonstration of a strange situation where spatial hole burning serves to stabilize single-frequency operation

Fiber Lasers

Examples for possible consulting activities:

- Develop a numerical model to calculate and optimize the performance of a certain type of fiber laser
- Identify performance limitations in terms of output power, wavelength tuning range, linewidth, etc.
- Develop fiber laser designs (with optimized fiber parameters, pump source, mirror reflectivities, etc.)
- Analyse and optimize Q-switched or mode-locked fiber lasers
- Compare fiber laser technology with competing technologies

The RP Fiber Power Software

The commercially available software **RP Fiber Power** (<http://www.rp-photonics.com/fiberpower.html>), developed by Dr. Paschotta, has the following key features:

- The integrated mode solver can calculate all guides modes of a fiber from a given refractive index profile. One obtains intensity profiles, propagation constants, group velocities and chromatic dispersion, fraction of power propagating within the fiber core, etc.
- One can also numerically simulate beam propagation in fiber devices – not only in simple fibers, but also in multi-core fibers, fiber couplers, etc. A lot of example cases on our website demonstrate the great versatility of the software.

The RP Fiber Power Software

- The software can calculate the distribution of optical powers and excitation densities in fiber lasers, amplifiers and ASE sources, taking into account
 - longitudinal and transverse spatial dependencies
 - arbitrarily complicated level schemes
 - influences from spontaneous and stimulated transitions, ASE, excited-state absorption, energy transfers leading to upconversion, etc.
- Besides calculating steady-state powers, the software can do dynamic simulations, e.g. for Q switching and pulse amplification.
- Ultrashort pulse propagation (for example, in pulse amplifiers and in mode-locked fiber lasers) can also be simulated.

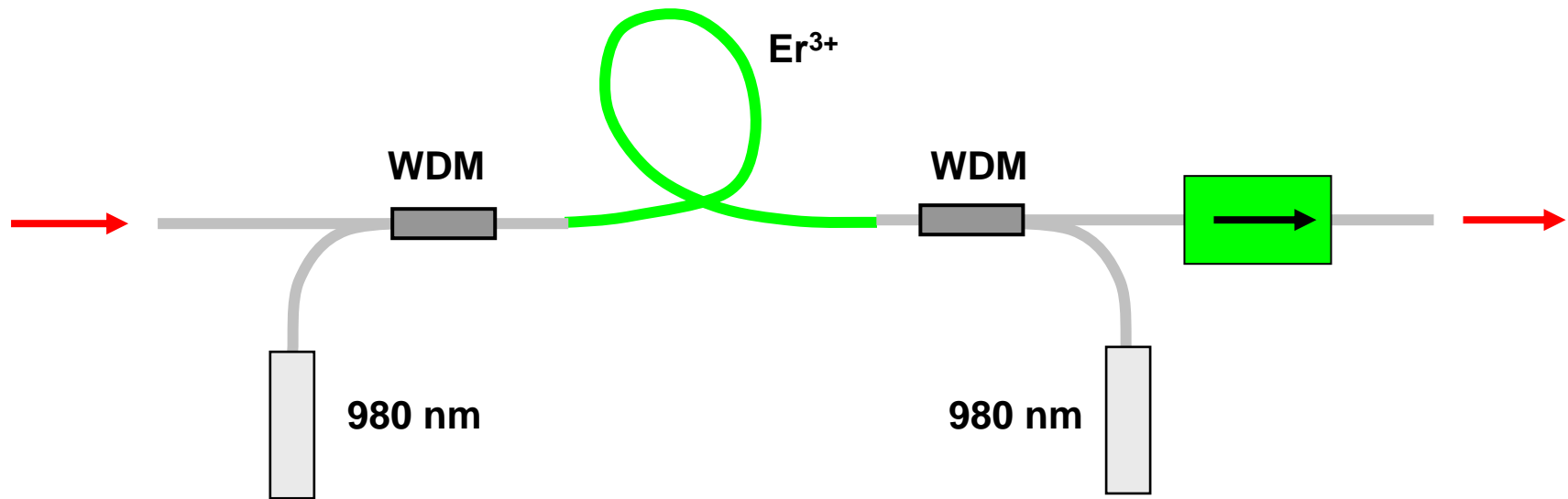
The RP Fiber Power Software

- The software has an extremely flexible user interface, with control via simple forms and/or via a powerful script language.

Careful documentation and helpful support is also available.

For a comprehensive description of **RP Fiber Power**, see the page <http://www.rp-photonics.com/fiberpower.html>, and download our brochure http://www.rp-photonics.com/RP_Fiber_Power.pdf.

Fiber Amplifiers



Fiber Amplifiers

- Fiber amplifiers are used for very different applications, e.g.:
 - Data transmission
(compensating losses in telecom fibers, providing power for nonlinear data processing devices, etc.)
 - Generation of high output powers
(continuous-wave or pulse amplification for material processing, driving nonlinear devices, etc.)
 - Generation of optical noise
(microscopy, device characterization)
- Fiber technology offers large gain and broad amplification bandwidth, but also comes with a bunch of technical difficulties

Fiber Amplifiers

Examples for previous activities of R. Paschotta:

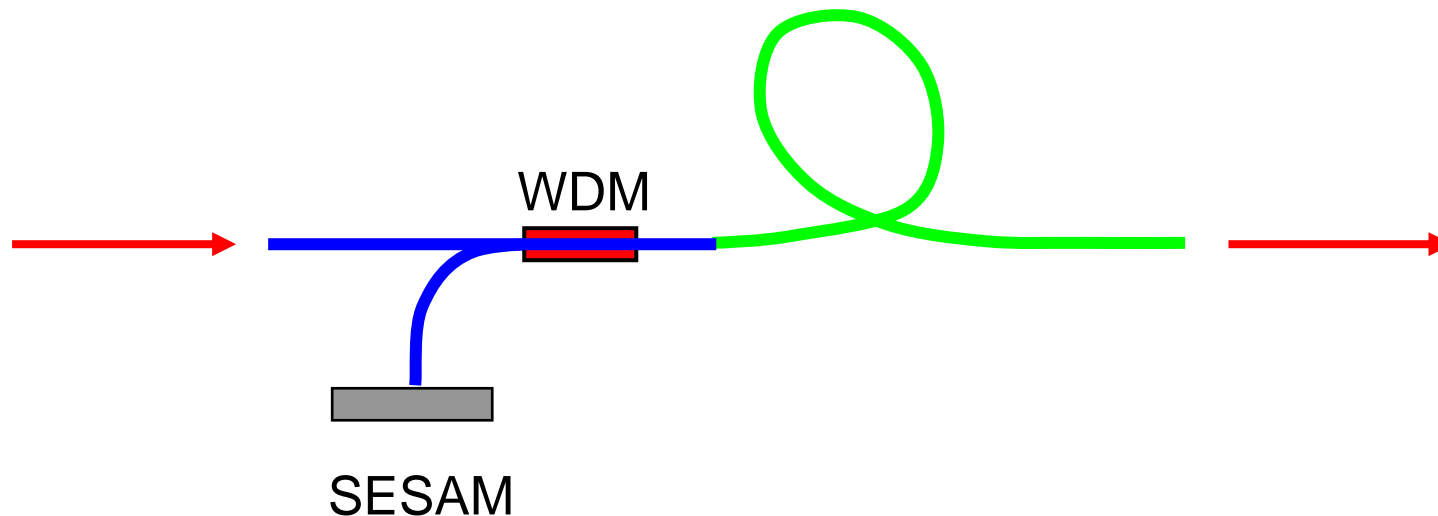
- Developed numerical computer models for various kinds of fiber amplifiers, e.g. with Yb- or Er-doped fibers; this expertise was used for the software **RP Fiber Power**.
- Worked out design guidelines for various devices
- Contributions to the invention of ring-doped fiber designs
- Demonstration of high-performance superfluorescence source

Fiber Amplifiers

Examples for possible consulting activities:

- Develop a numerical model to calculate and optimize the performance of a certain type of fiber amplifier
- Identify performance limitations in terms of output power, nonlinear distortions, etc.
- Develop fiber amplifier designs (with optimized fiber parameters, pump source, etc.)
- Analyze and optimize noise properties (noise figure, nonlinear distortions)

Q Switching and Mode Locking of Fiber Lasers



Q Switching and Mode Locking

- Fiber lasers can be used for pulse generation:
 - Q switching for generation of nanosecond pulses
(distance measurements, material processing)
 - Mode locking for generation of picosecond or femtosecond pulses
(time & frequency metrology, material processing, OPO pumping)
- Fiber technology competes with other technologies,
with commercial chances depending on the concrete demands

Q Switching and Mode Locking

Examples for previous activities of R. Paschotta:

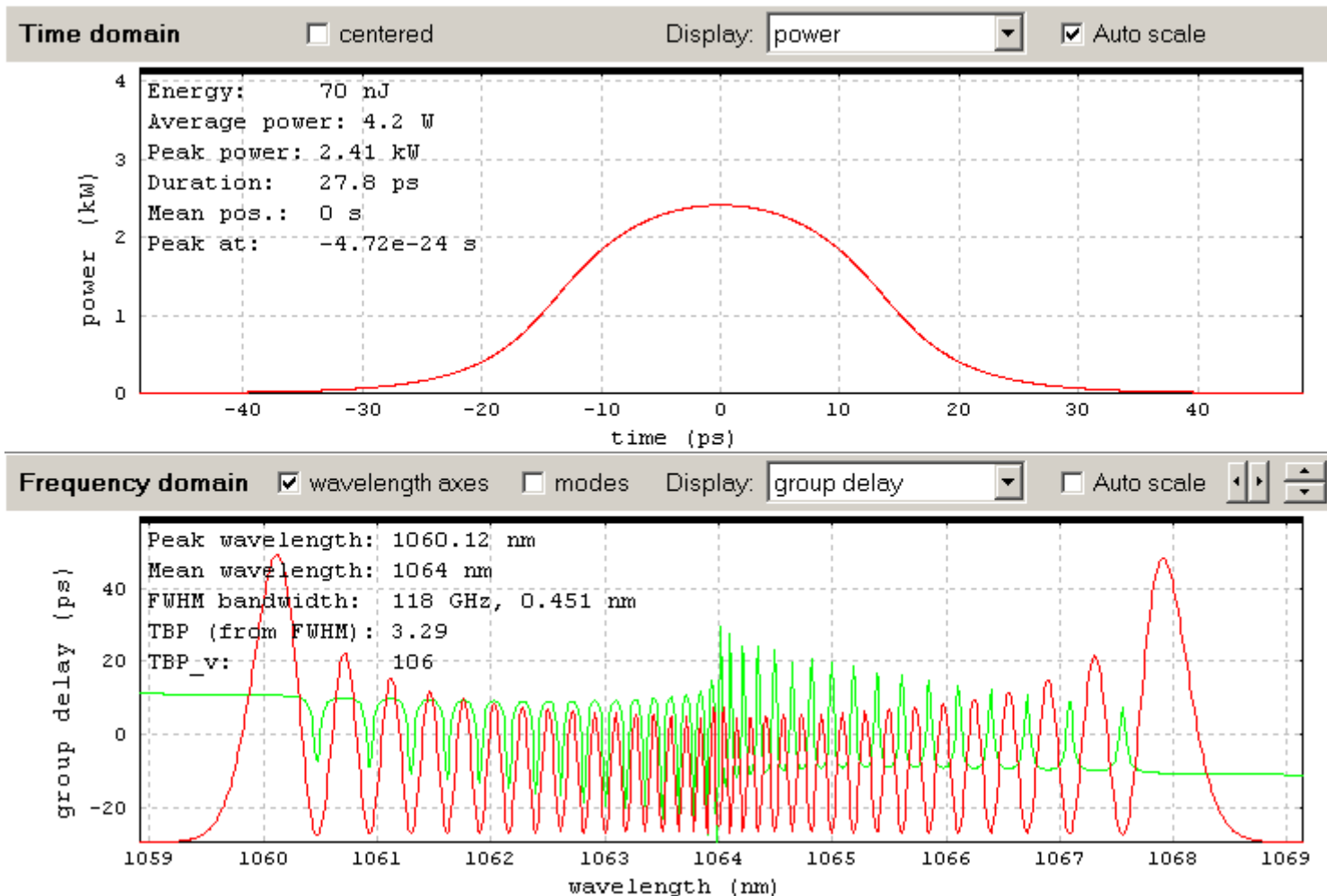
- Developed numerical computer models for pulse generation and amplification in fibers
- Demonstrated very high pulse energies at 1.5 μm with passive Q switching
- Worked out design guidelines for various devices
- Various contributions to mode-locked fiber lasers

Q Switching and Mode Locking

Examples for possible consulting activities:

- Develop a numerical model to calculate and optimize the performance of a Q-switched or mode-locked fiber laser
- Identify performance limitations in terms of output power, wavelength tuning range, linewidth, etc.; optimized device designs
- Compare fiber laser technology with competing technologies
(Note: deep and broad experience with various kinds of Q-switched and mode-locked lasers, including bulk lasers and semiconductor lasers)

Pulse Propagation in Fibers



Pulse Propagation in Fibers

- Fibers can be used transport optical pulses or to manipulate their properties, e.g.
 - to broaden their spectrum, e.g. for subsequent pulse compression
 - to stretch or compress them temporally
 - to generate a “chirp”
 - to amplify them with laser gain or Raman gain
 - to shift their center wavelength
- Apart from dispersion effects, a variety of nonlinearities can influence the pulse propagation

Pulse Propagation in Fibers

Examples for previous activities of R. Paschotta:

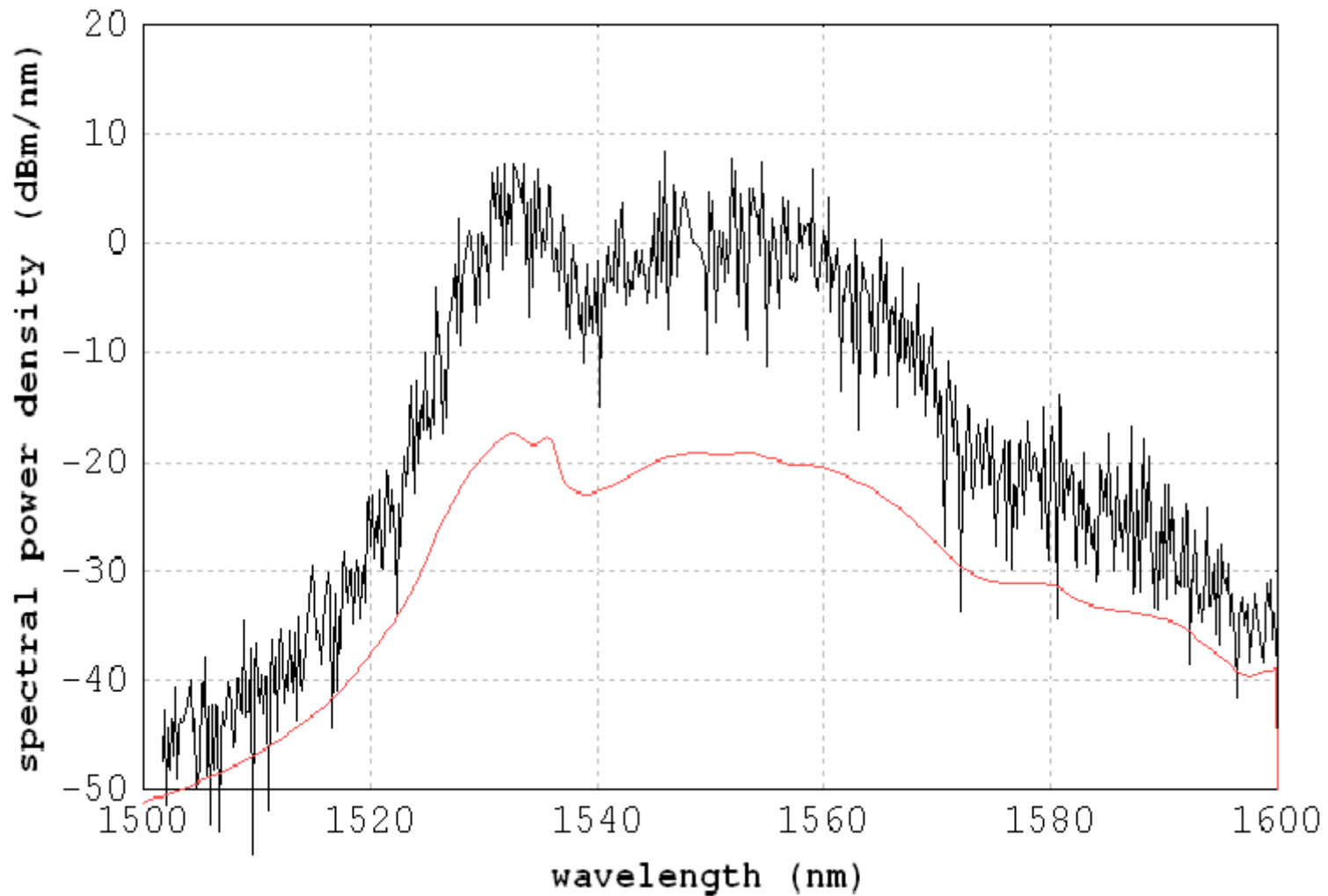
- Developed numerical computer models for pulse propagation in fibers, e.g. within fiber lasers or amplifiers, for pulse compressors, or for supercontinuum generation
→ **RP Fiber Power** software:
see <http://www.rp-photonics.com/fiberpower.html>
- Studied a wide range of fiber nonlinearities, including Kerr effect with self-steepening, Raman effect, Brillouin scattering
- Studied in detail soliton propagation effects
- Designed mode-locked fiber lasers

Pulse Propagation in Fibers

Examples for possible consulting activities:

- Use a numerical model to simulate the propagation of pulses in a laser, amplifier or compressor
- Identify performance limitations of fiber devices
- Optimize device designs, or identify problems with existing designs
- Compare fiber laser technology with competing technologies
(Example: compare picosecond or femtosecond fiber amplifiers with bulk amplifiers)

Noise in Fiber Devices



Noise in Fiber Devices

- Optical noise can arise in fiber devices through various effects, e.g.
 - as amplified spontaneous emission (ASE)
 - from quantum noise or input noise, amplified through nonlinear effects (e.g. modulational instability)
 - quantum effects related to nonlinearities (e.g. Raman interaction)
- Noise often limits the performance of fiber devices; its exact physical and quantitative understanding can be crucial for optimization of devices.

Noise in Fiber Devices

Examples for previous activities of R. Paschotta:

- Developed a numerical computer model for supercontinuum generation in microstructured fibers, and used it to quantitatively study the noise properties of the output (→ spectral coherence)
- Developed fiber amplifier models with amplified spontaneous emission (ASE)

Noise in Fiber Devices

Examples for possible consulting activities:

- Quantify noise effects in a fiber device, using analytical and/or numerical techniques
- Identify performance limitations
- Compare fiber laser technology with competing technologies
(Example: compare timing jitter potential of fiber lasers and other lasers)

Publications on Fiber Technology

Books:

- R. Paschotta, “Field Guide to Optical Fiber Technology”, SPIE Press, Bellingham (WA) (2010)
- R. Paschotta, “Encyclopedia of Laser Physics and Technology”, Wiley-VCH, Weinheim, Germany (2008)
- Various scientific articles:
see the [CV and publication list of Dr. Paschotta](#)