License agreement and manual[1]

fiberdesk™

last update 17.2.2025

[1] some functions might be restricted to higher versions, appearance of graphics user interface depends on actual fiberdesk version and operating system

Contents

1. General

1.1 System requirements

1.1.1. Software requirements

fiberdesk works stable on the following operating systems:

Microsoft® Windows® 7 / 8 / 8.1 / 10 / 11

In addition, because fiberdesk uses the Thales Sentinel USB Protection System, its drivers for the usage of the USB hardware lock are also required for dongles purchased before 2019. Later ones are driverless, the driver is included in the Windows system.

1.1.2. Hardware requirements

Required processor: Intel Pentium or compatible

Required/Recommended RAM: 1 GB or more

1.2 Software license

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Official web-site: www.fiberdesk.com

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9. Referencing Fiberdesk

If a scientific citation of fiberdesk is possible use a phrase similar to the following:

[X] simulations done using fiberdesk, www.fiberdesk.com

More specifically, if the predefined dispersion values are used for any kind of publication, please contact the author (webmaster@fiberdesk.com) for information on copyright and citation.

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2. Software Interface: Overview

The general graphical layout of **fiberdesk** is shown inFig. 2.1.

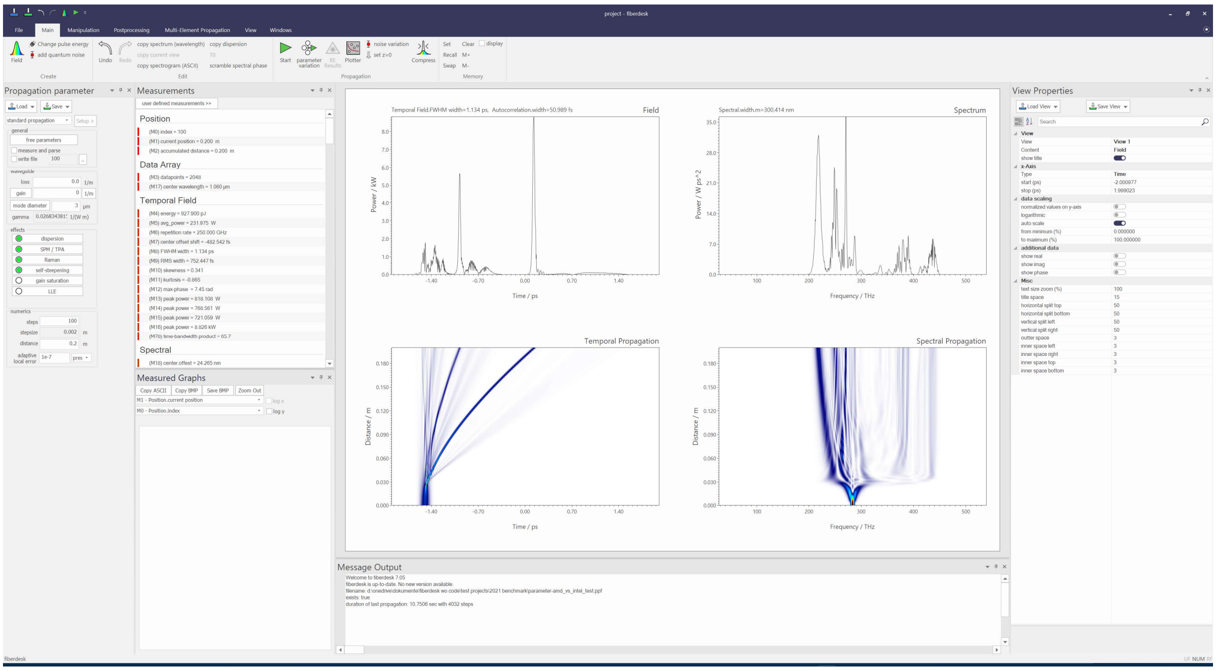


Fig. 2.1: Graphical User Interface (GUI).

fiberdesk uses a ribbon menu (**Fehler! Verweisquelle konnte nicht gefunden werden.**) with advanced features and easier access to the command structure. It is explained in section 3.1.

Beside the main view, additionally information and parameter setups are displayed in four attachable windows (dockable panes). These four windows are:

- the propagation parameter pane
- the measured value pane
- the output pane
- graph pane

More details can be found in section 3.2.

2.1 File Menu

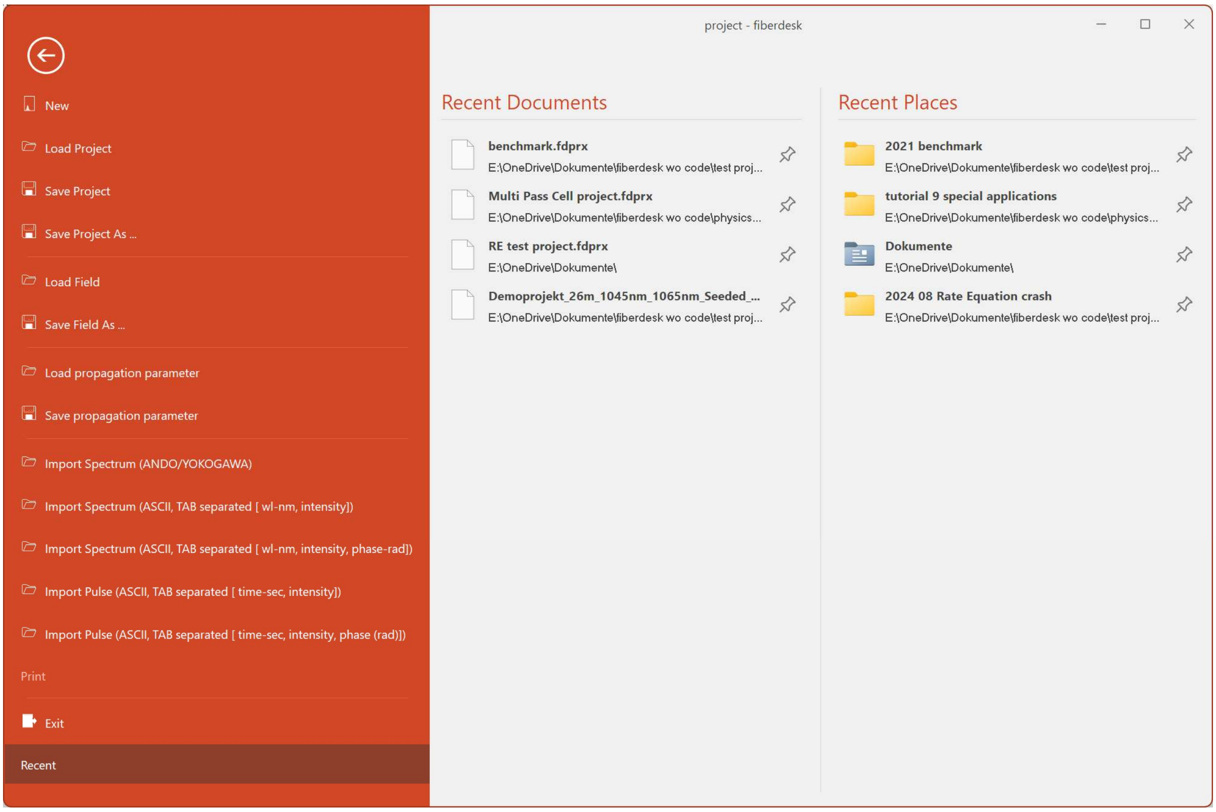


Fig. 2.2: The file menu.

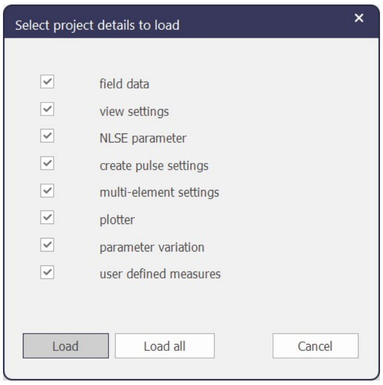
The file menu (Fig. 2.2) includes all command to control data connected to a file.

New

Creates a new project and sets most controls to standard values.

Load Project

Opens an existing project that has been saved. When attempting to open a project file, the following dialog box will appear:



The *file* includes the *data array* that samples the electric field, as well as the element container (see File Description), propagation parameter, view definitions, and dialog parameters. You can choose which parameters to reload, allowing you to retain certain parameters that you have already set or need to reuse. This provides you with control over maintaining specific settings.

Save / Save As ...

Saves the current project with all settings.

Load propagation parameters ...

Loads the propagation parameters from a specific file.

Export propagation parameters ...

Saves the propagation parameters to a specific file.

Import spectrum (ANDO)

Imports an ANDO spectrum file and sets the phase to zero.

Important for ASCII/ANDO imports: The actual data array dimensions are kept constant, thus, be sure to provide enough datapoints and the right spectral range for the given file. This means, first “create a pulse” with the right bandwidth and central wavelength.

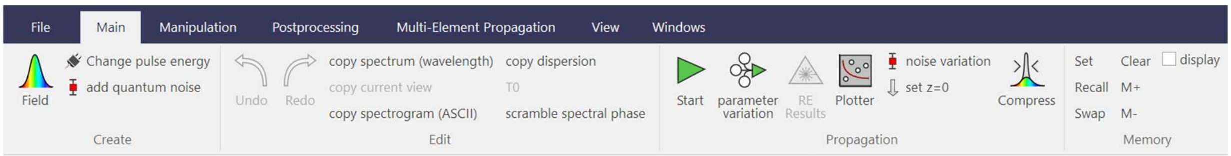
Close

Closes the current document file.

Exit

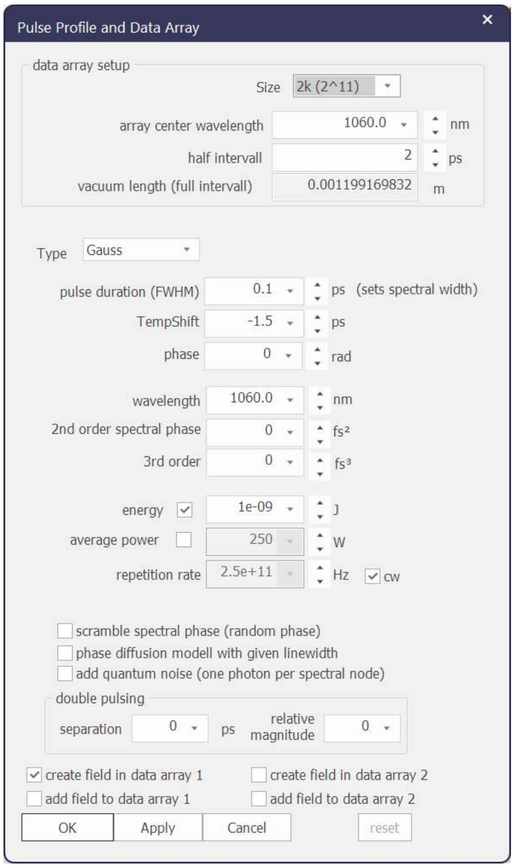
Quit fiberdesk.

2.2 Main



2.2.1. Create

Field



This calls the main dialog for setting up a simple pulse and the corresponding temporal and spectral parameters for the simulations.

Size (DP)

number of data points of the field

Type

shape of the temporal pulse intensity (Gauss, sech^2, Parabolic, Rect) Additionally, one can select a specific spectral shape

from file .. select a specific field file that has been saved before (menu File>Save Field) in the *.fieldx format.

Half interval (HI)

Half of the temporal width of the complete field. The dwell time is therefore given by t_{DW} = 2 * HI / DP. Of course, this sets the spectral width and resolution due to Fourier theorem.

Pulse duration (FWHM)

full width at half maximum of the pulse width

TempShift

offset of the position of the pulse center τ

Double pulse separation τ_{dp}

- Relative magnitude R

- Center wavelength: central wavelength of the pulse spectrum

- Chirp: linear spectral chirp in fs^2 with its definition:

$$A(T) = \ldots e^{-i\frac{C}{2}(\omega-\omega_0)^2 - i\frac{C_3}{6}(\omega-\omega_0)^6}$$

The double-pulse separation, temporal shift and relative magnitude is calculated from the complex single-pulse field amplitude A(T) by

$$A_{new}(T) = \frac{(1-R)A(T-\tau_{dp}+\tau)+(1+R)A(T+\tau_{dp}+\tau)}{2}$$

Scramble spectral phase (random phase)

It sets a random (uniform distribution) phase in the spectral domain, thus, the spectral lineshape is maintained, but the temporal domain does not contain pulse information anymore.

Phase diffusion modell with given linewidth

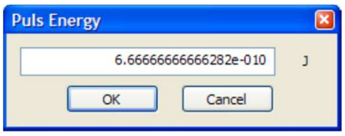
It randomizes the spectral phase according to Ref. 11.

Add Quantum Noise (one photon per spectral node)

Adds the energy of one photon in the spectral domain with random phase. Thus, energy might not be conserved due to the complex addition of the values.

Change pulse energy

Changes the pulse energy of the current pulse.



Add quantum noise

Adds one photon per spectral mode with random phase.

Use second field

Enables or disables the second data array for a second field that can be coupled through the NLSE by XPM or birefringence.

Please ask webmaster@fiberdesk.com for details, currently not contained in commercial versions.

2.2.2. Edit

Undo

Undo last change in the dataarray. The selected area is set to the full size of the dataarray.

Redo

Restore last undo step.

Copy spectrum (wavelength axis)

Copy spectrum to clipboard as ASCII. The wavelength axis is obtained by linear interpolation from the frequency axis.

Copy current view

Copy current view to clipboard as enhanced metafile (EMF).

Copy spectrogram as ASCII matrix

If spectrogram view is active, copy all values to clipboard as ASCII matrix.

2.2.3. Propagation

Start

Start the propagation using the current settings.

Parameter variation

Vary one or two parameters of a propagation using the dialog in Fig. 2.3.

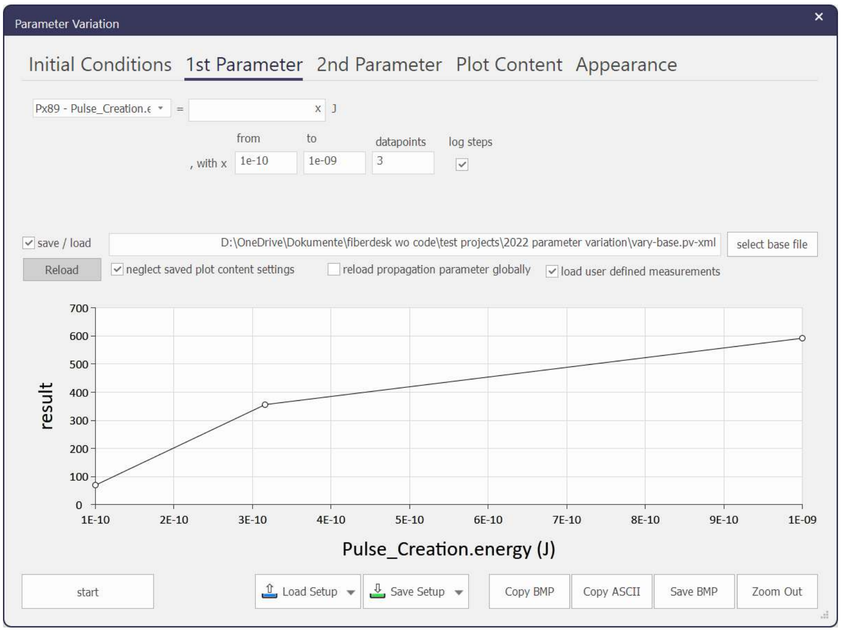


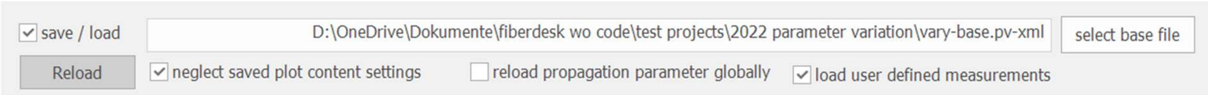
Fig. 2.3: Parameter Variation Dialog.

Depending on the parameter to vary, the field is create with the new parameter and propagated using the parameters set up so far. All measurements are done after propagation so that the results can be displayed without a new calculation.

The parameters are varied linearly or with equal logarithmic setup, if “log steps” is chosen.

A second parameter can be varied if selected.

The resulting fields of the parameter variation propagation can be saved or reloaded by choosing a base file:



The following files are saved for example:

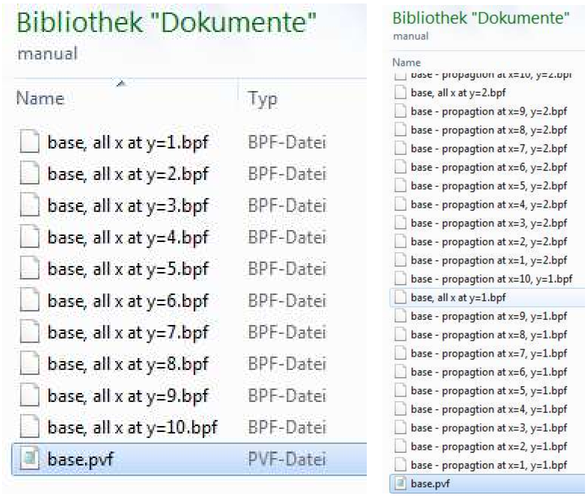


Fig. 2.4: File structure in the parameter variation dialog (left) without and (right) with individual propagation saved.

Each individual propagation can also be saved by combining the "save to file" option with the "write file" option in the general setup for the propagation parameter outside this dialog.

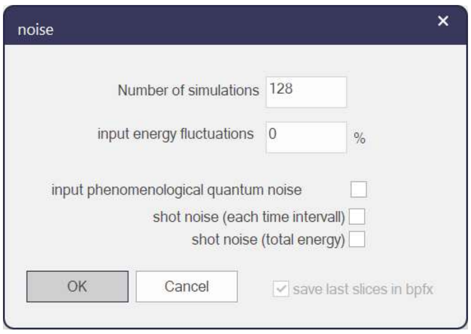
Set z=0

Set propagation position to zero.

include noise (deprecated, you should use the parameter variation tool)

Starts a propagation multiple times by adding specific noise sources on the initial pulse. The number of propagation is given by "Number of simulations".

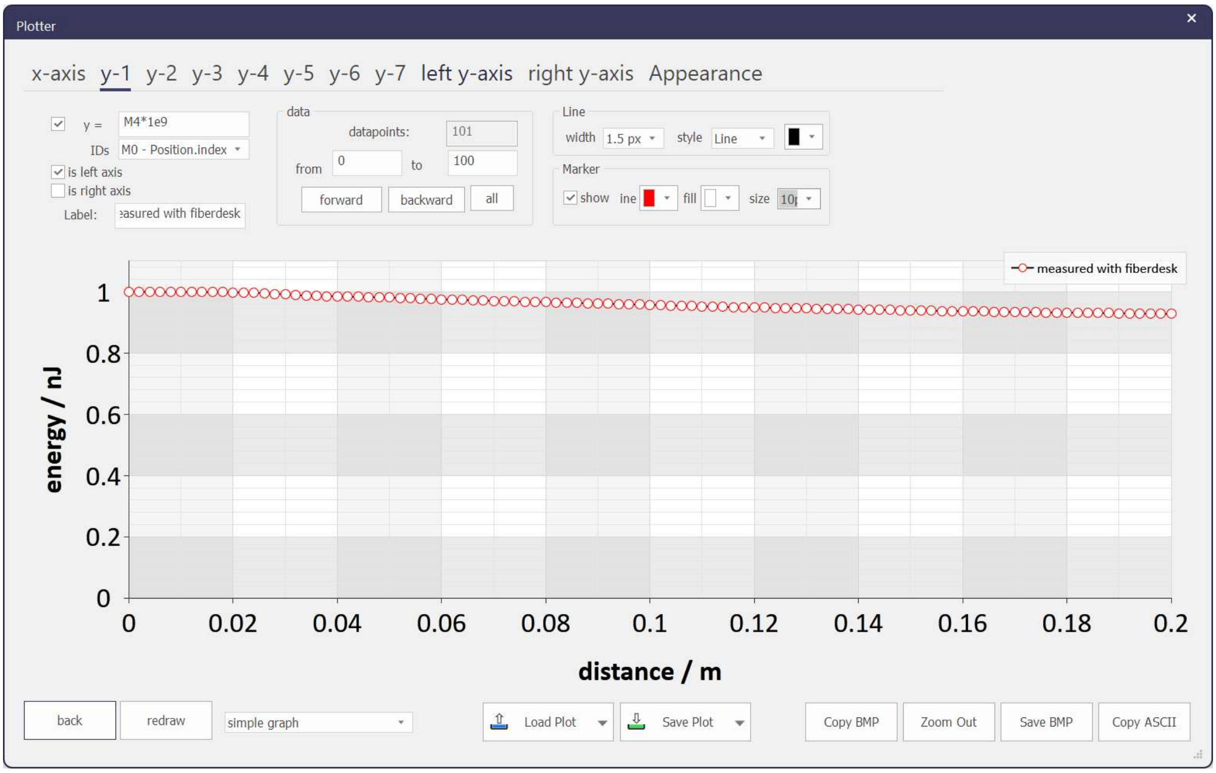
- input phenomenological quantum noise: one photon with random phase is added per frequency intervall
- shot noise (each time intervall): Poisson noise on each temporal datapoint
- shot noise overall energy: poisson noise variation of the pulse energy



If the option “save last slice in bpf” is chosen, the result of each propagation is saved in a file for further processing and analysis, see menu “postprocessing”. In combination with the usual “write file” option, each full propagation is saved in a file array.

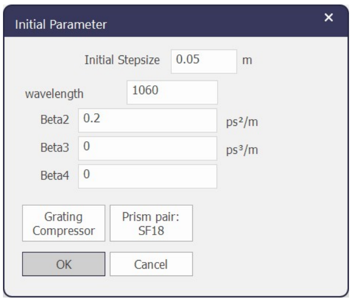
Plotter

The plotter allows to plot the measurement results in a more customized way. The x and y axis can be scripted and the design in detail configured.

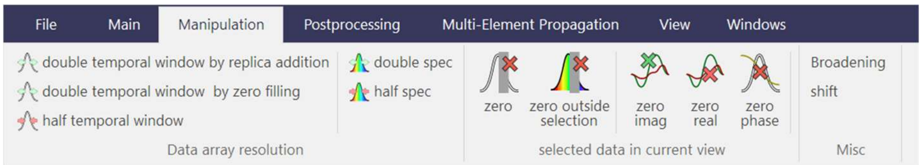


Compress

Minimizes the autocorrelation FWHM by a linear propagation (dispersion only) using the dispersion values given in the dialog.



2.3 Manipulation



2.3.1. Data array resolution

double temporal window by replica addition

Doubles the number of points by increasing the temporal range and copies the field to that areas. Resets the selection as well.

double temporal window by zero filling

Doubles the number of points by increasing the temporal range and set the new datapoints to zero. Resets the selection as well.

Half temporal window

Halfs the temporal windows symmetrically.

Doubles the number of points by increasing the spectral range. Resets the selection as well.

Double / half spec

Doubles / Halfs the number of points by decreasing the spectral range. Resets the selection as well.

2.3.2. selected data in current view

Zero

Set field to zero for all data points inside the selection.

Zero outside selection

Set field to zero for all data points outside the selection.

Zero phase / real / imag

Set values to zero in the whole selection.

Panel: Misc

exchange fields

If two fields are used, its content is exchanged.

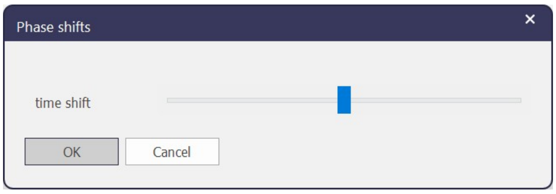
merge fields

If two fields are used, its content is merged in the first field.

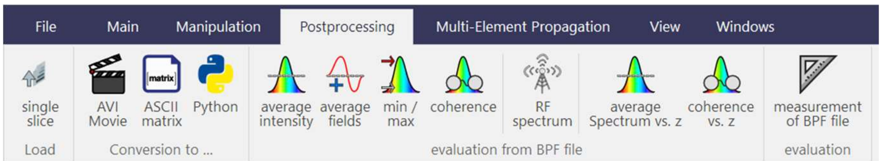
2.3.3. Misc

shift

Allows to shift the field in time.



2.4 Postprocessing



2.4.1. Panel: Load

single slice

Reload a previously saved slice from a beam propagation file. Choose the slice number by using the following slider control or manually type the requested slice:

During this slice selection, every view control (e.g. data selection and zoom) can be used. Use this function in prior to following visual post-procession tools (e.g. movie creation) or to check the slice from a long term propagation.

Reload propagation to recreate 2D propagation views.

Panel: Conversion to ...

AVI movie

The movie is created by using the current view. The following steps have to be done:

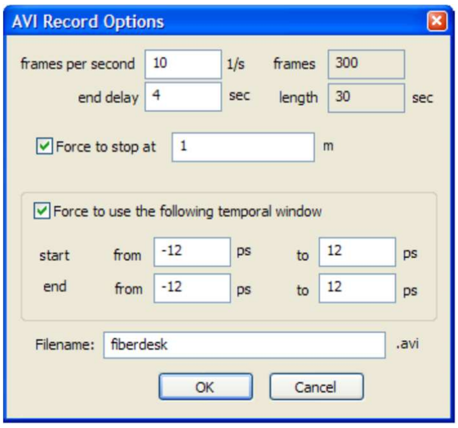
Select a previously saved propagation file.

Using the AVI creation dialog, one can specify the number of frames per second and an end delay, which shows the last frame for that time.

If the propagation is longer than required for the AVI use the option “force to stop at”.

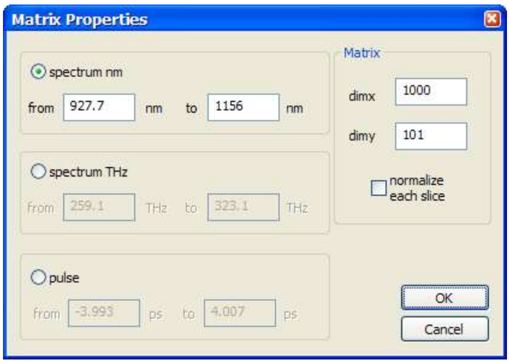
If a specific temporal window is given, the current selection is overwritten and the values of the dialog are used. This can be used to create an artificial co-moving time frame.

Choose a name for the AVI file, and then press OK to accept the settings. After the first screen is saved to the AVI file, select a compression scheme. The recommended scheme is “MS Video 1”.



ASCII matrix

Chose a previously saved propagation file. An ASCII copy of the temporal or spectral evolution is copied to the clipboard for further processing in other softwares, e.g. ORIGIN™. In the corresponding dialog, please chose the content, which is to copy and the dimensions of the ASCII matrix. Choose “normalize each slice” to do so.



2.4.2. Panel: Noise evaluation

mean and variance

Especially, if the propagation file contains data from the noise variation simulation, this function helps you to calculate the mean (average value) and the variance of the data. Decide if the spectrum or temporal field should be used for the evaluation. The result is copied to the clipboard in a three-column ASCII format.

min/max

The minimum and maximum values in the spectral or temporal domain are calculated from a previously saved propagation file. The result is copied to the clipboard in an ASCII format.

coherence

Calculates the coherence (see [4]) from a single propagation file according to the following equation: $|g_{12}(\lambda)| = \left| \frac{\langle E_1^*(\lambda) E_2(\lambda) \rangle}{\sqrt{\langle |E_1(\lambda)|^2 \rangle \langle |E_2(\lambda)|^2 \rangle}} \right|$

RF spectrum

Calculates the radio frequency spectrum of a series of pulses S_i by taking the Fourier transform of the array $|S_i|^2$. The temporal spacing t_{i+1}-t_i is given by the current repetition rate setting f_R, thus, the radio frequency range is $-f_R/2 \ldots f_R/2$. The result is copied to the clipboard in ASCII format.

<RIN> vs. z

Calculates the average relative intensity noise (RIN) along a previously saved propagation distance. A number of propagation files are required for this function. Each propagation file contains a single propagation. The propagations just differ in their noise properties.

<Spectrum> vs. z

Calculates the average spectrum along a previously saved propagation distance. A number of propagation files are required for this function. Each propagation file contains a single propagation. The propagations just differ in their noise properties.

coherence vs. z

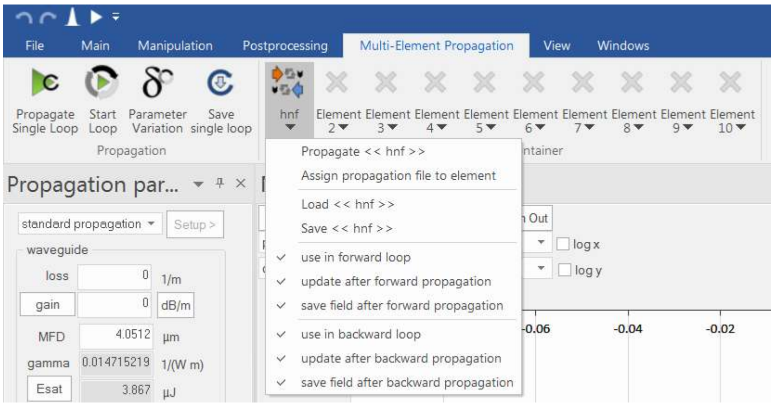
Calculates the coherence along a previously saved propagation distance. A number of propagation files are required for this function. Each propagation file contains a single propagation. The propagations just differ in their noise properties.

Panel: Misc

Measurement of BPF file

This function measures all values along a previously calculated and saved propagation file (*.bpf).

2.5 Multi-Element Propagation



Within this category previously saved propagation files can be assigned to a button (in the Element Container) for fast (or often required) propagations. Additionally, all propagation files can be used in a loop in “forward” and “forward and backward” direction. One can also directly load and save the assigned propagation parameter file. Use this panel for e.g. simulating short pulse resonators.

The buttons icon is changed to represent the possible usage:

Upper row:

- forward propagation,
- update after forward propagation
- save field after forward propagation

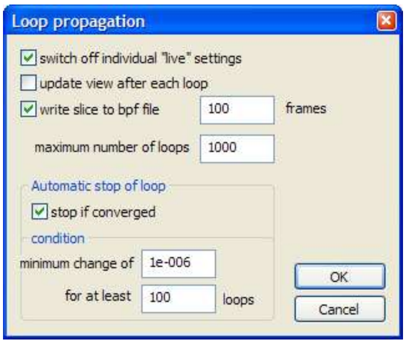
Lower row:

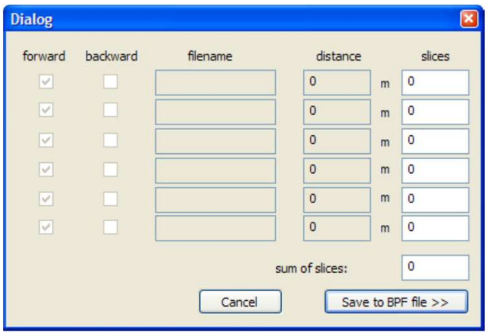
- backward propagation,
- update after backward propagation
- save field after backward propagation

2.5.1. Panel: Propagation

Start Loop

Executes the loop propagation, type the number of loops and start by pressing “OK”. The options “write to a propagation file” and “measure values” are switched off during a loop propagation. After each round trip the field can be saved to a *.bpf file with the option “write slice to bpf file”.

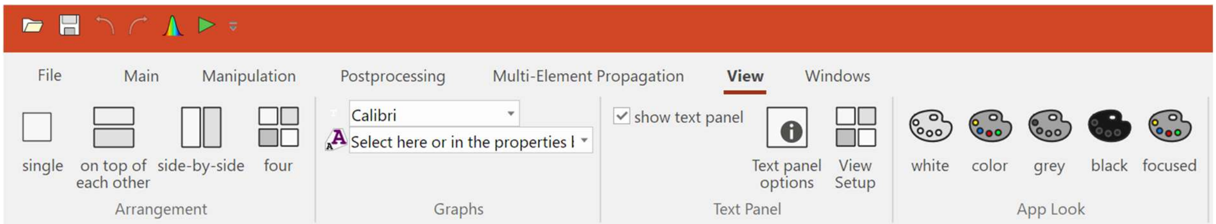




save single loop

The propagation within one roundtrip can be saved to a file by using this panel entry. The corresponding dialog resembles the loop structure and one has to specify the slices belonging to each segment.

2.6 View



This manages the configuration and presentation of the view.

However, the main setup is done using tha attached window “View Properties” described in the next section.

2.6.1. Panel: Arrangement

Select between one and four views simultaneous on the screen as indicated by the icons.

2.6.2. Panel: Font

You can choose to display different main fonts and its relative size.

Panel: Text

Select “Text Panel” to show a summary of the main variables, like distance and energy.

Text Panel options

Select the information that should be shown in the “Text Panel”.

View Setup

Set up the measured variables for each view and other details.

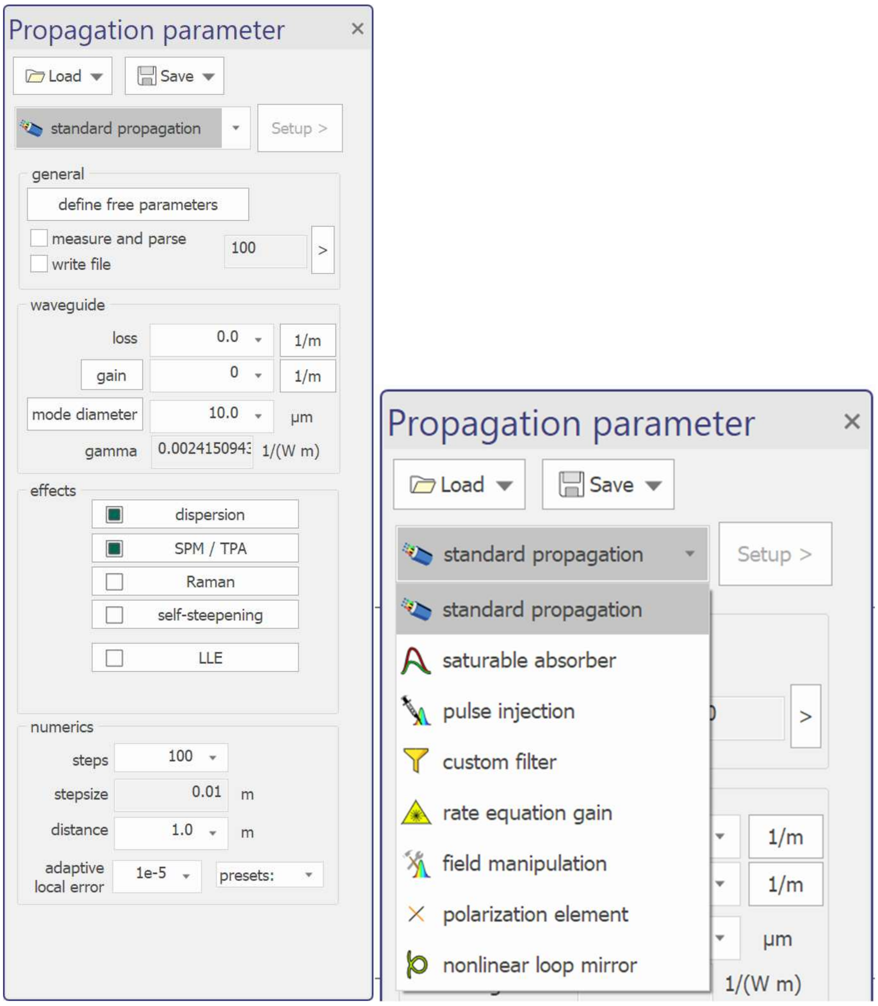
2.7 Attached Windows

Each docking control bars can be switched on or off using the windows category. They are described in the following:

2.7.1. Propagation parameter

The propagation parameter window shows most parameters required to setup your simulation and are related to the equations that are numerically solved.

There are six different propagation methods available: "standard fiber", "saturable absorber", "pulse injection", "custom filter", "rate equation gain", "polarization manipulation" and "nonlinear loop mirror". They can be chosen within the propagation parameter window, see next figure.



Standard Propagation

This propagation is based on solving the nonlinear Schrödinger equation. If all effects are considered, it has the following form:

$$\frac{\partial A}{\partial z} = -\frac{\alpha}{2}A + \int_{-\infty}^{\infty}\frac{g(\omega)}{2}\tilde{A}(\omega)e^{-i\omega T}d\omega + \sum_{n\geq 1}\beta_n\frac{i^{n+1}}{n!}\frac{\partial^n}{\partial T^n}A + i\gamma\cdot\left(1+i\tau_{shock}\frac{\partial}{\partial T}\right)\left(A(T)\int_{-\infty}^{\infty}R(\tau)\left|A(T-\tau)\right|^2 d\tau\right) \qquad 2.1$$

The normalized functional form R(t) includes the vibrational contribution of the delayed Raman responds to a fraction of f_R and the instantaneous electronical contribution to a fraction of (1-f_R).

$$R(t) = (1 - f_R)\delta(t) + f_R h_R(t)$$

The shock term is described by a single time scale τ_{shock}, which is defined as [6]:

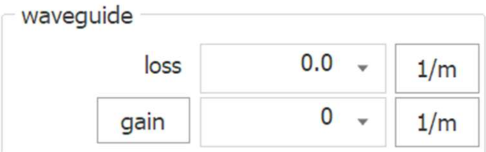
$$\tau_{shock} \cong \tau_0 + \tau_A = \frac{1}{\omega_0} - \left[\frac{1}{n_{eff}}\frac{dn_{eff}(\omega)}{d\omega}\right]_{\omega_0} - \left[\frac{1}{A_{eff}}\frac{dA_{eff}(\omega)}{d\omega}\right]_{\omega_0}$$

The parameter τ_A can be changed in the "self-steepening" dialog, see below.

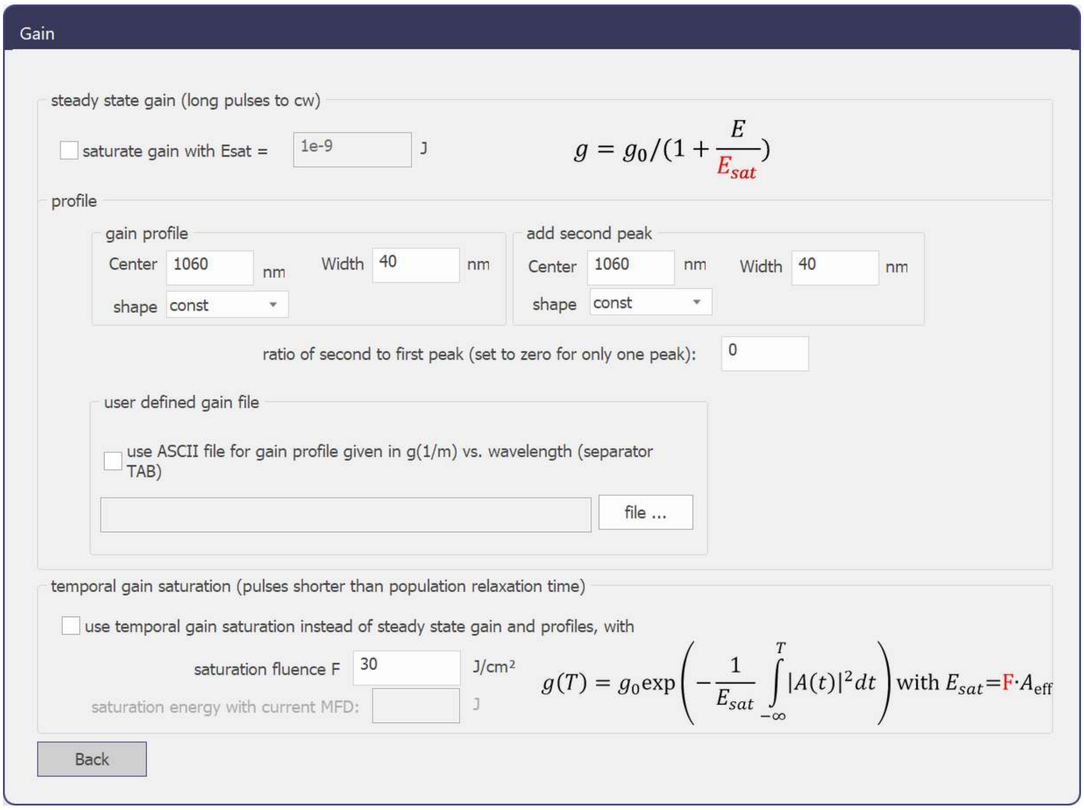
To change the parameters in this equation, the propagation parameter window is usually used.

There you can directly edit the following parameters as they appear directly or indirectly:

linear loss / gain



- in [1/m] or [dB/m], Click on the unit to change it.
- Click the button [gain] to choose:



gain profile: The gain profile can also be an addition of two different profiles.

The profiles have the following analytical forms, which are normalized and multiplied by the gain value. The parameters are converted to frequency domain for the calculation (center wavelength~ ν_c, width~$\Delta\nu$).

Lorentz	$\frac{1}{\pi}\frac{\Delta\nu}{\Delta\nu^2+(\nu-\nu_C)}$
Parabolic	Positive values of $1-2\left(\frac{\nu-\nu_C}{\Delta\nu}\right)^2$
N-th order Gauss (supergauss2: N=2 …)	$4\cdot\ln(2)\left(\frac{(\nu-\nu_C)^2}{\Delta\nu^2}\right)^N$
Asymmetric sech (reverse frequency axis for Asymmetric Lorentz)	$\nu<\nu_c$: $\cosh\left(\frac{\nu-\nu_c}{0.45\cdot\Delta\nu/2.041475}\right)^{-1}$ $\nu>\nu_c$: $\left(1+\frac{2\lvert\nu-\nu_c\rvert}{0.55\cdot 3.5\cdot\Delta\nu}\right)^{-2}$

Select a **gain profile from file**, an ASCII file, created by yourself in a separated dialog.

The ASCII file has to have the structure: <wavelength in nm> [TAB] <positive gain in 1/m>, e.g.

```
1000	0
1010	0.5
1020	0.6
1030	0.4
1040	0
```

- It includes setting *total* **gain saturation** – check this to simulate gain saturation effects.
- Alternatively, choose **temp gain saturation** – check this to approximately simulate the temporal gain saturation effects meaning that the front depletes the gain and is amplified more than the pulse trail. This can be observed for long pulses with a pulse energy close to the saturation energy of the fiber Esat, which is calculated automatically (for details see [2]).
-

MFD

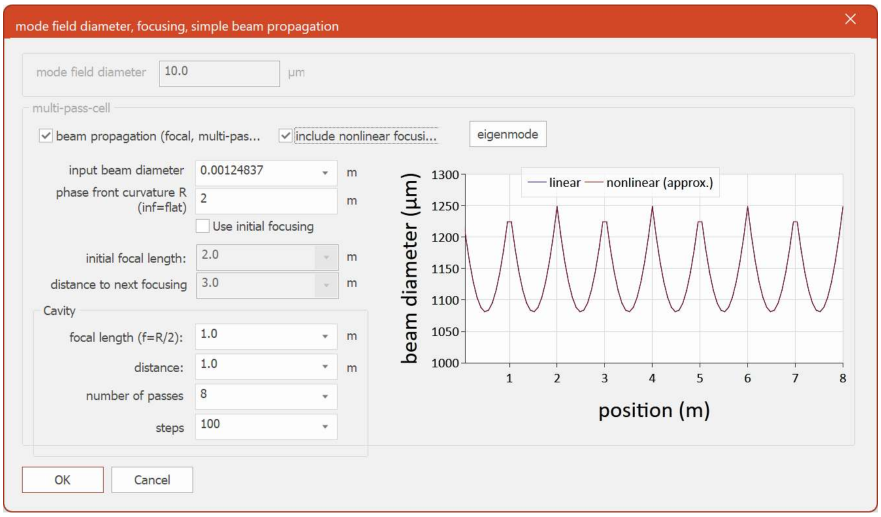
- Sets the mode field diameter of the propagation mode in [µm]. It is used to calculate the nonlinear coefficient g by $\gamma=\omega/c*n_2/A_{eff}$ with $A_{eff}=\pi*MFD$. Also it determines the saturation energy E_{sat} (see also [temp gain sat] below and [2]). The parameter n_2 can be changed in the “fiber parameter” dialog. For an advanced setup, especially using die mode diameter setup for simultaneous Gauss BPM simulation, see below.

Gauss Beam Propagation (Multi-Pass-Cell)

converts to


if selected

- click the “mode diameter button” to access the dialog. See tutorial on Multi-Pass-Cell for more information.

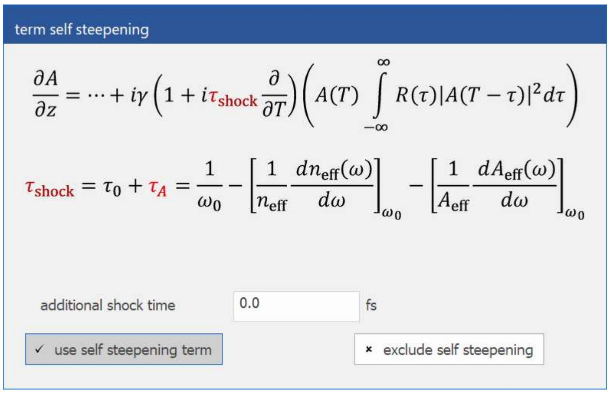


SPM

- check this to use the SPM term in the NLSE.

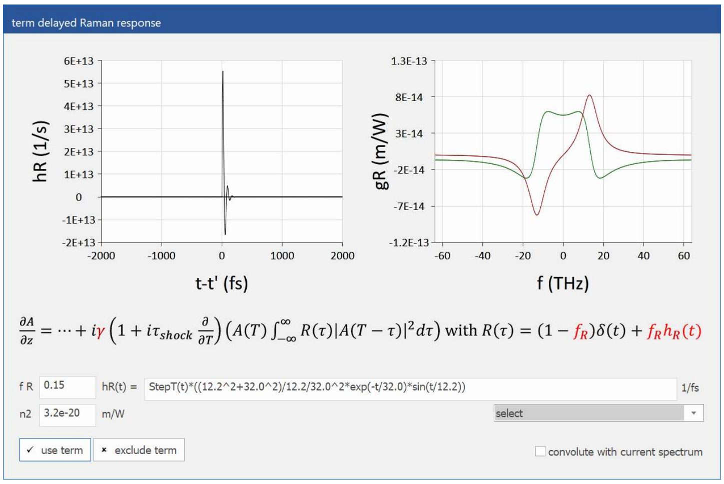
self steepening

- check this to simulate the self-steepening effect.
- it includes the (linear) dependence of the effective area with wavelength though an **additional shock term**, please see Ref. 6 for details.



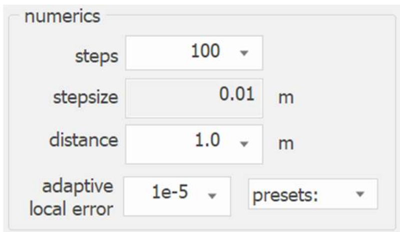
Raman response

- check this to simulate the delayed Raman response.
- The dialog allows for a detailed setup of the function h(t) or scripting your own.



steps, stepsize, distance

- Set the distance to propagate and the corresponding stepsize by these values. It determines the accuracy of the Split-Step algorithm. Even if the adaptive step size option help to avoid numerical errors, decrease the step size to ensure the numerical result.

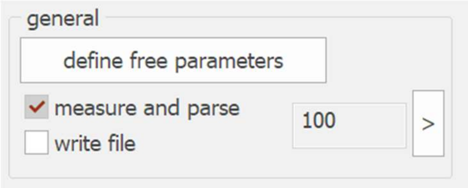


stepsize adaption

- Options: none/rough/normal/precise/accurate – This determines the adaptive stepsize control by means of the local error. The stepsize is reduced until the local error is below the given value. The smallest stepsize is 1 µm and therefor the highest precision used by the software. Set the stepsize adaption to “none” to control stepsizes smaller than 1 µm.

Measure and parse

- Select this option to measure and parse strings that you might have set variable during propagation. It will reinitialize the parameter of the NLSE. Set also the number of how many times you want to update these during the propagation.



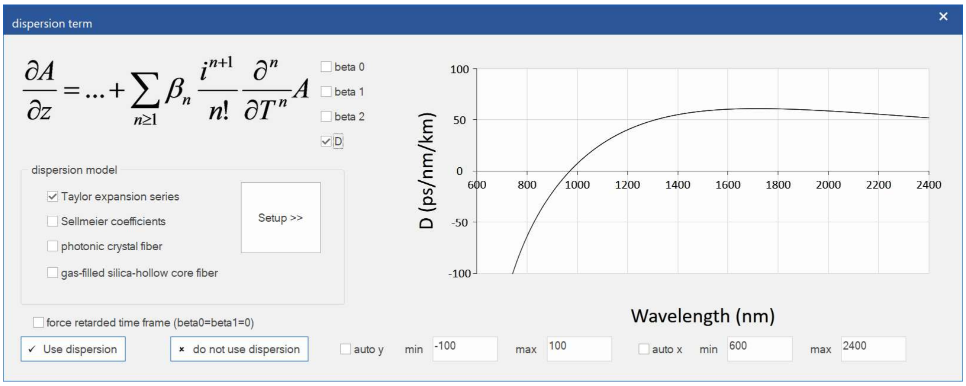
write file

Select this option to write a specific number of slices of the propagation to a propagation file (*.bpfx). Use this to write files that are required for most post-processing functions. If no filename is given, a fallback filename in the %APPDATA% directory is taken.

There are also several dialogs available to change additional parameters:

Dispersion

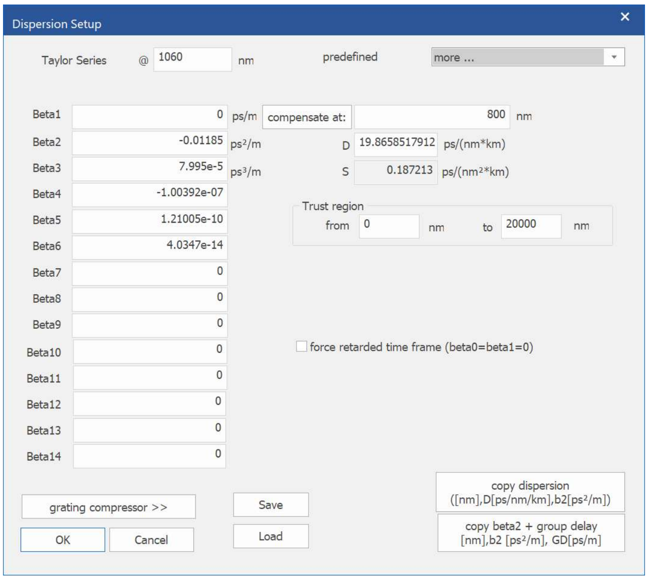
- is changed in the “Dispersion dialog” by using the following options:



- Taylor expansion series

It is specified by the coefficients β_n according to the following equation (Taylor series expansion):

$$\beta(\omega) = n_{eff}(\omega)\frac{\omega}{c} = \beta_0 + \beta_1(\omega-\omega_0) + \frac{1}{2}\beta_2(\omega-\omega_0)^2 + \frac{1}{6}\beta_3(\omega-\omega_0)^3 \ldots$$



The center wavelength/frequency of this Taylor series expansion ω_0 is also required. Specify a trust region. It determines in which wavelength range the Taylor series generates values, which are physically right. Outside this region, the dispersion is set to zero. If the range is set to zero, the full range is used for evaluating the Taylor series.

Additionally, it is possible to select several fibers from the pre-settings as well as to save or load the dispersion settings.

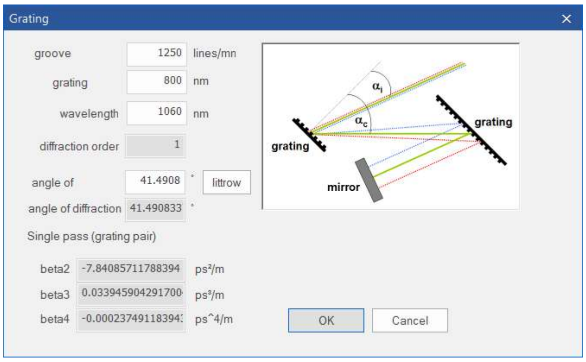
Automatically, the parameters of β_2 and β_3 are converted to the dispersion parameter D and its slope $S=dD/d\lambda$ according to:

$$D = -\frac{2\pi c}{\lambda^2}\beta_2$$

$$S = -\frac{2\omega^3}{(2\pi c)^2}\beta_2 + \frac{\omega^4}{(2\pi c)^2}\beta_3$$

If the center wavelength of the current spectral domain does not correspond to the Taylor series expansion wavelength of the dispersion, the Taylor series is automatically recalculated (internal). During this operation, a group delay (and fast varying amplitude due to the offset frequency) usually appears at the center wavelength of the pulse. To compensate for that, the option “always use retarded time frame” is used to set both values to zero ($\beta_0^{new}=\beta_1^{new}=0$). Thus, the retarded time frame is always at the center wavelength of the spectral domain and the most slowly varying amplitude envelope is used.

- grating compressor
- In the Taylor series expansion dialog, the dispersion of a typical grating compressor in single pass can be calculated. The drawing in the dialog visualizes the parameters (m = diffraction order).
- The dispersion is calculated according to:



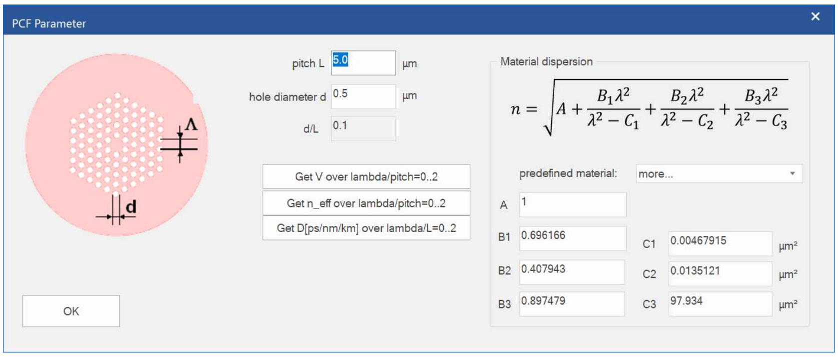
$$\sin(\alpha_c) + \sin(\alpha_i) = m\frac{\lambda}{\Lambda}$$

$$\beta_2 = -\frac{1}{c}\frac{m^2}{\omega^3}\left(\frac{2\pi c}{\Lambda}\right)^2\frac{1}{\cos(\alpha_c)^3}$$

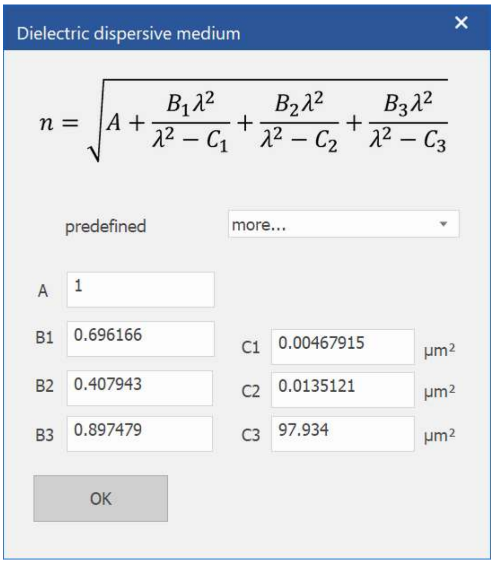
$$\beta_3 = -3\beta_2 f \quad \text{with} \quad f = \frac{1}{\omega} + \frac{m}{\omega^2}\frac{2\pi c}{\Lambda}\frac{\sin(\alpha_c)}{\cos(\alpha_c)^2}$$

$$\beta_4 = \beta_2\left(12f^2 + 3\frac{m^2}{\omega^4}\left(\frac{2\pi c}{\Lambda}\right)^2\frac{1}{\cos(\alpha_c)^4}\right)$$

- **fused silica photonic crystal fiber:** By specifying the hole to hole distance (pitch) and the hole diameter, the dispersion of a one missing hole solid core photonic crystal fiber can be used. The background material is assumed to be fused silica. Please see [3] for details.



- Sellmeier coefficients
- The well-known Sellmeier coefficients can also be used to describe the dispersion of a material. Several predefined materials are available. Please take a look at http://refractiveindex.info for more material data.
- Please also keep in mind that there are other definitions of the sellmeier equation, which might explain differences for coefficients.



Rate Equation gain

The propagation solves the NLSE similarly to "standard fiber" but includes the gain by solving the stationary rate equations. This can be used to model cw and quasi-cw amplification including ASE.

Background: The theoretical description of the laser process in fiber amplifiers is done by combining the local rate equation for the laser process and the power flow (propagation equation) for the fields along the fiber. They have been developed to predict and optimize Erbium-doped fiber amplifiers used for telecommunication application [7].

The local rate equation describes the dynamic of the emission and absorption processes of the rare earth ion within its host material by using its spectroscopic properties. A simple model for the energy level system for the Ytterbium-ion is shown in Figure 2.1 and shows some of the most important emission and absorption lines, which result from the Stark splitting of the upper and lower energy lines. It has been argued that for Erbium and Ytterbium fibers, a reduced two level model for the emission and absorption process can be used so that the effective emission and absorption cross section include the population density and cross section values [7, 8]. As an example, the effective cross sections of a typical Yb-doped fiber is shown in Figure 2.2.

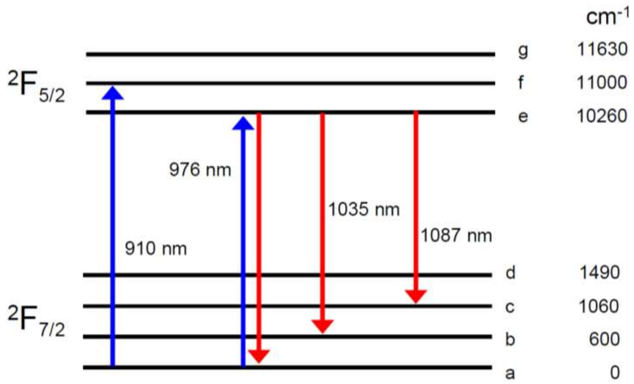


Figure 2.1: Energy level model for Ytterbium-ion in fused silica.

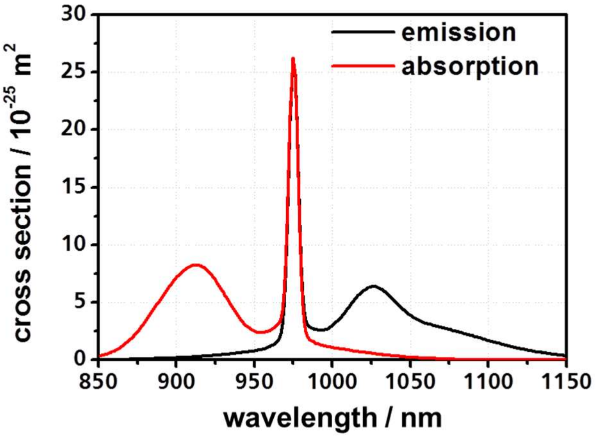


Figure 2.2: Typical emission and absorption cross section of an Yb-doped fiber.

The approximated system used in fiberdesk leads to the following equations for the forward (+) and backward (-) propagating signal (S) and pump powers (P) including spontaneous emission (SE)[2]

$$\frac{dP^{\pm}_{S/P}}{dz} = \Gamma^{S/P}\left(\pm\sigma^{S/P}_{\text{em}} N_2 \mp \sigma^{S/P}_{\text{abs}} N_1 + \alpha_{S/P}\right) P^{\pm}_{S/P} + SE_S \quad 2.2$$

with

$$SE_S = \pm 2 \cdot h\nu \cdot \Delta\nu \cdot \sigma^{S}_{\text{em}} N_2$$

where the total ion density $n_0=n_1+n_2$ is the sum of upper and lower population density and $\alpha_{P/S}$ is an additional loss (background loss) for the fields. It is assumed that the pump absorption can be described by a simple overlap factor Γ_p, which is the ratio of doped core area to pump core area. The upper population density for steady-state conditions is

$$n_2(z) = n_0 \frac{\sum_{k=S,P} \frac{\sigma^{k}_{\text{abs}}}{h\nu_k} \Gamma^k \frac{P^k(z)}{A_c}}{\sum_{k=S,P} \frac{\sigma^{k}_{\text{abs}} + \sigma^{k}_{\text{em}}}{h\nu_k} \Gamma^k \frac{P^k(z)}{A_c} + \frac{1}{\tau}} \quad 2.3$$

with τ as the upper state lifetime and the total power at a given position $P(z)=P^{+}(z)+P^{-}(z)$. The inversion level is defined as n_2/n_0. The solution of Eq. 2.2 and 2.3 and can be made

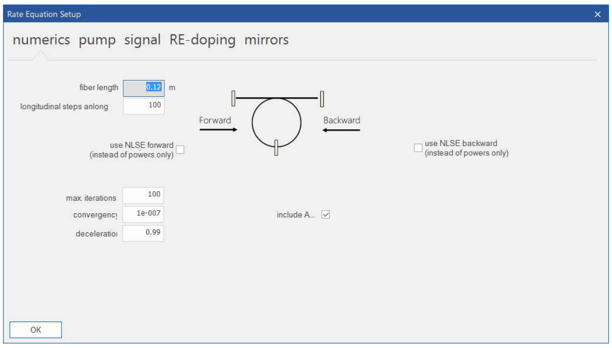
[2] for the signal only

for fiber amplifier but also for laser, if the boundary conditions at the laser mirrors (typically z=0, L) are included in the description for forward and backward propagating fields.

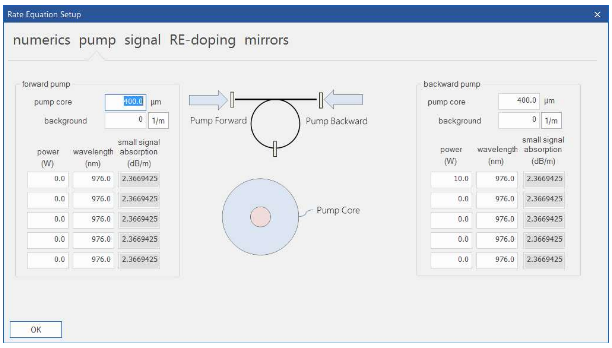
For ultra-short pulse propagation, the rate equations are combined with the nonlinear Schrödinger equation (Eq. 2.1) by calculation the spectral gain $g(\omega,z)=dP(\omega)/dz*1/P(\omega)$ with the results of the rate equation and then propagating the NLSE with that gain. However, the spontaneous term is added to the complex field by photons of random phase in that case.

In the main dialog, all parameters are set in various tabbed property pages including:

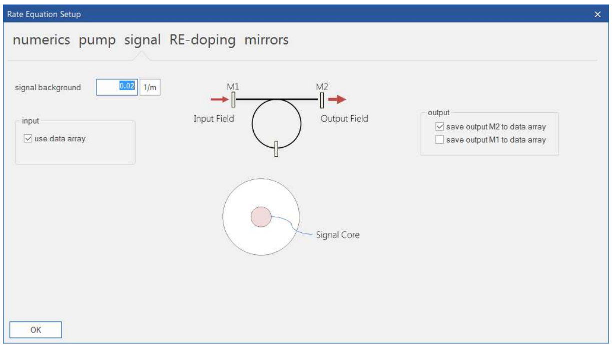
- Numerics



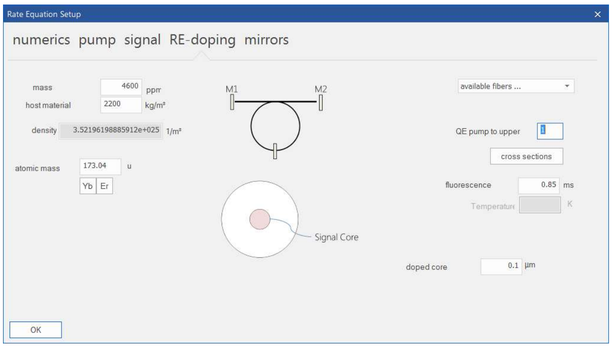
- Pump

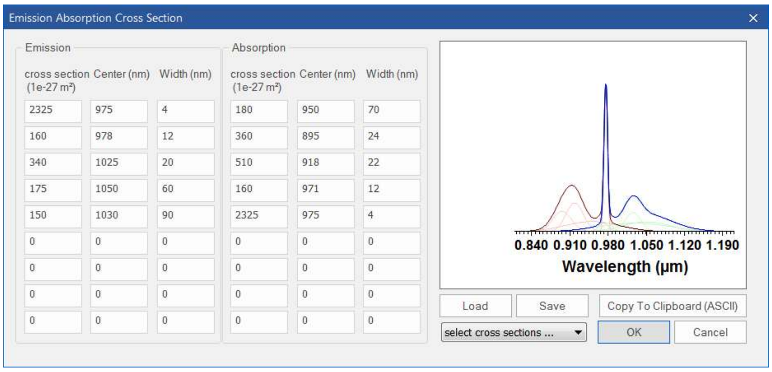


- Signal



- Doping, with its sub-menu for cross section setup. There, the cross sections can be included using a simple multi-Gaussian peak fit.





The equation for the cross-section fit is:

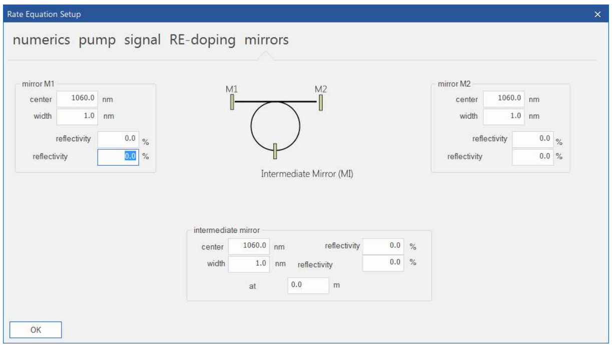
$$\sigma(\upsilon) = \sum_j \sigma_j e^{-\frac{1}{2}\left(\frac{\upsilon-\upsilon_0}{\Delta\upsilon}\right)^2}$$

-

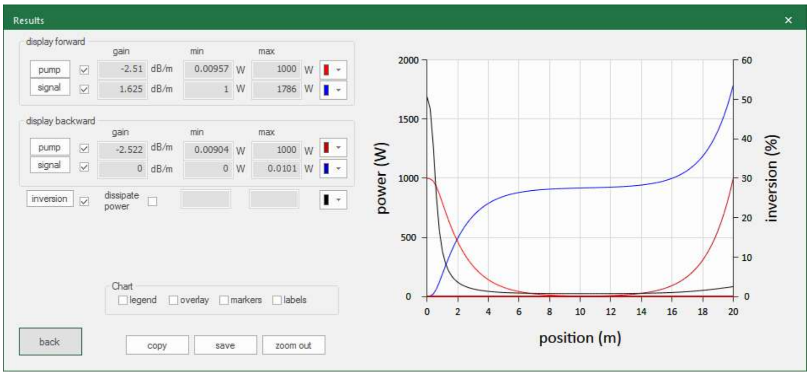
With υ as the frequency, υ_0 the center frequency of the cross-section peak, both expressed as wavelength (υ =c/λ) as well as $\Delta\upsilon$ given by

$\Delta\upsilon$ = 1.0/(2*sqrt(2.0 * log(2))*|c/(υ_0+Δλ/2)-c/(υ_0- Δλ /2)|

- where Δλ is the FWHM of the contributing peak.
- Mirrors

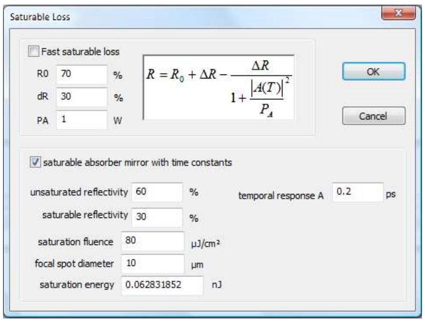


After propagation, the total powers and inversion can be accessed in the “main“ section, “propagation”->”RE Results”.



The options “live” is disabled during the calculation. However, you can “write to a propagation file” and measure or display afterwards (“Post Processing”).

Saturable Absorber



You can choose between an instantaneous saturation and a saturable element.

The first action of this element is to center the field temporally.

You can choose between an instantaneous saturation and a saturable element with a saturation that is decaying with a specific time constant.

The instantaneous saturation modifies the field intensity I(T) according to (*A* is the "field amplitude" with the unit of $J^{1/2}$):

$$I(T) = I(T) \cdot \left(R_{unsat} + \Delta R \left(1 - \left[1 + \frac{|A(T)|^2}{\tau_{dw} P_{sat}} \right]^{-1} \right) \right)$$

The unsaturable R_{unsat} and saturable reflectivity ΔR as well as the saturation power can be controlled.

The time dependent saturable absorber modifies the field according the following rate equation with the notations $q_0=\Delta R$ and the reflectivity $R=R_{unsat}+(\Delta R-q(t))$:

$$\frac{dq}{dt} = -\frac{q - q_0}{T_1} - \frac{|A(t)|^2}{E_{sat}} q$$

with:

q_0 – saturable reflectivity

E_{sat} – saturation energy

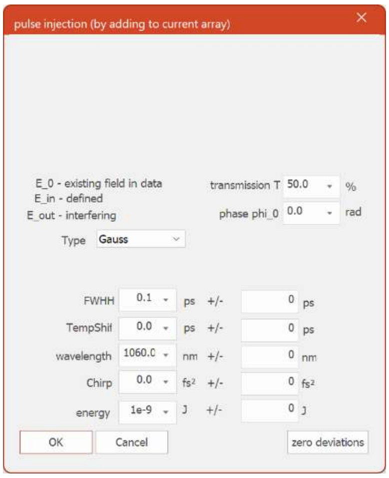
A(t) – field envelope in [$J^{1/2}$]

q(t) – response of SESAM

The unsaturable and saturable reflectivity can be controlled directly in the dialog. The saturation energy E_{sat} is controlled by controlling the focal spot and the saturation fluence (as known from semiconductor saturable absorber mirrors).

Pulse Injection

This method adds a pulse to the current data array, causing interference with the existing field. You must set a transmission parameter and phase.

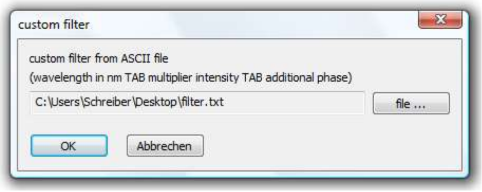


The parameters can vary randomly based on the uncertainty parameter set in the setup dialog.

Tip: For an interference-free pulse, use multi-element propagation. You can either add a high loss before this element to zero out the existing array and then inject a pulse, or achieve absolute zero by multiplying with zero using "manipulation" propagation.

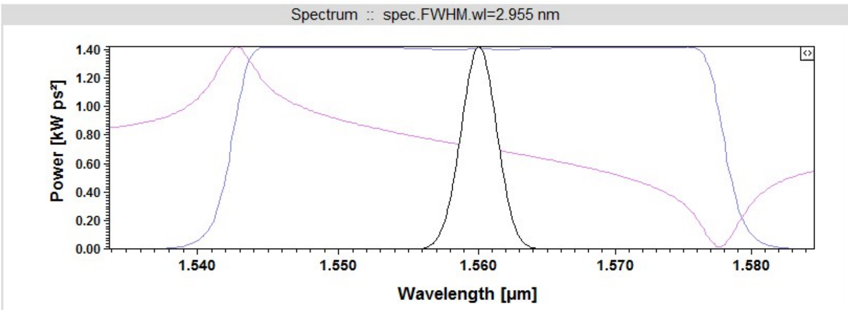
Custom Filter

This allows to select an ASCII file with a custom defined transmission T(ω) for the spectral intensity and an additional spectral phase φ(ω). It is combined with the spectral field amplitude as follows: $\widetilde{A}(\omega) \rightarrow \sqrt{T(\omega)} \cdot \widetilde{A}(\omega) \cdot e^{i\varphi(\omega)}$



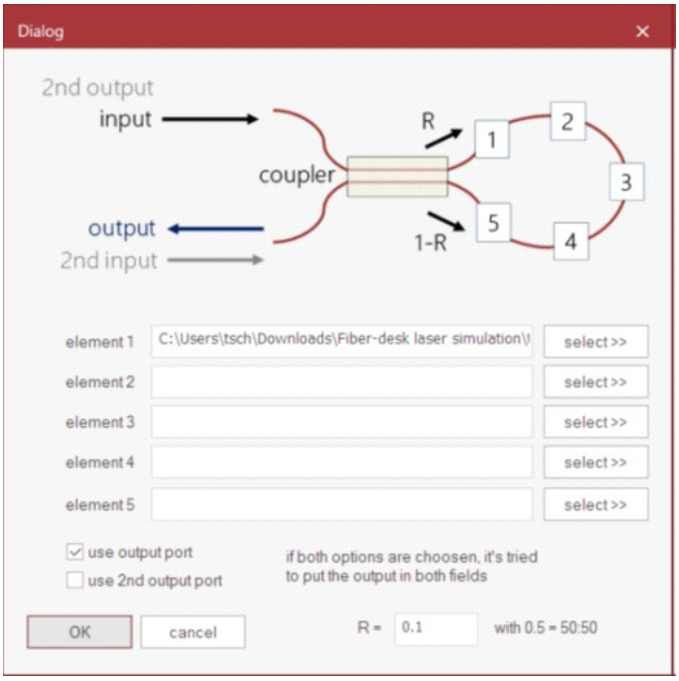
The ASCII file has to contain three columns with the values of the wavelength in nm, the transmission T and the phase in rad. The values have to be separated by “TAB” or “,”.

The imported data are displayed in the main view (normalized).



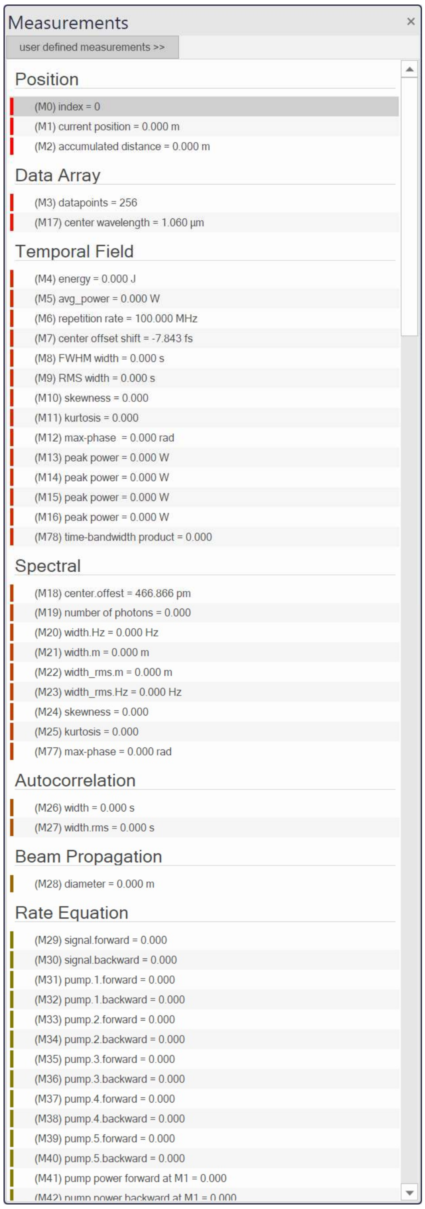
Nonlinear Loop Mirror

This allows to define a nonlinear loop mirror consisting of several elements that are previously saved as ppfx files. The current field is the input and the output is the coherent superposition of the results of the left and right clockwise propagating field. See tutorial 8 for details and examples.



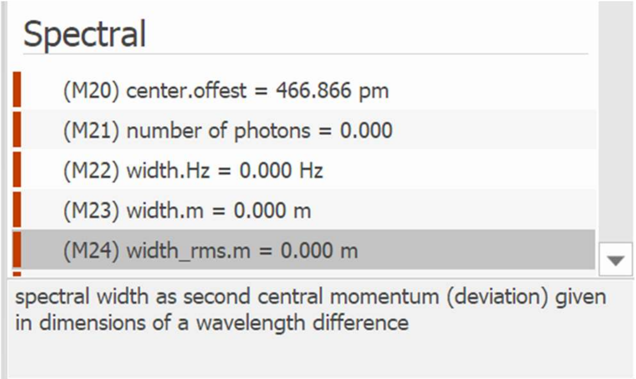
2.7.2. Measurements

The current dataarray is analysed almost after each modification. The results are displayed in this separate window. SI units are used. The description is usually intuitive and displayed in the bottom of the windows when clicked on a specific measurement. To keep it short, here is a description for some of the values:



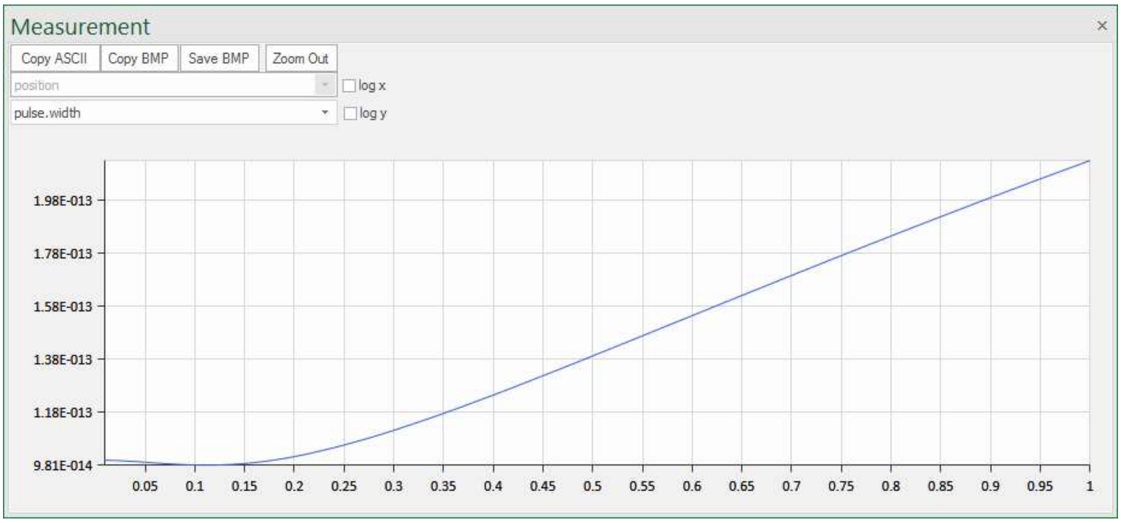
- datapoints – number of datapoints in current data array
- position – current propagation position
- FWHM – full width at half maximum
- rms – root mean square (second momentum)
- ac. – values belonging to the autocorrelation
- pulse. – values belonging to the temporal field intensity
- spec. – values belonging to the spectral field intensity
- theory. – parameters of the current propagation according to usually used normalization parameters (change is by “menu->manipulation->change T0”)
- t.b. product – time-bandwidth product
- Q – quality factor in time and spectral domain (FWHM/RMS/2.0) [1]
- (for more information ask webmaster @ fiberdesk.com)

To see a description for other parameters, click the parameter and a description is shown in the information window at the bottom of the control:



2.7.3. Measurement graphs

If the measurement is switch on (see propagation parameter window) during propagation, all measured value from the measurement result window are show with respect to the propagation distance in the “Graph” window.



Use the buttons on top to copy the content of the current graph to the clipboard in ASCII or BMP format or save it to a file. Zoom in to the values by moving to mouse onto the data and click left. Zoom out by the button on top.

2.7.4. Output

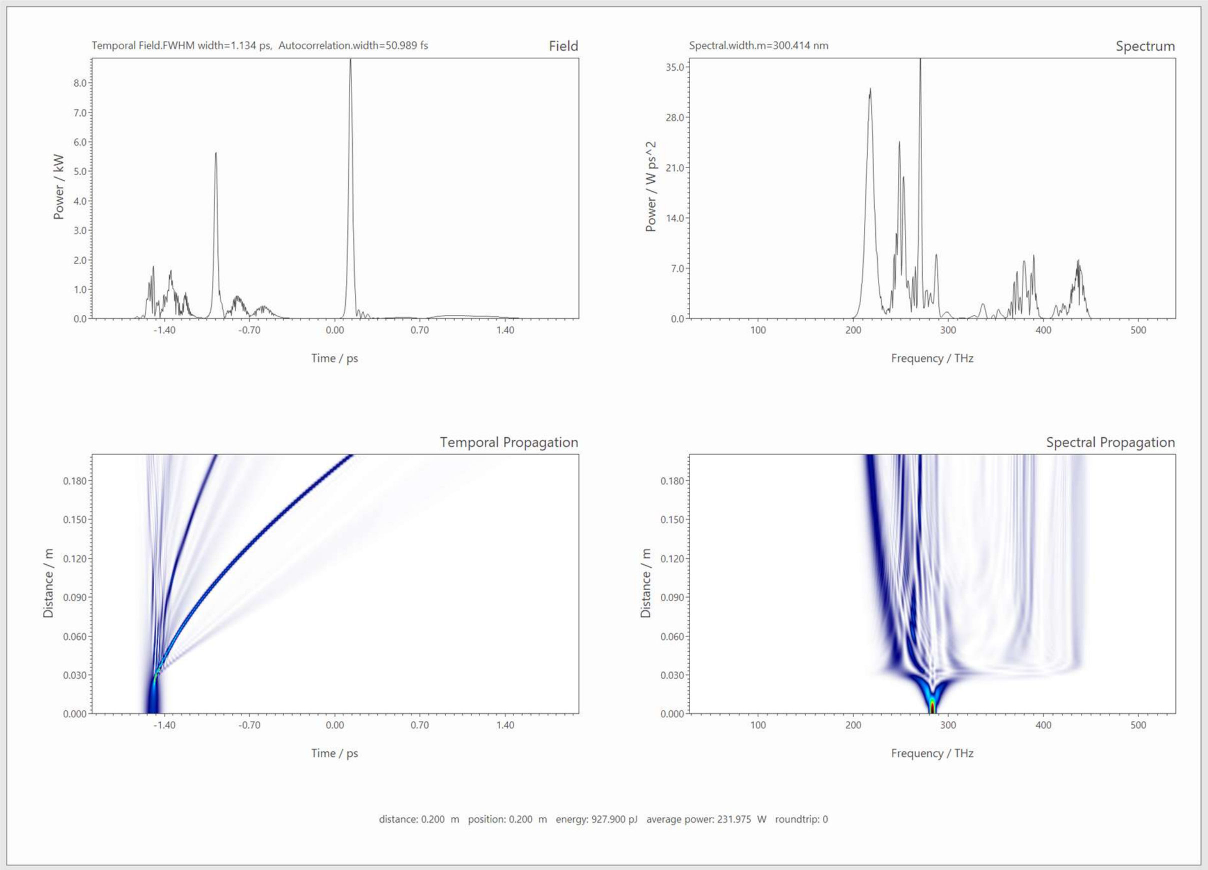
Several important information or results of the propagation are displayed in the output window.


Output
1Welcome to fiberdesk ...
2duration of last propagation: 43.2175 sec with 4774 steps
3duration of last propagation: 142.237 sec with 1000 steps
4

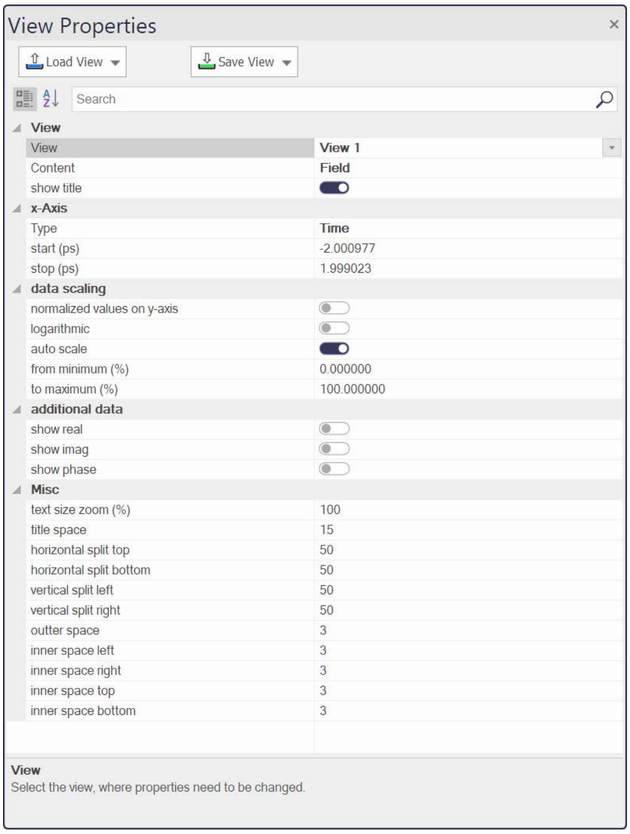
2.8 View interface

2.8.1. View

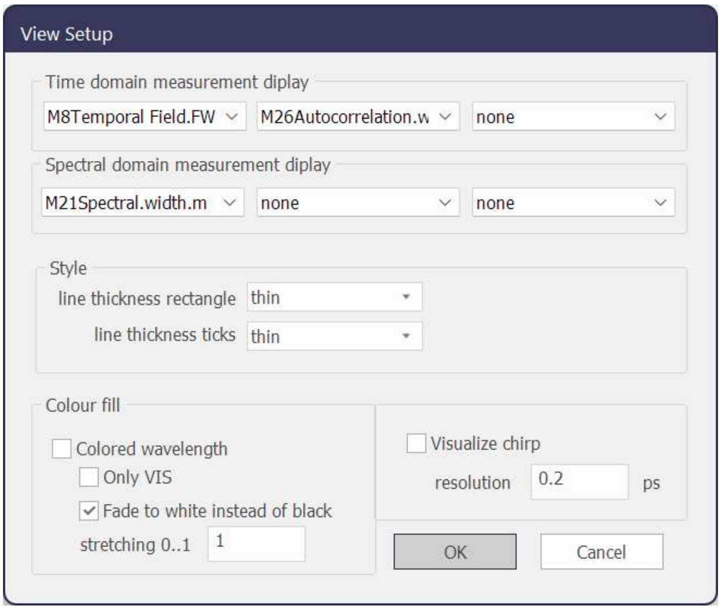
The general view can contain different views of the current electric field: the temporal field, its Fourier transformation as the spectral field and the autocorrelation. The number of views can be chosen in the ribbon menu (see ribbon control "View").



The control of the view is done in the view setup pane and is related to the selected view (e.g. simply by clicking into the view) In the bottom of the pane, a description of each property item is displayed – click on a specific item to read its description.



There it is possible to select up to three different measured values displayed in the view for a quick access.



If the option “colored wavelength” is chosen, each wavelength is colored individually. The colors are controlled by the options “only VIS” to highlight the visible wavelength (otherwise the whole current spectral range is used) and the option “Fade to white ...” to choose the colors of the wavelength that are out of the visible region.

Additionally, a fast algorithm is implemented to visualize the temporal position of the spectral components (chirp).

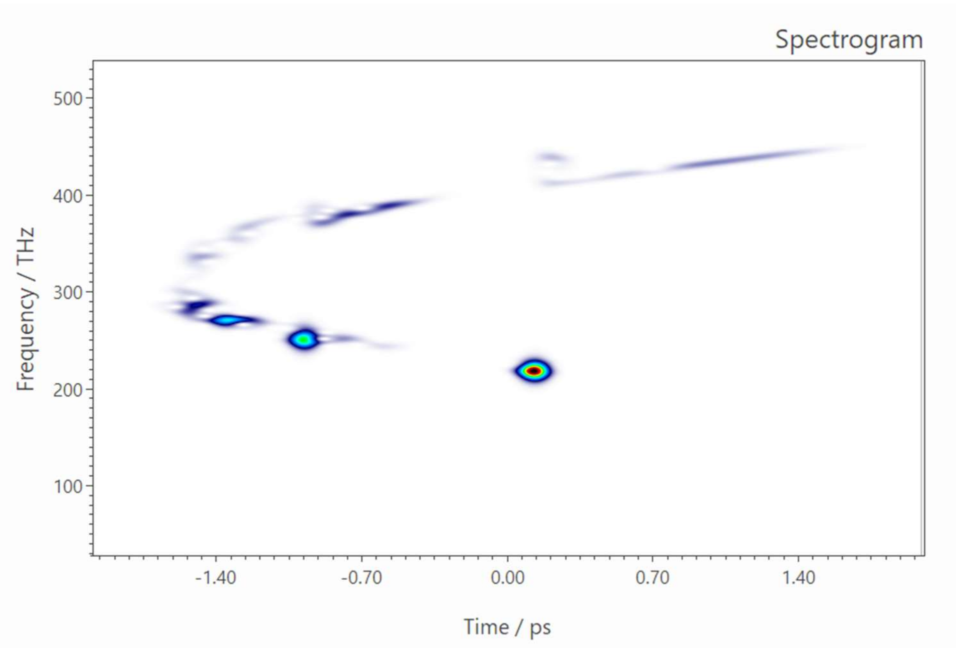
2.8.2. Spectrographic content

The spectrographic view shows a spectrally (wavelength) resolved temporal map of the electric field. This view is well known from the measurement technique of ultrashort pulse known as frequency resolved optical gating (FROG) [5]. It is calculated by the following equation:

$$S(t,\lambda) = \left| \int_{-\infty}^{\infty} e^{-i\,c/\lambda\,\tau} e^{-i(\tau-t)^2/T_{BW}^2} A(z,\tau)\,d\tau \right|^2$$

If the axis of the spectrum in the normal view is set to any of the frequency axis, the spectrogram is also calculated in time-frequency domain.

$$S(t,\omega) = \left| \int_{-\infty}^{\infty} e^{-i\omega\tau} e^{-i(\tau-t)^2/T_{BW}^2} A(z,\tau)\,d\tau \right|^2$$



In the view properties pane, the temporal resolution T_{BW} can be chosen.

2.9 References

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