How to work with Chi2D

02/2014

Contents

The GUI

1.1 Overview

The GUI of Chi2D as shown in Fig. 1 is divided into 5 sections:

1. Properties of the involved pulses
2. Settings for phase matching
3. Settings for the considered processes in the simulation
4. Simulation parameters
5. Settings for graphical output, results, and compressible check

If you place the cursor within a text box or a check box, you will get a tool-tip with some useful information as shown for the pulse energy in figure 1.

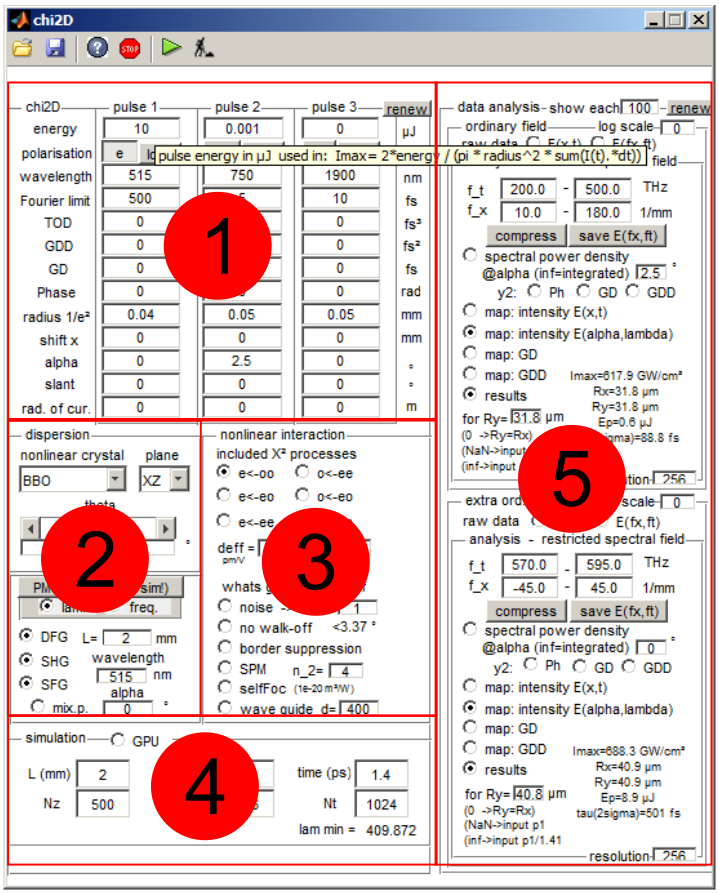
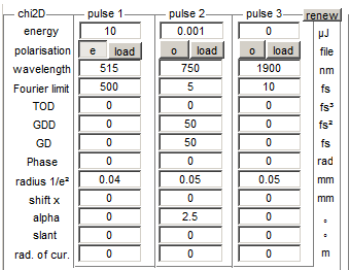


Figure 1: Sectioning of the GUI

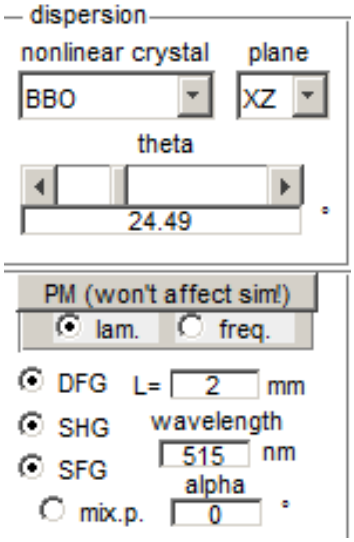
1.2 The different parts of the GUI

Pulse properties



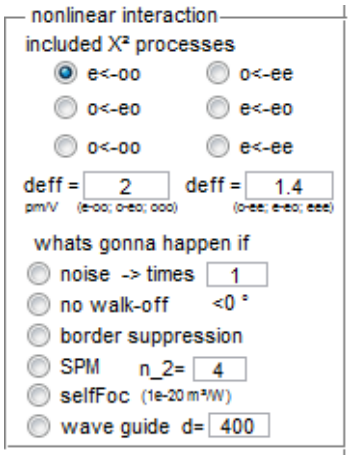
In this section the starting conditions of the involved pulses are set. If less then three pulses are to be inserted, simply set the energy of the others to zero. By clicking the “e” or the “o” button the polarization can be switched from ordinary to extraordinary and vice versa. Via the “load” button experimental data or results from previous simulations can be loaded.

Crystal properties



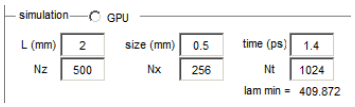
The settings for the crystal are set in the upper part. When changing the material of the crystal the corresponding transmission curve will pop up. In the lower part you have access to the analytical calculated phase-matching curves via the button “PM”. This won’t affect running simulations. Choose the analytical calculated phase-matching curves by selecting the nonlinear processes in section 3. You can restrict which processes should be displayed by the check boxes (DFG, SHG, SFG). To include the resulting mixing processes select “mix p.”. Set the angle alpha if the pump pulse is not propagation in the z-direction (angle OA-crystal towards z-direction = theta + alpha). The polarization of the involved fields is encoded in the color of the curves. (red - ordinary, blue - extraordinary, black - both for Type II)

Nonlinear interaction



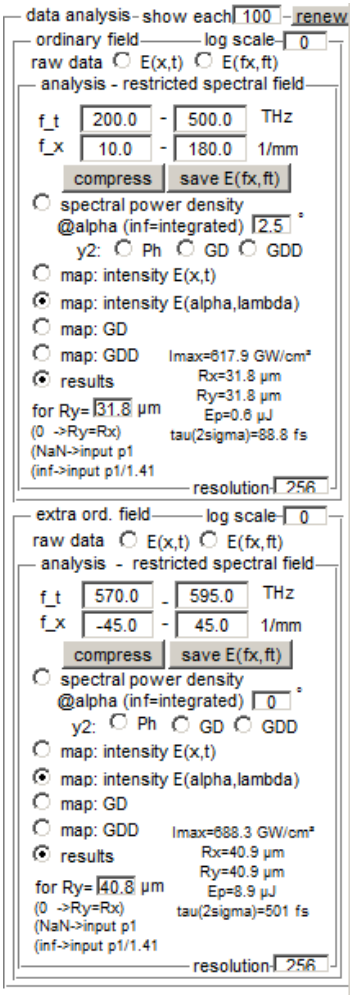
In this section the settings concerning the nonlinear processes for the simulation are set. Particularly it enables to choose which type of nonlinear processes will be considered by the simulation (Type I or Type II phase-matching and for which polarization). The nonlinear coefficient is not calculated by the program. Only suggestions are automatically set in. The correct values can be found e.g. by SNLO. "what's gonna happen if" are very experimental functions which can help in better understanding the process. The noise check-box adds a very weak intensity with a random phase for all elements in ft and fx. For a "times" factor of one this intensity approximately equals to one photon per frequency interval. "border suppression" adds a Super-Gaussian filter to suppress mixing products close to the limits of the spectral fields. "SPM" and "selfFoc" include intensity dependent phase with respect to n2. "wave guide" includes total reflection boundary condition at -d/2 and + d/2 to all involved pulses (!very experimental! - requires very small step sizes in z and x).

Simulation parameters



Select "GPU" if you have a CUDA capable graphic card in order to speed up a simulation. L defines the length of the nonlinear crystal and Nz the number of steps. Increase this number until the simulation result does not depend on the step size anymore. "size" defines the crystal aperture in x-direction and "time" the time window. Nt and Nx the respective sampling. Make sure that all initial and all generated pulses fit into the temporal and the spectral windows. Especially for signals generated at large angles (noncollinear DFG) and higher frequencies (parasitic SHG, SFG), a insufficient frequency range in the spectral domain can lead to artifacts which will change in frequency and angle for a different sampling in x and t. Make also sure that pulses leaving the temporal window don't influence the interaction region anymore.

Post processing and graphical output



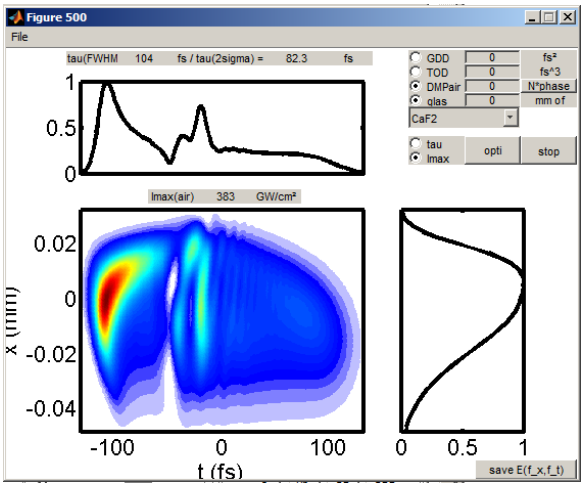
The right hand side of the GUI handles the post processing of the simulation data, which is the graphical output, the simulation results, and a check for the compressibility of the output pulses. All options can be found for both the ordinary field in the upper part and the extraordinary field in the lower part.

The ”raw data” displays the temporal and/or the spectral computational field arrays as they are processed in the simulation.

”analysis restricted fields” only uses the spectral field components within the limits which are set in ft and fx. This influences all shown results framed by the box. Please find the tooltip in the respective input field or check-box. The separated temporal signal can be saved and re-imported in section 1 for further processing.

If “results” is activated the values for $I_{\max}, R_{\mathrm{x}}, R_{\mathrm{y}}, E_{\mathrm{p}}$ and τ will be displayed in the lower right corner of the corresponding panel. Because of the (2+1) dimensional treatment of all involved pulses, for a estimation of the pulse energy, the beam radius in the unconsidered y-dimension has to be set in manually. One can set the size to a certain value $\neq 0$, to be the same as R_{x} ($R_{\mathrm{y}} = 0$) , the size given for pulse 1 (R_{y}=NaN) or to be a factor of $\sqrt{2}$ smaller the size of pulse 1 (R_{y}=inf). Which one is the best choice depends on the certain process and result. For example, for a broadband parametric amplification with small pump depletion and a larger seed beam size (R_{y}=inf) would be the right choice. The same situation with strong pump depletion would result in a signal beam size in Ry similar to the pump beam size (R_{y}=NaN), even if due to walk-off and noncollinear propagation the Rx-value is much larger.

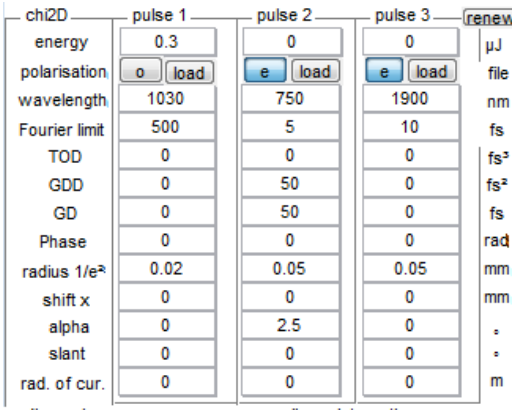
Pulse compression



The "compress" button in the section for post processing will open a new window. The pulse shown in the center part is the restricted output pulse for the selected polarization along its one propagation direction. Above the graph on its right hand side are the integrated profiles along the time and the space axis respectively. In the upper right corner the parameters which will be used to compress the pulse can be selected. Furthermore it can be chosen if the pulse duration or peak intensity or both should be optimized. Press "opti" to start the optimization algorithm. The DCM pairs used as default are the "DCM7" distributed by Venteon®. If a process ends with a fraction of a DCMPair, uncheck it so the value is rounded when the optimization process is restarted. Any phase distribution can be loaded by pushing the button right next to the DCM number field (wavelength[nm], phase[rad]). In this case this number is just a multiplier for the loaded phase distribution. The compressed pulse can be saved and re-imported in section 1 for further processing.

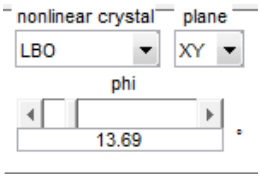
Example 1 - Simulation of an SHG process

Step 1 - Insert the parameters of the pump pulse

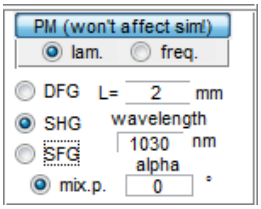


Insert at least values for the energy, wavelength, pulse duration and focal size of your pump into the corresponding panels belonging to pulse 1. The other ones are optional if known. Define the a second pump pulse in case of a SFG process, otherwise set the energy to zero.

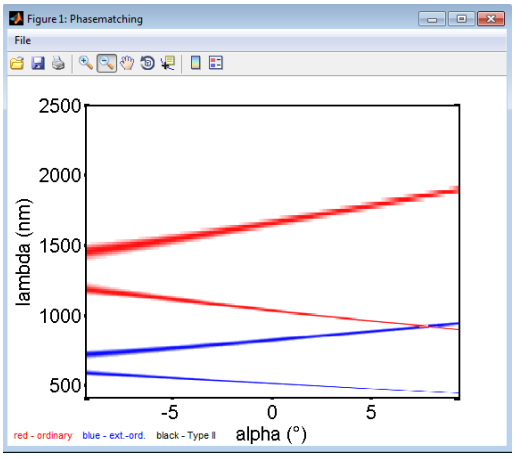
Step 2 - Set the phase matching



Choose the settings for the crystal: material and orientation of the crystal and the angle of the optical axis towards the main propagation direction z. If you don't know what settings to use, the programm SNLO (http://www.as-photonics.com/snlo) is a useful tool to get an idea.

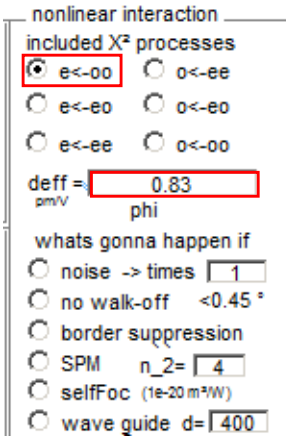


Press the button "PM" for the analytical phase-matching curves. This won't affect the simulation. Choose the analytical calculated phase-matching curves by selecting the nonlinear processes in section 3. You can restrict which processes should be displayed by the check boxes (DFG, SHG, SFG). To include the resulting mixing processes select "mix p.". Set the angle alpha if the pump pulse is not propagation in z-direction (angle OA-crystal towards z-direction = theta + alpha). The polarization of the involved fields is encoded in the color of the curves. (red - ordinary, blue - extraordinary, black - both for Type II)



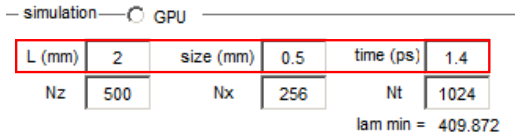
The figure shows the phase-matched wavelengths and polarization (red: ordinary, blue: extraordinary, black: both polarisations for type II phase matching). If the curve does not fit your requirements, tune the angle theta until your are satisfied. Use the tools from the toolbar to zoom in and out.

Step 3 - Select the processes you want to be included by the simulation.



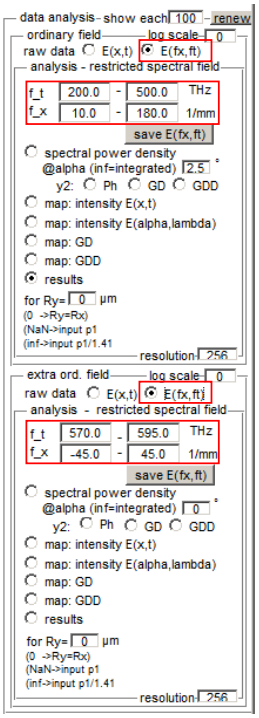
Select the processes you want to be considered by the simulation. For a pure type I SHG in LBO e.g. you just need to activate "e←oo". Furthermore, you might want to check if the given value for d_{eff} is correct.

Step 4 - Choose simulation parameters



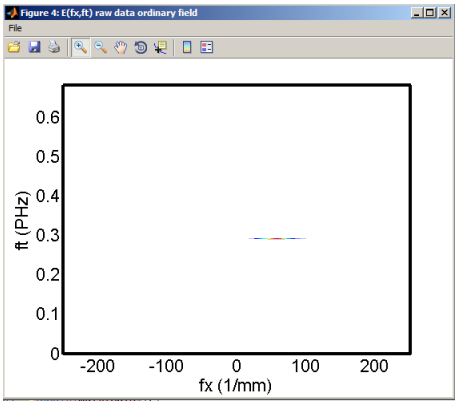
Set the length of your crystal, the size in the transversal direction and the time window. The size in space and time and the respective sampling should be large enough to all include input and generated fields in time and the Fourier domain.

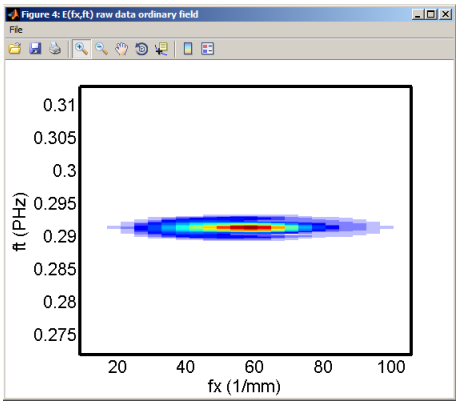
Step 5 - Get the simulation started



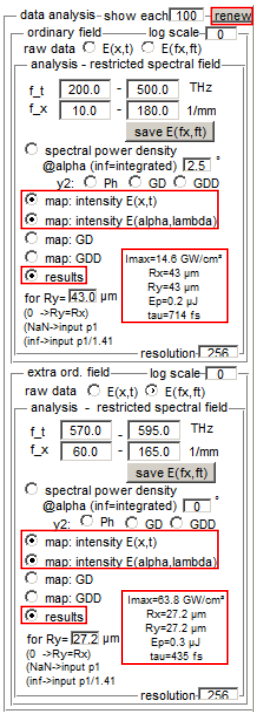
In a first step, select both "raw data E(fx,ft)" fields in the data analysis field and press the green play button in the GUI afterwards. You will get two figures containing the simulated fields for the ordinary and extraordinary polarization displaying the spatial and temporal frequency as shown below.

Use the magnifier to zoom in to the relevant area and edit the values accordingly for both polarizations. For the given example you would restrict the ordinary field in the spacial frequency fx from 10 mm^{-1} to 100 mm^{-1} and the temporal from 285 THz to 300 THz.

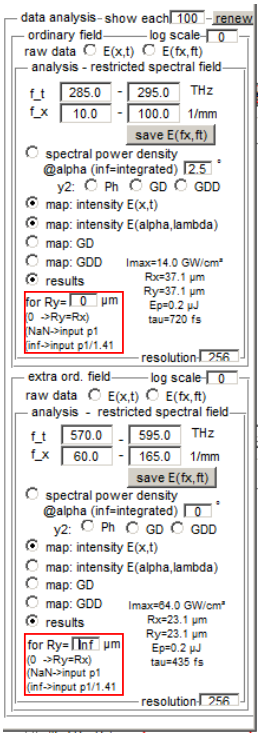




Step 6 - Selecting the shown plots and the size in the 3rd spacial dimension



Select the plots you are interested in. If you check “results”, the numerical values for the intensity, beam size, pulse energy and pulse duration will be displayed in the lower right corner of the associated area of GUI section 5. In order to estimate whether you have a strong or a negligible pump depletion, you should mark “map: intensity E(x,t)” for the field containing the pump. Press the “renew” button in the upper right corner.



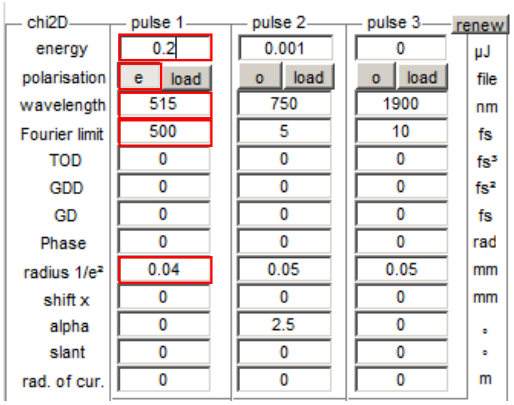
During the simulation just two spacial dimensions (the propagation direction z and a transversal one x) are considered. To estimate the pulse energy, one needs the information of the beam size in the 3rd spacial dimension y. During an $\chi^{(2)}$ process, the diameter of the generated field is a factor of $\sqrt{2}$ smaller then the generating one when the pump depletion is negligible and about the same size if depletion is dominant. Choose therefore $R_y = \text{inf}$ if the depletion is negligible and $R_y = \text{NaN}$ in the case depletion is dominant. For the pump you might want to choose $R_y = 0$ which is the equivalent for a symmetrical beam shape.

Step 7 - Batch processing

In order to do parameter studies, click on the "batch processing" button in the GUI. Select the parameter you want to scan on the left hand side, choose the number of steps and the step width according to your wishes. Please note that the step size is in SI units and the range is centered around the actual value set at the GUI.

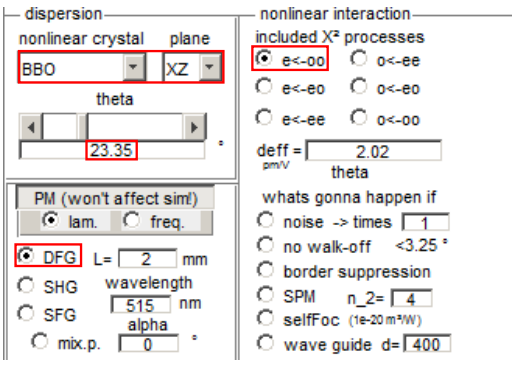
Example 2 - Simulation of an DFG process

Step 1 - Insert the parameters for the pump

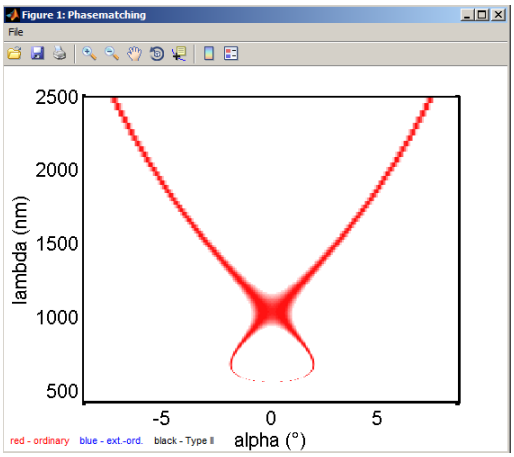


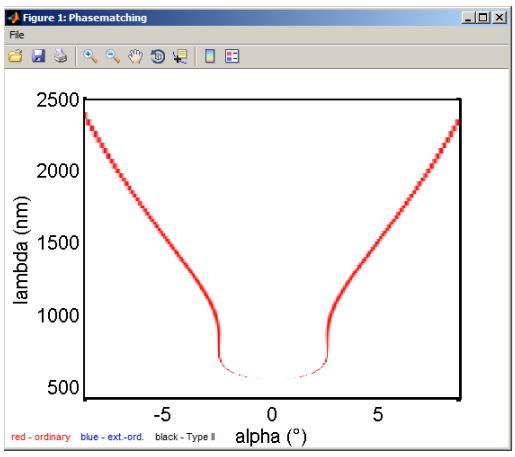
Start with inserting the parameters of the pump to *pulse 1* and choose whether your pump or your signal is propagation along the main direction z. In the example it's the pump ($\alpha = 0$).

Step 2 - Select the properties of the crystal for phasematching

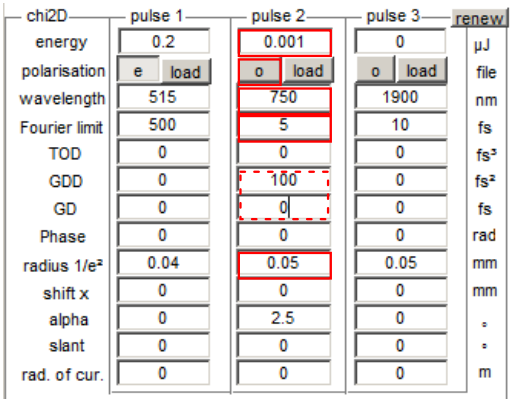


Select the crystal and its orientation and which type of phase matching and processes you are interested in. Press the button to show the phase matching curve and play with the angle until you are satisfied. The pictures below show the difference in the curve for tuning the angle from 23.35° to 24.49°. In the second case you achieve broadband phasematching for an ordinary polarized signal from 710 nm to 925 nm prospecting with angle of 2.5° with respect to the main propagation direction.





Step 3 - Insert the parameters for the signal



Insert the parameters of the signal to *pulse 2* by considering the phase matching properties. You may tune the delay of the two pulses by adjusting the GD