

Lecture 9: Multi-Pass Cell



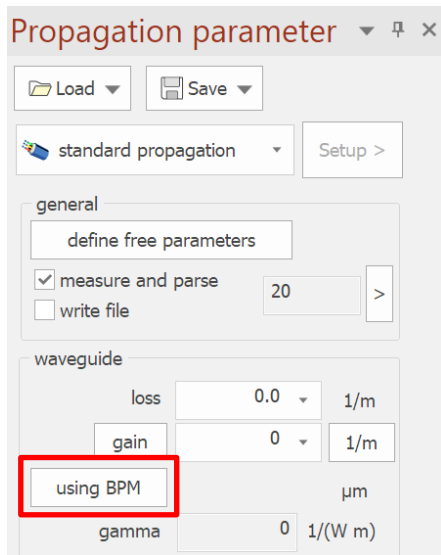
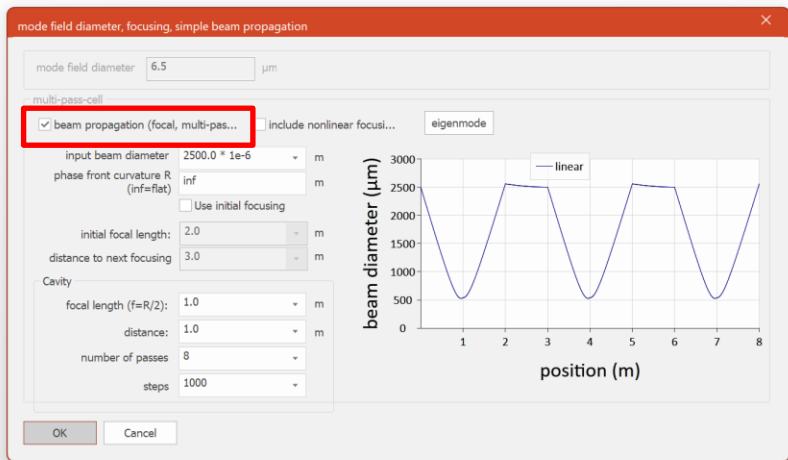
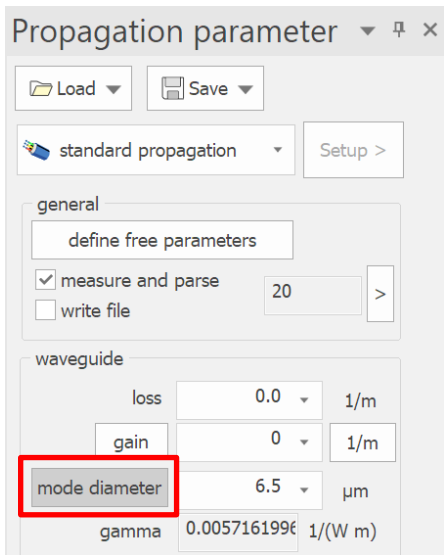
Multi-Pass Cell

The theory follows the hybrid and 1D model from the publication:

- Marc Hanna, Nour Daher, Florent Guichard, Xavier Délen, and Patrick Georges, "Hybrid pulse propagation model and quasi-phase-matched four-wave mixing in multipass cells," *J. Opt. Soc. Am. B* 37, 2982-2988 (2020)
- Nour Daher, Florent Guichard, Spencer W. Jolly, Xavier Délen, Fabien Quéré, Marc Hanna, and Patrick Georges, "Multipass cells: 1D numerical model and investigation of spatio-spectral couplings at high nonlinearity," *J. Opt. Soc. Am. B* 37, 993-999 (2020)

The beam with a certain size (= mode field diameter) is propagated by Gauss Optics (ABCD formalism) and at each step, the linear and nonlinear effects are considered according to the current beam size. This is a simple form of beam propagation (BPM).

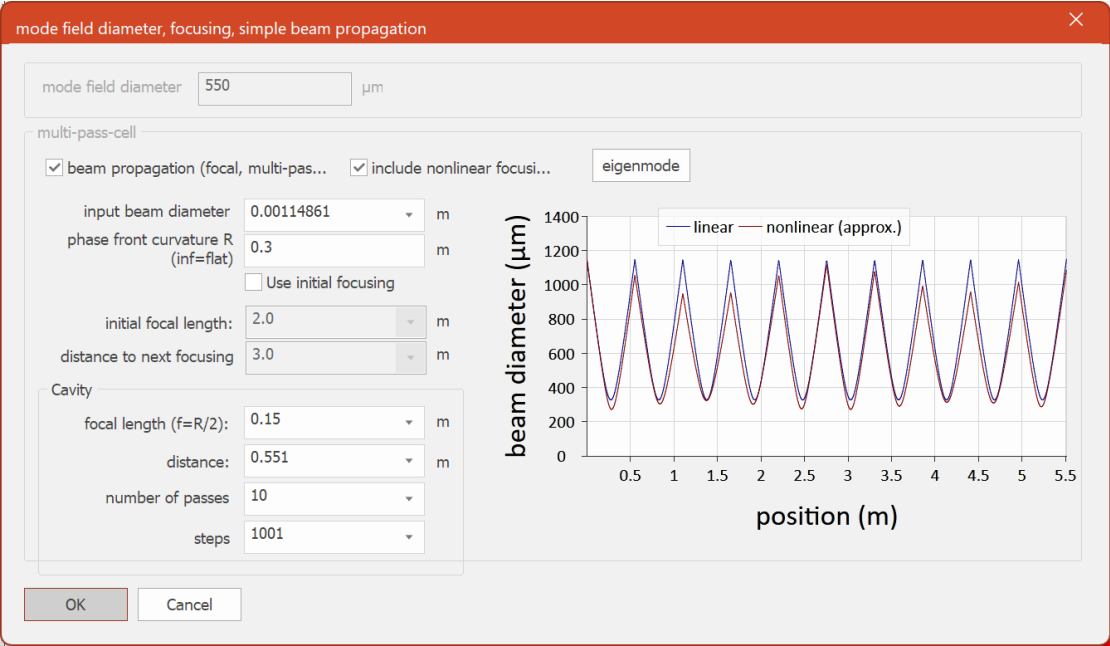
Therefore, the setup is done via the dialog of „mode field diameter“ in the standard propagation options, and once you select „beam propagation“, the button outside the dialog changes to „using BPM“.



Multi-Pass Cell

We follow the parameter of the publication, which come from: *L. Lavenu, M. Natile, F. Guichard, Y. Zaouter, X. Delen, M. Hanna, E. Mottay, and P. Georges, “Nonlinear pulse compression based on a gas-filled multipass cell,” Opt. Lett. 43, 2252–2255 (2018).*

- Setup the multi pass cell
- No initial focusing is required
- Include nonlinear focusing, of the actual peak power shall be included in the beam propagation. In the dialog, this is shown approximately for the current peak power in the field
- Once the cavity data is given, the eigenmode can be calculated to give the input beam and phase front
- Leave the dialog
- Start the propagation with „measure and parse“ switched on



Multi-Pass Cell

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- Define the pulse as Gaussian with 300 fs and 150 μJ
- Set the dispersion to „gas filled hollow core fiber“ and use the dispersion for xenon and a pressur of ~3.8 bar. Also the core diameter is made large as it is not a waveguide, so no resonances appear.
- The nonlinearity n2 is set to 2 e-22 m²/W (at 3.8 bar)
- Raman can be switched off (or fR=0.0)

effects

☒ dispersion
 ☒ SPM / TPA
 ☐ Raman
 ☒ self-steepening
 ☐ LLE

Pulse Profile and Data Array

data array setup

Size

1k (2^10)

array center wavelength

1030

nm

half interval

10

ps

vacuum length (full interval)

0.00599584916

m

Type

Gauss

pulse duration (FWHM)

0.35

ps

(sets spectral width)

TempShift

0

ps

phase

0

rad

wavelength

1030

nm

same as array

2nd order spectral phase

0

fs²

3rd order spectral phase

0

fs³

energy

150e-6

J

average power

150

W

repetition rate

100000

Hz

cw

☐ scramble spectral phase (random phase)
 ☐ phase diffusion model with given linewidth
 ☐ add quantum noise (one photon per spectral node)

double pulsing

separation

0

ps

relative magnitude

0

☒ create field in data array 1
 ☐ create field in data array 2
 ☐ add field to data array 1
 ☐ add field to data array 2

OK

Apply

Cancel

reset

self phase modulation / two photon absorption term

$$\frac{\partial A}{\partial z} = \dots + i\gamma(1 - f_R)|A(T)|^2A(T)$$

$$\gamma = \frac{\omega_0}{c} \frac{n_2}{A_{\text{eff}}} \text{ and } A_{\text{eff}} = \frac{\pi}{4} MFD^2$$

n2 m²/W
 fR
 TPA m/W

TPA is experimental so far

☐ saturate SPM
 saturation power GW/cm²

☒ use SPM and TPA
 ☐ exclude SPM

Gas filled silica hollow core fiber (fundamental mode)

predefined

more...

Helium

Argon (Börzsönyi et. al. 2008)

Neon (Börzsönyi et. al. 198)

Xenon

T0

273.15

K

B1

0.00322899

C1

40.301

B2

0.00355393

C2

59.578

B3

0.0606764

C3

112.74

actual

T

273.15

K

380000

Pa

fiber

inner structure thickness

100

nm

core diameter 2*R

800

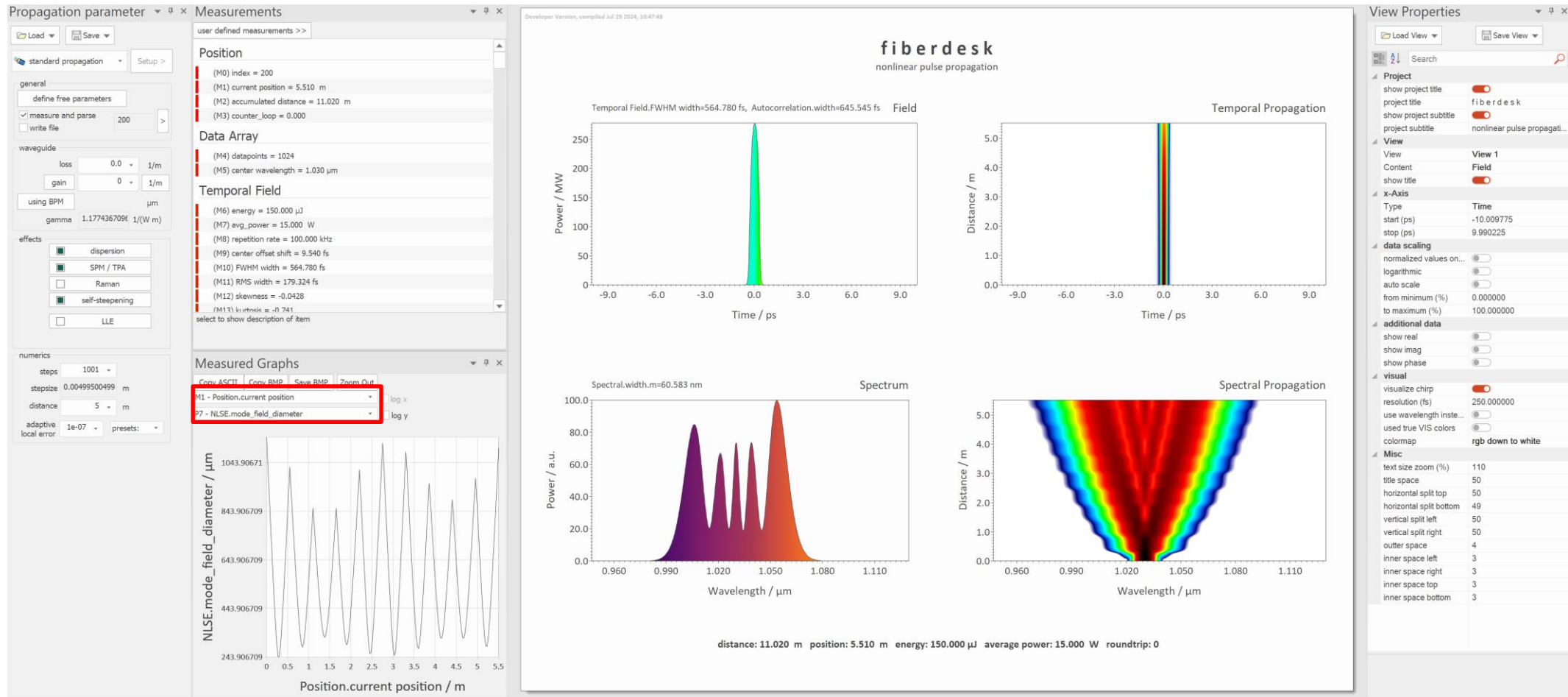
μm

OK

$$n = \sqrt{A + \frac{B_1\lambda^2}{\lambda^2 - C_1} + \frac{B_2\lambda^2}{\lambda^2 - C_2} + \frac{B_3\lambda^2}{\lambda^2 - C_3}}$$

Multi-Pass Cell

After propagation, the result looks like this, including the beam propagation in the measured graph.



Multi-Pass Cell

You can add the measurement of the B-Integral.

Please keep in mind that in comparison to the demonstration in lecture 1, in the example, the beam diameter changes and the calculation needs to be adapted like this:

user defined measurements

M87	0	0
M88	M15*P3/P4	1326476.04523002
M89	2*_pi*P5/M5/(_pi*(P7*1e-6/2)^2)	1.1774367096315e-09
M90	M88*M89	0.00156184159010063
M91	Sum("M90")	13.2176256434415
M92		0

☒ measure and parse

not switched on during propagation, no evaluation of
...asured values along the propagation length is done)

datapoints:

 from

 to

$$B = \int_0^L \gamma P_{Peak}(z) \cdot dz$$

with

$$\gamma = \frac{2\pi n_2}{\lambda A_{eff}}$$

M88 = $P_{Peak} \cdot L / \text{Steps} = M15 \cdot P3/P4$

M89 = $2 \cdot \pi \cdot n_2 / \lambda / (\pi \cdot (MFD_{\mu m} \cdot 1e-6/2)^2)$

M90 = $\gamma \cdot P_{peak} dz = M88 \cdot M89$

M91 = Sum(„M90“)

Hints:

- execution times are slowed down by complex measurements.
- Please check the meanings of the M values, as they might have changed in their number, depending on the actual version of fiberdesk

Multi-Pass Cell

The result resembles the publication graphs to a very good degree:

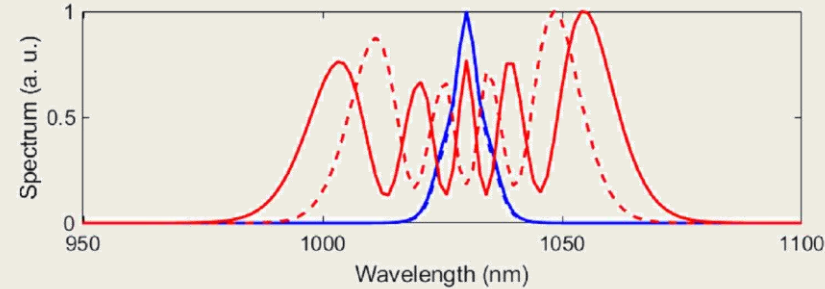
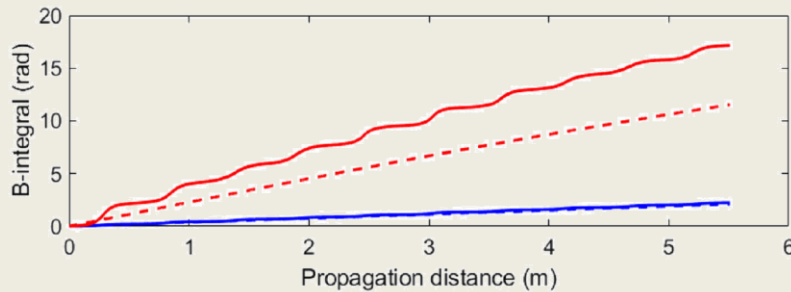
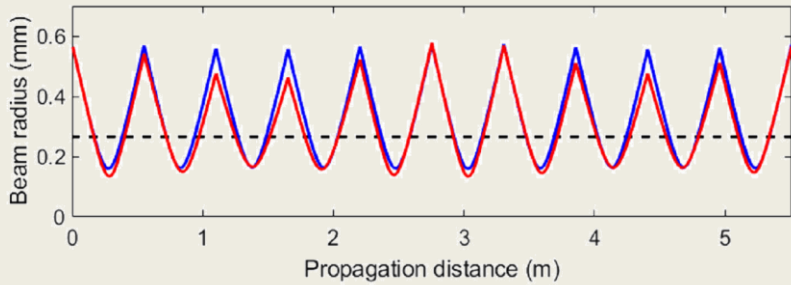
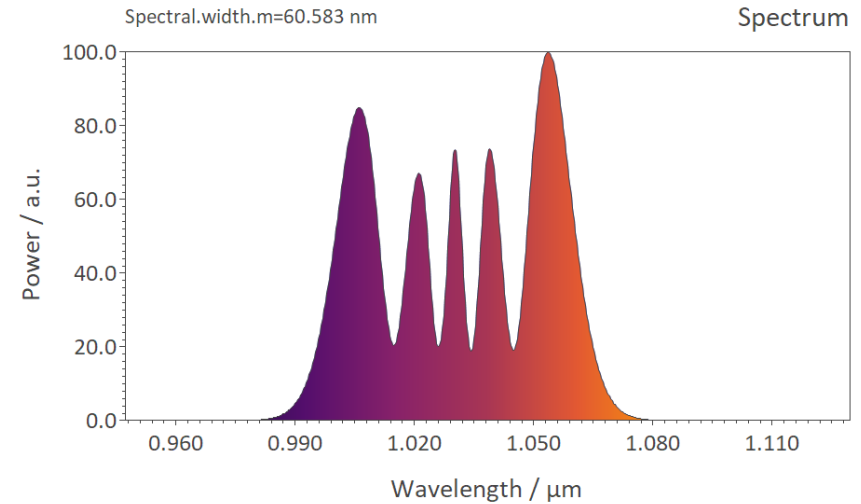
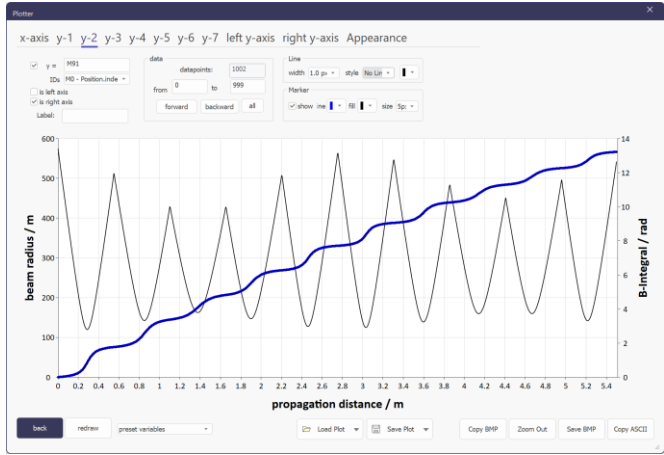
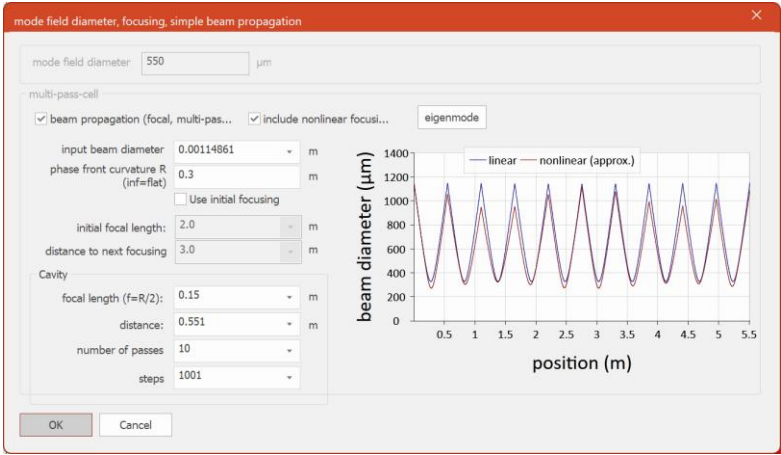


Fig 3 from: Nour Daher, Florent Guichard, Spencer W. Jolly, Xavier Délen, Fabien Quéré, Marc Hanna, and Patrick Georges, "Multipass cells: 1D numerical model and investigation of spatio-spectral couplings at high nonlinearity," *J. Opt. Soc. Am. B* 37, 993-999 (2020)