Leibniz Universität Hannover
Faculty of Mathematics and Physics
Institute of Quantum Optics

Title of the project

Student Project

Student name
Your name

Matr.-Nr.
Your student id.

E-mail
`Your e-mail address`

Supervisor
Your supervisor

Group
Theoretical Optics and Photonics

September 23, 2020

Abstract

Include a brief abstract with a low level of details, describing the topic and motivation of the student project.

Contents

1 Introduction

Introductory part specifying topic and context of the student project. It should briefly lay out what you are going to show in the project report. This is somewhat like a preview for the reader. To better link the project to the existing research literature, a brief summary of the original research article that was used as the starting point for the student project can be included. This brief summary should detail the topic of the article, the motivation of the presented study, and a list of the central findings of the article. Include about 30 references to support your report. Here you can find examples of how to format references to research articles [1], books [2], or other online media [3].

2 Methods

2.1 Mathematical model

Detail the computational problem studied in your student project. E.g., if you study the nonlinear Schrödinger equation you might start like this:

The computational problem studied in this student project is an initial value problem with periodic boundary conditions, consisting of the propagation of a complex-valued field $A(z,t)$ along the propagation coordinate z on a periodic t-domain of extend T, subject to the nonlinear Schrödinger equation (NSE)

$$\begin{cases} \partial_z A(z,t) = -\frac{i}{2}\beta_2 \partial_t^2 A(z,t) + i\gamma |A(z,t)|^2 A(z,t), & z \geq 0,\ -T/2 \leq t \leq T/2, \\ A(z,-T/2) = A(z,T/2), & z \geq 0, \\ A(z,t)|_{z=0} = A_0(t), & -T/2 \leq t \leq T/2. \end{cases} \tag{1}$$

The field $A(z,t)$ describes the complex envelope of an optical pulse and Eq. (1) models its z-propagation through a single-mode fiber governed by the group-velocity dispersion (GVD) parameter β_2, and the nonlinear parameter γ. The pulse dynamics is resolved in a frame of reference moving with the group velocity of the pulse.

2.2 Numerical method

Review numerical methods that are available to solve for the computational problem. Detail the numerical method you used to study the computational problem.

2.3 Implementation

If you like, elaborate on aspects of your implementation. An example of how to display a code-snippet is illustrated in code-listing 1. In particular, if you use a software development platform such as GitHub to host your developed code, you can point out and advertise that here. For a guide on how to structure your computational project, see Ref. [4].

Code-list. 1: Python function implementing a split-step Fourier method for solving the nonlinear Schrödinger equation.

```
def NSE_SSFM_simple(z, t, A0_t, beta2, gamma, nSkip):
    """Split step Fourier method using simple operator splitting

    Implements divide-and-conquer strategy to solve the nonlinear
    Schroedinger equation (NSE). Pulse propagation is performed
    using a simple splitting scheme.

```

```python
    NOTES:
        - uses abbreviations FT, specifying the DFT, and IFT,
          specifying its inverse. These are defined at the
          beginning of the script right beneath the imports.

    Args:
        z (array): samples along propagation distance
        t (array): time samples
        A0_t (array): time domain field envelope
        beta2 (float): 2nd order dispersion parameter
        gamma (float): nonlinear parameter
        nSkip (int): keep only each nSkip-th field configuration

    Returns: (z,Azt)
        z (array): z-samples at which field envelope is recorded
        Azt (array): resulting time domain field envelope
    """
    # -- convenient abbreviations
    dz = z[1]-z[0]
    dt = t[1]-t[0]
    # -- work arrays and data structures for results
    A_t = np.copy(A0_t)
    w = nfft.fftfreq(t.size,d=dt)*2*np.pi
    res_z = []; res_z.append(0)
    res_A = []; res_A.append(A0_t)

    for idx in range(1, z.size):
        # -- nonlinear sub-step
        A_t = A_t*np.exp(1j*gamma*np.abs(A_t)**2*dz)
        # -- linear sub-step
        A_t = IFT(np.exp(0.5j*beta2*w*w*dz)*FT(A_t))
        # -- store intermediate results
        if idx%nSkip==0:
            res_z.append(z[idx])
            res_A.append(A_t)

    return np.asarray(res_z), np.asarray(res_A)
```

3 Results

Summarize the numerical experiments carried out during your student project. Include figures like Fig. 1 to illustrate your findings. For a guide on publication ready scientific figures, see Ref. [5]. Take care to include enough detail so that someone reading your report is able to reproduce the results. Use subsections to structure your results in a meaningful way.

4 Discussion & Summary

Give a brief summary of what you did during your student project. This should also include the main results you obtained in the course of your project work.

Appendix

A Source code

You can list all your code as appendix. If you host your code on GitHub you can also point this out here.

References

[1] N. Akhmediev and M. Karlsson. Cherenkov radiation emitted by solitons in optical fibers. *Phys. Rev. A*, 51:2602–2607, 1995.

[2] P. G. Drazin and R. S. Johnson. *Solitons: An Introduction*. Cambridge University Press, Cambridge, 1989.

[3] E. Jones, T. Oliphant, P. Peterson, et al. SciPy: Open source scientific tools for Python. http://www.scipy.org/, 2001–2018. [Online; accessed 2020-03-09].

[4] W. S. Noble. A Quick Guide to Organizing Computational Biology Projects. *PLoS Comput. Biol.*, 5:e1000424, 2009.

[5] N. P. Rougier, M. Droettboom, and P. E. Bourne. Ten Simple Rules for Better Figures. *PLoS Comput. Biol.*, 10:e1003833, 2014.

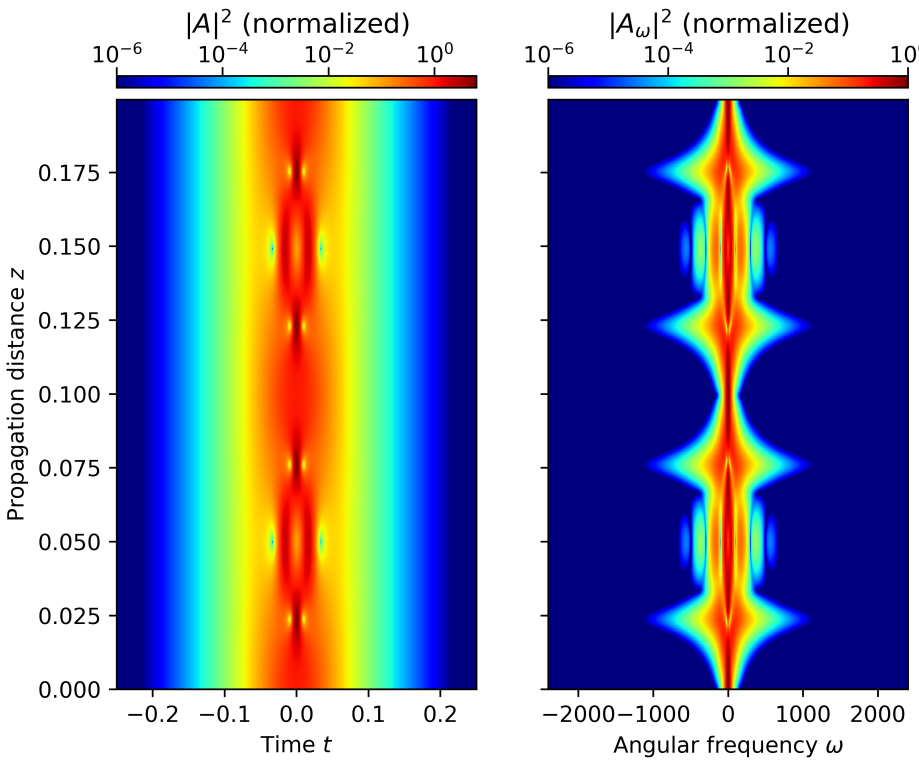

Fig. 1: Evolution of the intensity (left) and spectral intensity (right) for a soliton of order $N = 3$ governed by Eq. (1).