



HAL
open science

Temporal analogue of the Fresnel diffraction by a phase plate in linear and nonlinear optical fibers

Anastasiia Sheveleva, Christophe Finot

► **To cite this version:**

Anastasiia Sheveleva, Christophe Finot. Temporal analogue of the Fresnel diffraction by a phase plate in linear and nonlinear optical fibers. Conference on Lasers & Electro-Optics Europe, Jun 2021, Munich, Germany. pp.EP-P9. hal-03183263

HAL Id: hal-03183263

<https://hal.science/hal-03183263v1>

Submitted on 31 May 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Temporal analogue of the **Fresnel diffraction** by a phase plate in linear and nonlinear optical fibers

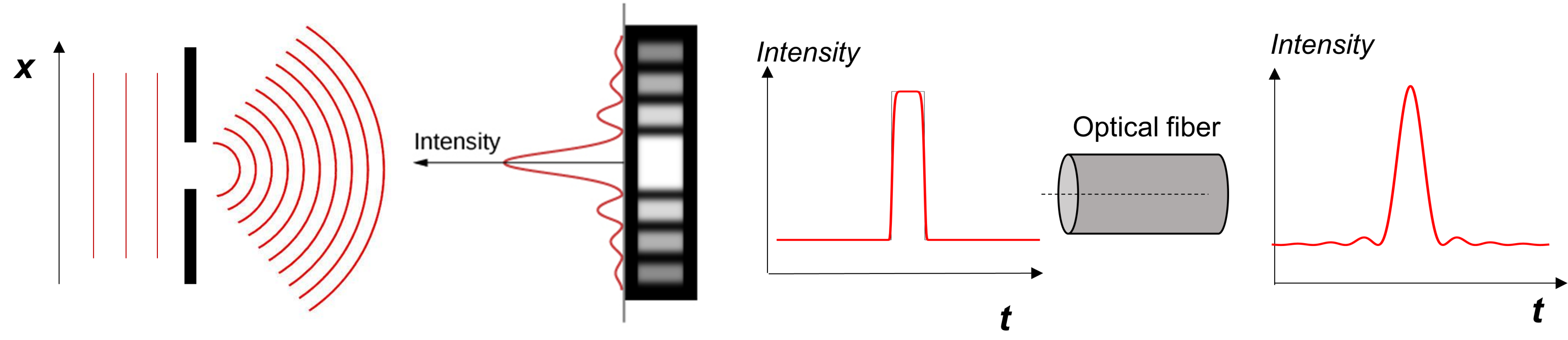
A. Sheveleva, C. Finot

Laboratoire Interdisciplinaire Carnot de Bourgogne, UMR 6303 CNRS-Université Bourgogne Franche-Comté, 21000 Dijon, France

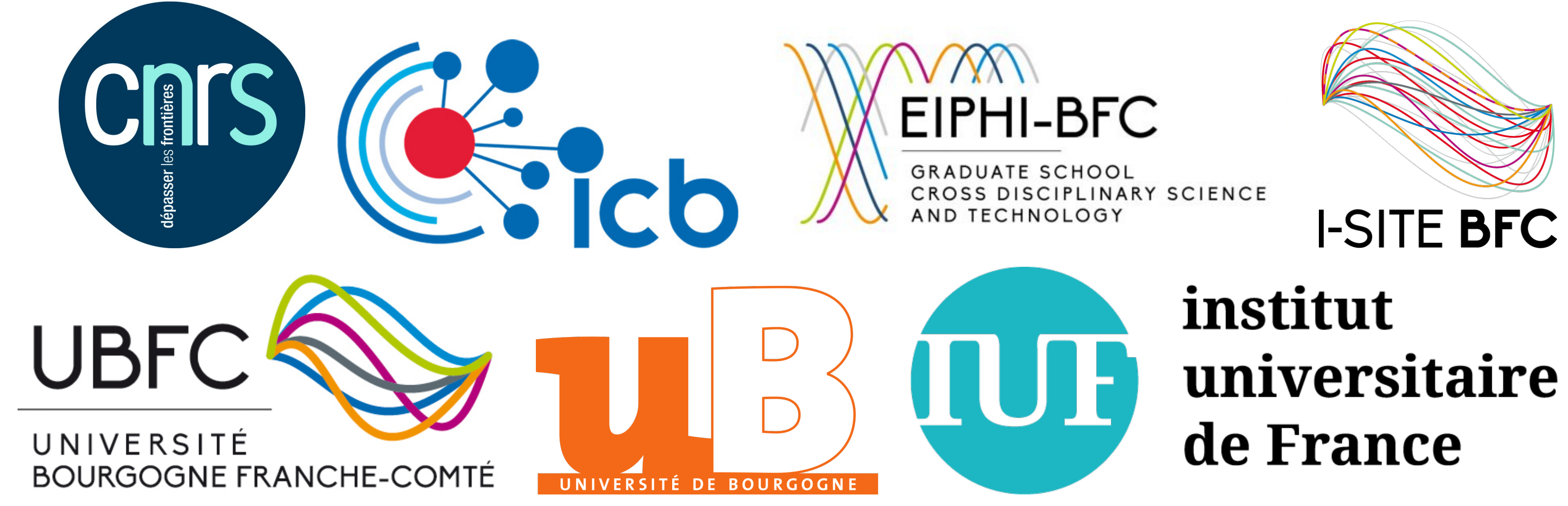
Introduction

SPACE : DIFFRACTION

TIME : DISPERSION

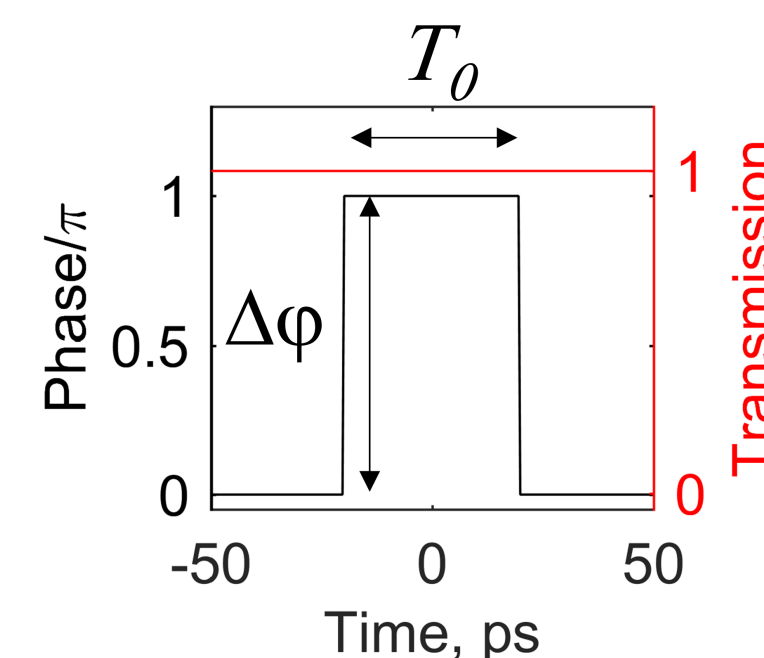
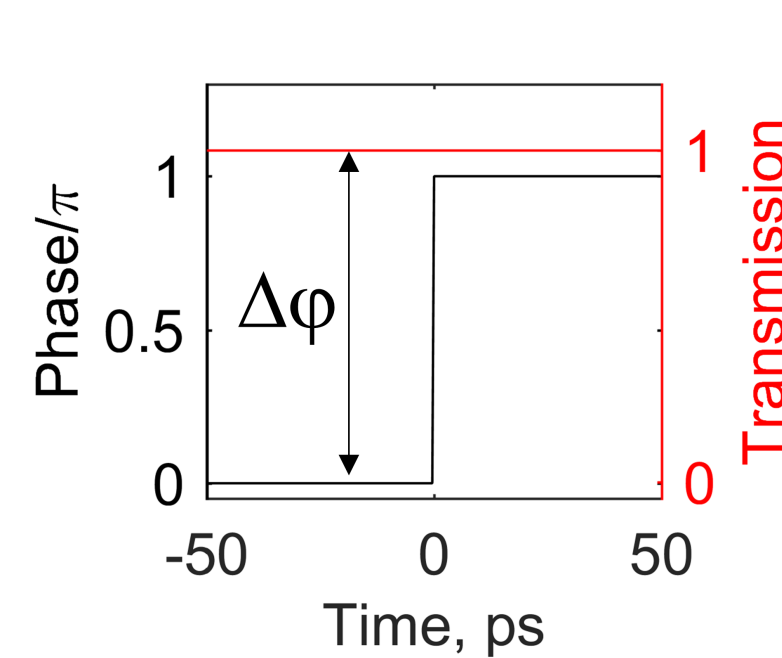
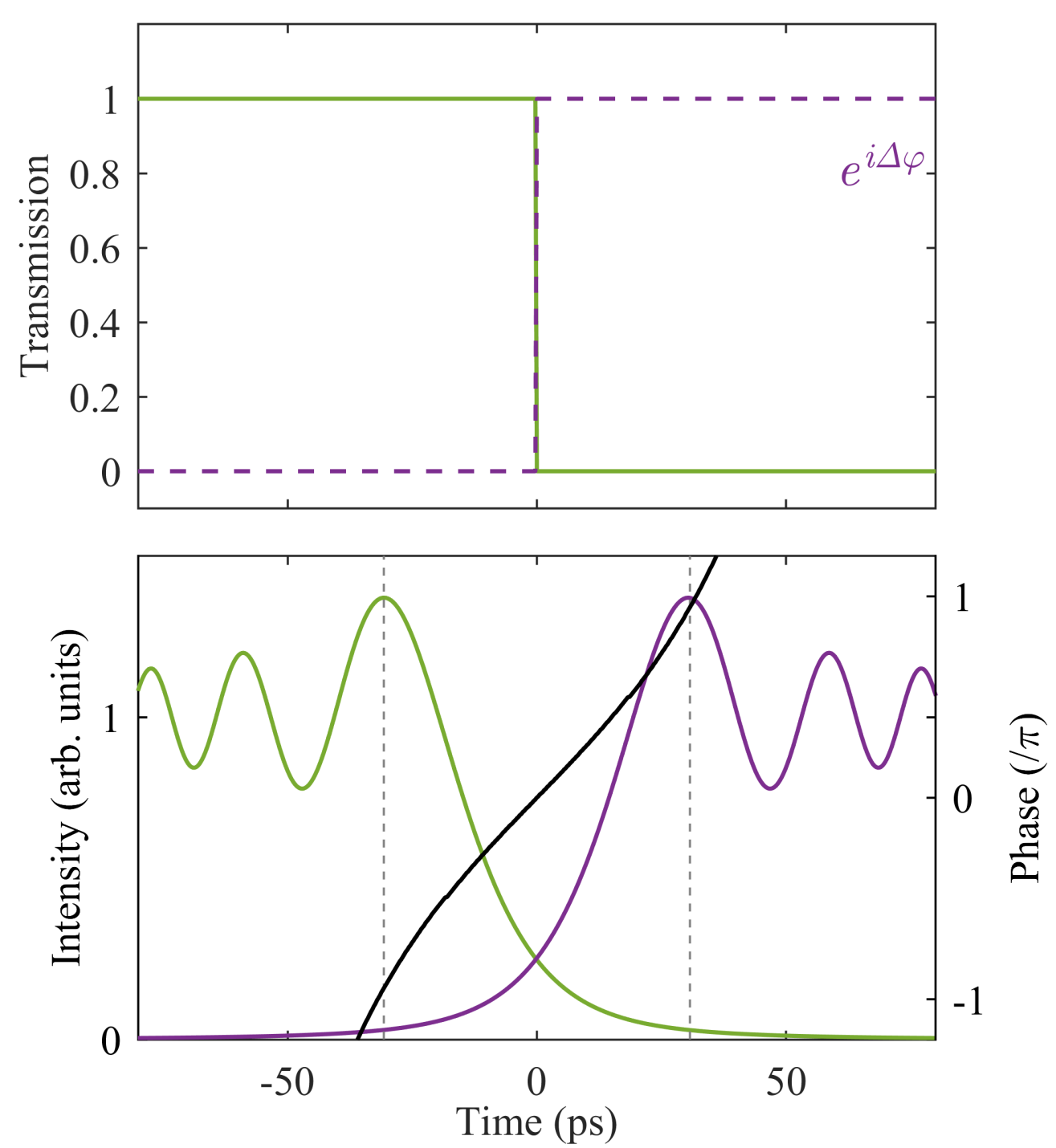


⇒ we can observe spatial phenomena in the ultrafast optics
⇒ we consider Fresnel diffraction on phase plates

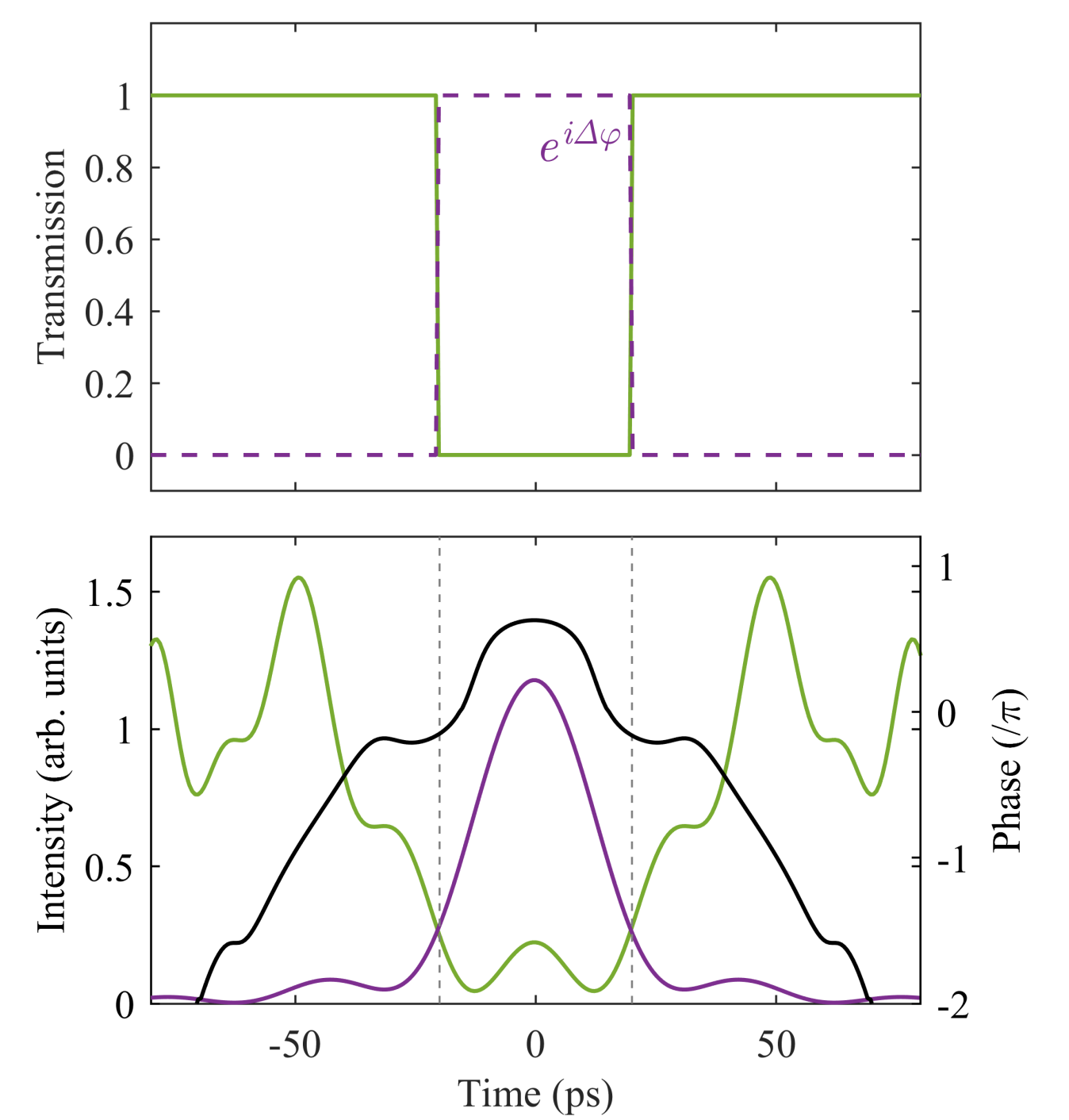


INTERPRETATION

Single phase transition



Double phase transition

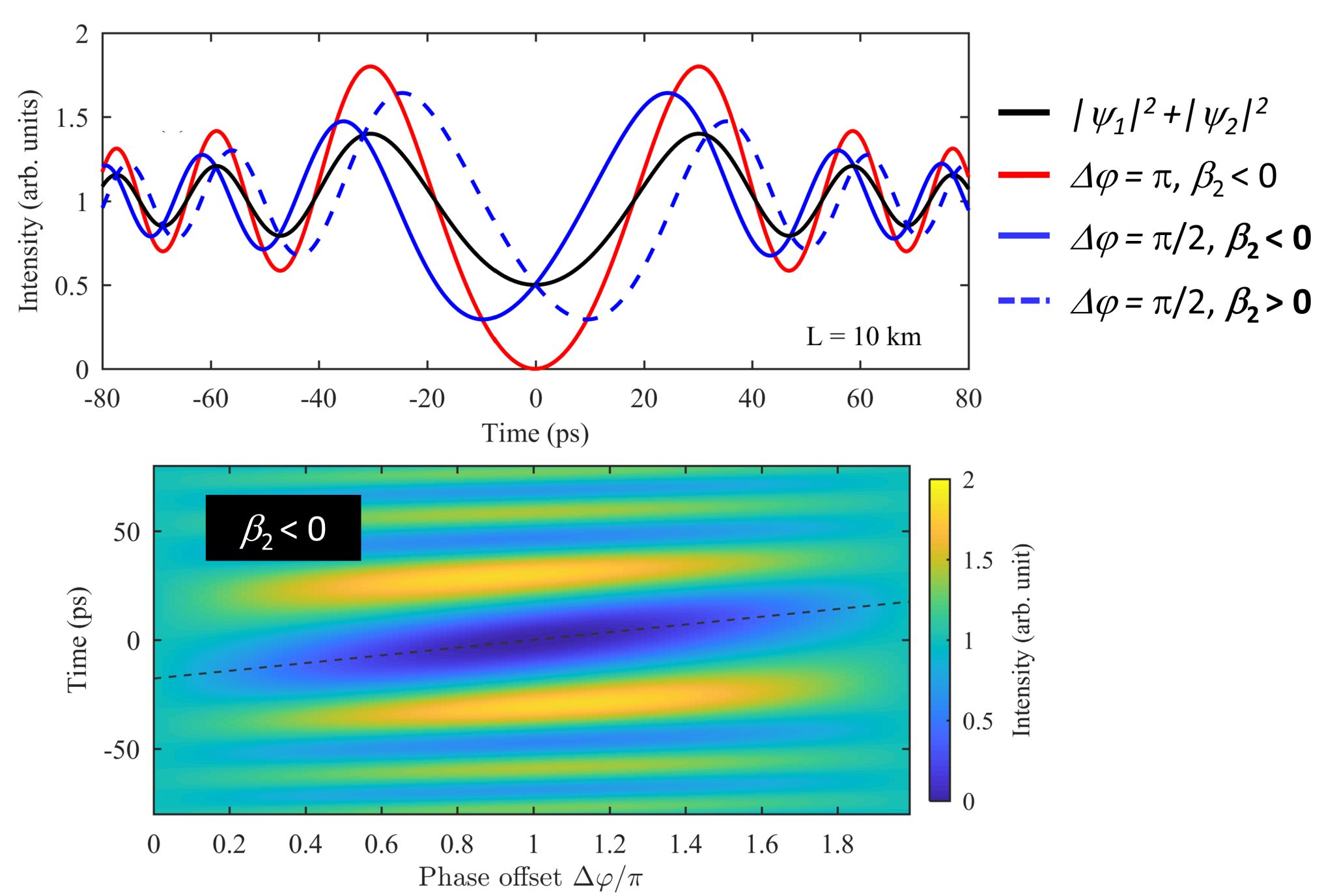


The phase transitions can be decomposed into **two semi-infinite screens** or into **opaque stripe and slit**, with one of the components additionally imprinting $\Delta\phi$ phase.

Output wave is the result of **two-waves interference**, where the intensity profile is defined by **the phase difference** (black lines) and is highly-dependent on $\Delta\phi$.

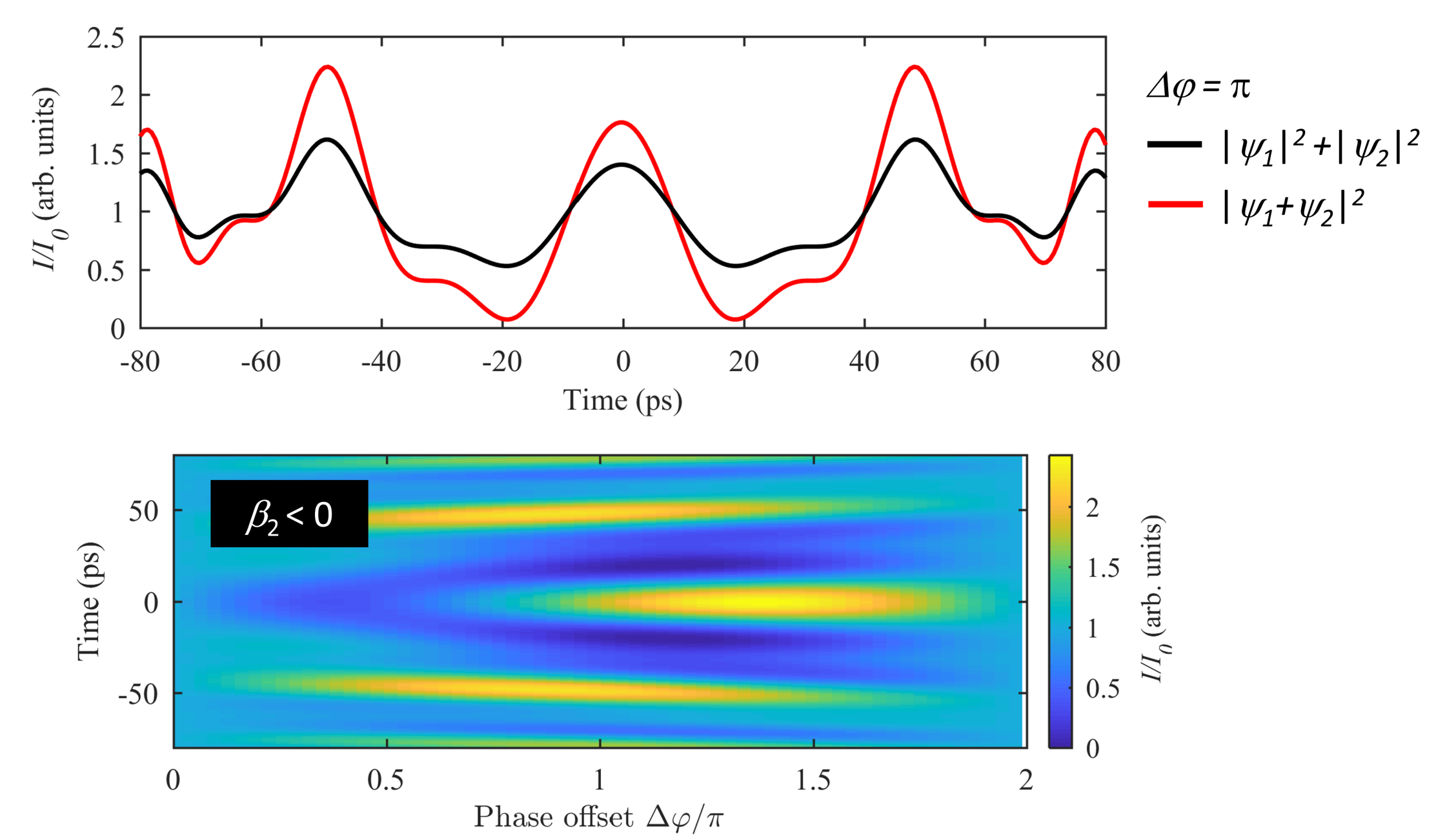
In all numerical (analytical) simulations we consider propagation in 10 km SMF-28 fiber with $\gamma = 1.1 / \text{W/km}$, $\beta_2 = \pm 20 \text{ ps}^2/\text{km}$

LINEAR PROPAGATION

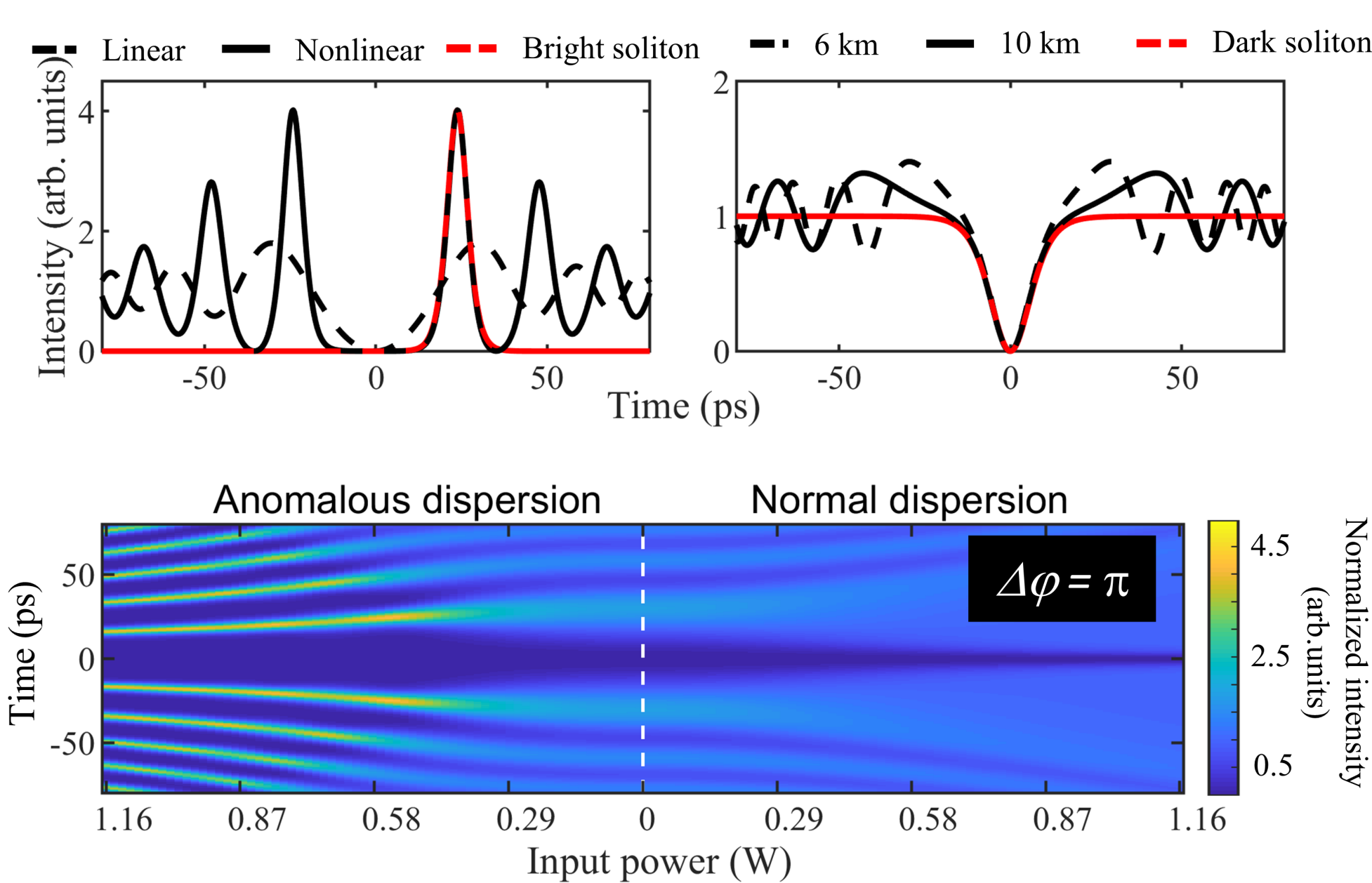


The waveforms are described by the **Fresnel integrals** (with the respective treatment and transitions to fiber optics).

- for the **single phase jump** one observes asymmetric profiles depending on $\Delta\phi$ and regime of dispersion
- for the **double phase jump** the intensity profiles are always symmetric with respect to $t = 0$, however it can be flipped with respect to $\Delta\phi = \pi$ in case of the opposite dispersion regime



NONLINEAR PROPAGATION

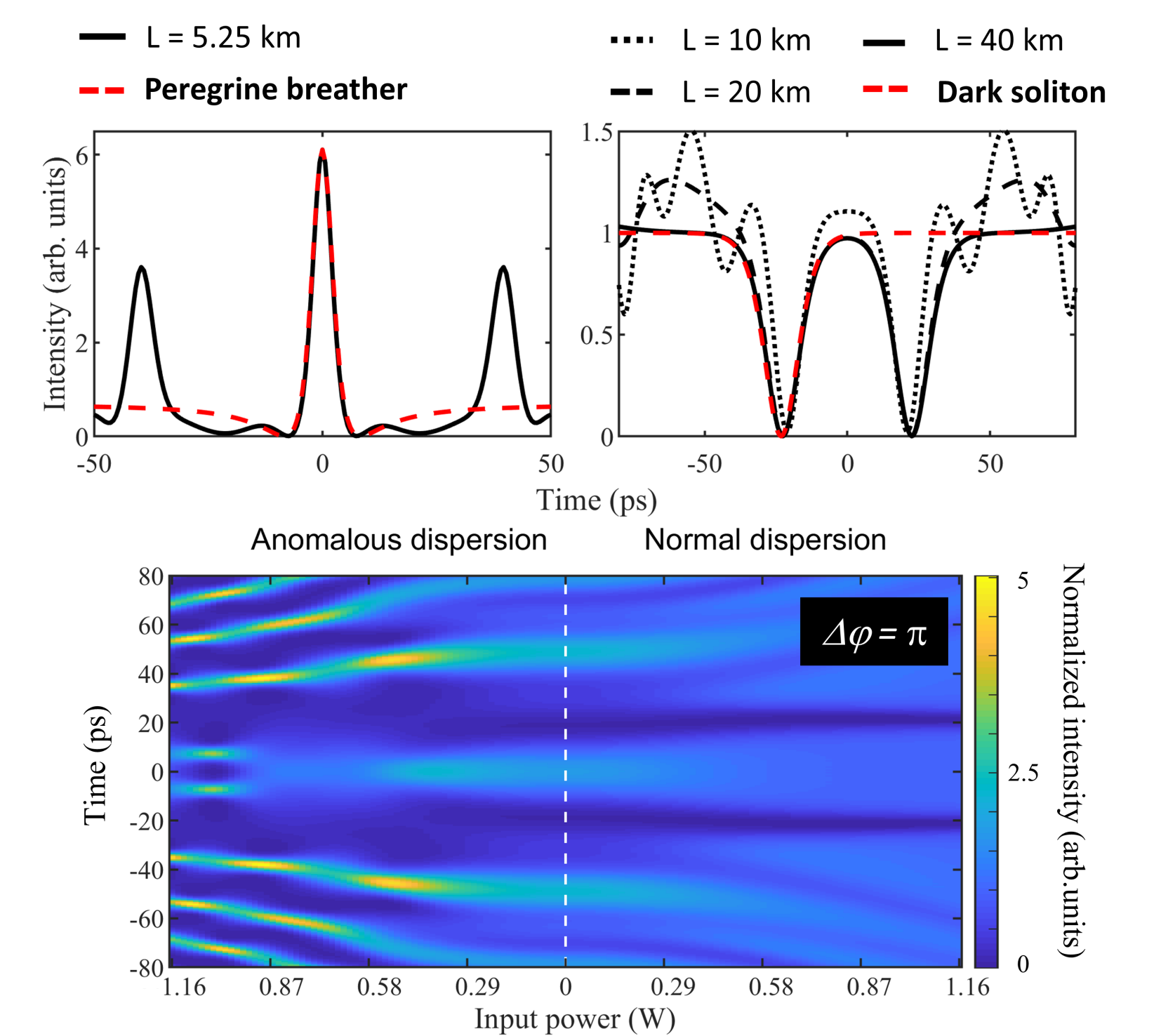


Nonlinear Schrodinger equation (NLSE) :

$$\frac{\partial a(t, z)}{\partial z} + i \frac{\beta_2}{2} \frac{\partial^2 a(t, z)}{\partial t^2} + i \gamma |a(t, z)|^2 a(t, z) = 0$$

Existing intensity peaks trigger nonlinear effects leading to formation of **coherent structures** throughout the propagation :

- **bright and dark solitons** in case of the single phase jump
- **a Peregrine breather and a pair of dark solitons** in case of the double phase jump



Conclusion

We study temporal intensity patterns emerging from diffraction by a phase plate.

- the results are interpreted in terms of interference of the diffracted waves on edge, stripe and slit
- in case of purely linear evolution a complete analytical framework is provided
- Kerr nonlinearity leads to the emergence of coherent structures

References

1. V. Torres-Company, J. Lancis, and P. Andrés, "Chapter 1 - Space-Time Analogies in Optics," in Progress in Optics, E. Wolf, ed. (Elsevier, 2011), pp. 1-80.
2. F. A. Jenkins and H. E. White, Fundamentals of optics - 4th edition (McGraw-Hill Inc., US, 1976).
3. M. Amiri and M. T. Tavassoly, "Fresnel diffraction from 1D and 2D phase steps in reflection and transmission modes," Optics Communications 272, 349-361 (2007).
4. A. Sheveleva and C. Finot, "Temporal Fresnel diffraction induced by phase jumps in linear and nonlinear optical fibres," Results in Physics 19, 103344 (2020).

