October 4th, 2021

Ken Mishina

Assignment

1 Plot spectrum

Answer the following problems and make a report.

Deadline target: October 12th

Problem

1.1 MATLAB Simulation

- Consider the following rectangular pulse $v(t)$

$$v(t) = \begin{cases} A, & |t| \leq \tau/2 \\ 0, & |t| > \tau/2 \end{cases} \quad (1)$$

- Draw rectangular pulse $|v(t)|^2$ and power spectral density $S(f)$ for $A = 1\ [\sqrt{\mathrm{mW}}], \tau = 25\ [\mathrm{ps}]$, observation time T (FFT window size) of 1.024 ns., number of sampling point of 2048 (=2^{11}).
- Check the Parceval's theorem.

$$\sum_{j=1}^{N} |v(j)|^2 = \sum_{k=1}^{N} \frac{|V(k)|^2}{N} \quad \text{and} \quad \frac{1}{T}\sum_{j=1}^{N} (|v(j)|^2)\Delta t = \sum_{k=1}^{N} \left(\frac{|V(k)|^2}{N}\Delta t\right)\Delta f$$

1.2 Fourier transform

Derive the Fourier transform $V(f)$ for the rectangular pulse $v(t)$ in eq. (1) theoretically.

2 GVD-induced pulse broadening

Answer the following problems and make a report.

Deadline target: October 22nd

<u>Problem</u>

2.1 Theoretical derivation

Derive eq. (3) from eq. (2)

Input pulse

$$A(0,T) = \exp\left(-\frac{T^2}{2T_0^2}\right) \quad \cdots (2)$$

Output pulse

$$A(z,T) = \frac{T_0}{\sqrt{T_0^2 - i\beta_2 z}} \exp\left[-\frac{T^2}{2(T_0^2 - i\beta_2 z)}\right] \quad \cdots (3)$$

Hint: See Section 3.2 "Dispersion-Induced Pulse Broadening" in [Ref. 1].

[Ref. 1] Govind P. Agrawal, "Nonlinear Fiber Optics", Cambridge, MA: Academic Press, 2012.

2.2 MATLAB Simulation

- Simulate "dispersion-induced pulse broadening" by the following step.

  Step 1. Prepare a Gaussian pulse $A(0,T)$ as initial waveform ($z = 0$)

  $$A(0,T) = \exp\left(-\frac{T^2}{2T_0^2}\right)$$

  Step 2. Compute the Fourier transform of the initial Gaussian pulse using Fast Fourier transform (FFT).

  Step 3. Compute the frequency spectrum at $z = L$

  Step 4. Compute the inverse Fourier transform of the spectrum after the propagation using IFFT.

  Step 5. Draw the pulses in time domain and the spectra in frequency domain before and after the propagation.

- Parameters:

  $T_0 = 12.5,\ 25$ [ps] , $L = 25,\ 50$ [km], $D = 17$ [ps^2/km], $\lambda = 1550$ [nm], $\beta_3 = 0$

  Observation time (FFT window size) of 512 ps.

  Number of sampling point of 2048 (=2^{11}).

3 Dispersion analysis on slab waveguide

Answer the following problems and make a report.

Deadline target: November 5th

3.1 Derive the eigenvalue equations (2.12) and (2.13) in [Ref. 2] from Maxwell's equations.

3.2 Derive Eq. (2.25) from Eqs (2.12) and (2.13) in [Ref. 2].

3.3 Draw dispersion curves for the TE mode in the symmetric slab waveguide shown in Fig.1 (like Figure 2.6 in [Ref. 2]).

3.4 Draw representative electric field distributions in the symmetric slab waveguide shown in Fig. 1. For example, use the parameters: Normalized frequency $v = 4$, $a = 1$, $m = 0, 1, 2$ (TE_0, TE_1, TE_2 mode)

[Ref. 2] Katsunari Okamoto, "Fundamentals of Optical Wavuguides, 2nd edition", Cambridge, MA: Academic Press, 2006.

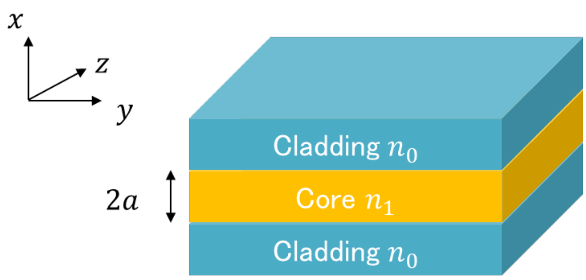

Fig.1

- Parameters: $a = 25\ \mu\text{m}$, $A = 1\sqrt{\text{mW}}$, $n_1 = 1.444$, $n_0 = 1.440$, $\lambda = 1.55\ \mu\text{m}$, $m = 0,1,\ 2$.
- Observe change of the electric field distributions varying the core size a

Example of output (Problem 1.3 and 1.4):