OptiSystem
Optical Communication System
and Amplifier Design Suite

Photonic Crystal Fiber Supercontinuum Generation

Applications

- Supercontinuum generation, pulse compression, solitons, etc.
- Bio-chemical and environmental sensing
- High-power beam delivery
- Extreme zero-dispersion wavelengths, dispersion flattened fibers, etc.
- Polarization maintaining and single-mode application
- Nonlinear processing
- Lasers and amplifiers
- Dispersion compensation

OptiMode Software Features

- VFEM mode solver is extraordinarily fast
- Triangular mesh can be adapted to accurately approximate the fine features of the geometry, refractive index profile and the electromagnetic fields
- Built-in VB scripting capabilities accelerate the design and optimization of complex waveguide profiles
- Exploiting the symmetric boundary conditions reduces the simulation domain, and modes of certain symmetry can be readily targeted
- Supports lossy, dispersive, and anisotropic materials in full-vector formulation
- Uniaxial perfectly matched layer (UPML) allows modeling leaky modes

OptiSystem Software Features

- Rapid prototyping of complex optical systems using extensive libraries of optical components
- Comprehensive libraries of linear and nonlinear propagation models
- Broad temporal and spectral visualization capabilities for signals along the optical systems
- Co-simulation with external software packages such as Matlab, Python, Scilab, and C++
- Compatible with other Optiwave software products such as OptiSPICE, OptiGrating and OptiBPM

Overview

Photonic crystal fiber (PCF) provides a unique platform for realizing the desired dispersion, birefringence, confinement, and mode multiplicity characteristics for myriad of applications. This can be attributed to the freedom in designing the shape, size and arrangement of holes and material composition of the PCF. Using the vector finite element method (VFEM) mode solver in OptiMode, modal analysis of arbitrary PCF designs can be performed, and the linear/nonlinear fiber model characteristics can be extracted. The parameters of the PCF can be used in OptiSystem to simulate the evolution of signals and to asses system performance.

Simulation Description

A solid-core silica PCF used for supercontinuum generation [1,2] is considered. Fig. 1 shows the fiber structure with the air-holes (diameter=1.3μm) arranged in the triangular lattice (pitch=1.7μm). Imposing the symmetric electric/magnetic boundary conditions along the X/Y axes in OptiMode reduces the simulation domain by a factor of 4. The triangular mesh is adapted to have finer resolution in the core in order to accurately approximate air-hole boundaries.

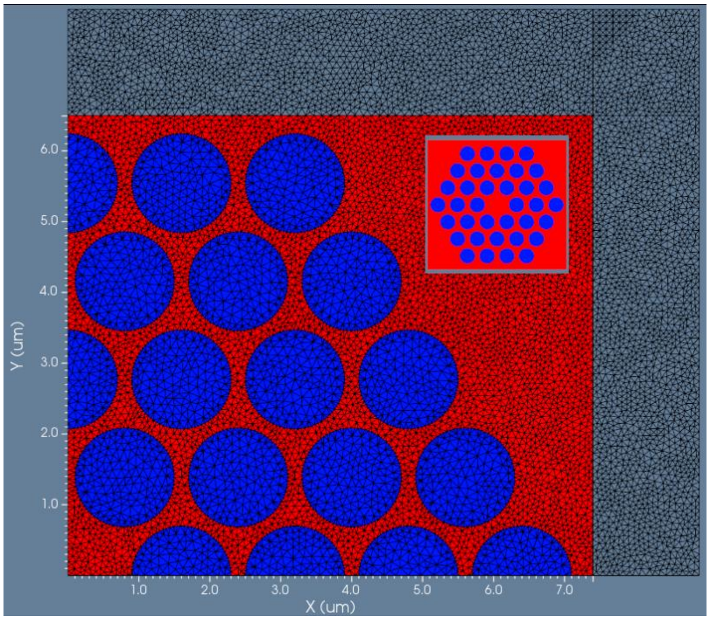

Figure 1: Schematic of the PCF (inset) and the actual simulation window with the FEM mesh superimposed.

Employing the modal analysis by the VFEM solver in OptiMode, the obtained fiber model parameters are listed in Table 1. The effective area, group velocity dispersion (GVD) and the 3rd order dispersion (TOD) can be calculated from the field profile of the fundamental mode at the pump wavelength (depicted in Fig. 2). The dispersion and effective modal index are shown in Fig. 3. The dispersion and the zero-dispersion wavelength (780nm) match the values reported in references [1,2]. Assuming typical values for the nonlinear refractive index of silica (n_2=3.5x10^{-20} m^2W^{-1}) and fractional Raman contribution to the nonlinear polarization (f_R=0.18), a supercontinuum can be generated from a 50fs input sech pulse with 10kW peak power in OptiSystem software. The temporal and spectral evolution of the pulse is shown in Fig. 4. Self-phase modulation, intra-pulse Raman scattering and self-steepening effects are considered in the nonlinear fiber model implemented in OptiSystem.

Another example related to the perturbation of an ideal soliton pulse by higher order dispersion and Raman scattering in the PCF is simulated in OptiSystem. A 20fs fundamental soliton pulse at 835nm with 837.56W peak power is considered. A comparison of the spectral and temporal shapes of the ideal case (balanced self-phase modulation and GVD induced broadening) and the perturbed case after 1m of propagation in the PCF is shown in Fig. 5.

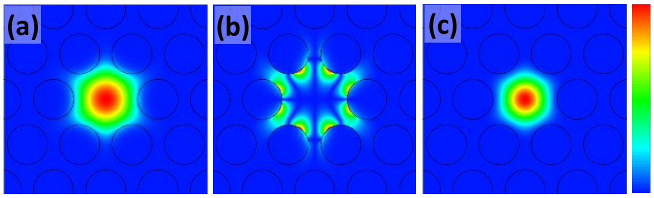

Figure 2: Electric-field amplitude profile (a) $|E_x|$, (b) $|E_y|$ and (c) power density (Poynting vector) of the X-polarized fundamental mode of the PCF at 835nm wavelength.

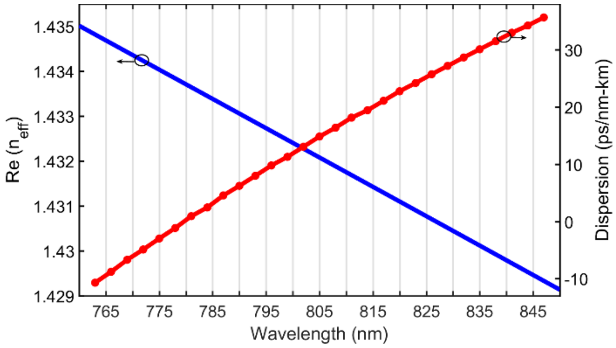

Figure 3: Modal effective index and dispersion parameter of the fundamental mode of the PCF calculated in OptiMode.

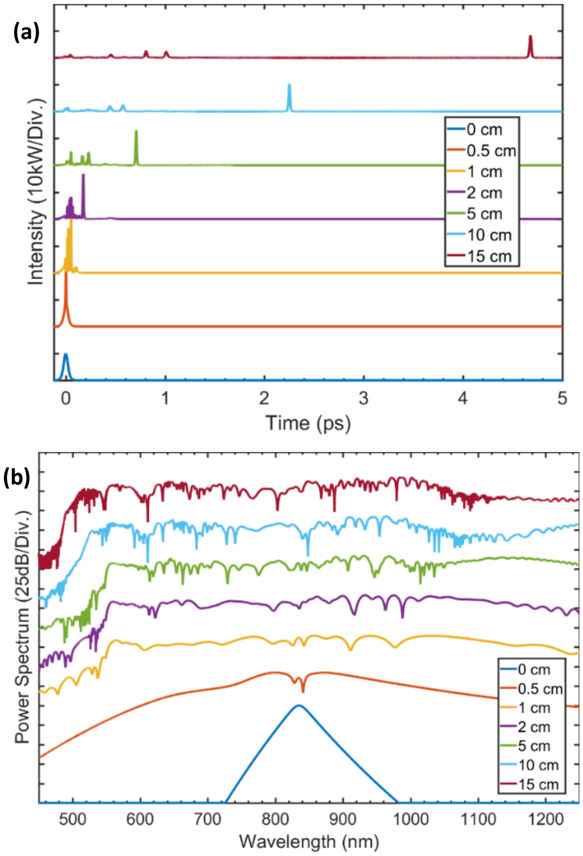

Figure 4: OptiSystem simulation results of the Evolution of a 50fs (FWHM) soliton pulse with 10KW peak power at 835nm wavelength after propagating different distances along the PCF: (a) temporal (b) spectral (50dB offset between the curves).

Table 1: PCF characteristics at λ=835nm obtained from OptiMode and used to simulate nonlinear pulse propagation in OptiSystem.

Group velocity dispersion (β_2)	-11.46 ps^{2}km^{-1}
Third order dispersion (β_3)	8.10x10^{-2} ps^{3}km^{-1}
Modal effective area (A_{eff})	2.41 μm^2

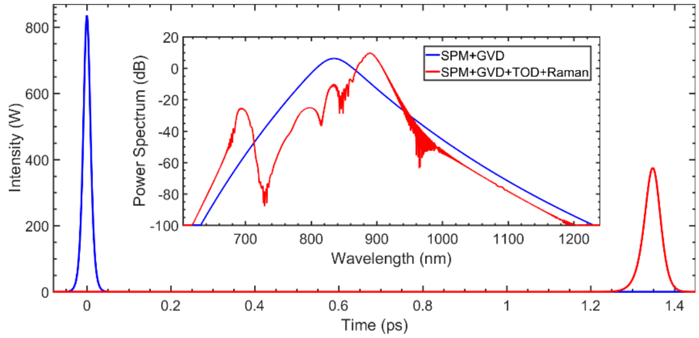

Figure 5: OptiSystem simulation of a 20fs soliton pulse at 835nm with peak-power of 837.56W after propagating 1m in the PCF.

References

[1] J. Ranka et al., "Visible continuum generation in air–silica microstructure optical fibers with anomalous dispersion at 800 nm," Opt. Lett. 25, 25 (2000).

[2] J. M. Dudley et al., "Supercontinuum generation in photonic crystal fiber" Rev. Mod. Phys. 78, 1135 (2006)