The influences of dispersions on supercontinuum in photonic crystal fiber

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Abstract. The generation of supercontinuum (SC) is the result of nonlinear effect and dispersion. In order to better understand the broadening mechanism of SC, this paper studies the influences of various dispersions on SC generation and evolution in photonic crystal fiber.

1. Introduction
Supercontinuum (SC) has many advantages, for example, wide spectral range, good stability, and excellent coherence. SC has become a research hotspot and has been widely used in many fields, such as communication, biomedicine, astronomy, industry and military[1-5].

In recent years, with the continuous improvement of laser and the continuous development of ultrashort pulse laser technology, the spectral width of SC is becoming wider and wider. More and more media can be used to produce SC, such as optical fiber, silicon waveguide, and bulk media. Silicon waveguide has the advantages of high nonlinearity, flexible dispersion parameter control and easy integration. However, due to the large loss caused by two-photon absorption effect, the spectrum broadening is limited, and with the increase of initial peak power, the spectrum broadening will appear saturation phenomenon. The power of SC generated by bulk transparent media is high, but it is not easy to generate ultra wideband and flat SC. Microstructured fiber is a very effective medium for SC generation. The flexibility of its structure design and special light guiding mechanism make it have incomparable advantages compared with traditional fiber. The microstructure in the cladding of photonic crystal fiber can make it present many characteristics that traditional fiber does not have, such as no cut-off single mode, adjustable zero dispersion point, and high birefringence. The dispersion characteristics can be changed by changing the air hole size and duty cycle of photonic crystal fiber. Combined with the current mature high-power fiber laser as its pumping source, the SC light source with high power, high flatness and wide band can be realized. By changing the structure of photonic crystal fiber, we can flexibly adjust its dispersion characteristics, so as to produce broadband and flat SC. Moreover, the high-power SC based on photonic crystal fiber can realize single-mode transmission in a wide frequency range [5-11].

In this paper, the influences of dispersion effects on SC in photonic crystal fiber are studied.

2. Theoretical Model
The model for pulse propagation in photonic crystal fiber is

\[
\frac{\partial A}{\partial z} + \frac{\alpha}{2} A + \sum_{m=2}^{\infty} i^{m-1} \frac{\beta_m}{m!} \frac{\partial^m A}{\partial T^m} = i\gamma |A|^2 A
\] (1)
where $A$ is the pulse envelope; $\alpha$ is fiber loss coefficient; $\beta_m$ which is dispersion coefficient of each order; $T$ is time scaled, and $\gamma$ is the nonlinearity coefficient which correspond to the $\gamma = 10.44e^{-5}$ w$^{-1}$cm$^{-1}$.

3. Numerical Simulation Analysis

The selection of photonic crystal fiber materials and the design of its structure determine its characteristic parameters, which affect the SC generation in photonic crystal fiber.

The properties of SC are discussed. In this paper, the evolution process of SC generated by 1550 femtosecond pulse propagating in photonic crystal fiber is numerically simulated by split step Fourier algorithm.

The influences of dispersion parameters of photonic crystal fiber on SC are studied.

The following is the simulations. The peak power ($P_0$) is 8 Kw, and the full width half maximum (FWHM) is 100fs.

(a) waveform

(b) spectrum
Fig1. Supercontinuum generated in the anomalous group velocity dispersion region ($\beta_2 = -206.00 \text{ fs}^2/\text{cm}$, and $\beta_3 = -0.05 \text{ e}^4 \text{ fs}^3/\text{cm}$)

(a) Waveform

(b) Spectrum
Compared fig 1, fig 2, fig 3 and fig 4, the SC spectrum oscillation is severe and the flatness is poor for in the anomalous group velocity dispersion region, while SC spectrum oscillation and flatness are good in the normal group velocity dispersion region. Third order dispersion is unfavorable for SC generation and evolution.
Fig. 3 supercontinuum generated in the normal group velocity dispersion region ($\beta_2=206.00 \text{ fs}^2/\text{cm}$, and $\beta_3=-0.05\times10^4 \text{ fs}^3/\text{cm}$)

Fig. 4 supercontinuum generated in the normal group velocity dispersion region ($\beta_2=206.00 \text{ fs}^2/\text{cm}$, and $\beta_3=0.05\times10^4 \text{ fs}^3/\text{cm}$)
4. Conclusion
In this paper, the influence of dispersion of photonic crystal fiber on SC generation is analyzed by numerical simulation. Third order dispersion is harmful to SC generation. Further study shows that photonic crystal fiber with minimal normal group velocity dispersion and small third-order dispersion is very effective for generating flat and ultra wide SC.

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