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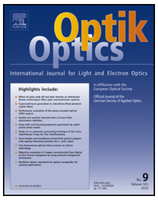

Original research article

Tunable microwave generation method based on birefringence photonic crystal fiber

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ABSTRACT

A new method is proposed to generate tunable microwave by using single-light source and birefringence photonic crystal fiber (PCF), which is based on the interaction and the coupling between the two polarizations of the initial Gaussian optical pulse in PCF. A full vector finite element is used to design a high birefringence PCF. The expressions of the microwave are derived by couple-mode theory. The proof of concept device consists of a light source, a birefringence PCF, a polarizer controller and a photodetector. The frequency of the generated pulses can be controlled by adjusting the parameters of the optical fiber system. The simulation results demonstrate the system can generate the frequency of microwave are 8.03–37.67 GHz and 26.82–125.5 GHz from two kinds of PCFs, respectively. The system is elastic, stable, brief and highly efficient.

1. Introduction

To provide high quality and capacity telecom service, microwave communication and optical fiber communication have been developed. Comparing with traditional electrical method, optical generation of microwave signal has attracted increasingly attention with its significant advantages. A number of techniques have been proposed for photonic microwave generation, such as optical injection locking [1], electro-optic phase modulation [2], electro-absorption modulator [3] and a very practical heterodyne method, which beats two laser beams to generate microwave signal [4], etc.

Photonic crystal fibers (PCFs) have gained considerable attention over the last decade years since first demonstrated in 1996 by Russell [5]. Compared with the normal optical fibers, PCFs have various particulars like endless single mode operation [6], controllable dispersion [7,8], high birefringence [9,10] etc. Already these properties have been widely used for fiber optics sensing [11], nonlinear fiber optics[12],precision optical instruments [13] and fiber optics communication fields [14]. As for total internal reflection PCF, making the two orthogonal directions of holes have different sizes, the fiber can obtain high birefringence. The excellent properties of high birefringence PCF have been widely used for optical fiber sensor [15], optical fiber polarization coupler [16], optical filter [17] and so on.

In this paper, we discuss a new optical method to synthesize microwave pulses. The method is based on single-light source and high birefringence PCF in order to generate microwave pulses. The effect is analyzed theoretically in an optical system based on pulse propagation in a high birefringence PCF. Results are given when the nonlinear effect can be neglected.

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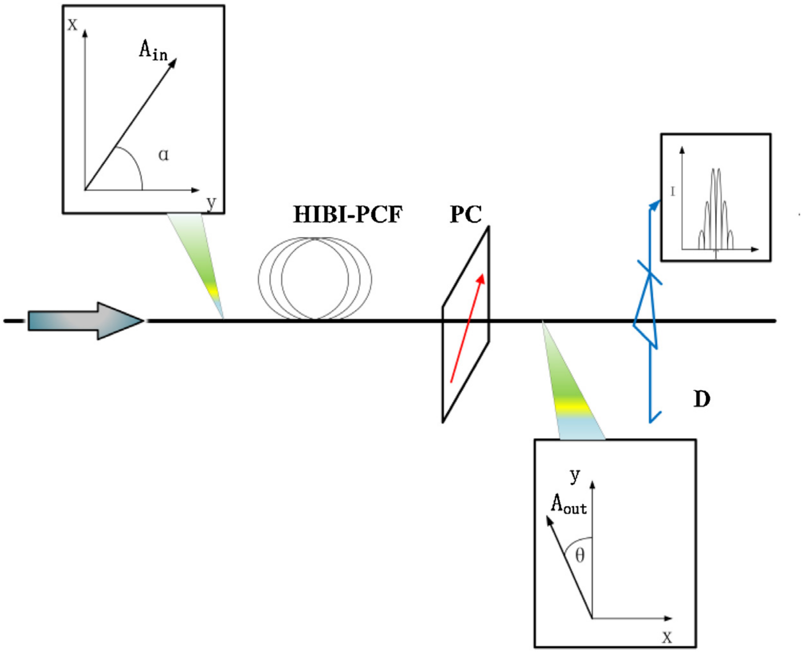

Fig. 1. Schematic description of an optical system used to generate microwave pulses.

Dispersion and high birefringence can be used to generate microwave pulses with a frequency that can be controlled by changing the parameters of the optical system.

2. Principal of the scheme design

Fig. 1 demonstrates a microwave generation system. It is mainly composed of a single-light source, a high birefringence PCF, a polarized controller (PC) and a high speed photodetector. The laser pulse transfers into the high birefringence PCF. The traveling pulse is separated into two polarization components: electric field $\vec{E}_x$ and the electric field $\vec{E}_y$, each aligns along the principal axis, x-axis and y-axis. Each component changes while propagating inside the PCF because of high birefringence and group velocity dispersion (GVD). As a result, the polarization state of the original input pulse is altered at the output of the fiber, we can suppose that the amplitude of the output linear polarization light wave is X_{out}, and it is aligned at an angle $\alpha$with respect to the x-axis. Lastly, we assume that the output intensity of the polarization detector is I_{out}.

The coupled wave equations for the two polarization components $\vec{E}_x$ and $\vec{E}_y$ are expressed as follow [18]:

$$\begin{cases} \dfrac{\partial A_x}{\partial z} + \delta \dfrac{\partial A_x}{\partial t} + \dfrac{j}{2}\beta \dfrac{\partial^2 A_x}{\partial t^2} + \dfrac{\alpha}{2} A_x = j\gamma \left(|A_x|^2 + \dfrac{2}{3}|A_y|^2 \right) A_x \\ \dfrac{\partial A_y}{\partial z} - \delta \dfrac{\partial A_y}{\partial t} + \dfrac{j}{2}\beta \dfrac{\partial^2 A_y}{\partial t^2} + \dfrac{\alpha}{2} A_y = j\gamma \left(|A_y|^2 + \dfrac{2}{3}|A_x|^2 \right) A_y \end{cases} \tag{1}$$

where γ is the nonlinear coefficient, β is the GVD factor, 2δ is the difference between the inverse group velocities of two polarization components, A_x and A_y are the envelopes of the field components, respectively, which are defined as follow:

$$\begin{cases} \vec{E}_x(z,t) = \vec{e}_x A_x(z,t) \exp(-j\omega_0 t) \exp\left(j\beta_x z\right) \\ \vec{E}_y(z,t) = \vec{e}_y A_y(z,t) \exp(-j\omega_0 t) \exp\left(j\beta_y z\right) \end{cases} \tag{2}$$

ω_0 is the carrier frequency. We neglect attenuation effect in the fiber since a fiber with a relatively short length can be used to implement the optical system.