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Raman effect on the polarization state in low-birefringence fiber

Si-Yuan Zhang, Wei-Guo Jia*, Yu Yu, Mei-Jie Wang, Qing Yan, and Hai-Long Qiao

School of Physical Science and Technology, Inner Mongolia University, Hohhot, 010021, China

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Abstract. In low birefringence fiber, by solving the coupled nonlinear Schrodinger equations contained the Raman effect for satisfy right- and left-handed circularly polarized light in the quasi-CW case, the relationship between the effective polarization beat length and changes of input power have been studied emphatically in low- and high input power situation considering the Raman effect or not. The results showed that the polarization state evolution cycles of the incident light can be changed and meanwhile the transmission distance of the incident light also can be changed due to Raman effect, regardless of the polarization of the incident light was along the slow axis or along the fast axis.

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Key words: low-birefringence optical fiber, Raman effect, state of polarization

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1 Introduction

Since the polarization instability of optical fiber was first observed in experiments, which has been attracted the interests in the research quickly. In the same year, H. G. Winful made qualitative explanation about polarization instability, and described the instability of polarization coupled equations and the phase-plane method in 1993. Then the articles on the polarization instability and nonlinear effects in related fields domestic and abroad have been published constantly [1], while the relationship between the polarization instability and Raman effect instead. According to this background, this article set the main body for Raman effect is how to influence the effective polarization beat length and changes of the input power.

*Corresponding author. *Email address:* `jwg1960@163.com` (W. G. Jia)

For some non-coherent communication applications, the polarization state should maintain stability when pulse propagating in optical fiber. In such requirements, polarization maintaining fiber [2] emerges as the times require including high birefringence fiber and low birefringence fiber. Compared to the ordinary optical fiber, low birefringence optical fiber [3-6] has good polarization properties. Application prospects are brighter in communication field, as well as in the non-communication field, such as optical fiber sensor [7-10] and fiber laser [11].

However, a series of new nonlinear effects are produced with the increase of input power in low birefringence fiber, for example, Raman effect generated by light and optical phonon interaction. The Raman effect will cause the polarization instability, which will bring a lot of trouble. The instability of polarization not only makes the signal amplitude changes, but also causes the signal waveform distortion. Even it can damage the quality of optical communication and the reliability of signals when serious. So the study of Raman effect has important realistic significance to the state of polarization.

In this paper, in low birefringence fiber, by solving the coupled nonlinear Schrodinger equations contained the Raman effect for satisfy right- and left-handed circularly polarized light in the quasi-CW case, the relationship between the effective polarization beat length and changes of input power have been studied emphatically in low- and high input power situation considering the Raman effect or not.

2 Theoretical model

In low birefringence fiber, the coupled nonlinear Schrodinger equations contained the Raman effect for satisfy right- and left-handed circularly polarized light in the quasi-CW case

$$\frac{\partial A_+}{\partial z} = \frac{i\Delta\beta}{2}A_- + \frac{2}{3}i\gamma'[\|A_+\|^2 + 2\|A_-\|^2]A_+, \tag{1}$$

$$\frac{\partial A_-}{\partial z} = \frac{i\Delta\beta}{2}A_+ + \frac{2}{3}i\gamma'[2\|A_+\|^2 + 2\|A_+\|^2]A_-, \tag{2}$$

where $\Delta\beta = 2\pi/L_B$ and $\gamma' = \gamma - \frac{3}{32}g''*(\Omega)$.$\Delta\beta$ is related to the modal birefringence of the fiber, and γ is the nonlinear coefficient of electrons, $g''*(\Omega)$ is parallel Raman gain [12-13]. The A_+ and A_- represent right- and left-handed circularly polarized states.

Consider first the low-power case and neglect the nonlinear effects, the solution is given by

$$A_+(z) = \sqrt{P_0}\cos(\pi z/L_B), \tag{3}$$

$$A_-(z) = \sqrt[i]{P_0}\sin(\pi z/L_B), \tag{4}$$

when the nonlinear effect can not be ignored, we get the normalized power p_+, p_- and the phase difference $\Psi = \phi_+ - \phi_-$, we use [14]

$$A_\pm = (\frac{3\Delta\beta}{2\gamma'})^{\frac{1}{2}}\sqrt{P_\pm}\exp(i\phi_\pm), \tag{5}$$