일차원 Kerr 비선형 광결정의 쌍안정 스위칭 특성

Bistable Switching Behaviors of One-dimensional Nonlinear Photonic Crystal with Kerr Medium

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Photonic crystal (PC) has special interests for their promising applications in three-dimensional photon control and integrated devices(1). In a nonlinear photonic crystal (NPC), optical intensity in a defect layer is greatly increased due to the location function of NPC and nonlinearity. The nonliearity of the defect layer is very much enhanced because the group velocity is reduced and the interaction time between light and nonlinear medium in the defect layer is enlarged. Optical limiting of low threshold(2-4), optical bistability device(5-11) and other NPC devices are studied widely. Bistable switching is one of the important ways to control the propagation of photons. The bistable optical devices of interference filters that use the thermal refractive index changes of inside film, have been proposed for a long time(6). In fact, an interference filter can be regarded as a typical one-dimensional nonlinear photonic crystal (1D-NPC) with the defect, and thus to study interference filer bistable device from PC point of view is significant(7-10).

Numerical simulation method for nonlinear medium is neither perfect nor universal. A nonlinear finite-difference time-domain (NFDTD) presented by Taflove(11) is a novel numerical approach to the simulation of optical nonlinear effects, such as Kerr and Raman. Recently, Tran has presented a simple and practical NFDTD solution for the simulation of short pulse propagation in a Kerr NPC (3). It is actually a followed approximation for Kerr response and it needs to solve the cubic equation in every step. In this article the intrinsic dispersive bistable switching in a 1D-NPC sandwiched with Kerr medium is analyzed. The Debye relaxation for Kerr medium response is introduced. Suppose that the Debye relaxation time is equal to the time increment in the finite-difference time-domain (FDTD) algorithm, an additional differential equation is given using forward-difference approximation. The properties of light output versus light input with a monochromatic triangularly modulated incident wave are analyzed and the method for implementing low threshold bistable switching is discussed in a symmetrical structured 1D-NPC.

The 1D-NPC considered in this paper is consisted with alternating layers of materials with high and low dielectric constants. The optical thickness for every layer is the same as the value of $\lambda_0/4$. The Kerr defect layer is centered in the multi-layered films. In convenience, we indicate the

1D-NPC structure as $(HL)^p$ $(D)^q$ $(LH)^P$, where H indicates high dielectric layer with refractive index n_H, L the low dielectric layer with refractive index n_L and D the defect layer with refractive index n_d, respectively. The symbol p is the number of couple of layers with high and low refractive indices, q is a multiple of the defect layer with an unit optical thickness of $\lambda_0/4$ and here λ_0 is the designed wavelength. Usually, p is an integer while q can be chosen as a non-integer number. In the following discussion, we refer the 1D-NPC $(HL)^p$ $(D)^q$ $(LH)^P$ as p-q-p structure for short. It is obvious that q=1 for a standard PC.

Generally, there are two methods to select a bistable switching operation. The first method is to select proper linear refractive index n_l of Kerr medium in defect layer while frequency in of the incident light is the same with the designed frequency λ_0 of 1D-NPC. The second method is to select proper frequency in of incident light according to linear refractive index n_l of Kerr media in defect layer. For standard PC, for example 3_1_3 structure, selecting the linear refractive index n_l but fixing incident frequency $\omega_{in}=\omega_0$ is difficult because defect mode is not falling into ω_0 region. Therefore, the second method is adopted for standard 1D-NPC 3_1_3. For symmetrical 1D-NPC of $q\neq1$ defect mode is able to be falling into the ω_0 region, so both methods are favorable. In fact the second method is favorable for the reason that selecting a proper Kerr medium sometimes is difficult. Of course the combination of both methods is more conveniently used in many cases.

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