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A Comparative Analysis of an All-Optical Switch Using Chalcogenide Glass and Gallium Arsenide Based on Nonlinear Photonic Crystal

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Abstract : This paper proposes a nonlinear photonic crystal ring resonator-based all-optical 2 × 2 switch. The nonlinear Kerr effect is used to evaluate the essential 2 x 2 components of the photonic crystal-based optical switch, including the bar and cross states. The photonic crystal comprises a two-dimensional square lattice of dielectric rods in an air background. In the background air, two different dielectric materials are used for this comparison study separately. Initially with chalcogenide glass rods, then with GaAs rods. For both materials, the operating wavelength, bandgap diagram, operating power intensities, and performance parameters, such as the extinction ratio, insertion loss, and cross-talk of an optical switch, have also been estimated using the plane wave expansion and the finite-difference time-domain method. The chalcogenide glass material (Ag20As32Se48) has a high refractive index of 3.1 which is highly suitable for switching operations. This dielectric material is immersed in an air background with a nonlinear Kerr coefficient of 9.1 x 10-17 m2/W. The resonance wavelength is at 1552 nm, with the operating power intensities at the cross-state and bar state around 60 W/μm2 and 690 W/μm2. The extinction ratio, insertion loss, and cross-talk value for the chalcogenide glass at the cross-state are 17.19 dB, 0.051 dB, and -17.14 dB, and the bar state, the values are 11.32 dB, 0.025 dB, and -11.35 dB respectively. The gallium arsenide (GaAs) dielectric material has a high refractive index of 3.4, a direct bandgap semiconductor material highly preferred nowadays for switching operations. This dielectric material is immersed in an air background with a nonlinear Kerr coefficient of 3.1 x 10-16 m2/W. The resonance wavelength is at 1558 nm, with the operating power intensities at the cross-state and bar state around 110 W/μm2 and 200 W/μm2. The extinction ratio, insertion loss, and cross-talk value for the chalcogenide glass at the cross-state are found to be 3.36.19 dB, 2.436 dB, and -5.8 dB, and for the bar state, the values are 15.60 dB, 0.985 dB, and -16.59 dB respectively. This paper proposes an all-optical 2 × 2 switch based on a nonlinear photonic crystal using a ring resonator. The two-dimensional photonic crystal comprises a square lattice of dielectric rods in an air background. The resonance wavelength is in the range of photonic bandgap. Later, another widely used material, GaAs, is also considered, and its performance is compared with the chalcogenide glass. Our presented structure can be potentially applicable in optical integration circuits and information processing.

Keywords : photonic crystal, FDTD, ring resonator, optical switch
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