Multi-Core Photonic Band-Gap Fiber Splitters Based on Highly-Selective Non-Proximity Resonant Coupling

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Abstract

We propose and numerically investigate the possibility of designing compact narrow-band splitters based on the resonant tunneling phenomenon in multi-core photonic band-gap fibers.

1 Introduction

Novel class of microstructured optical fiber (MOF) couplers was recently introduced [1], that operates by resonant rather than proximity coupling, where energy transfer is realized via transverse lightguides integrated into the fiber's cross-section. Such a design allows unlimited spatial separation between interacting fibers which in turn, eliminates inter-core crosstalk via proximity coupling. Controllable energy transfer between fiber cores is then achieved on highly directional transmission through transverse lightguides. The main advantage of this coupling mechanism is its inherent scalability as additional fiber cores could be integrated into the existing fiber cross-section simply by placing them far enough from the existing circuitry to avoid proximity crosstalk, and then making the necessary inter-core connections with transverse light "wires" in a direct analogy to the "on chip electronics integration".

One of the main challenges the technology currently faces, is the realization of various kinds of fiber-devices based on photonic crystal fiber (PCF) platforms and especially based on the new multi-core PBG fiber technology. To this end we devote the present paper to describe a novel class of splitters based on multicore photonic band gap (PBG) fibers. Through efficient modal [2] and beam propagation analysis [3], based on the finite element method (FEM), we theoretically investigate the possibility of synthesizing efficient ultra narrow-band splitters, suitable for filtering applications.

2 Numerical results and device characterization

The structure under investigation is shown in Fig. 1. The hollow core is formed in a silica based MOF with a cladding refractive index n = 1.45 by removing two rows of tubes and smoothing the resulting core edges. The pitch is Λ = 2 μm, while the air-hole size in the cladding is d/Λ=0.9 with a total of six hole layers. Fundamental band gap where the core guided modes are found, extends between 1.29 μm < λ < 1.40 μm. To form a splitter, operating at two distinct wavelengths, we place three hollow cores of N=5 periods apart from each other as shown in Fig. 1. Two dissimilar transverse resonators with d_1/Λ=0.7 and d_2/Λ=0.6 are then introduced by slightly reducing (high index defect) the diameters of the holes in the middle of the line, joining the cores. By an accurate modal analysis performed using an accurate FEM solver [2], in Fig. 2 we evaluate the effective indexes of the fundamental (solid line) as well as of the excited resonant modes (dashed lines) for vertically polarized state. From these results we can clearly see that the excited resonant modes crosses the effective index curve of the fundamental mode, at two wavelengths of λ_1 = 1.3384 μm and λ_2 = 1.3565 μm. The physical interpretation of this crossing is that the two excited modes at wavelengths of λ_1 and λ_2 can be effectively transferred via resonant coupling through the dissimilar resonators, from the

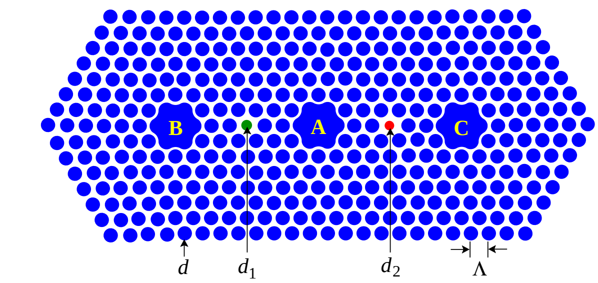

Fig. 1. Topology of a three-core PBG fiber splitter utilizing a non-proximity add-drop wavelength coupling mechanism.

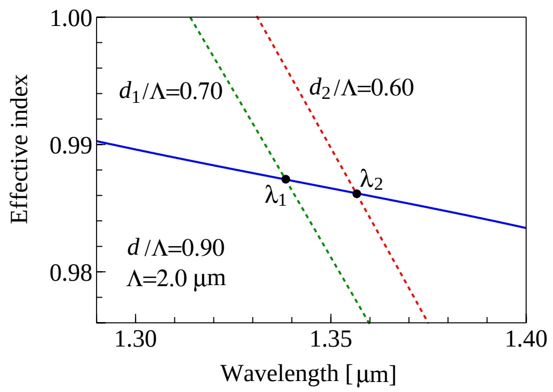

Fig. 2. Effective indexes of the fundamental (solid line) and the two excited resonant modes (dashed lines) of the multi-core PBG fiber splitter.

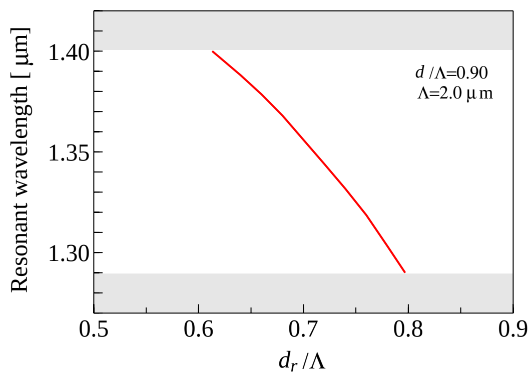

Fig. 3. Evolution of the resonant wavelength as a function of the resonator's normalized diameter d_r/Λ.

central input core-A into the output cores-B and C respectively. In Fig. 3 we show the evolution of the resonant wavelength for *y*-polarization as a function of the normalized resonator's diameter d_r/Λ. In Fig. 4 we plot the spectral characteristics of this novel type of PBG fiber splitter with fiber length of 2.7 mm, where we can observe a dual band-pass transmission response centered at the prescribed wavelengths. The highly selectivity in the filter's response we could obtain in this case indicates the potential capability of the non-proximity resonator's characteristics. The full widths at half maximum (FWHM) bandwidths of this filter are 1.2 nm and 1.1 nm respectively, and a transmission of 95% at the resonant wavelengths of λ_1 and λ_2 could be achieved.

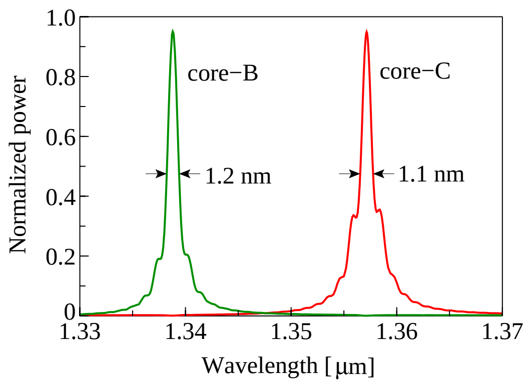

Fig. 4. Band-pass filtering characteristics of three-core PBG filter splitter at the two resonant wavelengths of λ_1 = 1.3388 μm and λ_2 = 1.3572 μm.

3 Conclusions

To summarize our work, we have proposed and numerically investigated the propagation properties of a novel bandpass filter based on the resonant tunneling phenomenon in a three-core PBG fiber. The design strategy of realizing multi-core couplers based on the resonant tunneling effect in PBG fibers, according to the best of our knowledge, is reported here for the first time. Results of a full vectorial finite element modal analysis confirmed by beam propagation method have been presented for a variety of quantities related to the fiber's propagation characteristics. The high suppression of the side-lobes in comparison to previous reported filters based on conventional fiber technology [4],[5] as well as the ultra-narrowband response and the short coupling length, are the main advantages of the proposed PBG fiber architecture.

4 References

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