Matching of narrow-band photonic crystal filters and waveguides to free space and dielectric waveguides

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It is well known that micro-cavities formed by local defects within an otherwise perfect photonic crystal structures can trap light at wavelengths within the stop-band of the background crystal. Since the micro-cavities resonate at a well-defined frequency with an ultra-narrow bandwidth, they can potentially be used as high Q filters. An array of equally spaced identical micro-cavities forms the Coupled Cavity Waveguide (CCW) - a narrow band waveguide whose central frequency and bandwidth are determined by the micro-cavities nature and their inter-spacing, respectively. Such devices can be used as optical or millimeter wave filters, routers, and multiplexers/demultiplexers with obvious applications in RF and optical communication systems.

A fundamental condition for the practical efficacy of micro-cavity filters and CCWs as sub-systems in a realistic multi-component system, is the ability to match them to structures external to the background photonic crystal, such as free space, dielectric slab waveguides, or optical fibers. This matching problem can be formulated as an optimization problem by which one seeks the minimum of a properly defined Standing Wave Ratio (SWR), with respect to limited variations of the dielectric structure/geometry in the neighborhood of the interface between the sub-system (micro-cavity, CCW) and the external structure. Formally, however, it is clear that the entire sub-system structure has to be accounted for to provide a proper solution of the wave-problem. This naturally calls for a sub-structuring procedure. The sub-system impedance matrix and its inverse are computed a-priori and remain unchanged during the optimization process, while the much smaller impedance matrix associated with the interface neighborhood (which constitutes the optimization search domain) and its inverse are re-calculated at every search step.

In this work, we use the sub-structuring methodology to match CCW devices. Several matching configurations are demonstrated and their corresponding performances are discussed.