Zigzag coupled-resonator optical waveguides with abrupt bends

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Coupled-resonator optical waveguides (CROW) are an interesting slow-light medium consisting of a 1D chain of optical resonators coupled together to form a device that acts as a plain waveguide with very high group index. The resonators used can be any high-Q optical device, such as microrings, microcylinders, or photonic crystal nanocavities; here we study photonic crystal CROW.

Problematically, CROW are inflexible in their properties, as the group index-bandwidth product is fixed, depending on the coupling between, and therefore the spacing of, the individual resonators. Particularly in a photonic-crystal medium with discrete lattice spacing, this lack of flexibility is unfortunate.

However, as was pointed out in the original proposal for CROW by Yariv *et al.,* (Opt. Lett., **24,** 11, p. 711) this 1D chain need not be arranged in a straight line, so long as the symmetry of the cavity-cavity coupling is preserved. As far as the authors are aware, no experimental demonstration of idea has been made to date.

Our CROW is made of L3-type photonic-crystal cavities, which have two axes of symmetry. This allows for the traditional linear geometry, wherein all the cavities are placed along a single line; or alternatively the one used here, wherein alternate cavities are placed in a zigzag arrangement, as shown in Figure 1. This zigzag is possible for both Γ-M and Γ-K propagation, with performance that is, on a per-cavity basis, equivalent.

As this arrangement matches the symmetry of the cavity mode, the bends do not induce any loss (*cf.* Kuramochi, *et al.,* JSAP Spring 2014 17a-PA1-3 for comparison). They do, however, allow more cavities to be fit into a smaller space, increasing the group index. Moreover, for Γ-M oriented waveguides, the amount of offset for the alternate cavities (θ) does not affect the length of the device, allowing easy like-for-like comparisons and usage.

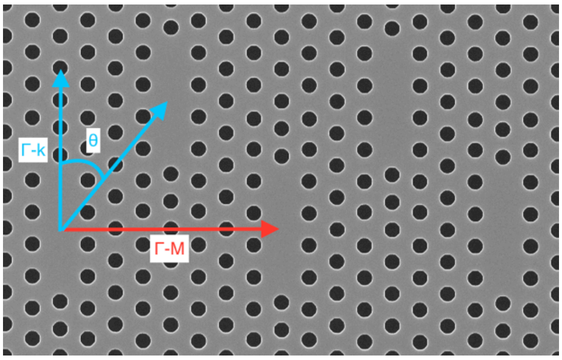

Figure 1: An SEM of a θ=41° transverse (Γ-M) zig-zag crow

The bandwidth of these devices varies from 1-9 nm, maximized at θ=35°, or an offset of 5 holes from the waveguide centerline, at which the group index was ~60. The maximum group index was ~135, at a bandwidth of 1 nm.

A final note for devices made exploiting this idea is that it need not be used on every step. A waveguide in an arbitrary direction or shape can be made for any choice of θ simply by zigzagging every *n*th step. This allows the bandwidth and group index of the device to be chosen, and then written between any two points of interest on chip.

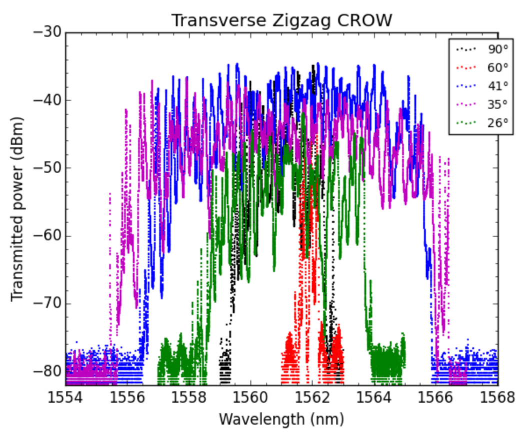

Figure 2: Transmission spectra for various angles of zigzag. The noise in the passband is largely due to Fabry-Perot noise.

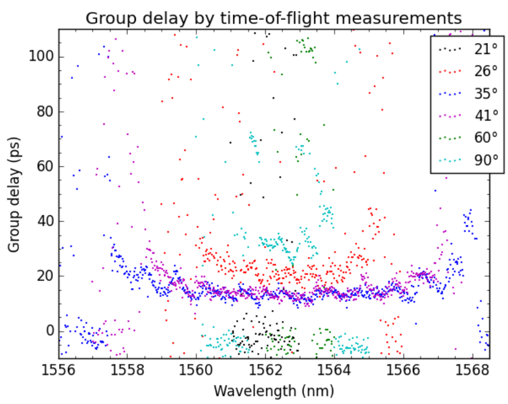

Figure 3: Slow-light measurements by single-pulse time-of-flight measurements vs. a reference W1 waveguide. At 1562 nm, n_g varies from 60 to 130 depending on θ.