operating at the same group index ($n_g = 30$) [18]. The similarity is underlined by the −24 dB conversion efficiency for 90 mW coupled input pump power. The dispersion curves and the cutoffs in transmission of these two waveguides are also shown in Fig. 4 to compare the red shifts in the slow light region. For the airbridge waveguide, the red shift in the slow light region was smaller for $n_g = 30$ than $n_g = 60$, as expected, while the red shift is almost non-existent for the oxide-clad waveguide. Because of the wide bandwidth (13 nm) of the slow light region with the lower group index of 30, this red shift did not influence the linear relationship between the FWM conversion efficiency and the pump power and the conversion efficiency is maintained. Figure 4 confirms the possibility of using oxide-cladding to overcome the thermal detuning observed in airbridge waveguides at high cw input powers.

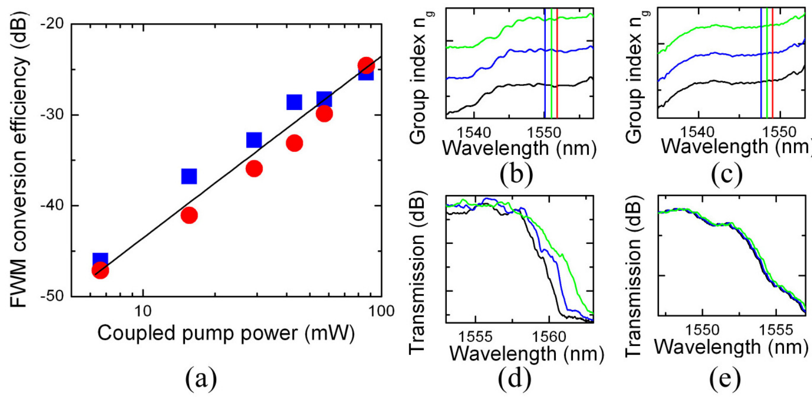


Fig. 4. (a) Experimental (dots) and calculated (lines) values of the FWM conversion efficiency as a function of coupled input pump power in airbridge (blue square dots) [18] and oxide-clad (red circle dots) engineered slow light PhC waveguides of 396 µm lengths with a group index of $n_g = 30$. (b)(c) Group index curves and (d)(e) transmissions for (b)(d) airbridge and (c)(e) oxide-clad waveguides for coupled pump powers of 0 mW (black), 35 mW (blue) and 90 mW (green). The color lines in (b)(c) represent the position of the pump, probe and idler of the FWM process.

## 4. Conclusion

We have shown that a relatively high FWM conversion efficiency of −28 dB is possible in a slow light PhC waveguide, using a coupled cw input power of only 15 mW. The waveguide is 296 µm long and exhibits a constant group index of $n_g = 60$ over a useful bandwidth of $\Delta\lambda = 4$ nm. Somewhat surprisingly, we also observe a thermal detuning of the waveguide for higher input power, which we associate with heating due to linear losses at surface defects and the high energy density in the slow light regime. By embedding the waveguide in silica, we show that this issue can be addressed based on the passivation and the much better thermal conductivity provided by the silica overlayer. Since embedding the PhC in silica reduces the refractive index contrast, it is more difficult to achieve high group index operation ($n_g > 50$), but once such designs are available, we are confident that conversion efficiencies approaching −10 dB can be achieved with waveguides of only a few 100 µm in length. The compact geometry of slow light PhC waveguides and the mechanical stability provided by the oxide cladding allows much tighter integration and improves the CMOS compatibility of PhC devices for optical signal processing.


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