interfering wave (crosstalk, XT). The amplitude of the XT wave is non-negligible (~ 0.2), as inferred from the FEM analysis of the isolated waveguide crossing depicted in Fig. 1(b) which reveals an XT value of $\sim -15\,\mathrm{dB}$. The proposed switching element has been thoroughly analyzed in the context of vectorial 3D FEM calculations, using prismatic elements. Particular details on the numerical implementation have been reported in [2,3]. The port transmittances versus wavelength are provided in Fig. 1(c); the irregular shape of drop port transmittance confirms the presence of interfering waves as suggested above. It is important to observe the substantial improvement in ER, with the through and drop ports demonstrating an ER of $10.8\,\mathrm{dB}$ and $9\,\mathrm{dB}$, respectively, at the marked wavelength ($1537\ \mathrm{nm}$). In addition, an ER exceeding $8\,\mathrm{dB}$ is sustained in a wavelength window of $3.2\,\mathrm{nm}$ which can accommodate four 100-GHz-spaced WDM channels.

III. MULTI-MODE INTERFERENCE SWITCHING ELEMENTS

An alternative approach for constructing a 2×2 switch exploits the beating between two modes in a longitudinal configuration, such as the MMI coupler shown in Fig. 2(a). The MMI section is restricted to a width that supports only two modes: the fundamental TM_{00} mode which has a symmetric E_y component and the TE_{00} mode which has an anti-symmetric E_y. A geometrical dispersion diagram (real part of n_{eff} and L_{prop}) is shown in Fig. 2(b) for both the heated and unheated states. Changing the temperature results in a modification of the phase constants and for sufficient propagation length (L_{MMI}) exchanges the output ports. The inherent losses of the plasmonic modes limit the switch performance in two ways: (a) insertion losses increase with the necessary length L_{MMI} for achieving phase inversion and (b) the different level of losses experienced by the TM_{00} and TE_{00} modes tends to limit the ER and beyond some point, further approaching L_{MMI} is detrimental to the ER. A key element is the design of the input coupler in order to excite both modes at equal proportions. For this class of longitudinal structures with a well defined propagation axis, we are basing our analysis on a finite element beam propagation method (FE-BPM), which is combined with a Padé wide-angle extension [3]. This computational technique ensures fine resolution in the device cross-section, natural treatment of the large jumps in material properties at metal/loading interface and correct capturing of the longitudinally varying sections (input/output couplers). Fig. 2(c) shows the evolution of the extinction ratio along the propagation direction and the interplay between the phase accumulation effect (which tends to increase ER) and the unbalanced level of losses between modes (which tends to suppress ER). Careful design of all parameters can lead to an ER of $17\,\mathrm{dB}$ at an IL level of $12\,\mathrm{dB}$.

ACKNOWLEDGMENT

This work was supported by the European FP7 project PLATON and the HERACLITUS II research fellowship.

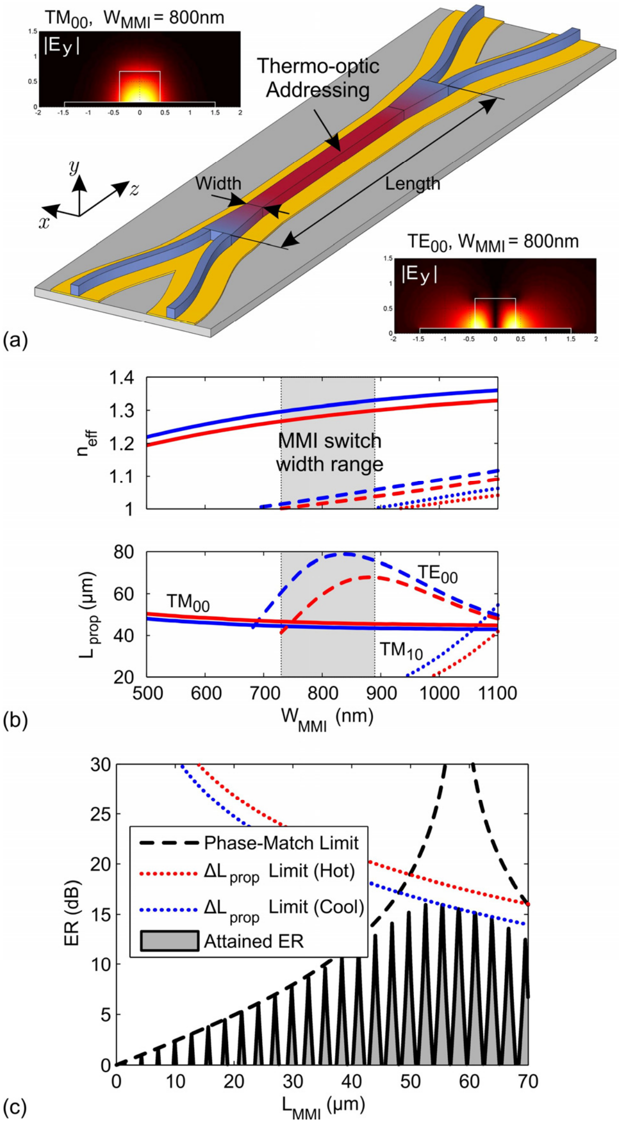

Figure 2. (a) MMI-based switching element. (b) Geometrical dispersion diagram. Gray region indicates the targeted MMI-section width. (c) ER evolution along the device length showing also the limiting bounds due to phase accumulation (dashed black) and the differential losses between TM00 and TE00 in hot (red dotted) and cold (blue dotted) states. ER stays always below the lowest of the three limiting factors. W_{MMI}=800 nm, feeding waveguides are $500\times600\ \mathrm{nm}^2$ and made of a polymer with $\mathrm{TOC} = -3 \times 10^{-4}\ \mathrm{K}^{-1}$, ΔT=100K.

REFERENCES

[1] T. Holmgaard and S. I. Bozhevolnyi, "Theoretical analysis of dielectric-loaded surface plasmon-polariton waveguides," *Phys. Rev. B*, vol. 75, 245405, 2007.

[2] O. Tsilipakos, T. V. Yioultsis, and E. E. Kriezis, "Theoretical analysis of thermally tunable microring resonator filters made of dielectric-loaded plasmonic waveguides," *J. Appl. Phys.*, vol. 106, 093109, 2009.

[3] O. Tsilipakos, A. Pitilakis, A. C. Tasolamprou, T.V. Yioultsis, E. E. Kriezis, "Computational techniques for the analysis and design of dielectric-loaded plasmonic circuitry," *Opt. Quant. Electron.*, in press.