for each specific mode inside the coaxial cavity. Here, L is the length of the coaxial structure, p the order of the resonant mode and ϕ_r a phase shift acquired in reflections of the mode at the cavity output [31]. If ϕ_r is small enough, the resonant condition becomes $k_z' L = p\pi$. Using the length of the nanocoax structure (L), each resonant order mode was calculated. Thus, as indicated in Fig. 4, the peak at 647 nm is due to a superposition of resonant longitudinal modes with orders p = 7 and 6 of the TE_{11} and TE_{21} modes, respectively, while at 591 nm the superposition is by orders 6 and 8 of the TE_{11} and TE_{31} modes, respectively. In both cases, such superposition of modes is the reason for the strong far field transmission reported in the experimental data. The coefficients of the modes superposition were not calculated in the present work. The peaks that appear in the calculated transmittance at 761 nm and 874 nm are related to the same process and due to order p = 3 of TE_{31} and TE_{21} modes, respectively. It is important to note that the weak transmittance at wavelengths shorter than 550 nm is due to the short propagation length of all the modes, since the plasma resonance wavelength occurs around such a wavelength, resulting in highly attenuated modes, Fig. 3(b).

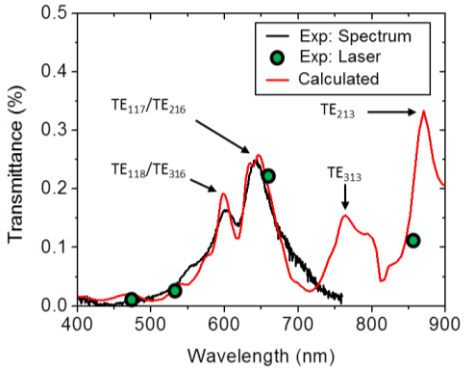

Fig. 4. Experimental (black line and green circles) and calculated (red line) transmission. Circles were obtained using single wavelength sources. The resonant modes discussed in the text are indicated.

4. Conclusions

In summary, experimental observations of plasmonic and photonic modes propagating in nanocoax structures are presented for the first time, using near-field microscopy. Comparison between NSOM experiments and calculations demonstrate that the experimental data are related to the propagating electromagnetic field in the nanocoax structure. By calculating $\boldsymbol{k}_z$ of each mode, we determined the propagation lengths and conclude that the TE_{11}, TE_{21} and TE_{31} modes can propagate along the full nanocoax length and couple to the far field, in the spectral range analyzed experimentally. These results are relevant to understanding the physics of propagated fields in nanocoax structures and their potential applications in the subwavelength nanoscale manipulation of light including, for example, polarization-preserving optical waveguides for optical communication.

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