Waveguiding properties of a ribbed plasmonic waveguide

Christopher A. Jones, Stefan F. Helfert and Jürgen Jahns

Introduction  Plasmonic waveguides consisting of a metal core with surrounding dielectric media are of great interest for the integration of ‘optical’ waveguides [1]. They can be considerably smaller than traditional integrated optical waveguides. A serious drawback however is due to the high dissipative losses introduced by the metal. This is usually inversely correlated to the field reach within the surrounding dielectric. It is possible to decrease the attenuation by choosing the surrounding dielectric accordingly. This will however usually lead to larger field reach causing problems such as cross talk. A possibility to reduce the dissipative losses is to reduce the amount of metal in the core and this can be achieved by ribbing the waveguide in transverse direction (z) as can be seen in in Figure 1.

Fundamentals  The numerical results are computed with the Method of Lines [2], an eigenvalue method for partial differential equations. The metric by which the wave guiding performance is judged is the figure of merit $FoM = \tau^{\frac{1}{2}}$. Where $\tau = \frac{(\Delta W)}{\lambda_0}$ is the transmittance and $\sigma^2$ the variance as gauge for the field reach of the transmitted floquet mode.

Results  Beginning with the distance between the ribs in Figure 1 far left, the FoM increases continuously up to approximately $L_1 = 85 \text{ nm}$ where resonance between the excited wave and the geometry occurs. Beyond this it peaks briefly and then drops off noticeably. The propagation properties are hardly influenced by the rib thickness, so long as it is less than 3 nm. Beyond that the attenuation climbs leading to reduced transmittance. The parameter with the greatest effect, be it on a very small scale (note the abscissa scaling), is the rib length $\Delta W$. The maximum FoM is at the point of origin i.e. the unstructured waveguide. Resulting from the maximum $\tau$ at that point. The field width however has its minima at small negative values for $\Delta W$, meaning the rib is cut out of the underlying metal slab. The dependance on thickness of the underlying metal slab $W_1$ shown on the far right is analogous to the behavior of an unstructured plasmonic waveguide excited by the even mode. The attenuation rises continuously the thicker the waveguide is chosen to be due to the reduced coupling of the plasmonic wave on each side of the metal slab. The field reach however has a clear minima at roughly 60 nm, resulting in a maximum FoM at this point.

Conclusion  Reduced attenuation due to the reduced ratio of metal and dielectric media is so far not apparent. The minimum occurs for the unstructured waveguide. The field reach however can be reduced through the ribbed structure opening up the possibility of reducing the distance between two plasmonic waveguides.

References