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Super Long-range Surface Plasmon Polaritons in a Silver Nano-slab Waveguide

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Plasmonic waveguides open unique prospects for the design of the highly integrated nano-optical devices, as they transmit surface plasmon polaritons (SPPs) with subwavelength localization [1]. Also, the plasmonic waveguides are based on a metal, so they have easy access to electronics, thus offer the possibility of inducing electro-optic effects in waveguide components.

A metal in the waveguides introduces high propagation losses, resulting in the limitation of application range. Recently, long-range SPPs (LRSPs) [2] with low propagation losses have extensively been studied as key elements in important applications of plasmonics. We have already reported in theory that the shorter waveguide width made the propagation length longer [3]. Here, we experimentally demonstrate the increase of LRSP propagation length in a slab-shaped silver waveguide as the width decreases.

Figure 1 shows the relation between propagation losses of LRSPs and the waveguide width, calculated by finite-element method (FEM). It is found that the propagation losses can be significantly reduced when the waveguide width becomes shorter than the wavelength; we named this mode “super LRSPs”.

For the experimental demonstration of super LRSPs, we fabricated slab-shaped waveguides by FIB milling (Fig. 2a). The waveguide consists of a slab-shaped silver film embedded between SiO_2 and index-matched polymer. Input and output couplers are defined on the edge of each waveguide to in- and out-couple SPPs.

Figure 2c shows the measured intensity from the output coupler as a function of the waveguide length (experimentally observed emission from the output is presented in Fig. 2b). From a simple exponential fit to data, a SPP propagation length of 43.1 μm is extracted, while calculated one is 42.1μm. It means that we successfully demonstrated the propagation property of the fabricated waveguide.

The relation between propagation length of LRSPs and the subwavelength waveguide width will also be discussed in this presentation

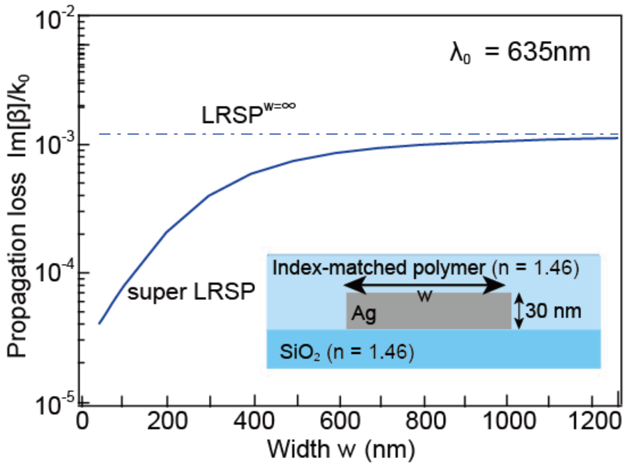

Fig. 1: (a) Imaginary part of effective index of LRSPs versus the waveguide width. The dotted line shows the propagation loss of the waveguide with infinite width. The solid line presents how the propagation loss changes as the waveguide width decreases. Inset: Schematic of the cross sectional view of the waveguide.

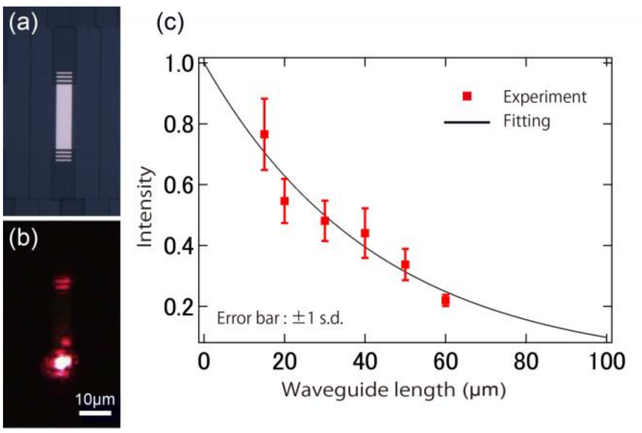

Fig. 2: (a) Optical image of the waveguide (The Ag thickness is 30 nm and the width is 5 μm). (b) Experimentally observed emission from the output when the input is illuminated by a laser (λ = 635 nm). (c) The output intensity versus the wavelength. The red plot shows the output intensity experimentally measured and the black solid line means a simple exponential fit. The error bar presents ±1s.d.

References

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