Ultralong-range propagation of plasmon-polaritons in a thin metal film on a one-dimensional photonic crystal surface

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We present experimental results on ultralong-range surface plasmon-polaritons, propagating in a thin metal film on a one-dimensional photonic crystal (1D PC) surface over a distance of several millimeters. This propagation length is about two orders of magnitude higher than the one in the ordinary Kretschmann configuration at the same optical frequency. We show that a long-range surface plasmon-polaritons propagation may take place not only in a (quasi-)symmetrical scheme, where a thin metal film is located between two media with (approximately) the same refraction index, but also in a scheme where the thin metal film is located between an appropriate 1D PC and an arbitrary (air, water, etc.) medium.

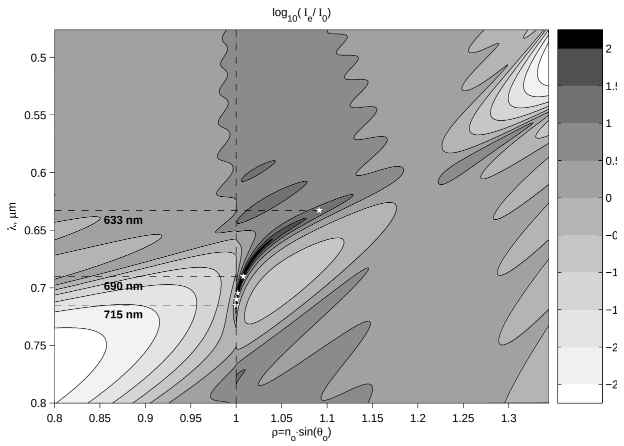

Fig. 1 The calculated dispersion of the test 1D photonic crystal structure and measured experimental points (white pentagrams) at different wavelengths. The photonic band gap is clearly seen as light areas with an enhancement much less than 1. The photonic band gap vanishes near Brewster's angle ($\rho_{Br} \simeq 1.2$ in this system), where no reflection of the TM wave takes place from the SiO_2/Ta_2O_5 interface. The optical surface mode is seen as a dark curve with an enhancement more than 100 inside the band gap.

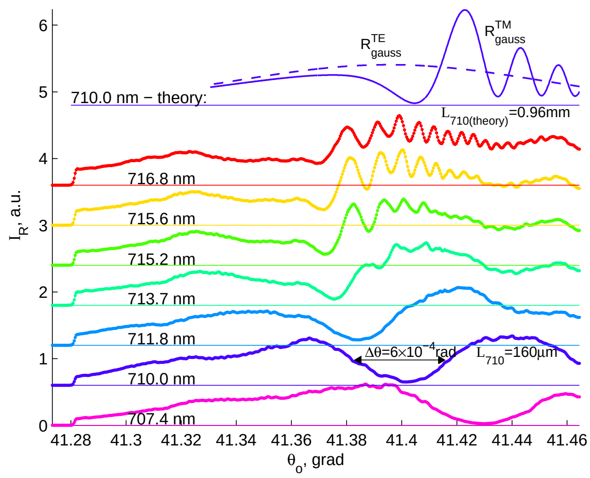

Fig. 2 Angular resonance curves at different wavelengths. Each curve is up-shifted by 0.6 a.u. from the previous one for good visibility. The diode array was shaded at $\theta_0 \leq 41.28$ to mark the zero level. The interference near the plasmon resonance curves at $\lambda > 714$ nm is a new distinguishing feature of ultralong-range SPPs in the Kretschmann-like configuration (see [1] for details).

Figures 1 and 2 show our experimental and theoretical results. The following 1D PC structure was used in experiments: substrate/$(HL)^{14}H'M$/air, where H is a Ta_2O_5 layer with thickness $d_2 = 100.0$ nm, L is a SiO_2 layer with $d_1 = 155.7$ nm, H' is a Ta_2O_5 layer with $d_2' = 98.4$ nm, and M is a gold layer with $d_3 = d_M = 5$ nm. The prism and substrate were made from BK-7 glass. The RIs of the substrate, Ta_2O_5, SiO_2 and Au at $\lambda = 710$ nm, were $n_0 = 1.513$, $n_2 = 2.13$, $n_1 = 1.45$ and $n_3 = n_M = 0.2 + i4.14$ correspondingly. The Ta_2O_5/SiO_2 multilayer was deposited by ion sputtering. The gold film was deposited by ion-assisted rf-frequency diode sputtering.

The propagation length at $\lambda = 715.2$ nm is estimated to be $L_{715} \simeq 0.8$ mm, which is about two orders of magnitude higher than L_{SPP} in the ordinary Kretschmann scheme at optimal film thickness at the same wavelength ($L_{SPP} \simeq 8$ μm). So we have used the unique tunable properties of 1D PCs for the excitation of SPPs along a thin metal film in that wavevector range where they become ultralong-range SPPs and may exist in an asymmetric configuration. The ultralong-range surface plasmon-polaritons are potentially important for biosensors, plasmonics, and other applications.

References

1. V.N. Konopsky and E.V. Alieva, "Long-range propagation of plasmon polaritons in a thin metal film on a one-dimensional photonic crystal surface," Phys.Rev.Lett. **97** 253904 (2006).