A metal film perforated with subwavelength-size periodic holes exhibits an extraordinary enhanced optical transmission in certain spectral ranges compare to the geometrical transmission of the same number of individual holes [1—3]. This enhancement is related to the excitation of surface plasmon polaritons (SPs) on a film with a periodic hole array [2,3]. The SP behaviour on the periodically structured surfaces attracts enormous attention itself due to possible numerous applications of the surface polariton optics as well as due to the SP localisation phenomena and related surface enhanced optical processes such as Raman scattering and second-harmonic generation.

Here we report the first 2D numerical modelling of transmission spectra of and near-field distribution of transmitted light over a metal film with a periodic hole array. The excitation and subsequent scattering of surface polaritons by the array acting as a polaritonic crystal (in analogy with photonic crystals for photons) results in the enhanced transmission at the wavelengths corresponding to the surface polariton Bloch waves. The transmitted light distribution at the wavelengths at which there is no SP excitation is related to a hole itself (Fig. 1 a). The transmitted light distribution at the wavelengths of the SP resonances depends strongly on the direction of propagation of the excited SPs. The lowest energy surface polariton ($\lambda \approx 1400$ nm) is launched in the direction of a vertical axis of the images (Fig. 1 e) while the other SP mode ($\lambda \approx 800$ nm) propagates at the 45° direction to the vertical (Fig. 1 c). The resulting intensity distribution is caused by the SP scattering in a periodic structure.
The near-field distribution of light over a surface under the enhanced transmission conditions reveals the strongly localised spots of high intensity. The parameters of the localisation indicate on a high quality factor related to the high efficiency of the SP reflection from holes. This makes possible to create the SP reflectors and other elements of SP optics (Bragg mirrors, resonators, polaritonic crystals, etc.) employing periodic structures on metal surfaces.

Figure 1. Transmitted light intensity distribution for (a,b) 330 nm, (c,d) 800 nm, and (e,f) 1420 nm wavelengths at the distance of (a,c,e) 15 nm and (b,d,f) 100 nm above the surface. The hole diameter and array periodicity is 300 and 900 nm, respectively. Polarisation of the incident light is along a vertical axis of the images.

References