Giant Second-Harmonic Generation Enhancement in the Presence of Tamm Plasmon-Polariton

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Abstract: Giant enhancement of the second harmonic generation in metal/photonic crystal (PC) system observed in the vicinity of Tamm plasmon-polariton resonance due to strong electromagnetic field localization at the metal and PC interface.
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1. Introduction

Tamm plasmon-polaritons (TPP) in photonic crystals (PC) are optical analogues of electronic density localization at the boundary of periodic atomic potential [1]. These states manifest themselves experimentally as narrow peaks in transmittance spectra of metal/photonic crystal (Me/PC) systems [2].

The effects of second-harmonic generation (SHG) enhancement due to electromagnetic-field localization are well known in nonlinear optics. The localization can be reached in the spectral region of surface- or local-plasmons-polariton [3,4] or of microcavity-mode [5] resonance. According to Ref. [2] in the presence of Tamm plasmon-polariton, electromagnetic field is localized at the boundary of metal and PC. Thus TPP-induced SHG enhancement is expected.

2. Samples and setup

The studied samples consist of 6 pairs of ZrO_2/SiO_2 (average thicknesses 110 nm and 145 nm, respectively) quarter-wavelength Samples are deposited on quartz substrate using thermal evaporation. Optimal thickness of the top most layer was calculated to be 225 nm, therefore additional 80-nm layer of SiO_2 was deposited on the sample surface. Then structure was covered by a 30-nm-thick gold film allowing good field localization in the TPP mode.

As a source Ti:Sapphire laser was used, providing 130 fs pulses with 80 MHz repetition rate. Fundamental wavelength was tuned in the range of 720-800 nm. The incident beam was focused to the 40-μm-wide spot at the sample. Pump pulse fluence at the sample was about 100 $\mu J \cdot cm^{-2}$. Angle of incidence to the sample was 20°. Experiment was set in *pp* combination of fundamental and second-harmonic (SH) radiation polarization. Second-harmonic spectra were measured with 1-nm resolution. The SH beam was collected through a lens and a 9-mm-thick BG39 filter to reject any residual fundamental light. The signal was detected with a gated photon counter, each point being recorded for at least 20 s.

3. Results and discussion

Figure 1 shows transmittance spectrum (solid line) and SH spectrum (black circles) of the Au/PC sample. The resonance near 774 nm in transmittance spectrum is associated with the excitation of the TPP. According to the theory and numerical calculations, in the presence of TPP, electromagnetic field is localized at the interface of metal and photonic crystal. Main part of SH in metals is generated by the surface, so enhancement of local electromagnetic field leads to enhancement of the SH signal from the metal film. SH spectrum of the 30-nm-thick gold film is shown for the reference with magenta triangles. The spectrum demonstrated no features and average signal level corresponds to the SH signal generated by the Au/PC sample out of the TPP resonance. Sharp peak in the SH spectrum of the Au/PC sample is observed in the vicinity of the TPP resonance. Maximum SH signal from the sample is observed at 774 nm. The 60-times TPP-induced enhancement of the SH signal is achieved.

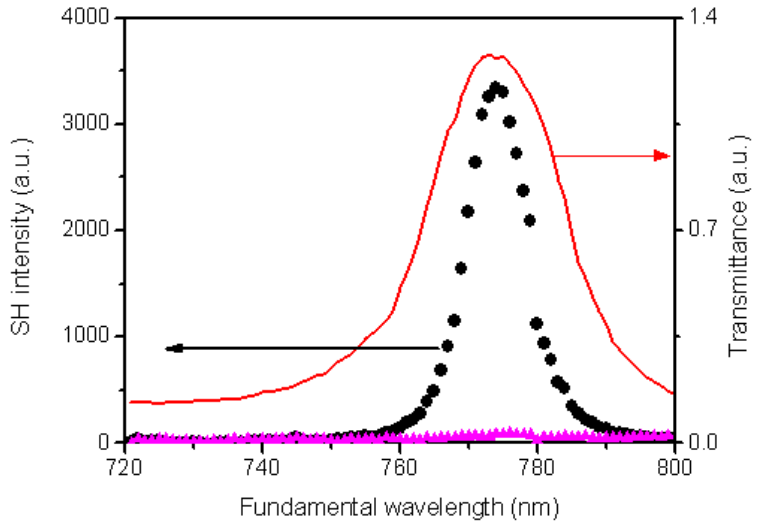

Fig.1. (Color online) Black circles – experimental SH spectrum of theAu/PC sample. Magenta triangles – experimental SH spectrum of the 30-nm-thick gold film. Red (solid) curve – experimental linear transmittance spectrum of the Au/PC sample.

4. Conclusions

In conclusion, the experimental proof of SHG enhancement in Au/PC system in the presence of TPP is obtained. . The 60-times TPP-induced enhancement of the SH signal is shown. This is an experimental evidence of the electromagnetic field localization in the TPP mode at the boundary of metal and photonic crystal.

5. References

[1] I.E. Tamm, JETP **3**, 34 (1933).
[2] A. Kavokin, I. Shelykh, and G. Malpuech, App. Phys. Lett. **87**, 261105 (2005).
[3] H. J. Simon, D. E. Mitchell, and J. G. Watson, Phys. Rev. Lett. **33**, 1531 (1974).
[4] R. Antoine, M. Pellarin, B. Palpant et al., J. App. Phys. **84**, 4532 (1998).
[5] T. V. Dolgova, A. I. Maidykovski, M. G. Martemyanov et al., App. Phys. Lett. **81**, 2725 (2002).