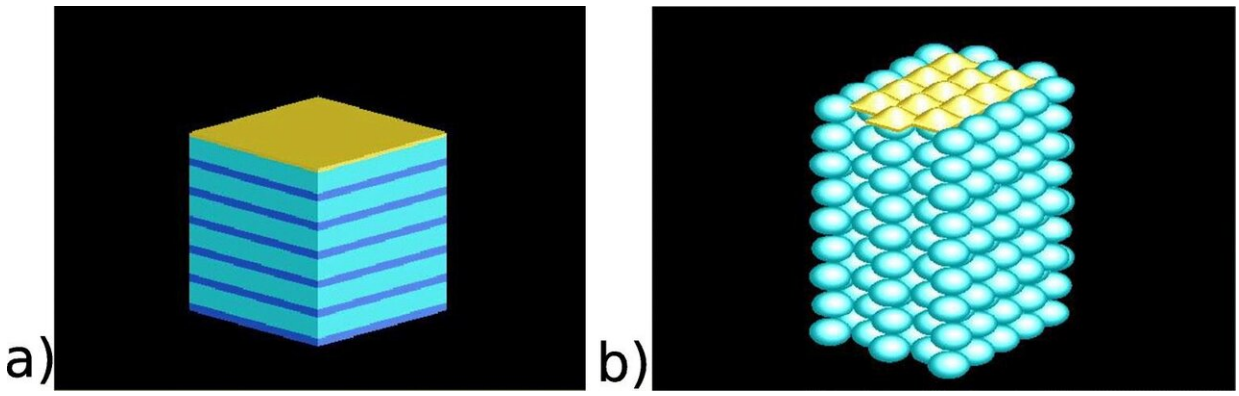
Laser and sensor research to be advanced by new inquiries into plasmonic-photonic crystals

August 12 2019, by Artyom Koryukin, Yury Nurmeev



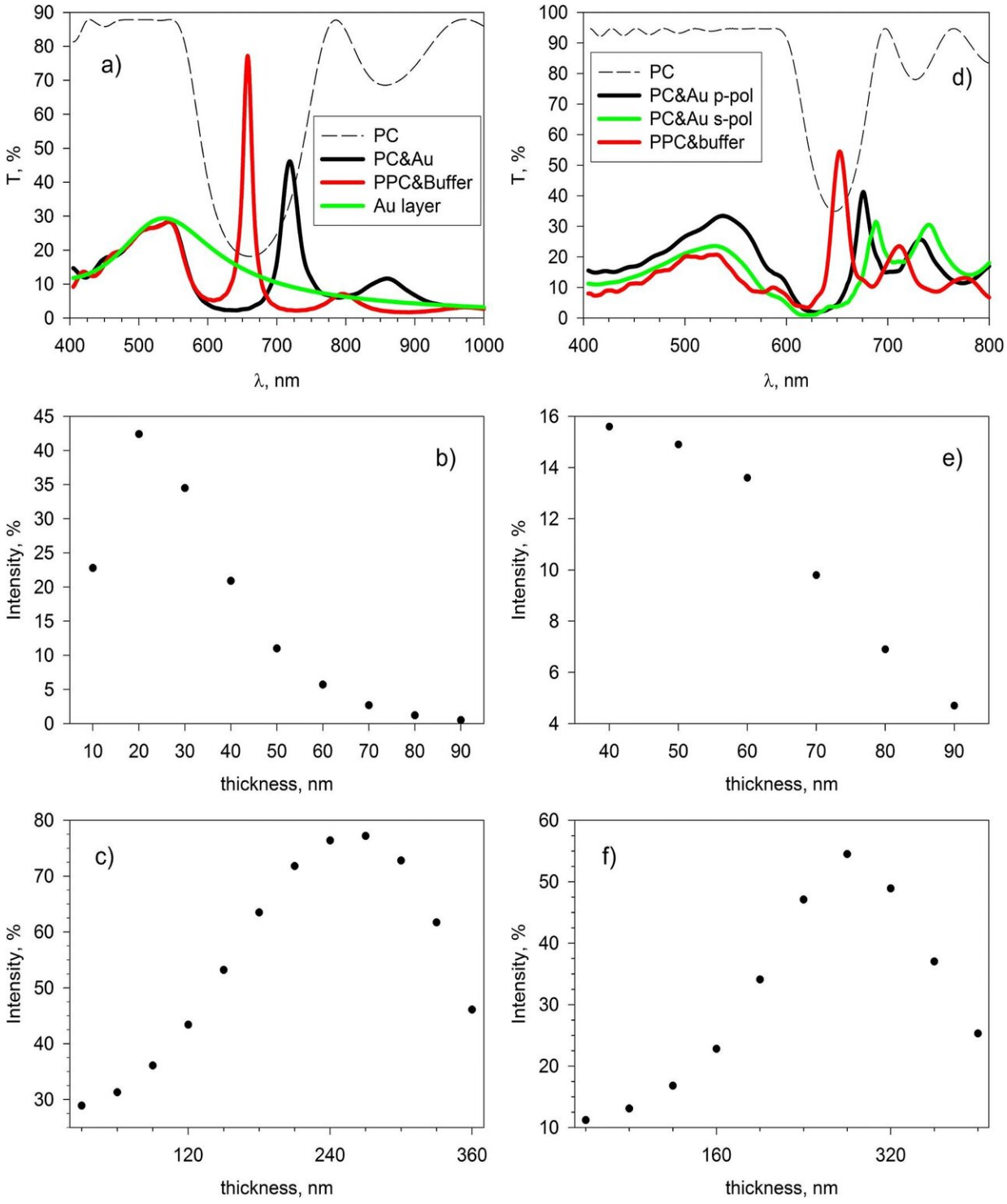
Schemes of PPC with equal effective refractive index and structure period. a 1D PPC and b 3D opal-like PPC. Credit: Kazan Federal University

A group of researchers led by Professor Myakzyum Salakhov has been working on the problem of optical states in plasmonic-photonic crystals (PPCs).

First Category Engineer Artyom Koryukin says that the research was dedicated to modeling light transmission throughout photonic crystals with a continuous gold layer on their surface. Photonic crystals don't pass a certain wavelength of light. This is called the photonic bandgap—the range of light wavelength where propagation through a crystal is

difficult. PPCs, on the other hand, allow the passage of light of a certain wavelength through this photonic bandgap. The problem of three-dimensional opal-like PPCs (OLPPCs), however, is that they don't admit light of certain wavelengths.

In this work, conditions are defined for the passage of a beam of light with the wavelength of the photonic bandgap and certain polarization through an OLPPC. To achieve this goal, different versions of PPCs were modeled. The main conditions to pass such a beam are both the continuity of the gold layer with a thickness of about 40 nm, and the use of light with polarization. Transmittance of light across a PPC is accompanied by excitations of the optical Tamm states. One-dimensional PPC has a light transmission pass band inside the photonic bandgap in both polarizations. Three-dimensional PPCs do not have light transmission pass bands inside the photonic bandgap because of a non-continuous gold layer (shaped like separate nano-caps or nano-crescents on the surface of a PPC). So the used OLPPCs have this unique feature—a light transmission pass band inside the photonic bandgap with certain polarization due to the excitation of the hybrid mode of the optical states.

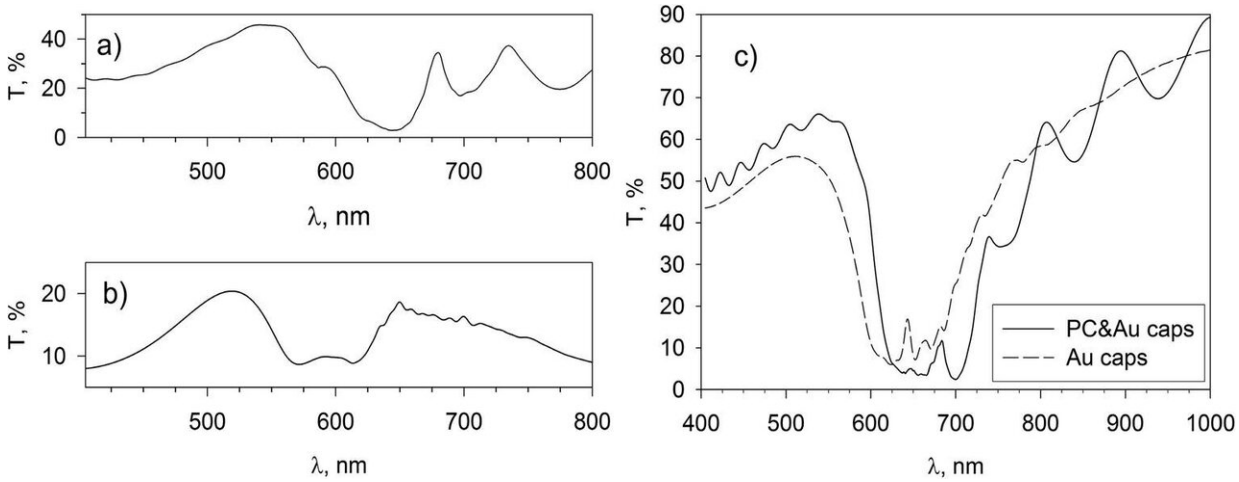


a) Transmission spectra of 1D PC and PPC. Dashed line is the spectrum of PC. Thick line is the spectrum of PC with the 30-nm Au layer. Red line is the spectrum of PC with the 30-nm Au and 270-nm buffer layers. The thin line is the calculated transmission spectrum of the 30-nm Au layer. b) Intensity of

transmission peak of the 1D PPC for different values of the thickness of the Au layer. d) Transmission spectra of 3D PC and PPC. Dashed line is the spectrum of PC. Thick line is the spectrum of PC with the 40-nm Au layer (p-polarization). Red line is the spectrum of PC with the 40-nm Au and 280-nm buffer layers. Thin line is the spectrum of PC with the 40-nm Au layer (s-polarization). e) Intensity of the transmission peak of the 3D PPC plotted as a function of the thickness of the Au layer Credit: Kazan Federal University

OLPPCs with the hybrid mode of the optical states can be used in high-polarization-sensitive sensors. "We assume that the hybrid mode can be useful for improving the control of light in PPCs. New types of resonators based on OLPPCs can be used for the strong interaction of light and matter," adds Mr. Koryukin.

The group is planning to create a theoretical description of the model of such processes. Additionally, they want to find effective applications for OLPPCs, such as strong light-matter interactions with a single photon source.



a) Transmission spectrum of PPC with the 30-nm Au layer. b) Transmission

spectra of stand-alone the 40-nm Au continuous layer. c) Transmission spectra of PPC with caps. Solid line is the spectrum of PC with the 40-nm Au caps. Dashed line is the spectrum of stand-alone the 40-nm Au caps Credit: Kazan Federal University

More information: A. V. Koryukin et al. Hybrid Mode of Optical States in Opal-like Plasmonic-Photonic Crystals, *Plasmonics* (2018). DOI: 10.1007/s11468-018-0880-6