Electrically Tunable Nanostructured Color Filter

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Plasmonic nanostructures with a strong and spectrally narrow birefringence have been developed. Strong color effects depending on the polarization have been observed, which could have applications in optoelectronic devices such as displays or multispectral imagers.

Surface plasmon resonances in metallic nanostructures enable the confinement and manipulation of the electromagnetic field well below the diffraction limit, thus opening new paradigms for optical devices. In addition, subwavelength resonators are able to act on the phase of the light, making them essential building blocks for metasurfaces. This project aims to the development of a colored optical retarder and its integration in optoelectronic devices. This is achieved by design and fabrication of plasmonic nanostructures showing a strong and spectrally narrow birefringent effect that yields a color effect which can be actively controlled by, *e.g.*, liquid crystals.

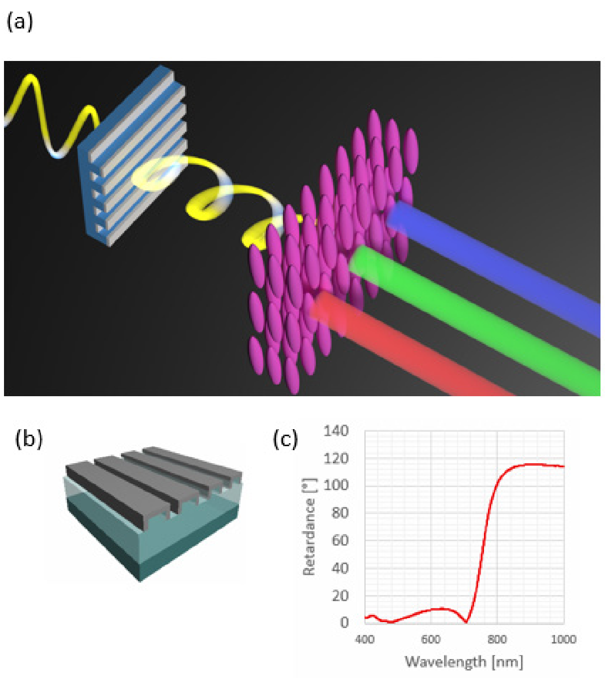

Figure 1: (a) Plasmonic retarder between a polarizer and a liquid crystal-based polarization analyzer, allowing to generate a variety of colors as a function of the voltage applied to the liquid crystal cell. (b) Plasmonic phase retarder made of a deep subwavelength array of silver nanowires. (c) Measured phase retardance between polarization along and across the wires.

The basic working principle of the device is shown in Figure 1. A plasmonic phase retarder can generate different colors in transmission when placed between crossed polarizers and the output polarization is rotated [1]. The plasmonic phase retarder consists of a periodic array of deep-subwavelength metallic nanowires. The light polarized across the nanowires (TM) excites a plasmon resonance. A first entrance polarizer prepares the incident light in a polarization state oriented at 45° from the nanowires orientation. A phase retardation between TM and TE polarization yields an elliptically polarized light in transmission. A polarization analyzer based on liquid crystal cells allows to project the transmitted light onto a polarization state whose orientation depends on the applied voltage. Interferences between the different birefringent contributions lead to a color effect in transmission.

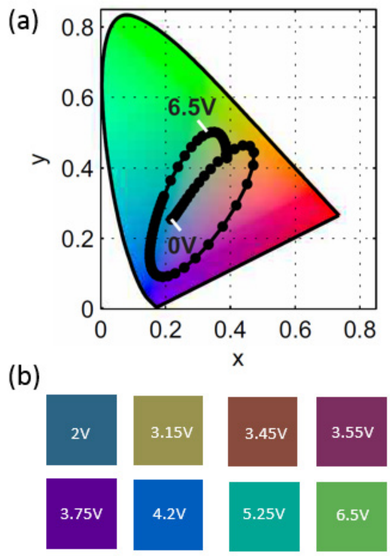

Figure 2: (a) CIE plot of color range spanned by the system. White: colors obtained by mechanical rotation of an analyzing polarizer. Black: colors obtained by increasing the voltage applied to the liquid crystal cell from 0 V to 6.5 V. (b) Colors at particular voltages.

A broad variety of colors can be spanned upon application of a voltage in the range between 2 V and 6.5 V (Figure 2). In particular, red is obtained from the plasmonic structure, blue from the LCC and green from the combination of cyan and yellow from the plasmonic structure and the LLC, respectively. Other colors such as violet, magenta, yellow, cyan, turquoise and different tones of white are generated at intermediate voltages. Overall, an area above 70% of the color gamut of standard RGB filters is generated with a single filter. This spectral selectivity is added in transmission without any loss in the image resolution. Compared to liquid crystal tunable filters, the resonance spectral width of the transmitted light is decreased from 180 nm to 120 nm in the green range. The presented approach is foreseen to be implemented in a variety of devices including miniature sensors or smart-phone cameras to enhance the color information, ultra-flat multispectral imagers, wearable or head-worn displays as well as high resolution display panels.

Funding from Nano-Argovia is gratefully acknowledged.

• Paul Scherrer Institute

•• Rolic Technologies Ltd.

[1] L. Dümpelmann, A. Luu-Dinh, B. Gallinet, L. Novotny, Four-fold color filter based on plasmonic phase retarder, ACS Photonics 3: 190−196, 2016.