Electrically switchable plasmonic polymer metasurfaces for video-rate beam switching and multi-focal metaobjectives

Harald Giessen[1], Julian Karst[1], Derek de Jong[1,2], Moritz Floess[1], Dominik Ludescher[1], Yohan Lee[1], Monika Ubl[1], Sabine Ludwigs[3], Paul V. Braun[2], and Mario Hentschel[1]

[1] *4th Physics Institute and Research Center SCoPE, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany*

[2] *Department of Materials Science and Engineering, Materials Research Laboratory, and Beckman Institute for Advanced Science and Technology, University of Illinois Urbana-Champaign, Urbana, IL 61801, USA*

[3] *IPOC-Functional Polymers, Institute of Polymer Chemistry, University of Stuttgart, Pfaffenwaldring 55, 70569 Stuttgart, Germany.*

E-mail: giessen@physik.uni-stuttgart.de

Miniaturizing optical components is key to achieve ultimate spatiotemporal control of light. Active subwavelength nanoantennas and metasurfaces are a prime candidate to achieve this goal, whose functionalities are currently limited by the proposed switching schemes.

We introduce nanoantennas and metasurfaces from *metallic polymers* which can be electrically switched in the infrared spectral range via CMOS-compatible voltages of ±1V (Fig. 1A) [1]. The concept is based on an electrically driven metal-to-insulator transition. A positive voltage turns the polymer metallic and the nanoantennas exhibit a strong plasmonic resonance (right). In contrast, a negative applied voltage (left) switches the polymer into the insulating state with no nanoantenna resonance present. The electrical switching between ON- and OFF-state occurs fast, permitting video-rate switching frequencies of up to 30 Hz.

Using such nanoantennas we demonstrate, on the one hand, an electrically switchable metallic polymer metasurface for ultra-high-contrast active beam switching (Fig. 1B). On the other hand, we realize an electro-active metaobjective comprising two metalenses-on-demand [2]. The state of metalenses can be set fully independently. Non-volatile operation is used to set the refractive power of the individual metalenses either ON or OFF. Such, four different metaobjective states become possible. By using gel electrolytes, our metadevices can even be integrated into state-of-the-art on-chip electro-optic components [3,4].

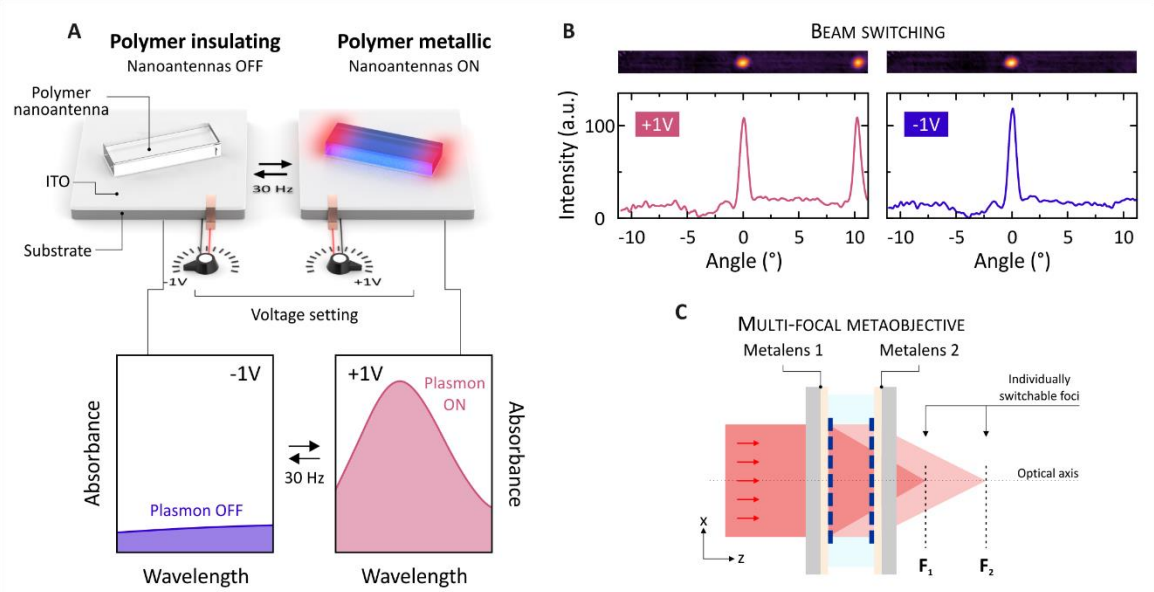

Fig. 1 (A) Concept of electrically switchable nanoantennas made from metallic polymers. Right: Nanoantenna ON-state at applied voltage +1 V, plasmonic resonance observed. Left: Antenna OFF-state at -1 V, no plasmonic resonance observed. Switching is possible with video-rate frequencies of 30 Hz. (B) Metallic polymer plasmonic metasurface for ultra-high-contrast active beam steering. Camera images and intensity profiles in the ON- (left) and OFF-state (right). (C) Multi-focal metaobjective comprising two stacked metalenses-on-demand. The state of each metalens can be set individually in a non-volatile operation.

References

[1] J. Karst et al., "Electrically switchable metallic polymer nanoantennas", Science **374**, 612 (2021).
[2] J. Karst et al., "Electro-active metaobjective from metalenses-on-demand", Nature Communications **13**, 7183 (2022)**.**
[3] D. de Jong and J. Karst et al., "Electrically switchable metallic polymer metasurface device with gel polymer electrolyte", Nanophotonics (2023), in press, https://doi.org/10.1515/nanoph-2022-0654.
[4] Y. Lee, J. Karst, M. Ubl, M. Hentschel and H. Giessen, „Dynamic beam control based on electrically switchable nanogratings from conducting polymers", Nanophotonics (2023), accepted.