Tuneable asymmetric responses via multilayers of Babinet patterns

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Metamaterials constructed with plasmonic nanoresonator arrays of specific symmetry properties can result in asymmetric optical responses. Nonreciprocal phenomena include asymmetric cross-polarized reflection (AR_{cross}) and transmission (AT_{cross}) in Tellegen materials and asymmetric co-polarized transmission (AT_{co}) in artificial moving media [1]. In our previous studies we presented multilayers constructed with consecutive periodic patterns of Babinet complementary miniarrays of spherical plasmonic nanoresonators that exhibit asymmetric optical responses [2, 3]. Comparison of tri-layers proved that all optical responses are larger for the cx-cv-cx multilayer in both inspected azimuthal orientations, except the co-polarized reflectance, and ΓX azimuthal orientation is more preferable. The (i) NIM, (ii) asymmetric transmission, (iii) asymmetric polarization rotation is accompanied by magnetic dipoles with precession trajectory is of (i) large amplitude, small ellipticity and tilting (ii) small amplitude, large ellipticity and intermediate tilting, (iii) intermediate amplitude and ellipticity, large out-of-plane tilting. The cx-cv-cx multilayer possesses better Tellegen coupling (artificial moving) characteristics compared to the cv-cx-cv layer, based on the larger AT_{cross} and AR_{cross} (AT_{co}), Tellegen parameter, and larger cumulated polarization rotation ($\sum=(\beta_f-\alpha_f)+(\beta_b-\alpha_b)$), despite the predominantly larger detuning between AT and ∑ maxima. The original multilayers exhibit considerable ∑ in the interval of Tellegen parameters' modulation (at 750 nm /705 nm for cx-cv-cx in the 0° /90° azimuthal orientation). Optimization performed to reach ∑~90°, by illuminating the multilayer with p-polarized light from backward, in the azimuthal orientation corresponding to the outgoing polarization orientation achieved in case of forward illumination ($\alpha_b:=\beta_f$), resulted in appearance of generalized Faraday rotation phenomenon in the interval of vanishing transmission of the multilayers. Both the maximal ∑ and it's spectral location were tunable by varying the coupling between the constituent layers. Optimization of non-reciprocity originating from magnetic field emulation via controlled out-of-plane tilted magnetic dipole generation is in progress, by setting criteria on the residual optical signals.

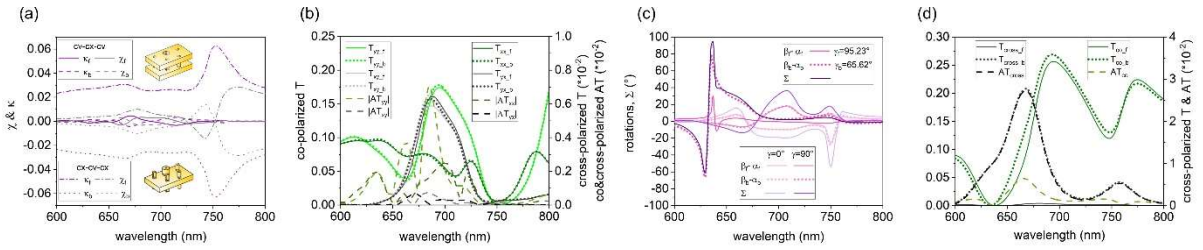

Figure 1 (a) Tellegen parameter of original tri-layers, (b and d) polarization selectively read-out asymmetric transmission and (c) ∑ cumulated rotation, of (a, b) original and (d) optimized cx-cv-cx tri-layers of Babinet complementary miniarrays (concave: cv, convex: cx).

[1] V. S. Asadchy, A. Diaz-Rubio and S. A. Tretyakov: "*Bianisotropic metasurfaces: physics and applications*", Nanophotonics **7(6)** (2018) 1069–1094.
[2] E. Tóth, B. Bánhelyi, O. Fekete, M. Csete: „*Metamaterial properties of Babinet complementary complex structures"*, Scientific Reports **13** (2023) 4701.
[3] E. Tóth, O. Fekete, B. Bánhelyi, M. Durach, Zs. Szabó, M. Csete: „*Layered Babinet complementary patterns acting as asymmetric negative index metamaterial*", Scientific Reports **14** (2024) 29568.