Reconfigurable Photonic Metamaterials (RPM)

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Abstract: We demonstrate the first temperature driven mechanically reconfigurable photonic metamaterial (RPM) providing tunability at optical frequencies.

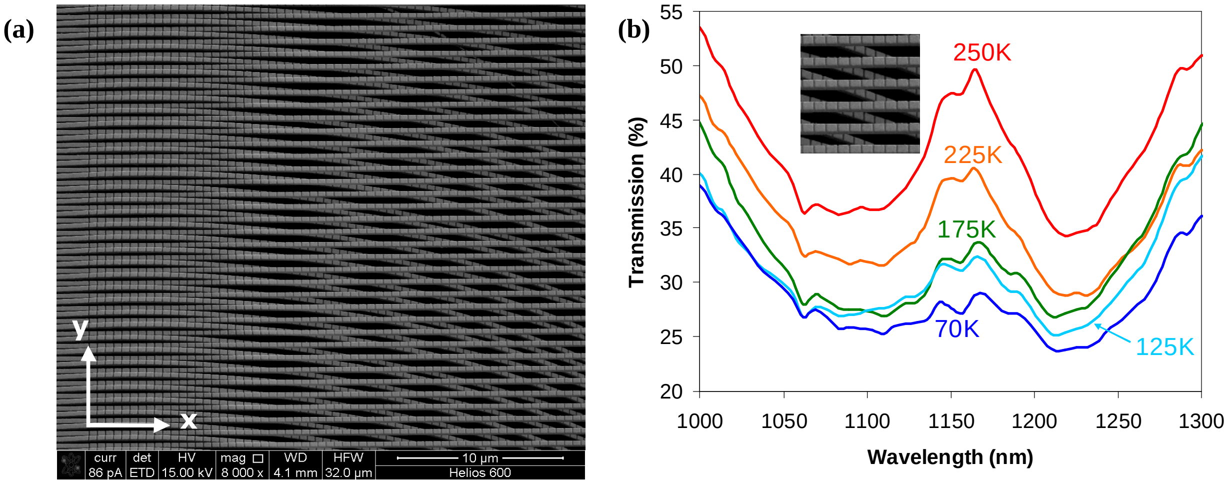

Fig.1: Locally periodic RPM of dipole resonators. (a) SEM micrograph the metamaterial consisting of 500nm×450nm×50nm gold dipole resonators fabricated by focused ion beam milling on a 100nm thick silicon nitride membrane. (b) Y-polarized transmission spectra as a function of temperature acquired close to the disconnected end of the cantilevers. The inset shows the locally periodic 5µm×5µm measurement area.

Being closely linked to resonant phenomena, most metamaterial functionalities are narrow-band and thus tunability is essential for most real world applications. Lack of tunability has largely kept metamaterials at the proof-of-principle stage with little practical importance. Here we introduce the first mechanically reconfigurable photonic metamaterial providing tunability at optical frequencies.

RPMs offer an opportunity to achieve precise control of metamaterial properties through mechanical deformation of nanoscale metamaterial structures. The difficulty of achieving a large deformation within an individual meta-molecule has been circumvented by placing nanoscale metamaterial resonators on 10s of micrometer long bimaterial cantilevers, which bend upon temperature changes. By alternating double-connected and single-connected cantilevers, we create locally periodic structures in which the distance (and thus coupling) between neighbouring resonator strips is controlled by temperature. The cantilever-bending results from the different thermal expansion coefficients of the gold plasmonic resonators and the supporting silicon nitride membrane.

Fig. 1 illustrates this concept for the simplest case of simple rectangular plasmonic resonators cut by focused ion beam milling from a 50nm gold layer covering a 100nm thick silicon nitride membrane. The structure is periodic in the y-direction and locally periodic in the x-direction on length scales up to about 5µm. Fig. 1(b) illustrates for a measurement area close to the disconnected ends of the 50µm long cantilevers how dramatically the metamaterial properties depend on temperature. At a temperature of 250K two transmission resonances at 1100nm and 1220nm and a pass band in between can be clearly identified. As the temperature is decreased to 70K the disconnected end of the cantilevers bends towards the metamaterial membrane and the pass band vanishes almost completely, here the relative transmission change is -50%. The pass band recovers when the temperature is increased back to 250K, indicating reversible tuning.

At the conference we will demonstrate temperature-controlled reversible tuning for mechanically reconfigurable photonic metamaterials and we will discuss the strategies for faster and more convenient electric control of such structures.