Magnetic field for controlling electromagnetic tunable metasurfaces operating in the terahertz band

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Metamaterials (MMs) are engineered structures with unique macroscopic properties derived from their microscopic design, which can be tunned using external excitation. This paper presents a system for tuning THz MM using magnetic force driven (MFD) mechanism, highlighting the design, analysis, and results of a magnetic field generating unit for modulation of split ring resonator (SRR) cantilever.

Keywords: electromagnetic metasurface; terahertz band, magnetic actuation, MEMS, magnetic circuit design

1. Introduction

Metamaterials (MMs) are artificially engineered structures whose macroscopic properties are derived not from their chemical composition but from their specific, precisely designed microscopic geometric structure (sub-wavelength). Currently, MMs exhibit engineered acoustic properties (e.g., directional sound insulation/attenuation, invisibility), thermal properties (e.g., heat dissipation), mechanical properties (e.g., shock control), as well as multimodal properties, such as optomechanical (movement control of microstructures using light). Recently, due to the advancements in high-frequency technologies, considerable attention has been devoted to the research of electromagnetic MMs, which consists of units smaller than the wavelength of the electromagnetic radiation they are designed to control (periodic or quasi-periodic arrays of sub-wavelength size units). Owing to their precise structure, MMs can exhibit extraordinary characteristics not found in natural materials, such as a negative refractive index or both negative permittivity and permeability [1]. This opens entirely new possibilities for interacting with electromagnetic waves and leads to novel applications of these materials in practical science. One of the greatest interests is placed in the THz band application. The 2-D form of a MM is referred to as a metasurface (MS). One approach to tuning MS involves the utilization of magnetically driven micro-electro-mechanical systems (MFD-MEMS), wherein the geometry of the structural element is modulated by a magnetic field. These structures are employed in various applications, including light switches, micromirror actuators, and metrological devices. Nonetheless, the application of MFD-MEMS mechanisms in the realm of tunable terahertz MS remains significantly constrained (in comparison to electrostatic, piezoelectric, or electrothermic mechanisms) [2]. This paper presents the concept, analysis, construction and results of a system for tuning a terahertz MS based on the use of a magnetic field source, which enables the adjustment of the frequency of the MS components containing a split ring resonator (SRR). The idea pertains to the application of an appropriately designed SRR cantilever, whose position varies depending on the characteristics of the interacting magnetic field (Figure 1).

2. Results and discussion

The objective of the work was to develop a system for generating a magnetizing field with a high gradient capable of deflecting the microcantilever of SRR. Consequently, the proposed solution consists of two branches of magnetic circuits (Figure 1a, top right corner). Each branch is constructed from a coil and a magnetic path made of laminated anisotropic electrical steel sheets that reduce magnetic reluctance, direct, and concentrate the magnetic flux. The coil of the magnetic circuit branch measures 300 mm in length, has an inner diameter of 50 mm and an outer of 110 mm, and contains approximately 1200 turns of 2 mm copper wire. The MS of designed SRRs is placed in the air gap of approximately 5 mm between the pole pieces of the magnetic circuit which generates a magnetic field of approximately 0.1 T. The details of the design, analysis of operation and verification measurements will be presented in the final version of the paper.

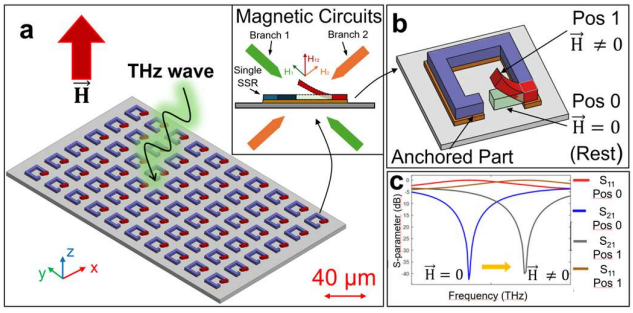

Figure 1: Part a: Magnetic field tunable metasurface operating in THz band; top right: Concept of magnetic source unit. Part b: Magnetically forced deflection of cantilever of split ring resonators (SRR). Part c: Shift of resonant characteristic due to the SRR cantilever deflection.

References

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