Electromagnetic Wave Theory and Applications

Academic and Research Staff
Professor David H. Staelin, Dr. Bae-Ian Wu

Graduate Students
Isaac Ehrenberg and Baile Zhang.

Novel Design of 3D Metamaterial

Sponsor
Auto-ID Lab

Project Staff
Dr. Bae-Ian Wu, Isaac Ehrenberg

Recent studies have investigated the design of low profile antennas that rely on materials engineered to have specific electromagnetic properties, specifically artificial magnetic conductors (AMC). An AMC has the unnatural property of zero degree phase deflection of a reflected plane wave, which would enable antennas to achieve a higher gain without the quarter wave conducting backplane that would normally be required. Towards the goal of constructing an AMC, several designs have been studied including mushroom structures, Hilbert-Peano curves, Jerusalem Crosses and dipole or slot arrays. In this project, we report on the investigation of an AMC that was constructed with a novel fabrication process, and utilized a new design based on the C ring structures normally used in the design of metamaterials. This design can be used to achieve AMCs of relatively low frequency, and can be assembly with relative ease over a very large area making it ideal for application with low profile low frequency antennae.

Stacking of Meta-foils

Project Staff
Dr. Bae-Ian Wu

The THz meta-foil is a purely metallic space-grid that comprises parallel upright S-strings interconnected by metal lines running orthogonally to the S-strings and intersecting them in their nodes of oscillation such as to preserve the well-known S-string resonance. The importance of meta-foils rests on the fact that they consist of metal only and are no longer influenced by any supporting or embedding dielectrics. The meta-foil can be tailored and shaped according to the application and can be used at higher temperatures. Stacking of meta-foils is a way towards 3D metamaterials and advanced optical functions. The coupling of an electromagnetic wave to the meta-foil is maximized for normal incidence with a broad useful angular range of about $\pm 30^\circ$. The resonance spectra exhibit the typical magnetic left-handed and electric right-handed peaks. The amplitude of the left-handed peak grows with decreasing density of interconnecting lines. The spectra are insensitive to mechanical bending and to heating. When stacking meta-foils, two main parameters are the relative orientation and the distance between foils. In the case of two foils at 25μm gap with S-strings parallel, we find the same magnetic and electric resonances as for the single foil with a transmission and FWHM smaller than that of a single foil. However, the transmission is significantly larger than the product of the single transmissions which may indicate an interaction via evanescent fields. If we rotate foils by 90° such that the individual directions of S-strings are orthogonal, the magnetic peak is lost, while an electric peak is still maintained. This finding can be explained by the orthogonal structure of S-strings and interconnecting lines. Besides building 3D metamaterials, stacking of meta-foils may be used for polarization devices and the variable suppression of the magnetic peak as well as the control of the transmission.

Publications

Optical force on a cylindrical cloak under arbitrary wave illumination
Hongsheng Chen; Baile Zhang; Kemp, B.A.; Bae-Ian Wu: Optics Letters, v 35, n 5, p 667-9, 1 March 2010

Optical delay of a signal through a dispersive invisibility cloak
Baile Zhang; Bae-Ian Wu; Hongsheng Chen: Optics Express, v 17, n 8, p 6721-6, 2009

Experimental verification of reversed Cherenkov radiation in left-handed metamaterial
Sheng Xi; Hongsheng Chen; Tao Jiang; Lixin Ran; Jiangtao Huangfu; Bae-Ian Wu; Jin Au Kong; Min Chen: Physical Review Letters, v 103, n 19, p 194801 (4 pp.), 6 Nov. 2009

Reversed Cherenkov radiation in unbounded anisotropic double-negative metamaterials
Zhaoyun Duan; Bae-Ian Wu; Jie Lu; Jin Au Kong; Min Chen: Journal of Physics D: Applied Physics, v 42, n 18, p 185102 (6 pp.), 21 Sept. 2009

Lorentz force and radiation pressure on a spherical cloak
Hongsheng Chen; Baile Zhang; Yu Luo; Kemp, B.A.; Jingjing Zhang; Lixin Ran; Bae-Ian Wu: Physical Review A (Atomic, Molecular, and Optical Physics), v 80, n 1, p 011808 (4 pp.), July 2009

Guiding waves through an invisible tunnel
Jingjing Zhang; Yu Luo; Hongsheng Chen; Jiangtao Huangfu; Bae-Ian Wu; Lixin Ran; Jin Au Kong: Optics Express, v 17, n 8, p 6203-8, 2009

Spherical cloaking using nonlinear transformations for improved segmentation into concentric isotropic coatings
Cheng-Wei Qiu; Li Hu; Zhang, B.; Bae-Ian Wu; Johnson, S.G.; Joannopoulos, J.D.: Optics Express, v 17, n 16, p 13467-78, 2009

High directive antenna with virtual aperture
Baile Zhang ; Bae-Ian Wu; Hongsheng Chen: 2009 IEEE International Symposium on Antennas & Propagation & USNC/URSI National Radio Science Meeting, p 4 pp., 2009

A rigorous analysis of plane-transformed invisibility cloaks
Yu Luo; Jingjing Zhang; Hongsheng Chen; Lixin Ran; Bae-Ian Wu; Jin Au Kong: IEEE Transactions on Antennas and Propagation, v 57, n 12, p 3926-33, Dec. 2009

Response of dispersive cylindrical cloaks to a nonmonochromatic plane wave
Blanchard, C.; Bae-Ian Wu; Porti, J.A.; Hongsheng Chen; Baile Zhang; Morente, J.A.; Salinas, A.: Journal of the Optical Society of America B (Optical Physics), v 26, n 11, p 2117-24, Nov. 2009

Electromagnetic detection of a perfect invisibility cloak
Baile Zhang ; Bae-Ian Wu: Physical Review Letters, v 103, n 24, p 243901 (4 pp.), 11 Dec. 2009

Free-space electromagnetic metamaterials from the far infrared to the visible
Moser, H.O.; Linke Jian; Bahou, M.; Casse, B.D.F.; Kalaiselvi, S.M.P.; Gang Liu; Maniam, S.M.; Pengda Gu; Ao Chen; Heussler, S.P.; bin Mahmood, S.; Li Wen; Jin Au Kong; Hongsheng Chen; Xiangxiang Cheng; Bae-Ian Wu: AIP Conference Proceedings, v 1092, p 66-70, 2009

An analytical method to study the effects of a substrate in surface-enhanced Raman scattering
Shao Ying Huang ; Bae-Ian Wu; Baile Zhang; Yee Hui Lee; Liberman, V.; Rothschild, M.: Journal of Applied Physics, v 106, n 11, p 114306 (6 pp.), 1 Dec. 2009