LEFT-HANDED MATERIALS BASED ON MAGNETIC NANOCOMPOSITES

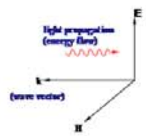
Y. Liu (PD), X. Zhang (PhDPhysics), and J. Q. Xiao

University of Delaware • Center for Composite Materials • Department of Physics and Astronomy

What is a Left-handed Material?

- Negative magnetic permeability
- Negative dielectric permittivity

$$\vec{E}(\vec{r},t) = \vec{E}_0 e^{-ikz-\beta z-i\omega t}$$
$$\vec{H}(\vec{r},t) = \vec{H}_0 e^{-ikz-\beta z-i\omega t}$$
$$\vec{E}\times\vec{H} \Rightarrow -\vec{k} = \omega\sqrt{\varepsilon\mu}$$



Physics Properties of LHM:

1. Reversed Doppler effect – the frequencies shift reflected by LHM opposite to the normal material
2. Reversed Cerenkov effect.
3. Reversed Snell's law – incident wave is at the same side of normal line.
4. Plate lens: a thick enough plate can focus wave

Key Idea for LHM in Magnetic Nanocomposites

Magnetic permeability is negative because of ferromagnetic resonance for RCPW

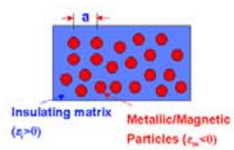
$$\mu_{+} = 1 + \frac{\omega_m}{(\omega_0 + j\alpha\omega) - \omega}$$

Dielectric constant is negative for metal below plasma frequency.

$$\varepsilon = 1 - \frac{\omega_p^2}{(\omega - j\gamma)\omega}$$

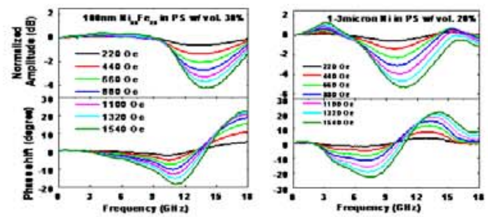
Negative e_{eff} can be achieved for D>> a

$$\varepsilon_{eff} = f\varepsilon_m + (1-f)\varepsilon_i$$



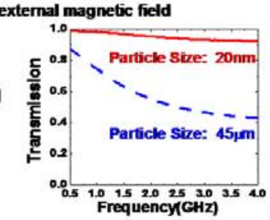
Small Particles and polymer matrix are used to get small damping.

Experiment: Possible Sign of mLHM

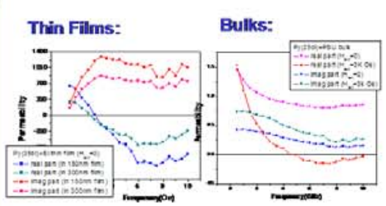


Phase shift can be enhanced by changing the composition and external magnetic field

Low loss with small particles



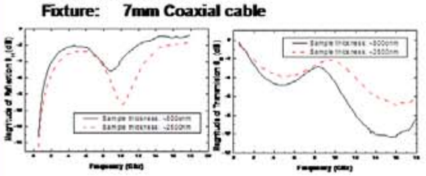
Negative Permeability



$\mu < 0$ can be achieved in magnetic composites

Sign of Thin Film mLHM in Coaxial Cable

Sample: Fe/SiO_2, Multilayer (Fe:~11nm)
Substract: ceramics
Fixture: 7mm Coaxial cable

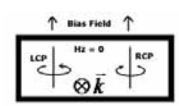


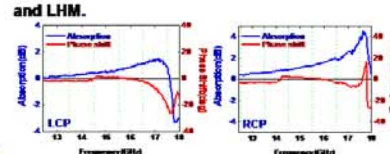
For normal metal film, the reflection increases as wavelength grows. For LHM theory, there is a window in which the reflection decreases

Sign of mLHM in Rectangular Waveguide

LCP and RCP waves exists at different positions in a rectangular waveguide

Samples at these two positions show the difference between RHM and LHM.





Conclusions and Future Work

1. Magnetic nanocomposites are potential LHM: mLHM.
2. mLHM is different from current isotropic LHM: mLHM is anisotropic and chiral.
3. mLHM can be achieved in bulk quantities and can have special applications.
4. Future work: demonstrate the negative index in mLHM
5. Future work: prove the unique properties of mLHM

Acknowledgements

This work is supported by the Army Research Laboratory through the Composite Materials Research program.