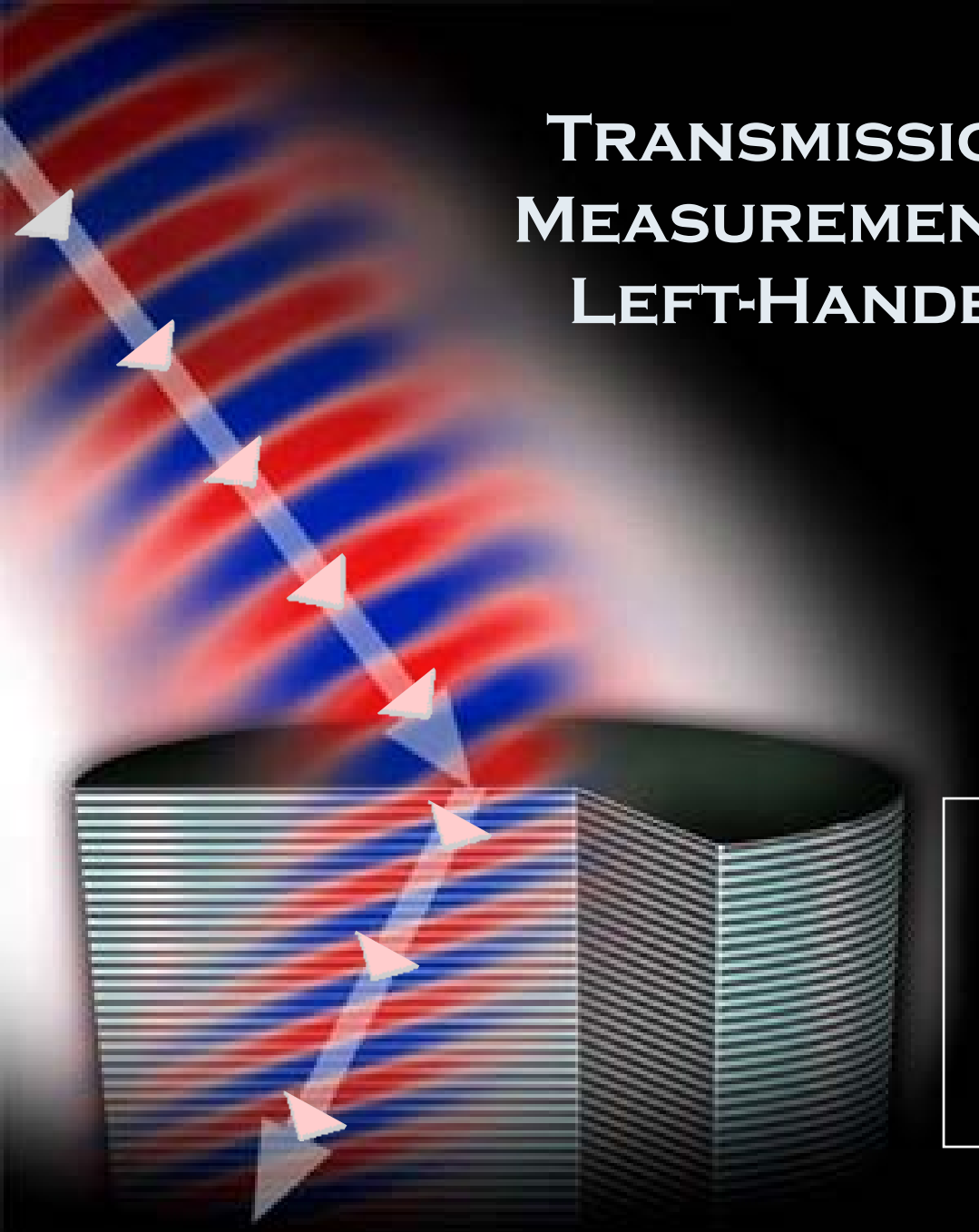


Transmission and Reflection Measurements of Mid-Infrared Left-Handed Metamaterials

Eugenia Zah[1], Joshua Newman[1], Samantha Sandfort[1], Nevin Raj[1], Phillip Braun[1], and Claire Gmachl[1]

1 Princeton University
MIRTHE

Motivation

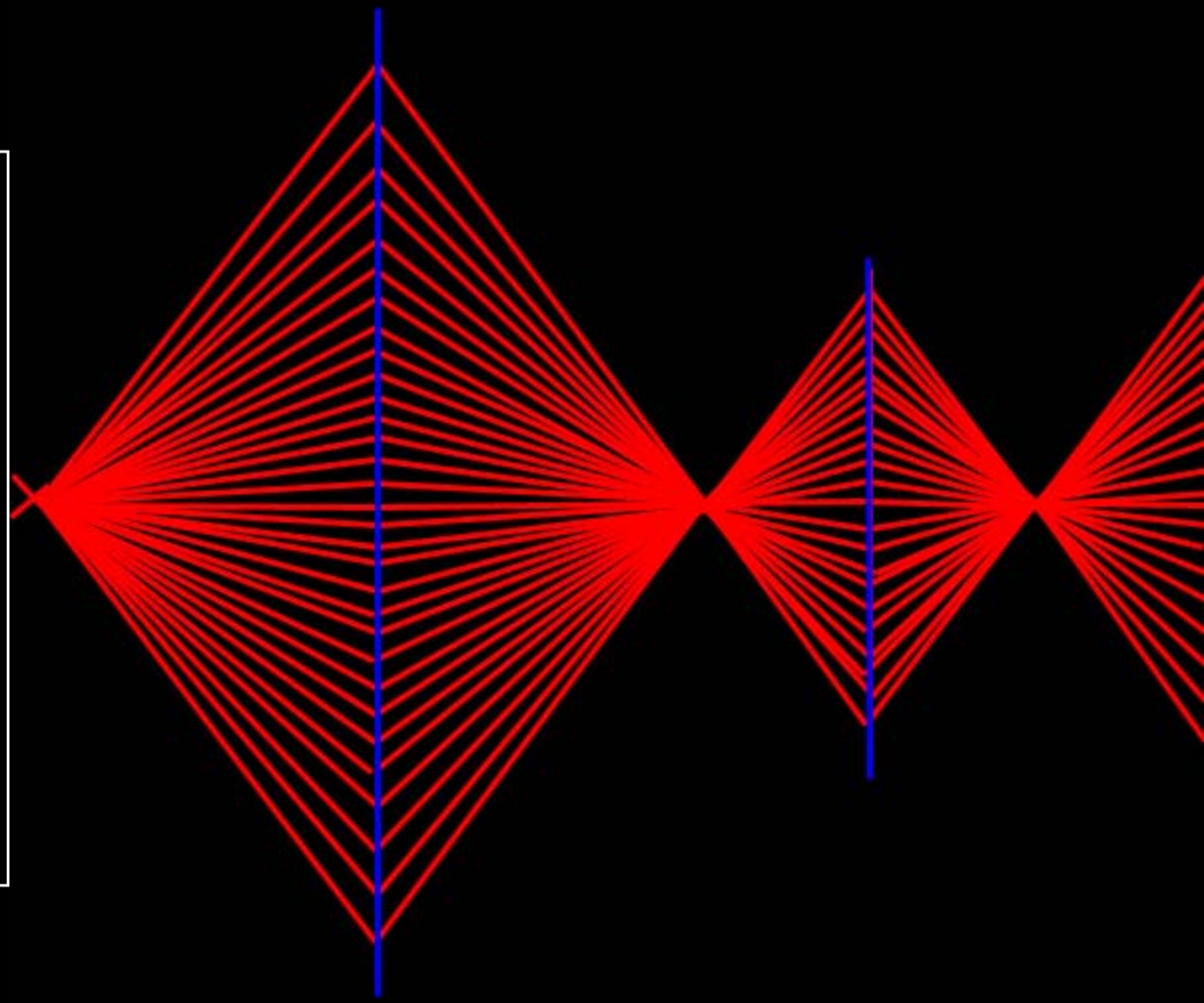
Future Applications

Gas Sensing

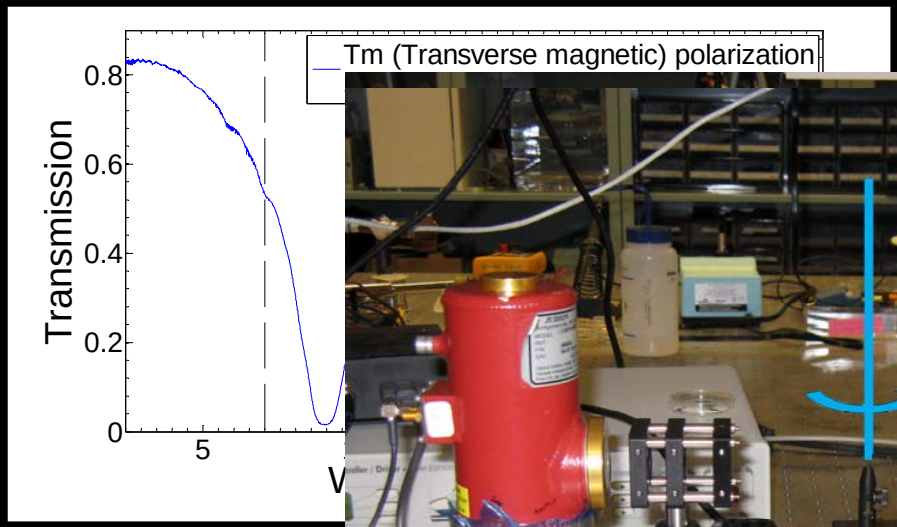
Imaging

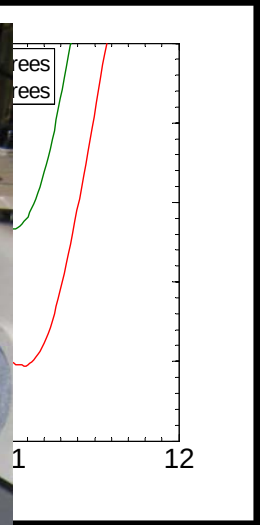
Lenses without resolution limits

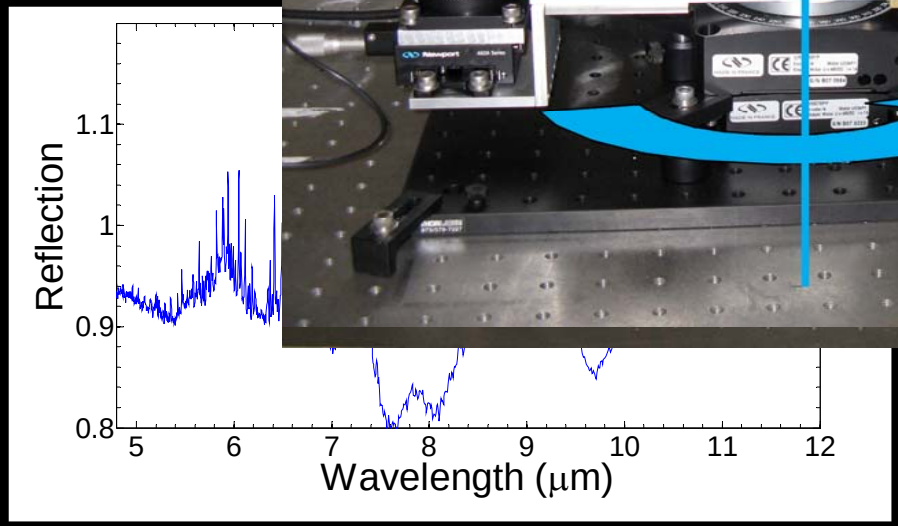
Determine Waveguide properties



Results


Tm (Transverse magnetic) polarization
Transmission
0.8
0.6
0.4
0.2
0
5


rees
rees
1
12


Reflection
1.1
1
0.9
0.8
5
6
7
8
9
10
11
12
Wavelength (μm)

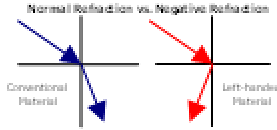
Transmission and Reflection Measurements of Mid-Infrared Left-handed Metamaterials

Eugenia Zah[1*], Joshua Newman[1], Samantha Sandfort[1], Nevin Raj[1], Phillip Braun[1], and Claire Gmachl[1]

Left-Handed Metamaterials

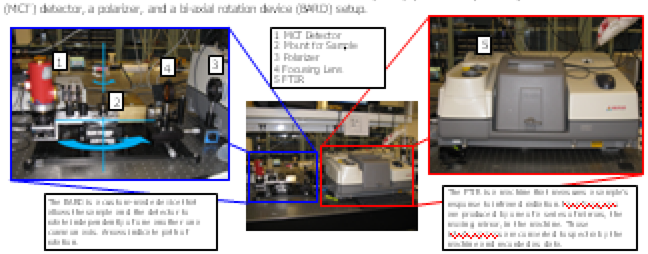
In 1967, Russian physicist Victor Veselago coined the term "left-handed materials" to describe materials with negative permittivity and permeability. He predicted the fabrication of new materials that could exhibit negative refraction or bend light in the opposite direction of the usual forward energy flow. Negative-index materials were first produced in 1999 and are a relatively new development. Today we are working with more advanced materials than those first created in 1999. In order to further understand these materials, we characterized them through transmission and reflection measurements.

Normal Refraction vs. Negative Refraction



Equipment

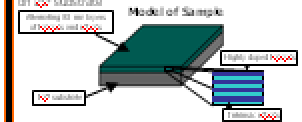
In order to take our measurements we used a Fourier transform infrared (FTIR) spectrometer, mercury-cadmium-telluride (MCT) detector, a polarizer, and a bi-axial rotation device (BARD) setup.



Samples

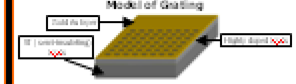
Sample A: 20 μm thick sample of alternating 80 nm highly-doped InGaAs and intrinsic AlInAs layers grown on InP substrate

Model of Sample



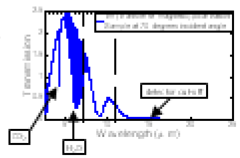
Sample B: Sample A with Au Grating

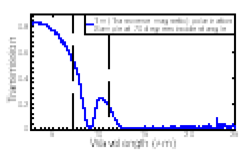
Model of Grating



Transmission

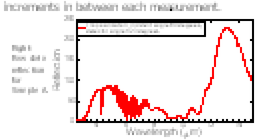
We took measurements by varying the angle at which the source hit the sample or incident angle from 0–90 degrees. A strong resonance appeared between angles 40-70 degrees.

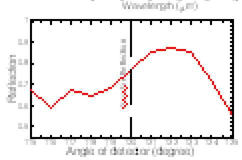


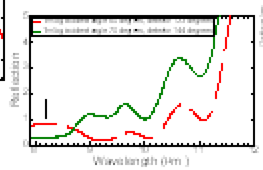


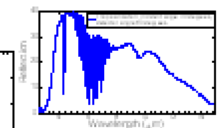
High Resolution Reflection

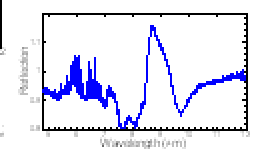
For our reflection measurements, we changed the angle at which the detector received the reflected light. According to the law of reflection, the angle at which light hits a reflective surface will equal the angle at which the light is reflected. Thus, following this law, the angle at which we set the detector was equal to double the incident angle of the sample. However, this did not imply that all samples would follow this law. But using the law of reflection as a standard, we tested the reflection of the light 5 degrees above and below double the incident angle moving the detector in 1 degree increments in between each measurement.











Conclusion

Through our transmission and reflection measurements, we were able to successfully characterize left-handed metamaterials. The study of left-handed materials is a relatively new field of research with many opportunities for scientists. With our measurements we can further understand the waveguide properties of these materials. In the future, the data we collected may help scientists develop better left-handed metamaterials, which can be used for various applications including gas sensing, imaging, or the ability to produce lenses without resolution limits.

[1] Department of Electrical Engineering, Princeton University, Princeton, New Jersey 08544, USA.

*Contact:

www.mirthecenter.org