Wide-band metamaterial perfect absorber in the long wave infra-red (LWIR) region

[1]**Janardan Nath**, [1]**Farnood Rezaie**, [1]**Deep Panjwani, and** [1]**Robert E. Peale**
[1]Department of Physics, University of Central Florida, Orlando FL 32816

http://www.ucf.edu
http://physics.cos.ucf.edu

Abstract

Uncooled bolometers are resistive IR detectors which detect change in resistivity due to heat generation by IR radiation. Highly efficient thin film IR absorbing coating is required for such absorbers. Metamaterial absorbers with thin layers of metal-dielectric-metal structure have been reported to produce perfect absorption with sharp band and absorption over wide angle. However, obtaining broadband absorption for applications with such absorber has been a challenge so far. We demonstrate a CMOS compatible thin metamaterial broadband absorber in the range from 8-14 microns with ~98% absorption. The absorber has a 3 layer metal-dielectric-metal structure which is fabricated using vacuum deposition methods and standard photo-lithography. A dispersive dielectric (SiO_2) is used to achieve multiple absorption bands. MDM cavity theory and FDTD simulations are used to design the absorber. Angle dependent reflectivity measurements confirm wide-angle absorption bands which are also polarization independent.

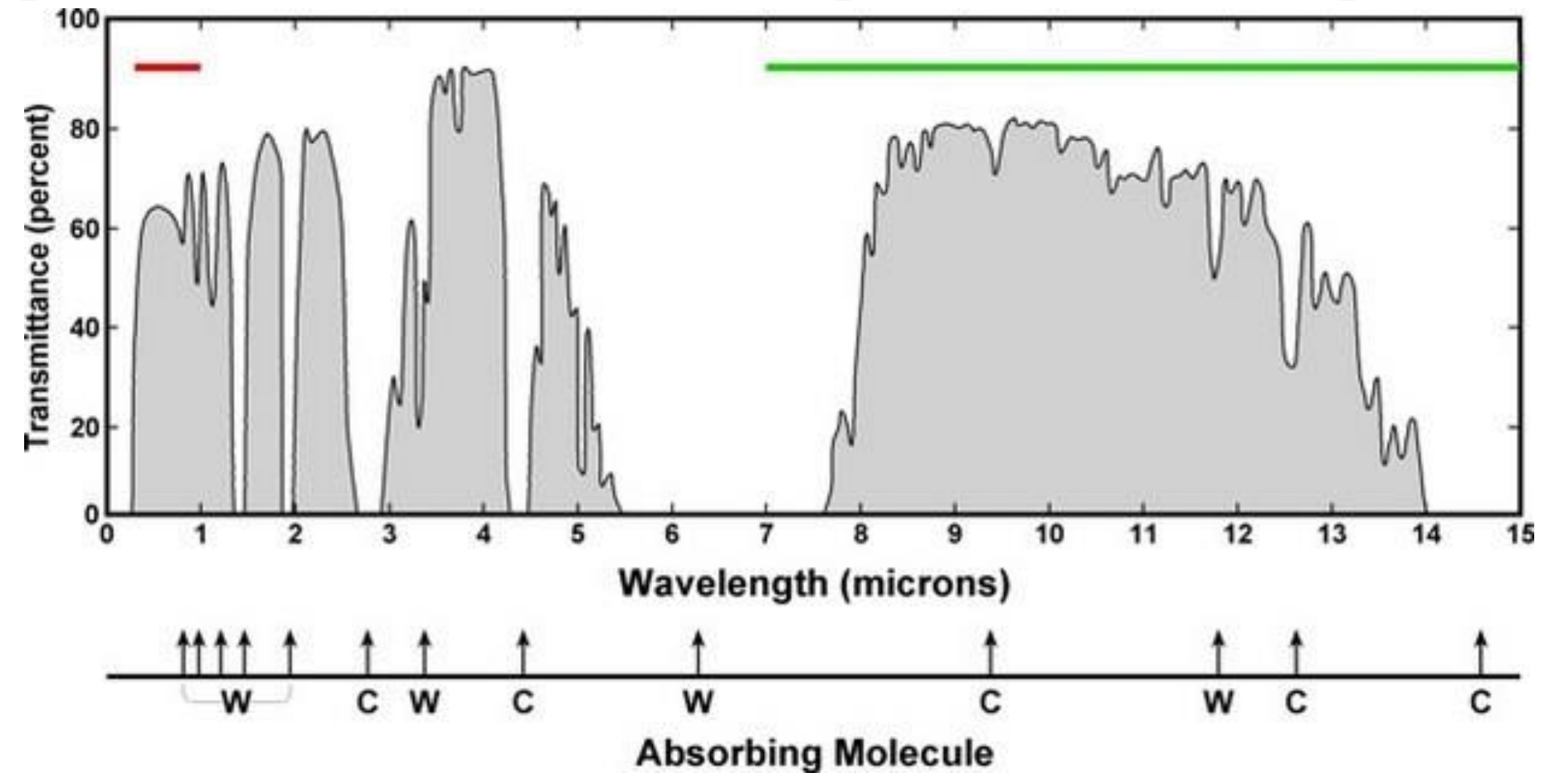
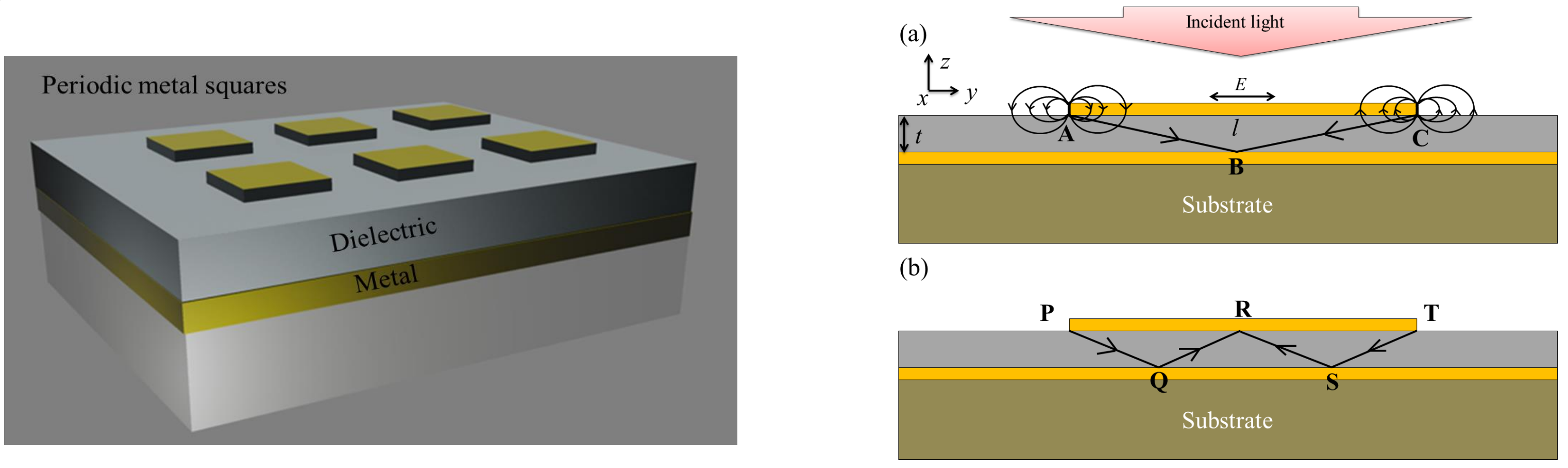


Figure above shows atmosperic transmission windows. IR bolometers aims to detect in these windows

MDM cavity metamaterial perfect absorber



Schematic diagram of the absorber.

The path difference between the points A, B and C is

$$\Delta = (b+1)n(\lambda)\sqrt{t^2 + l^2/(b+1)}$$

The phase difference including -p for reflection from metal is

$$\phi = \frac{2\pi\Delta}{\lambda} - b\pi$$

Using the condition that $\cos\phi = 1$ for standing waves formation

$$\lambda(b,m) = \frac{2(b+1)n(\lambda)}{b+2m}\sqrt{t^2 + l^2/(b+1)^2}$$

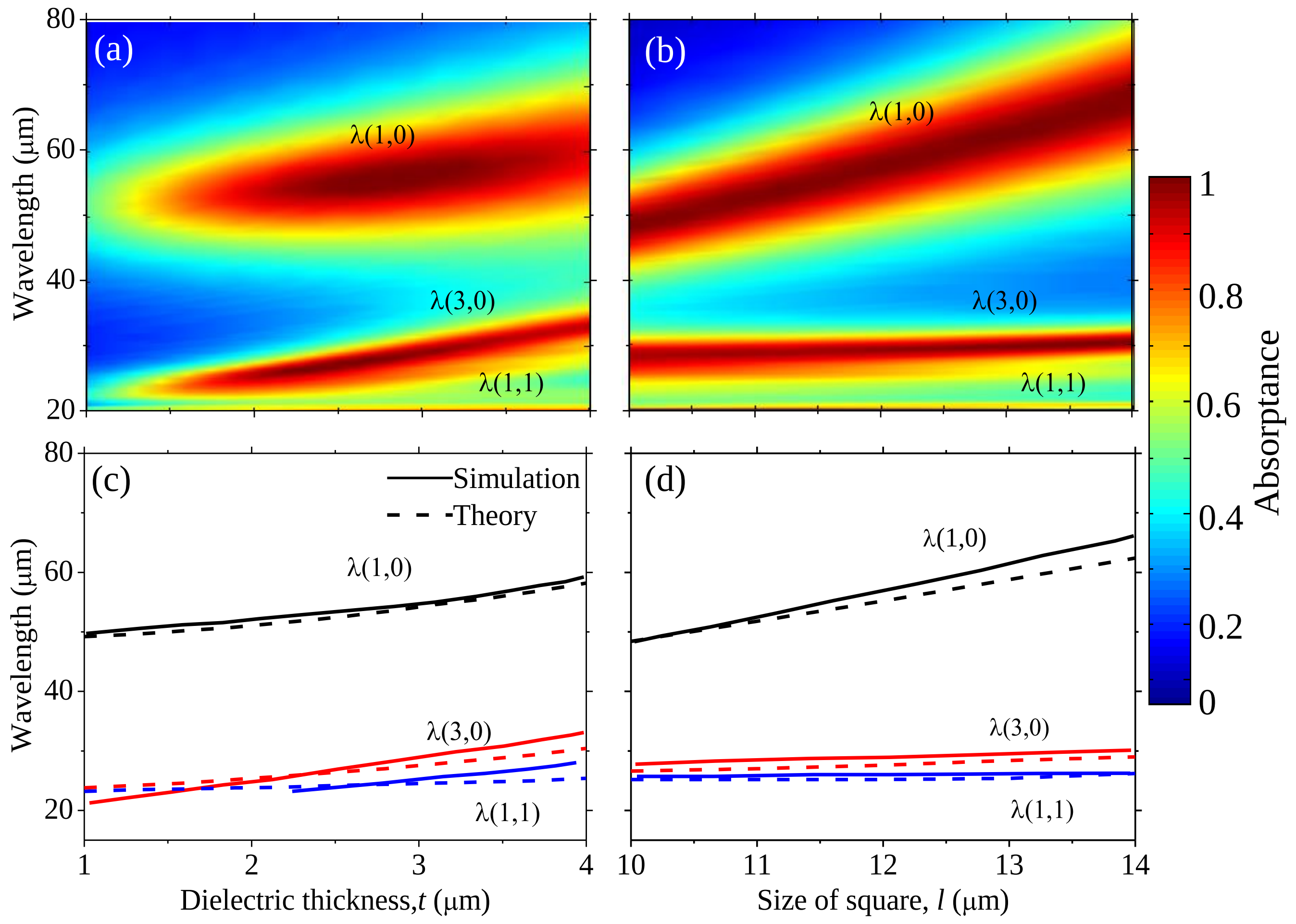
For *m*=0, 1, 2…
b=1,3,5….

$$\lambda(1,0) = 4n(\lambda)\sqrt{(t^2 + l^2/4)}$$

For *b*=1, *m*=0

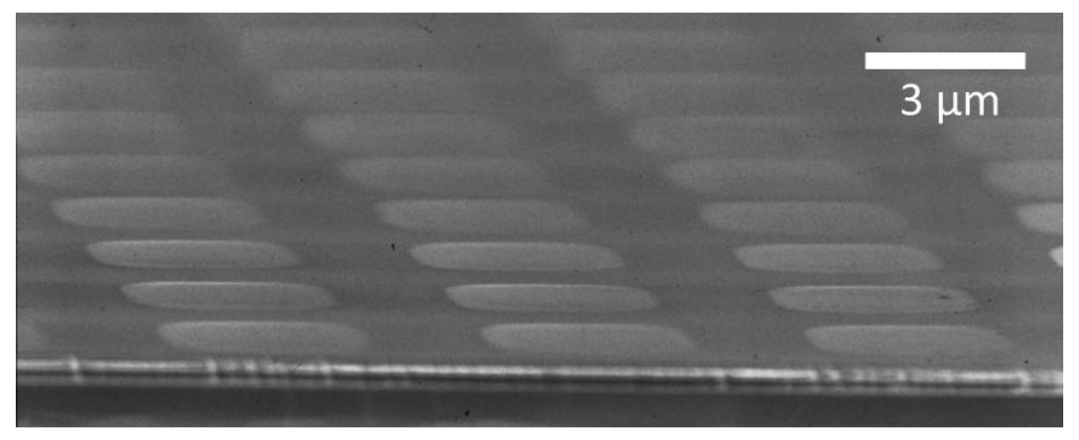
$$\lambda(3,0) = \frac{8n(\lambda)}{3}\sqrt{(t^2 + l^2/16)}$$

For *b*=3, *m=0*

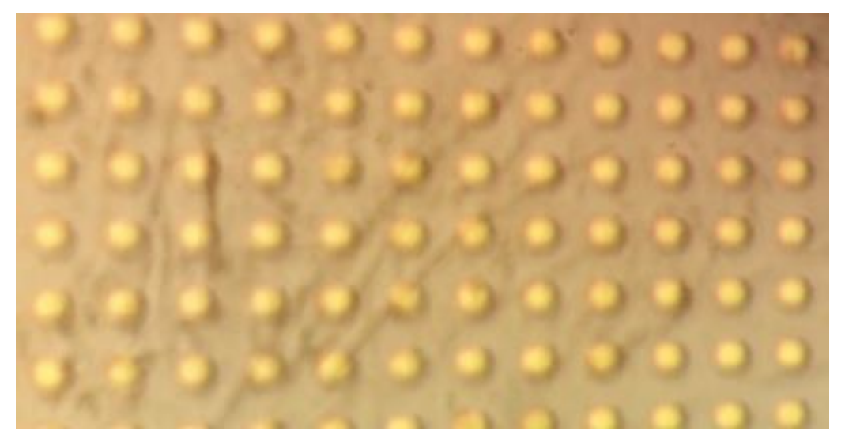


Colormap of absorptance as a function of wavelength and (a) dielectric thickness or (b) size of squares. Analytically (dashed line) and numerically (solid line) calculated resonance wavelengths as a function of (c) dielectric thickness, (d) size of squares.

Fabrication



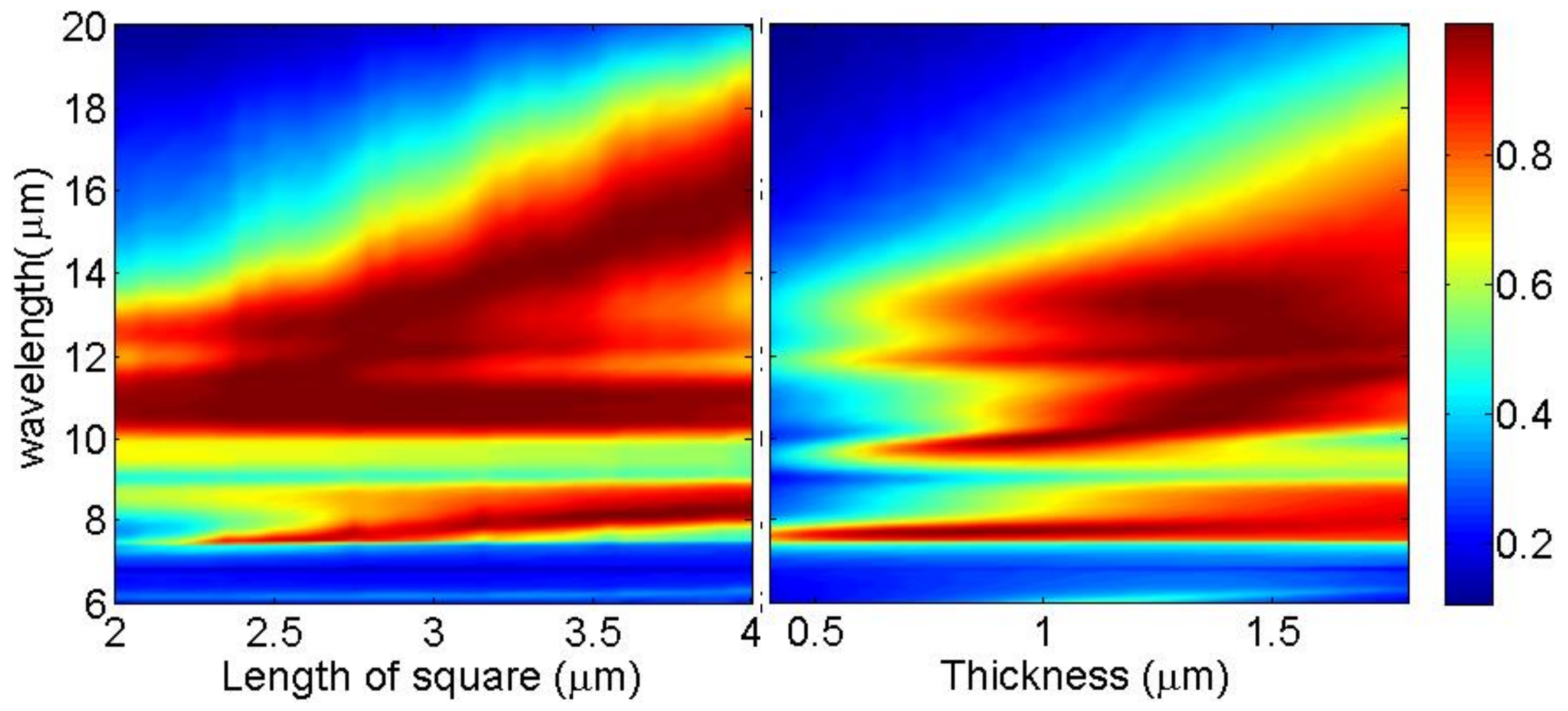
SEM image of the sample



Optical microscope image

First, a 10 nm Cr sticking layer followed by 200 nm of gold were deposited on glass or Si substrate. A second 10 nm Cr sticking layer was then deposited followed by evaporation of the SiO_2 dielectric spacer. Square patterns of gold were fabricated on the SiO_2 film by standard photolithography, DC sputtering, and lift-off.

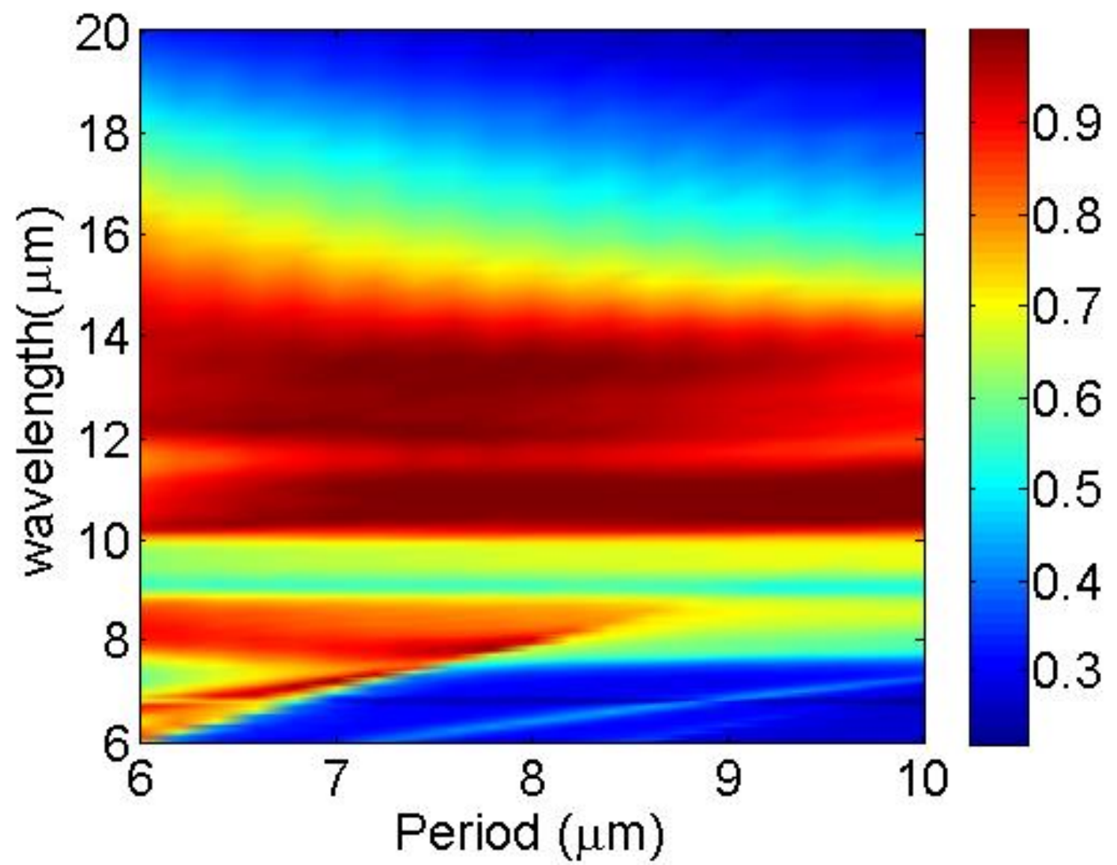
Simulation results for braodband LWIR absorber



Colormap of absorptance as a function of wavelength and (left) dielectric thickness or (right)size of squares.

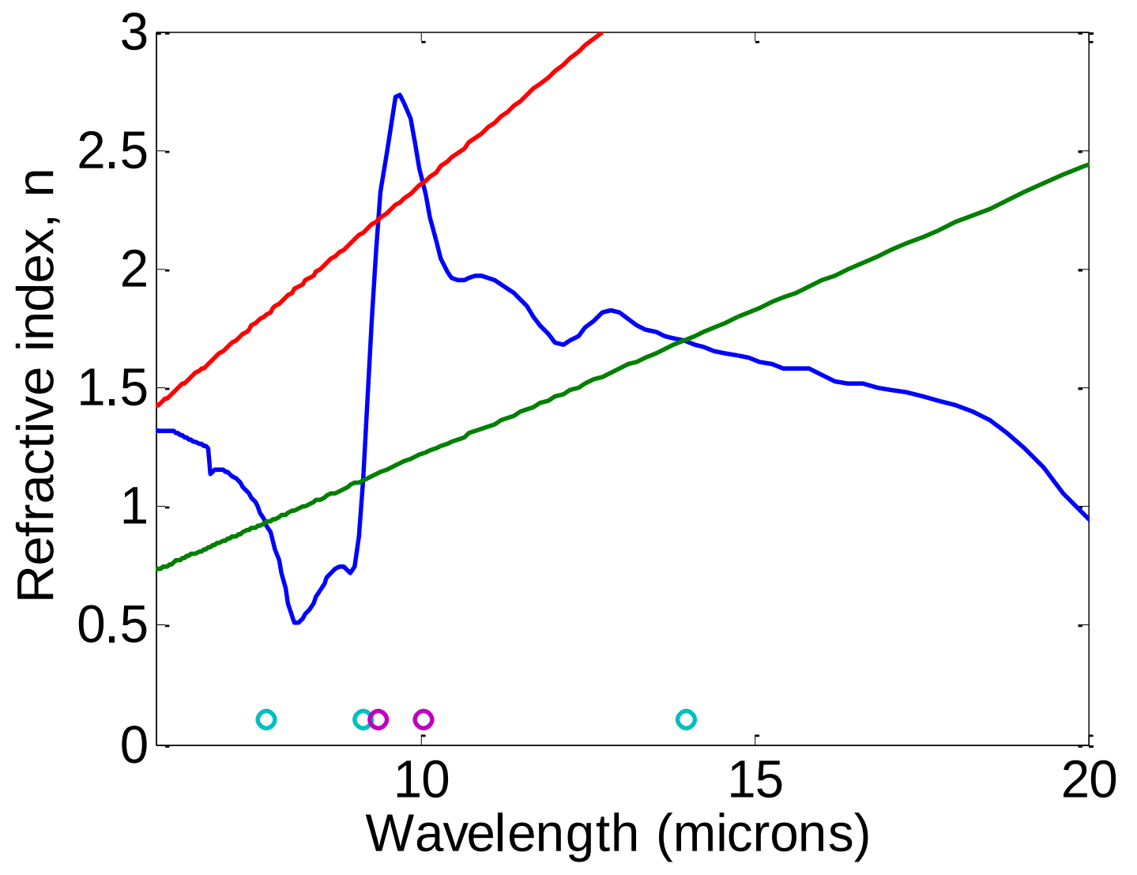
The squares can be considered as isolated and non-interacting

Image of aimulated absorptance as a function of wavelength and period of the squares. The size of the squares and thickness of the dielectric are *l*=3 microns and *t*=1.4 microns, respectively. *l* and *t* remains constant as period varies from 6-10 microns. Absorption band remain little effected by the change in period.



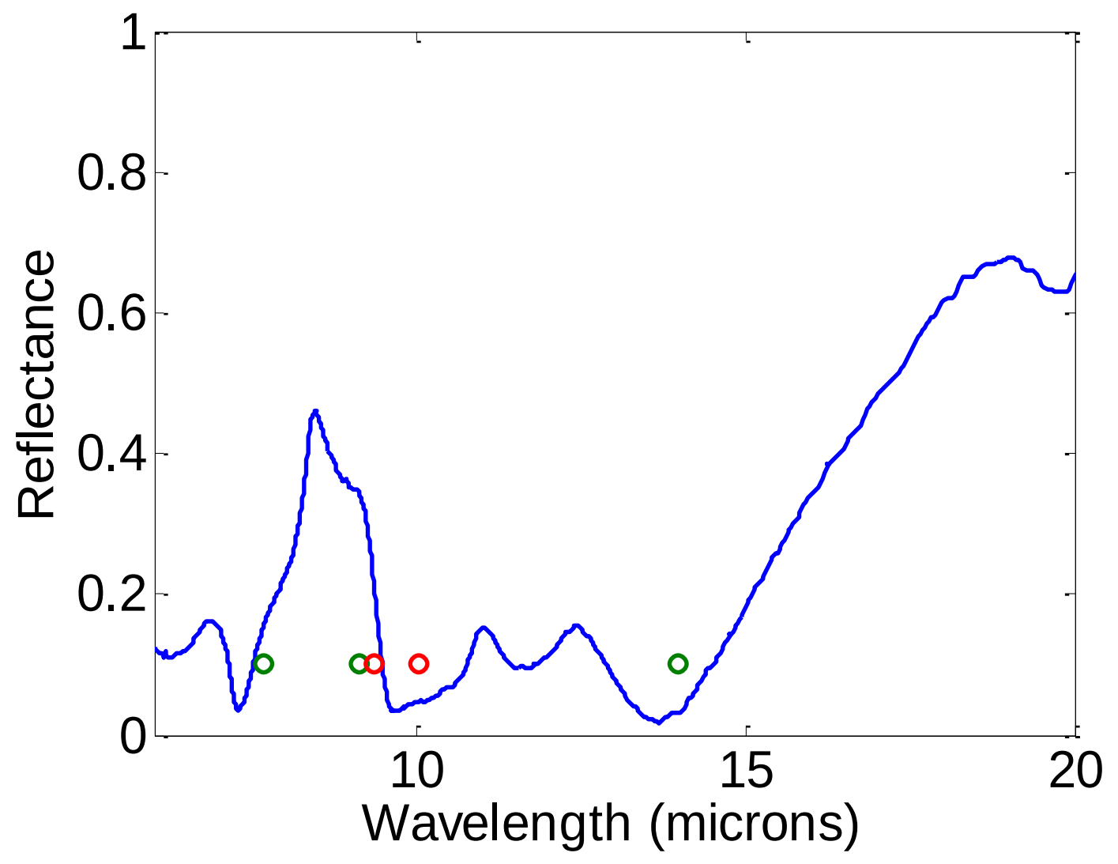
Theoretical calculation of resonance wavelengths

A dispersive dielectric gives multiple solutions for resonane wavelength for the same order of resonance. Blue line in the figure represent refractive index, *n* of SiO_2, green and red lines represent first order and second resonance conditions. Intersection of these lines with SiO_2 refractive index gives the solutions. Multiple resonances are predicted by theory.



Experimental reflectance spectrum of a absorber shows strong broad band absorption

Experimental reflectance spectra of a fabricated mid-IR absorber using a BOMEM DA8 FTIR spectrometer. The measurement was done at near normal (~8 deg) incidence. More than 80% absorption is obtained from 8-14 microns.



Summary

We experimentally demonstrated of a metamaterial perfect absorbers LWIR regions. The absorber has a simple 3 layer structure with thickness of only 1.5 microns. Strong braodband absorption is obtained from 8-14 microns which is useful for IR bolometers working in this range. Absorption remains more than 80% from 8-14 microns. Such thin, CMOS compatible absorber has potential use in thermal imaging.