Interference modulation by electrostatic actuation

John Thomas
M. Tech, CeNSE
SR. No. 11287

Outline

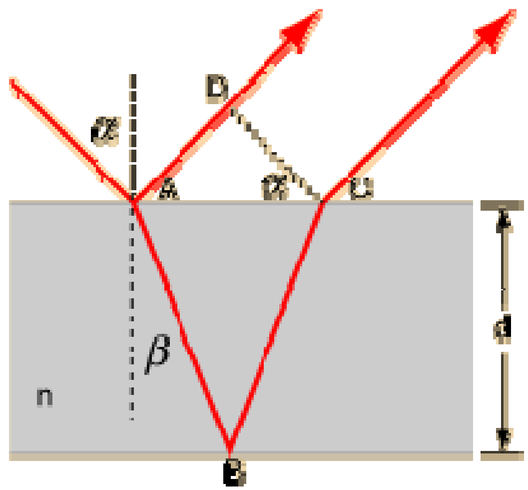
* Introduction
* Color production by Interference
* Simulation using comsol
  * RF module… Reflection from Thin film stack
  * Issues in coupling RF module and Electromechanics
  * Reflection from Metal-Air-Dielectric structure with predefined gap
* Summary
* References

Introduction

Sources of color

- Light from emissive devices….. Lamps
- Light reflected from absorbers…Dyes, gemstones, minerals
- Light by dispersion and scattering….prisms, blue sky
- Light by interference….soap films, peacock feather

Color production by interference



Light reflected from
Oil thin film

Phase change = π: Destructive → $2nd\cos\beta = m\lambda$; Constructive → $2nd\cos\beta = (m-\frac{1}{2})\lambda$

Phase change = 0: Constructive → $2nd\cos\beta = m\lambda$; Destructive → $2nd\cos\beta = (m-\frac{1}{2})\lambda$

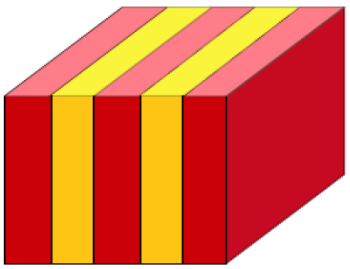
Fig. wikipedia and
Hyperphysics web

1D photonic crystal

The stacking of multiple planar layers produce selective reflection. When the number of periods is large, the optical response can be approached by assuming an infinite number of periods, which can be called a one-dimensional photonic crystal.

$$\lambda = \frac{2a\sqrt{\overline{n}^2 - \sin^2\theta_i}}{m}$$

1-D

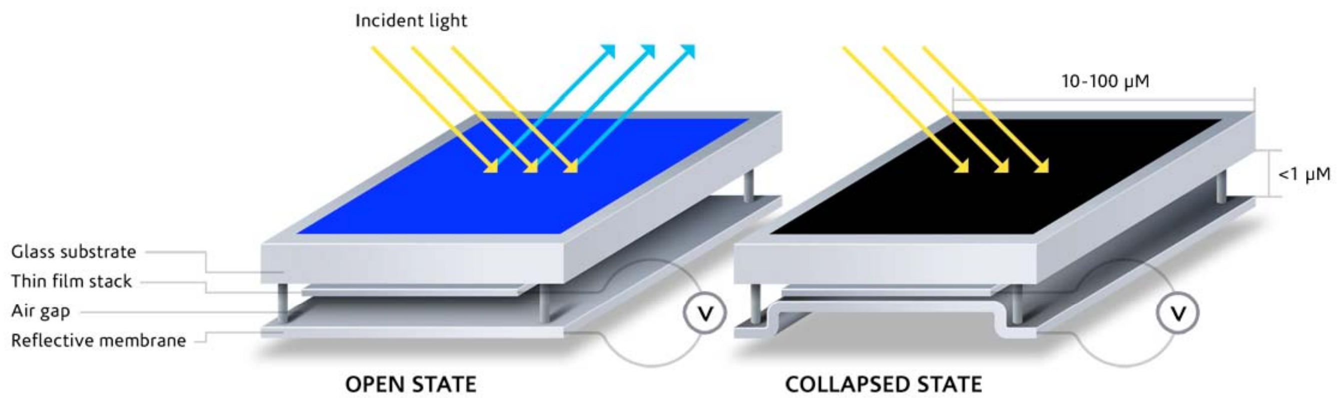


Priscilla Simonis and Serge Berthier,
Photonic Crystals – Introduction, Applications and Theory

iMoD displays

* Interference modulation by electrostatic actuation is the working principle of iMoD display.
* The iMoD pixel is essentially a combination of thin film stack – air gap – transparent conductive electrode.
* The length of the air gap changes as we apply voltage across the electrode and thin film stack.
* The change in length of air cavity modulates the wavelength of reflected light.

iMoD pixel



Operating principles of IMOD, white paper by Qualcomm MEMS technologies

Modeling issues

* The optics part of the simulation requires materials with good transparency in visible spectrum.
* The electromechanics part needs materials with good electrical conductivity.
* Materials good in electrical domain are poor in optical domain and vice versa.
* The promising materials for this applications are Indium doped tin oxide (ITO), graphene etc. But the simulation requires optical, electrical and mechanical properties of these novel materials, which are hard to find in journals and internet. So the work was done with a predefined air gap between a metal and dielectric film.

Simulations performed

1. Reflection from a thin film stack

In this simulation, I have designed a thin film stack consists of silicon dioxide substrate and thin films of magnesium fluoride and titanium dioxide. The reflection spectra for different wavelengths were simulated and found that the stack reflects maximum at 580 nm.

2. Reflection from a metal-air-dielectric structure

In this simulation, I have designed aluminium-air-silicon nitride thin film strucuture. Reflection from this structures were studied. It was observed that reflected light wavelegths change as we vary the length of the air gap.

Optics of Thin film coatings

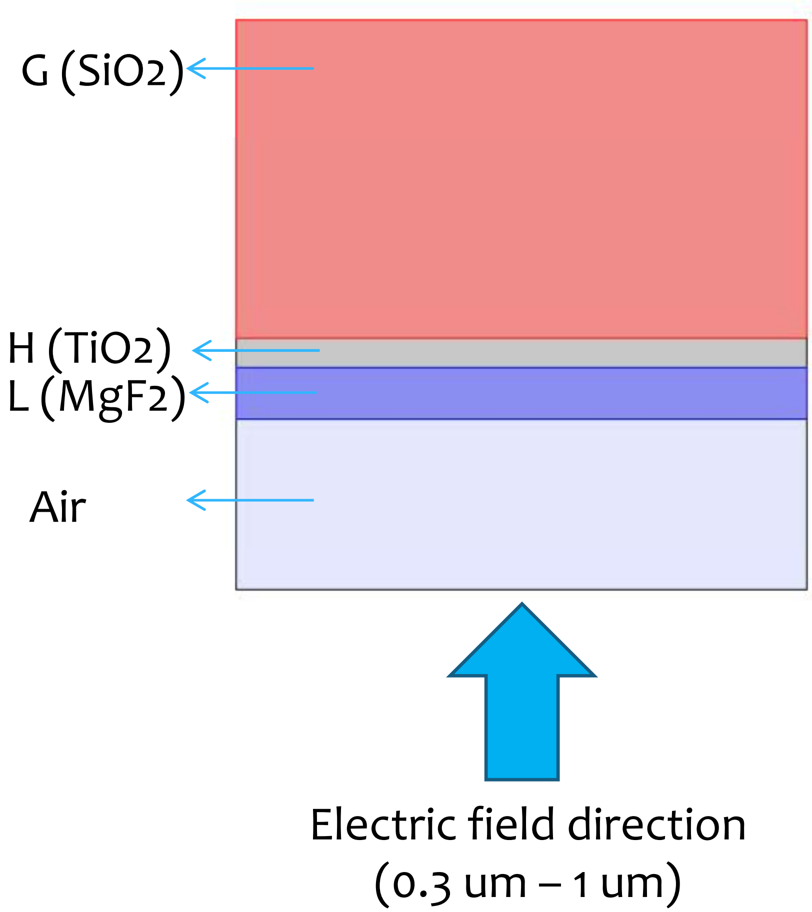
A quarter-wave stack of thin film can be used as a high reflecting optical element. The arrangement of the stack is given as

$$g\,(HL)^n\,a$$

where g indicates glass substrate, H and L indicate high and low index materials respectively, n indicates the number of layers of HL pair. and 'a' indicates air.

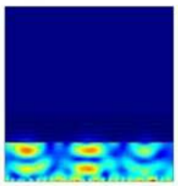
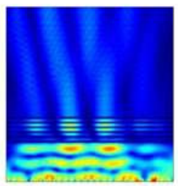
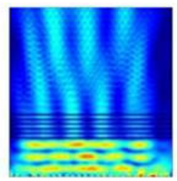
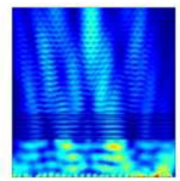
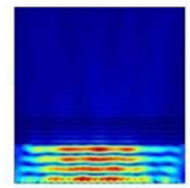
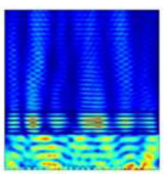
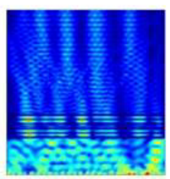
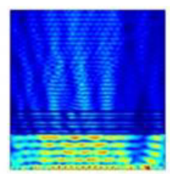
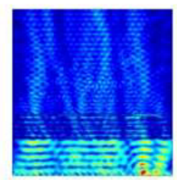
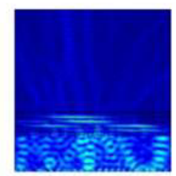
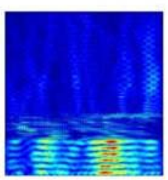
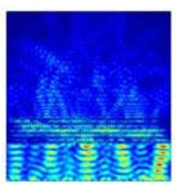
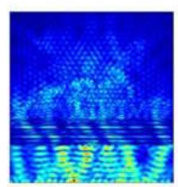
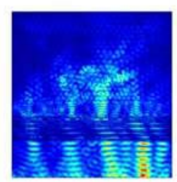
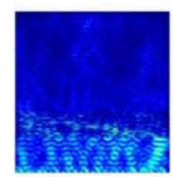
The thickness of the stack H and L pair taken as ¼ th of the wavelength of the light in the corresponding medium.

Simulation of stack with $(HL)^5H$ combinations

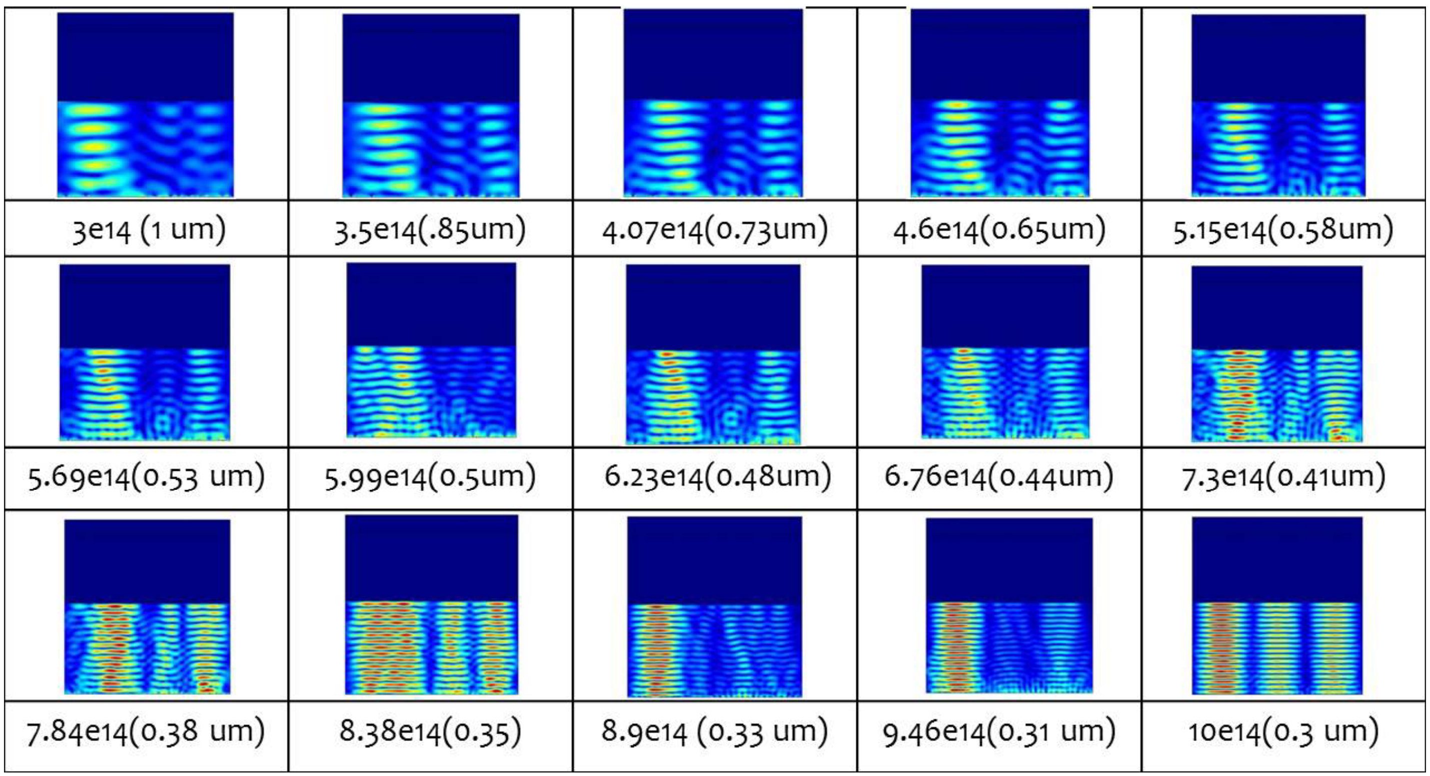


Material	Ref. Index	Thickness (nm)
Air	1	arbitrary
L (MgF_2)	1.38	90.6
H (TiO_2)	2.4	52.1
G (SiO_2)	1.45	arbitrary

Simulation of stack with $(HL)^5H$ combinations

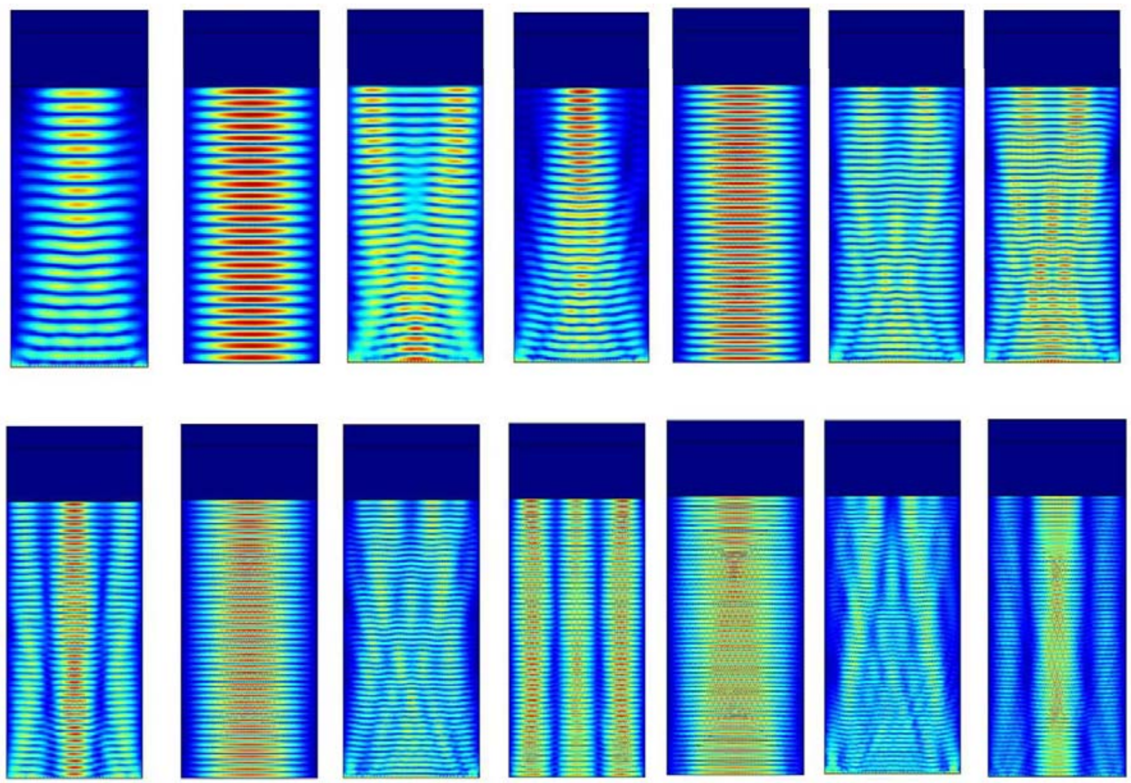
				
3e14 (1 um)	3.5e14(.85um)	4.07e14(0.73um)	4.6e14(0.65um)	5.15e14(0.58um)
				
5.69e14(0.53 um)	5.99e14(0.5um)	6.23e14(0.48um)	6.76e14(0.44um)	7.3e14(0.41um)
				
7.84e14(0.38 um)	8.38e14(0.35)	8.9e14 (0.33 um)	9.46e14(0.31 um)	10e14(0.3 um)

Simulation of reflection from a 2 µm thick Al



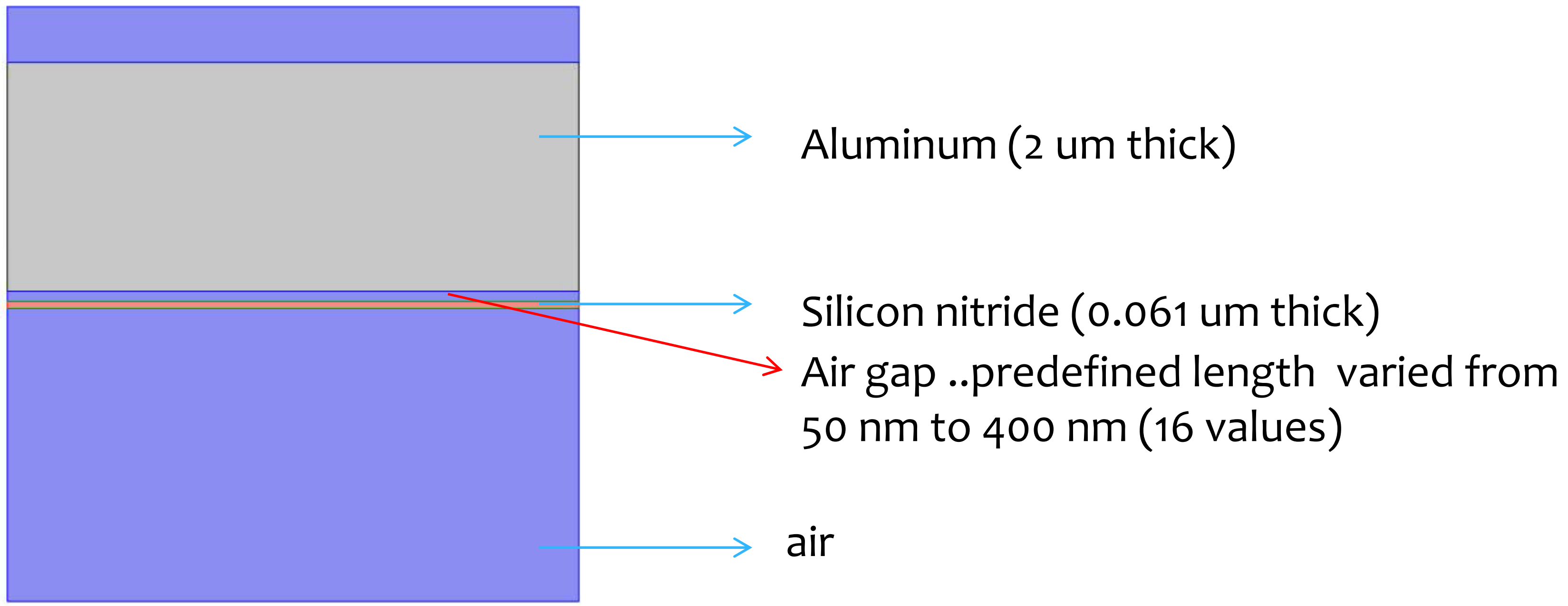
Optical Path Length (OPL) in air is 2 um

Simulation of reflection from a 2 μm thick Al



Optical Path Length (OPL) in air is 8 um

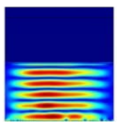
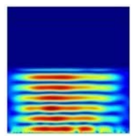
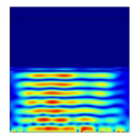
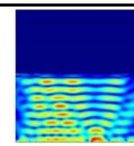
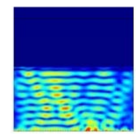
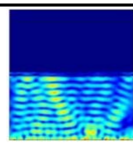
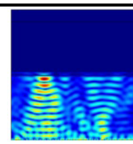
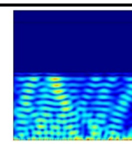
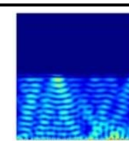
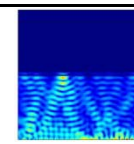
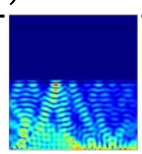
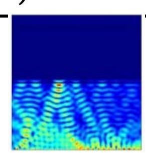
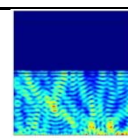
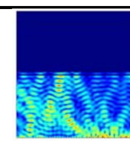
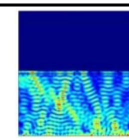
Simulation of Reflection from Metal-Air-Dielectric combination



Simulation of reflected field for air gap of 150nm, 200nm, 300nm and 400 nm length are shown in following slides.

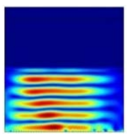
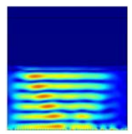
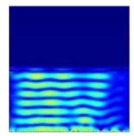
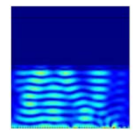
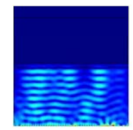
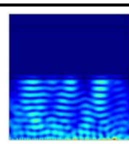
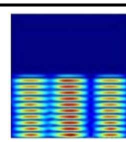
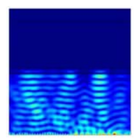
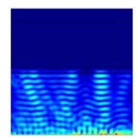
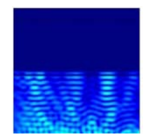
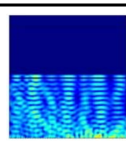
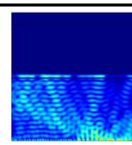
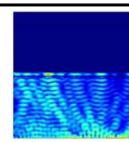
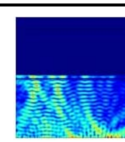
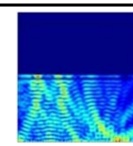
Simulation of Reflection from Metal-Air-Dielectric combination

Air gap 150 nm

				
3e14(1 um)	3.5e14(0.85 um)	4.07e14(0.73)	4.6e14(0.65)	5.15e14(0.58 um)
				
5.69e14(0.53 um)	5.99e14(0.5 um)	6.23e14(0.48 um)	6.76(0.44 um)	7.3e14(0.41 um)
				
7.84e14(0.38 um)	8.3e14(0.35 um)	8.9e14(0.33)	9.4e14(0.31)	10e14(0.3 um)

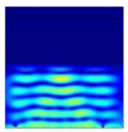
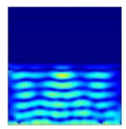
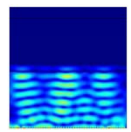
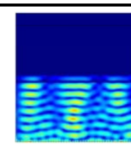
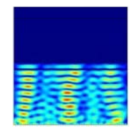
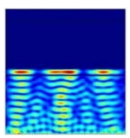
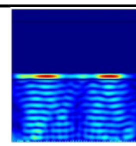
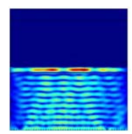
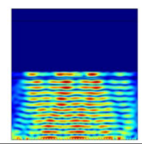
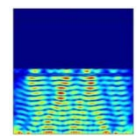
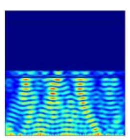
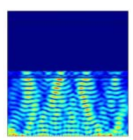
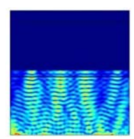
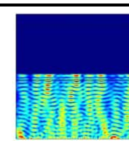
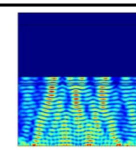
Simulation of Reflection from Metal-Air-Dielectric combination

Air gap 200 nm

				
3e14(1 um)	3.5e14(0.85 um)	4.07e14(0.73)	4.6e14(0.65)	5.15e14(0.58 um)
				
5.69e14(0.53 um)	5.99e14(0.5 um)	6.23e14(0.48 um)	6.76(0.44 um)	7.3e14(0.41 um)
				
7.84e14(0.38 um)	8.3e14(0.35 um)	8.9e14(0.33)	9.4e14(0.31)	10e14(0.3 um)

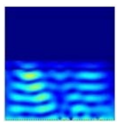
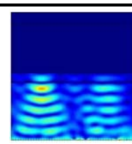
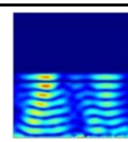
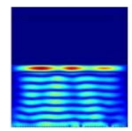
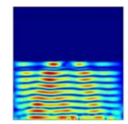
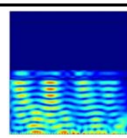
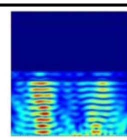
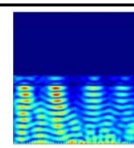
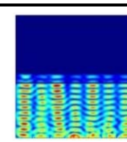
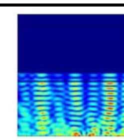
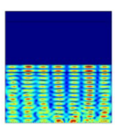
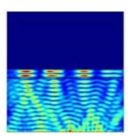
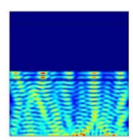
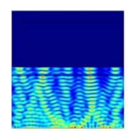
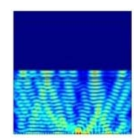
Simulation of Reflection from Metal-Air-Dielectric combination

Air gap 300 nm

				
3e14(1 um)	3.5e14(0.85 um)	4.07e14(0.73)	4.6e14(0.65)	5.15e14(0.58 um)
				
5.69e14(0.53 um)	5.99e14(0.5 um)	6.23e14(0.48 um)	6.76(0.44 um)	7.3e14(0.41 um)
				
7.84e14(0.38 um)	8.3e14(0.35 um)	8.9e14(0.33)	9.4e14(0.31)	10e14(0.3 um)

Simulation of Reflection from Metal-Air-Dielectric combination

Air gap 400 nm

				
3e14(1 um)	3.5e14(0.85 um)	4.07e14(0.73)	4.6e14(0.65)	5.15e14(0.58 um)
				
5.69e14(0.53 um)	5.99e14(0.5 um)	6.23e14(0.48 um)	6.76(0.44 um)	7.3e14(0.41 um)
				
7.84e14(0.38 um)	8.3e14(0.35 um)	8.9e14(0.33)	9.4e14(0.31)	10e14(0.3 um)