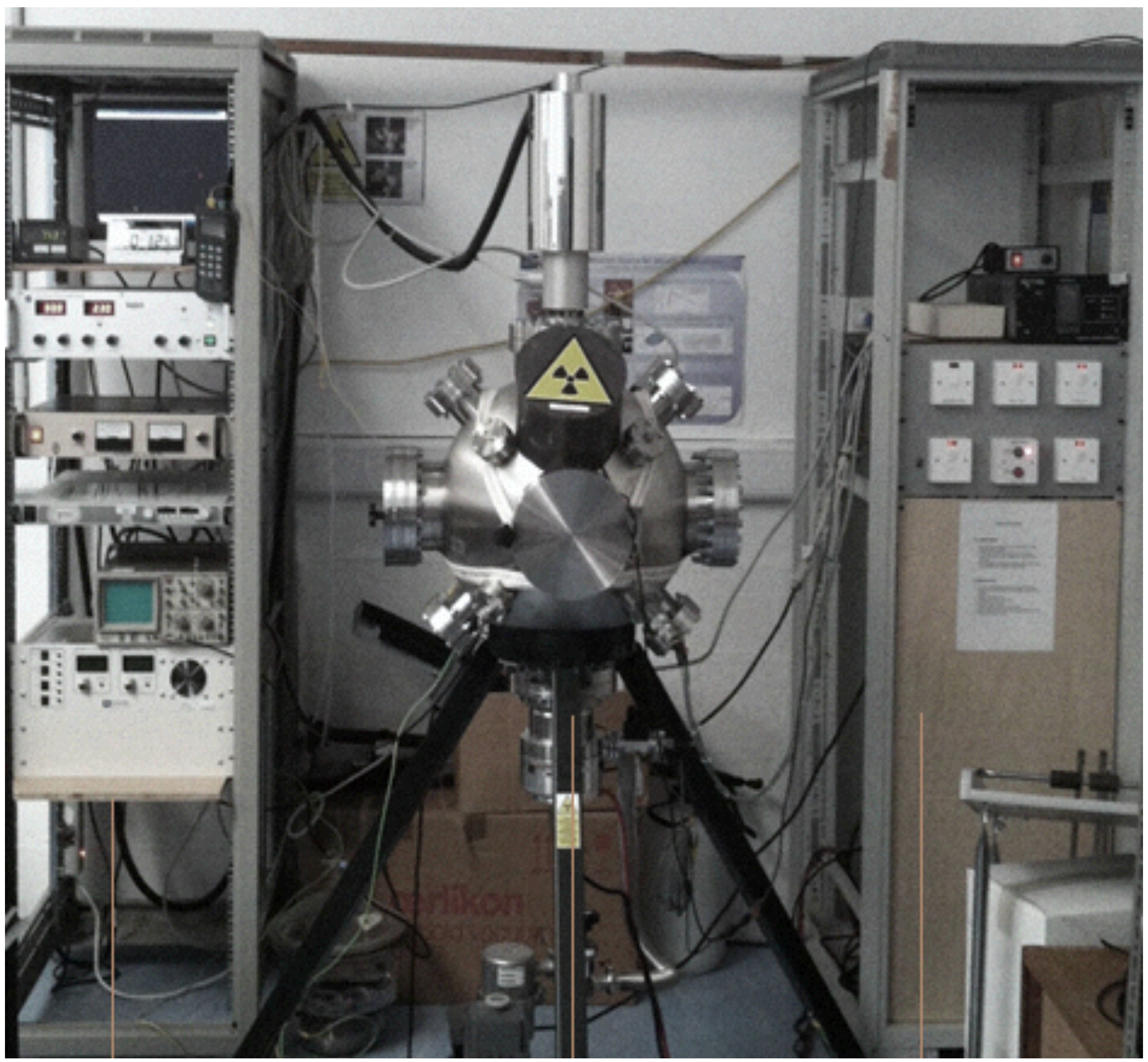
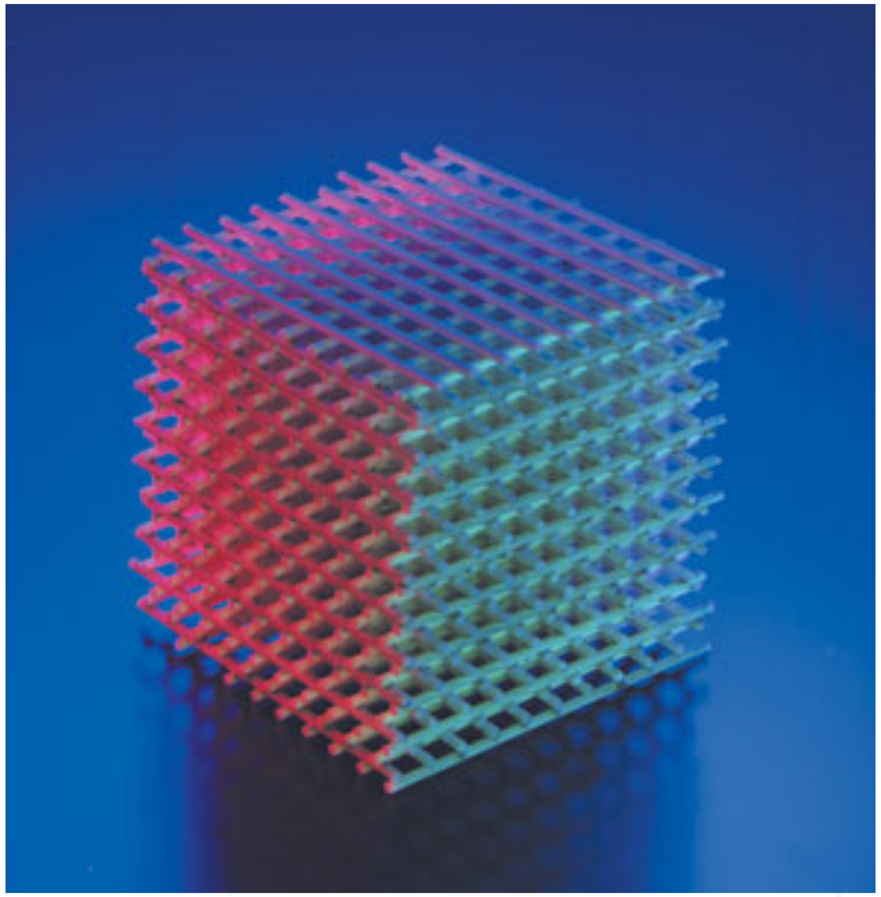
TMD Presentation



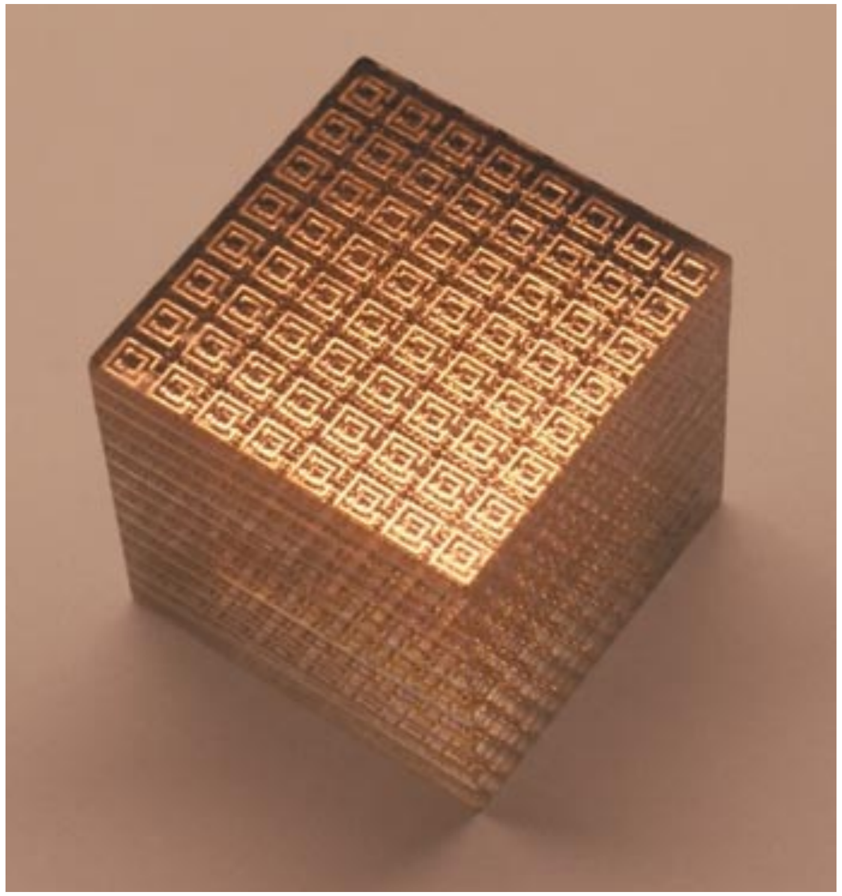
Rebecca Seviour
University of Huddersfield

Photonics

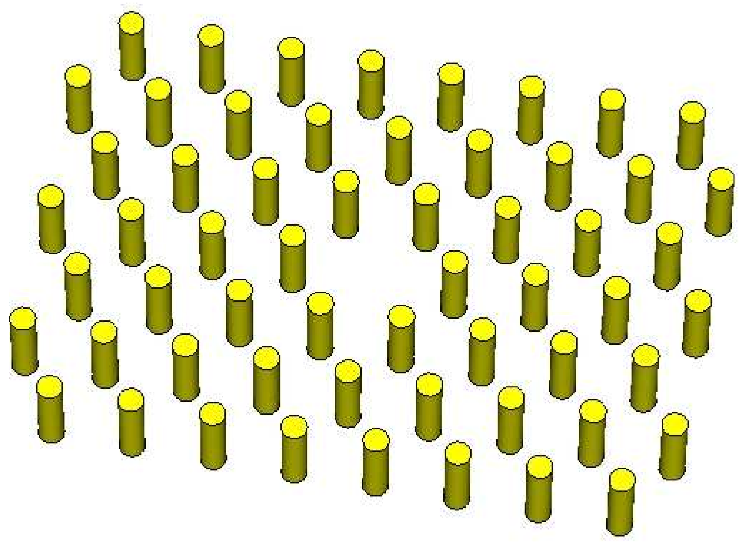


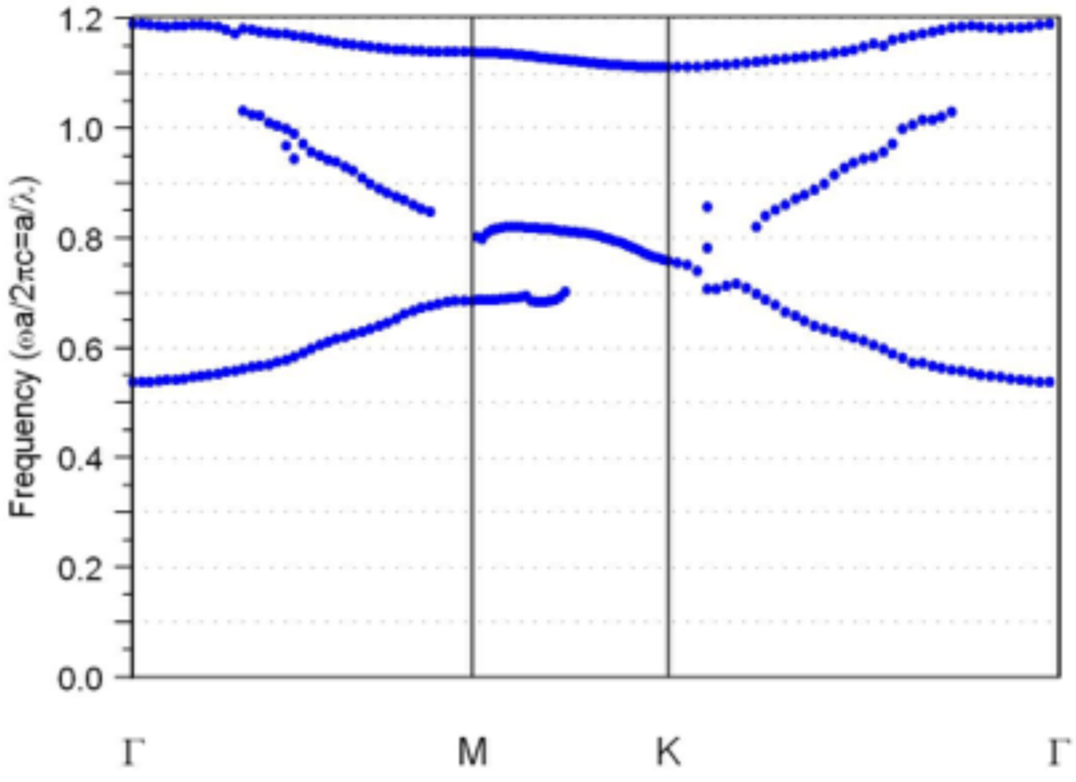
$a \sim \lambda$

Metamaterials

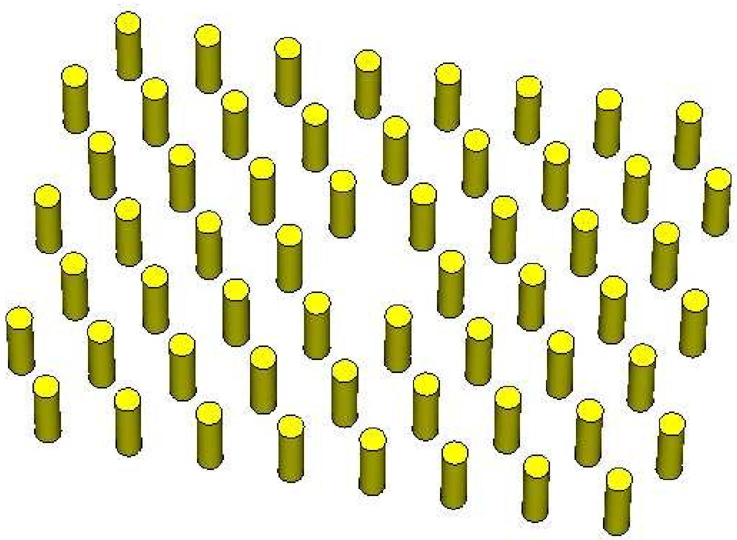


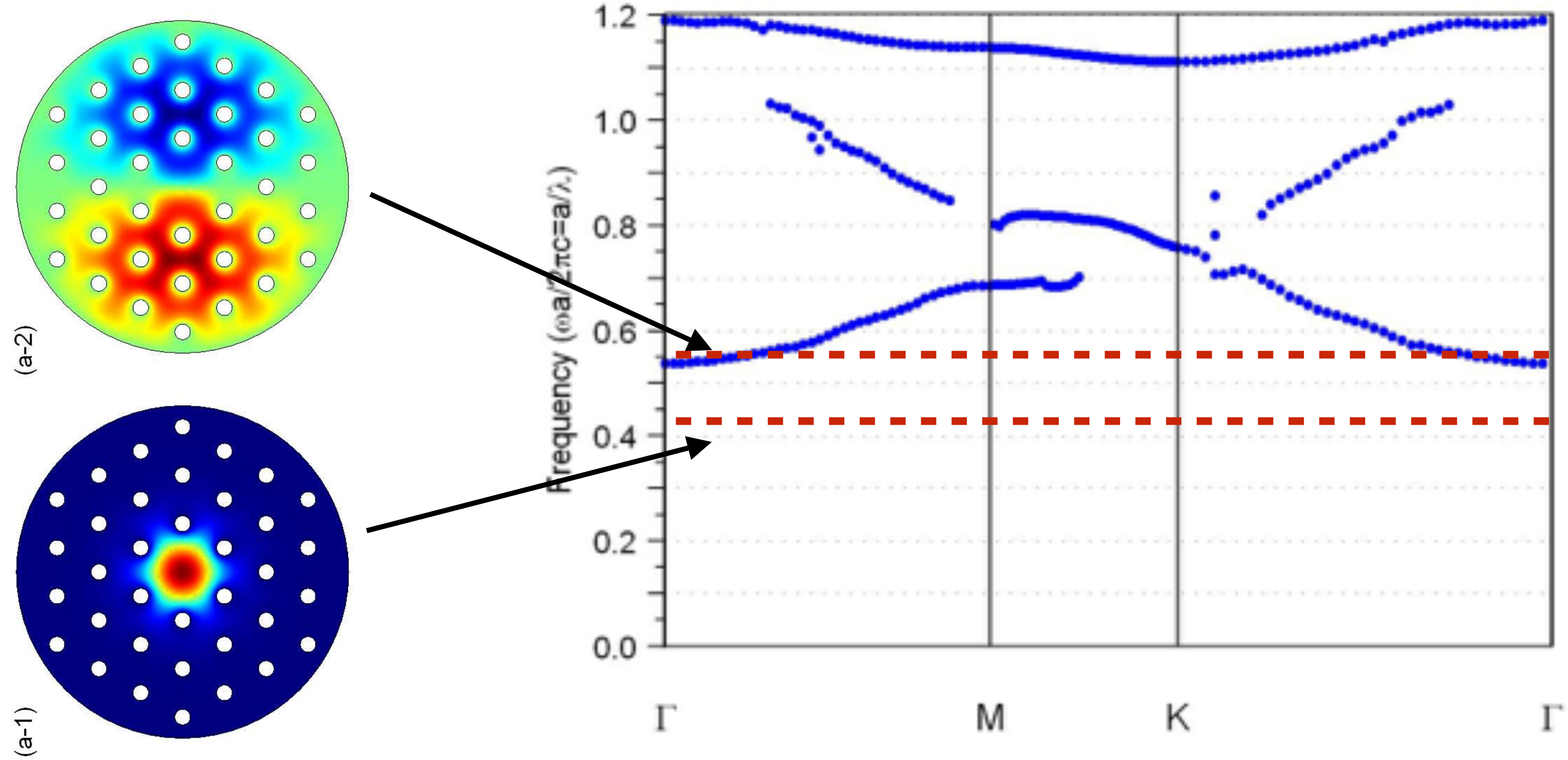
$a << \lambda$

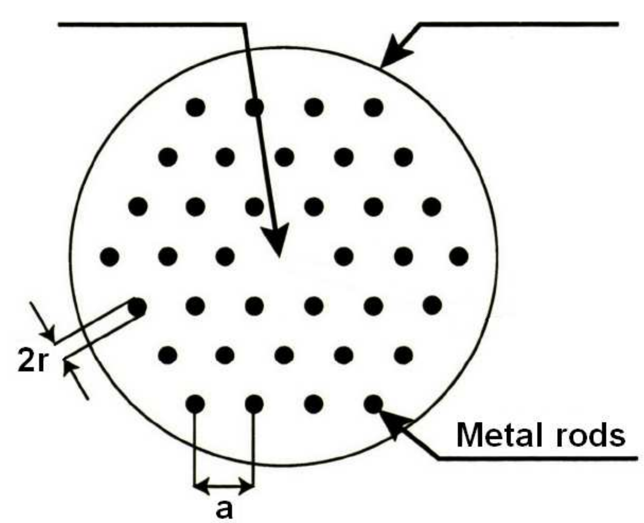




Frequency (ωa/2πc=a/λ)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Γ
M
K
Γ

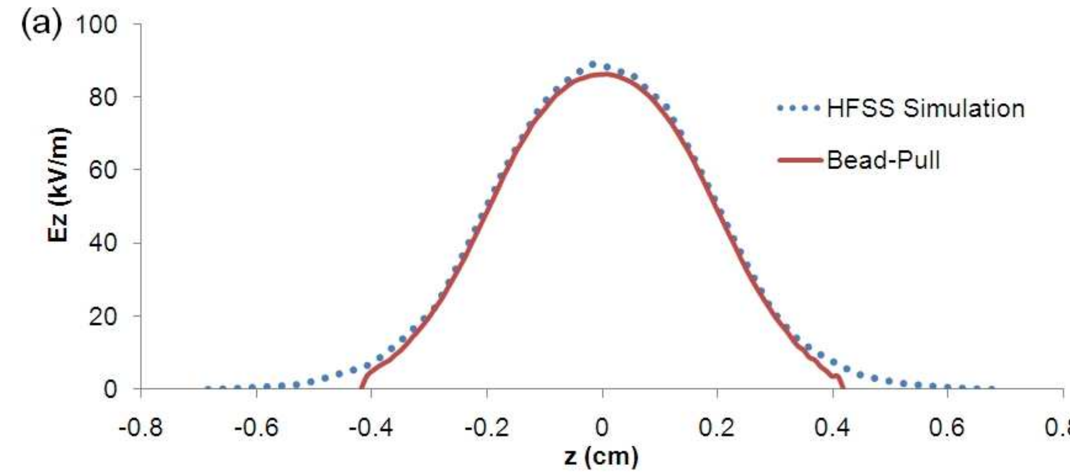


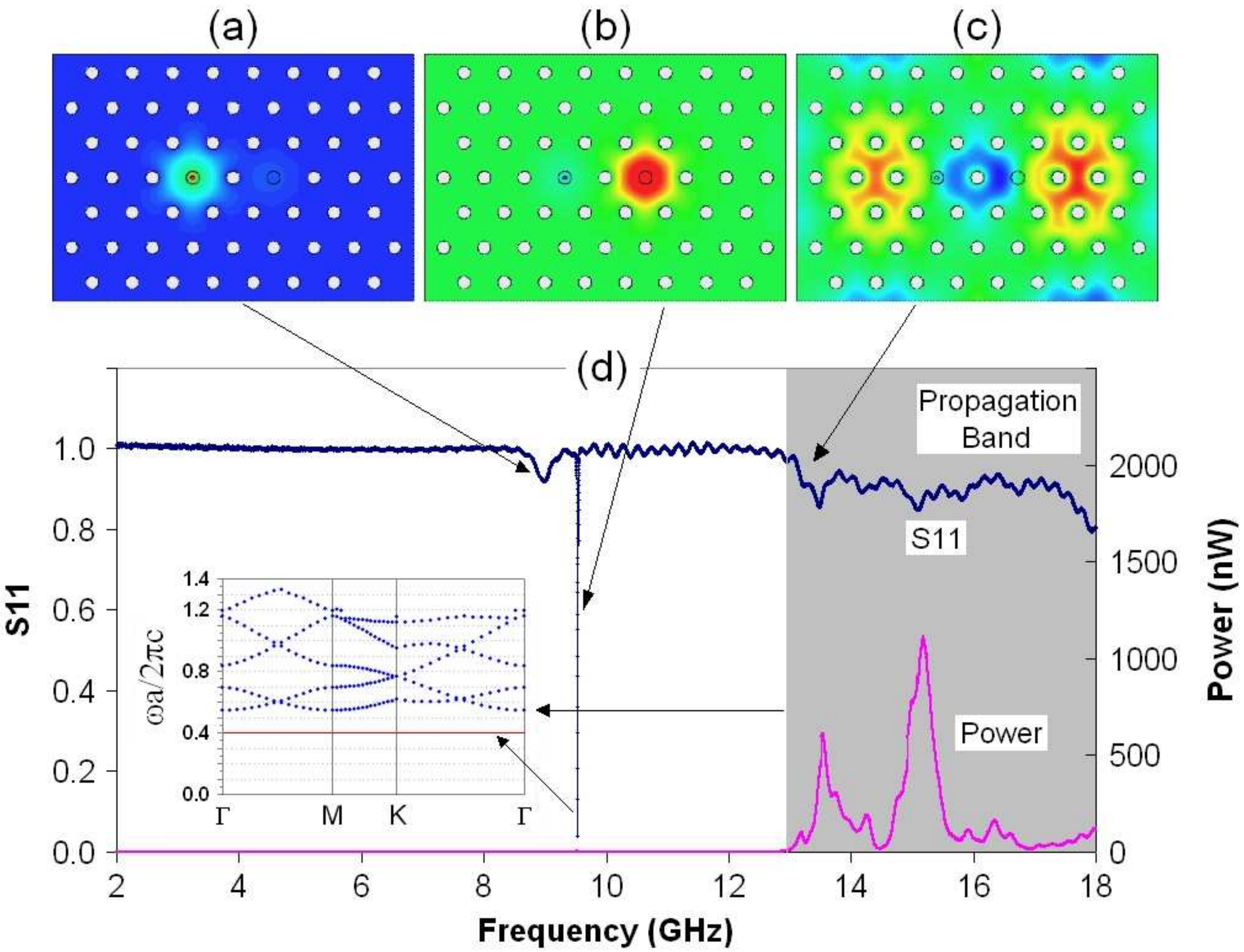

(a-2)
(a-1)
Frequency (ωa/2πc=a/λ)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Γ
M
K
Γ

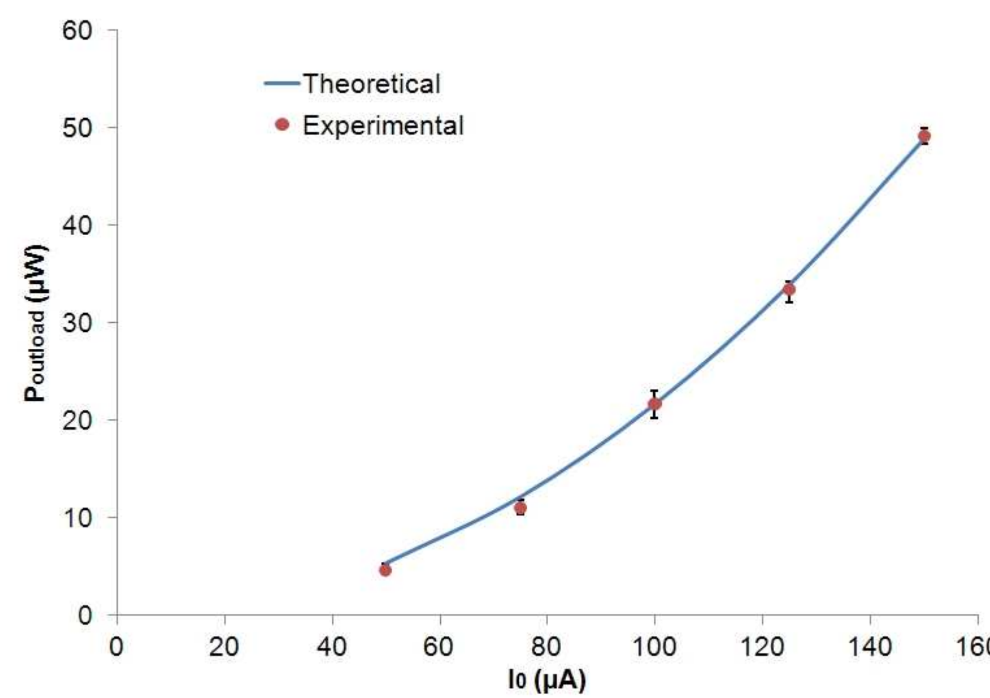

2r
a
Metal rods

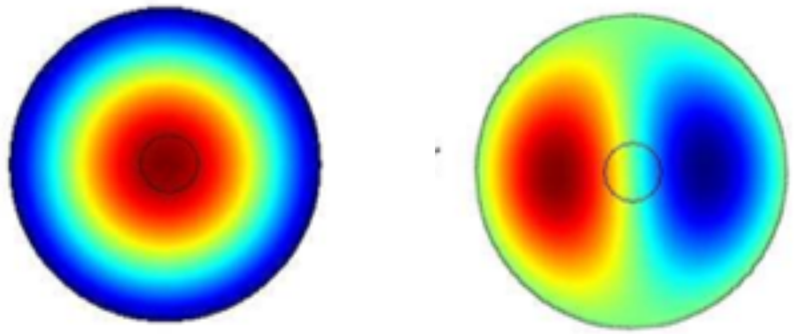
Experimental - Numerical Verification

	HFSS results	Measurement results
input PC, $f_{0,in}$ (GHz)	9.54234	9.5422
output PC, $f_{0,out}$ (GHz)	9.53987	9.5379



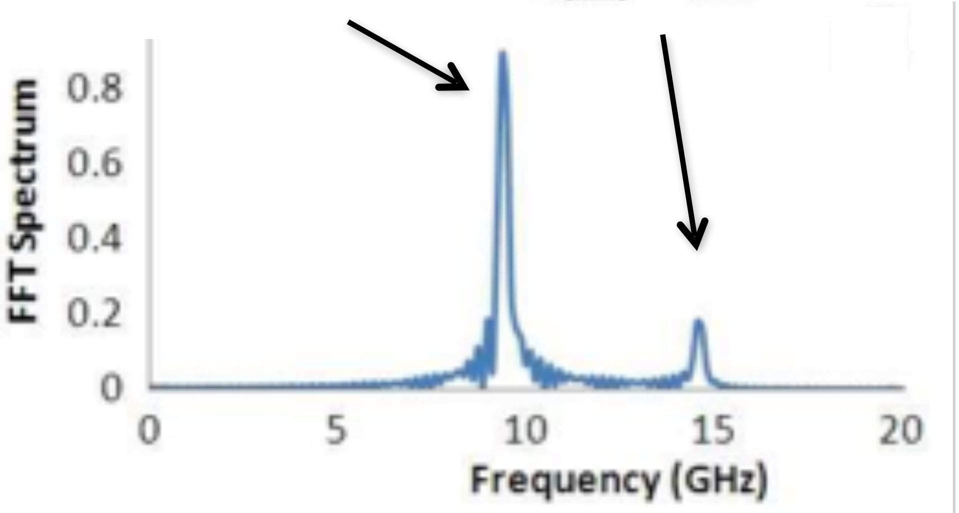


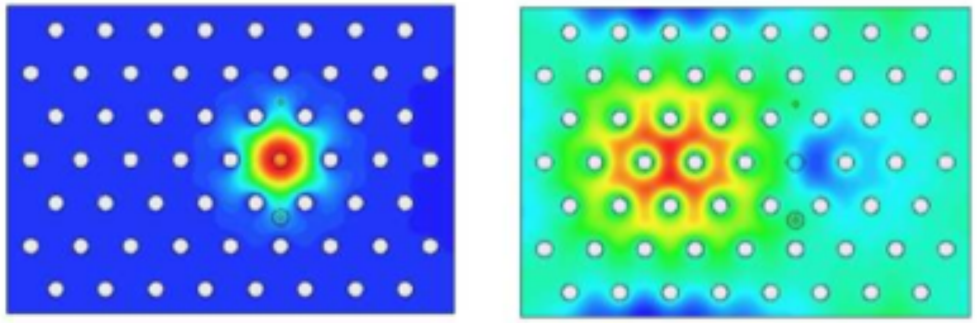




f_0 = 9.532 GHz
Q_{ohmic} = 3850

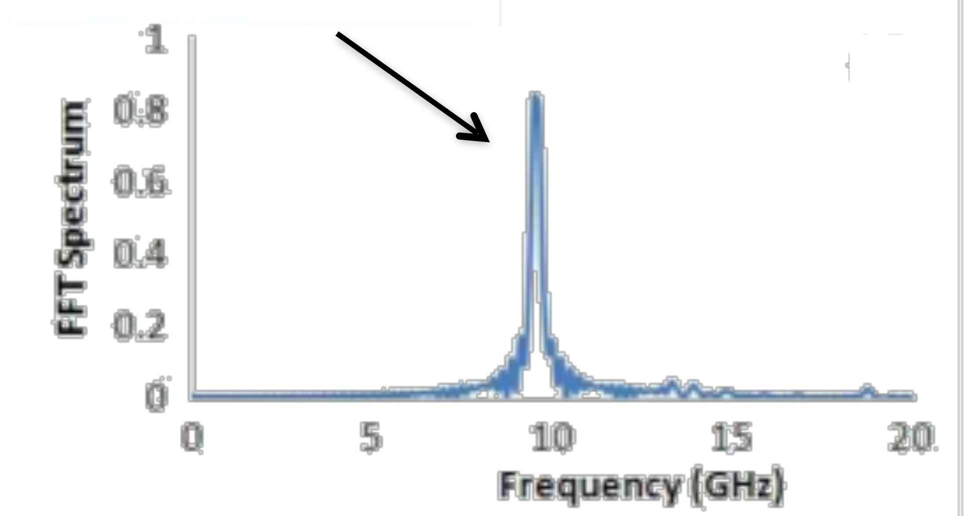
f_1 = 14.82 GHz
Q_{ohmic} = 4600

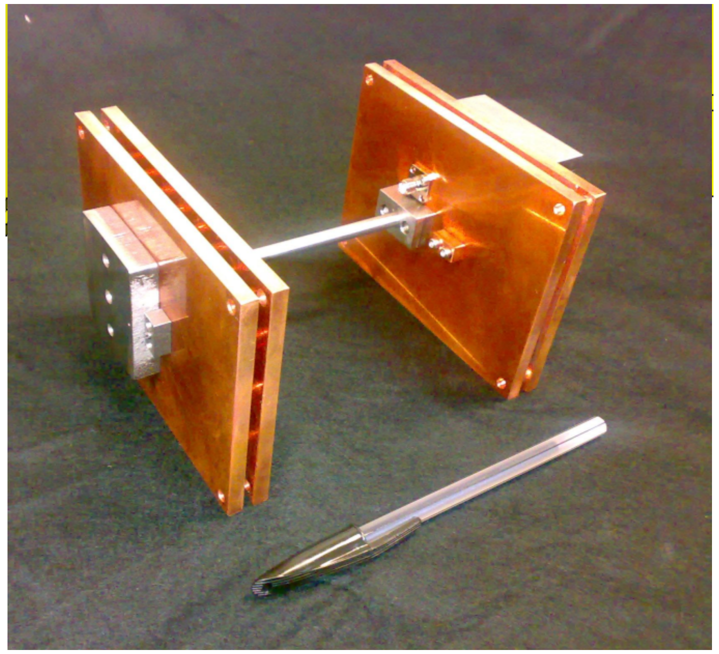


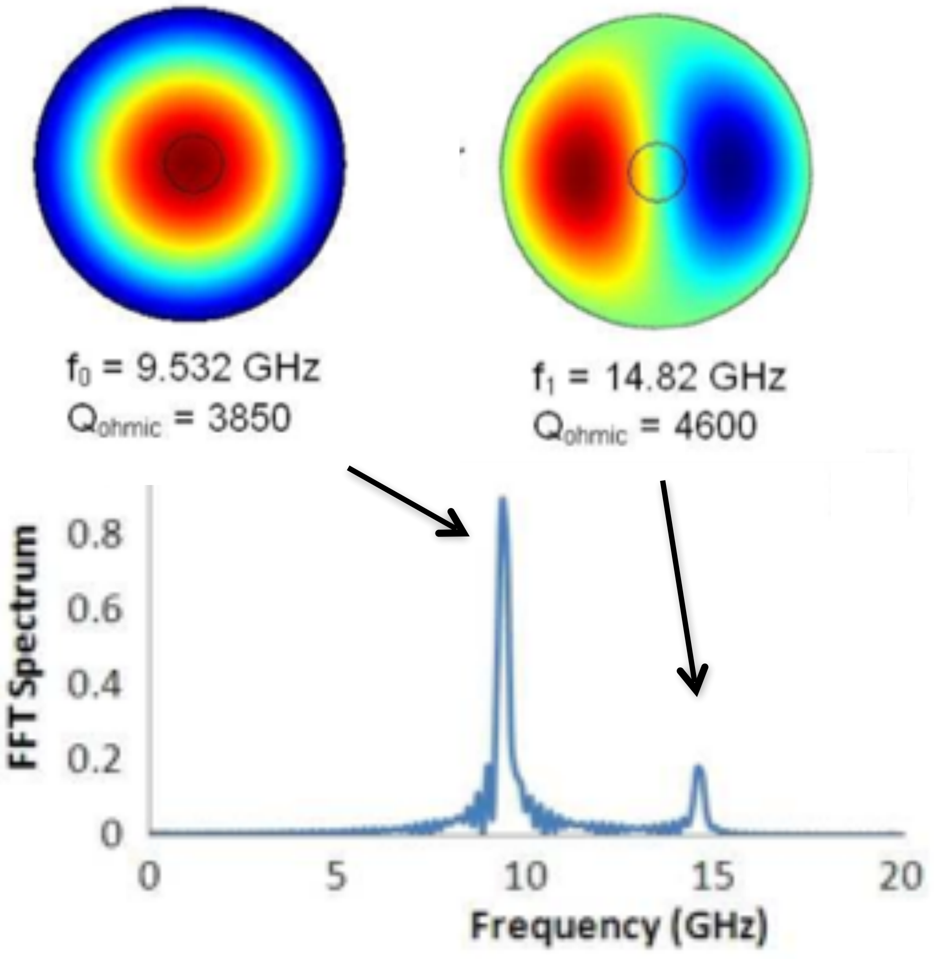


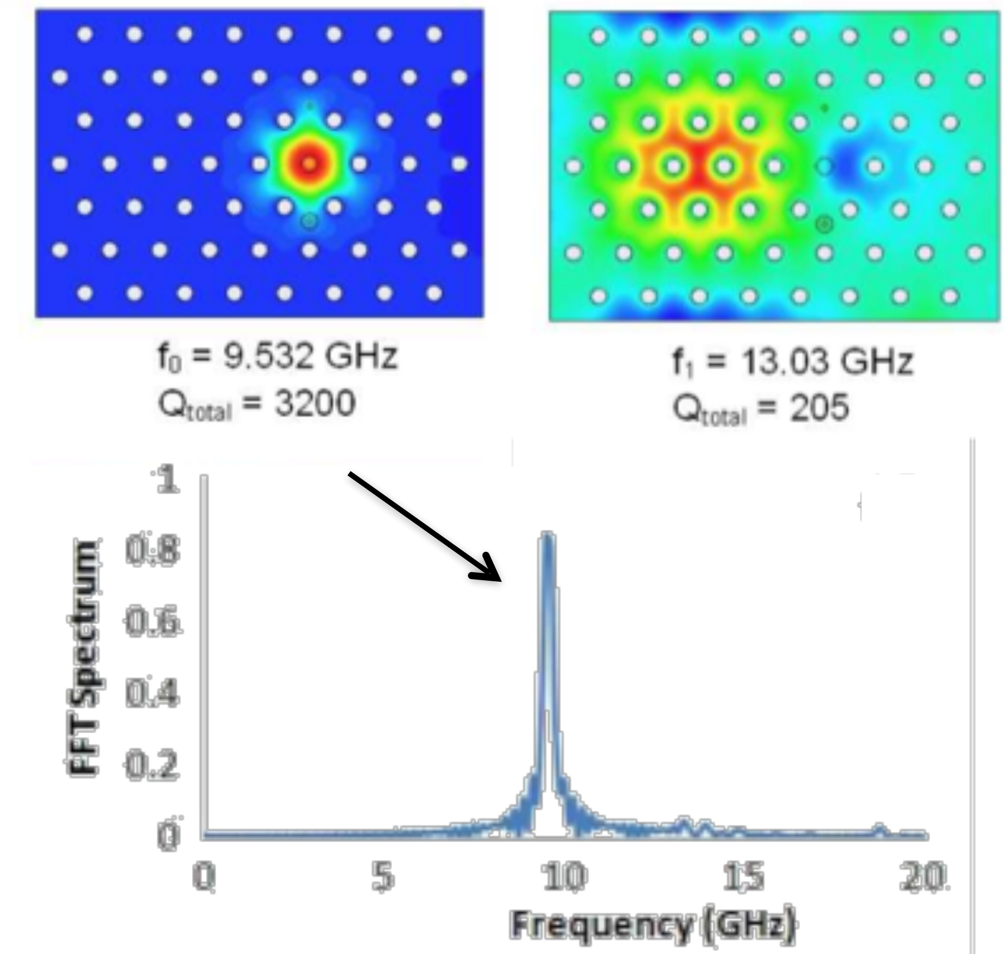
f_0 = 9.532 GHz
Q_{total} = 3200

f_1 = 13.03 GHz
Q_{total} = 205

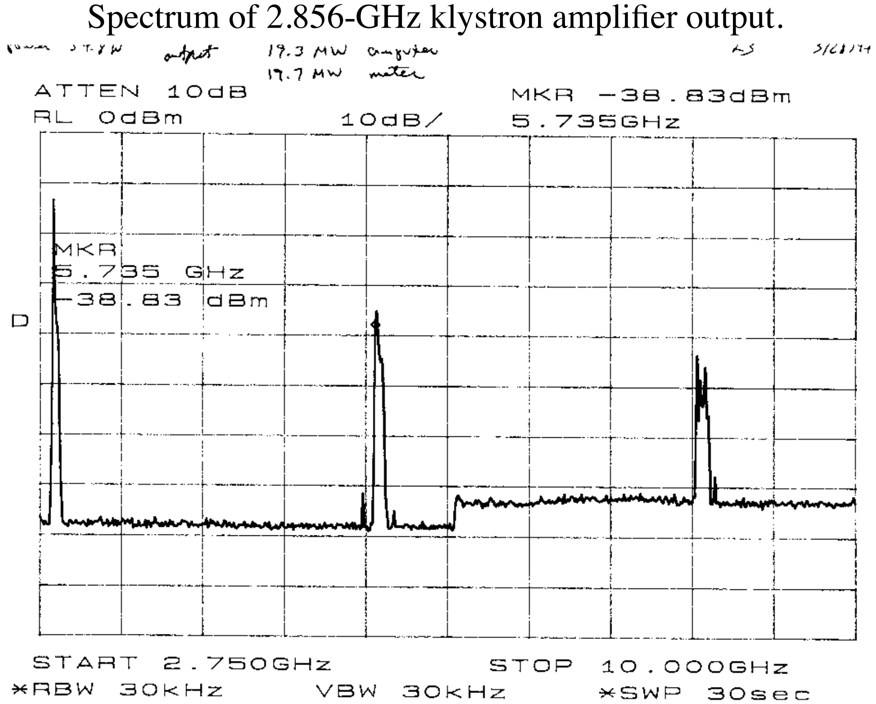




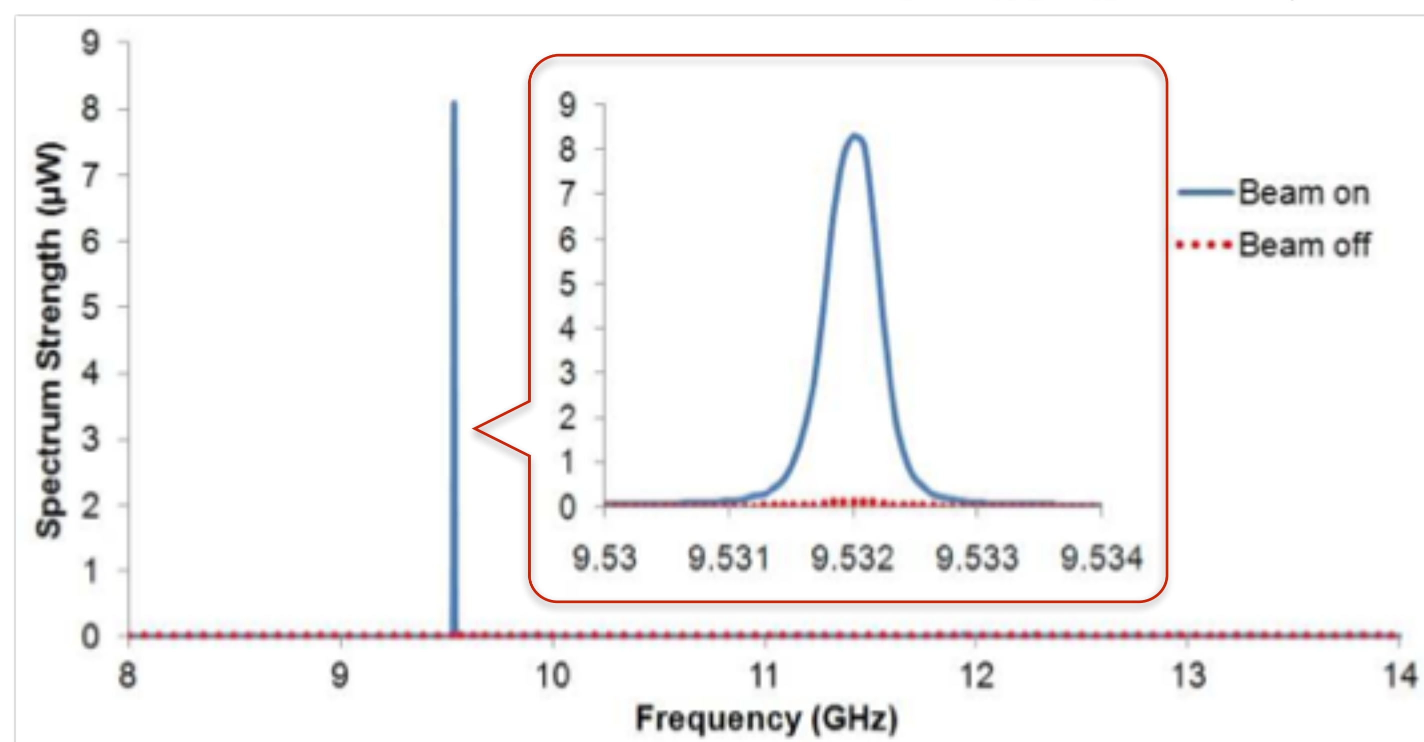




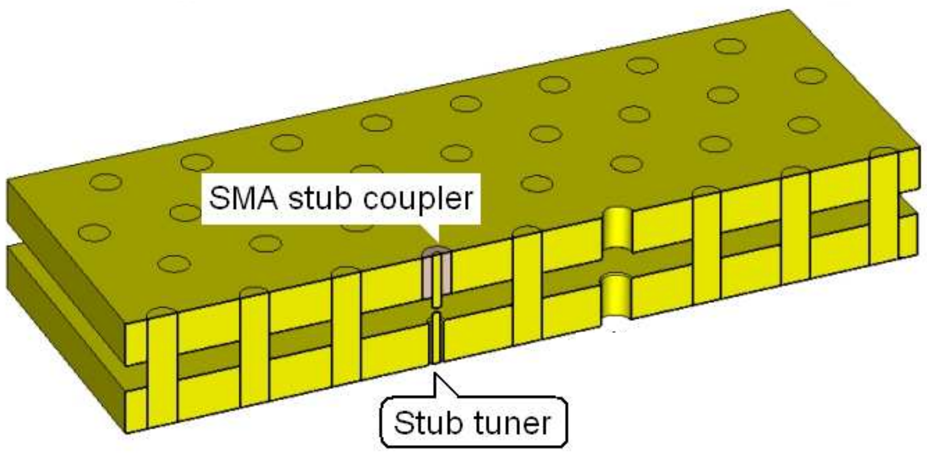
Spectrum of 2.856-GHz klystron amplifier output.



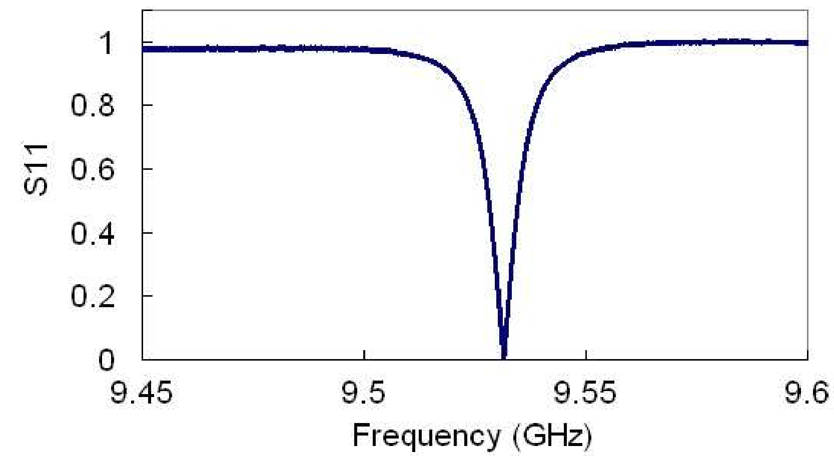
Yoon Kang, Ali Nassiri, IPAC 1998



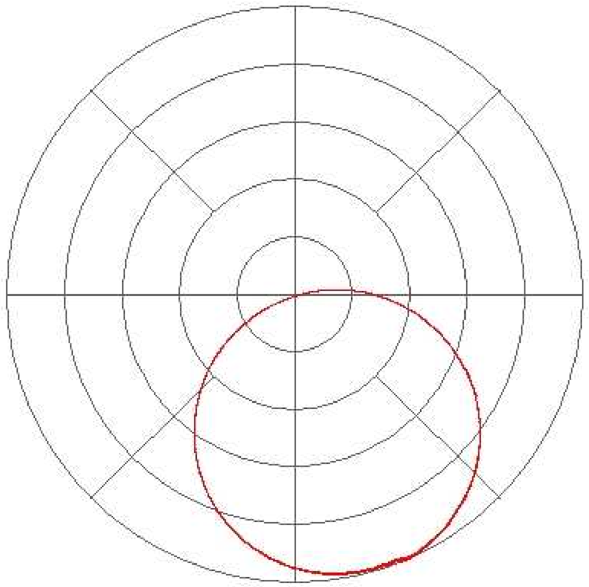
Coupling



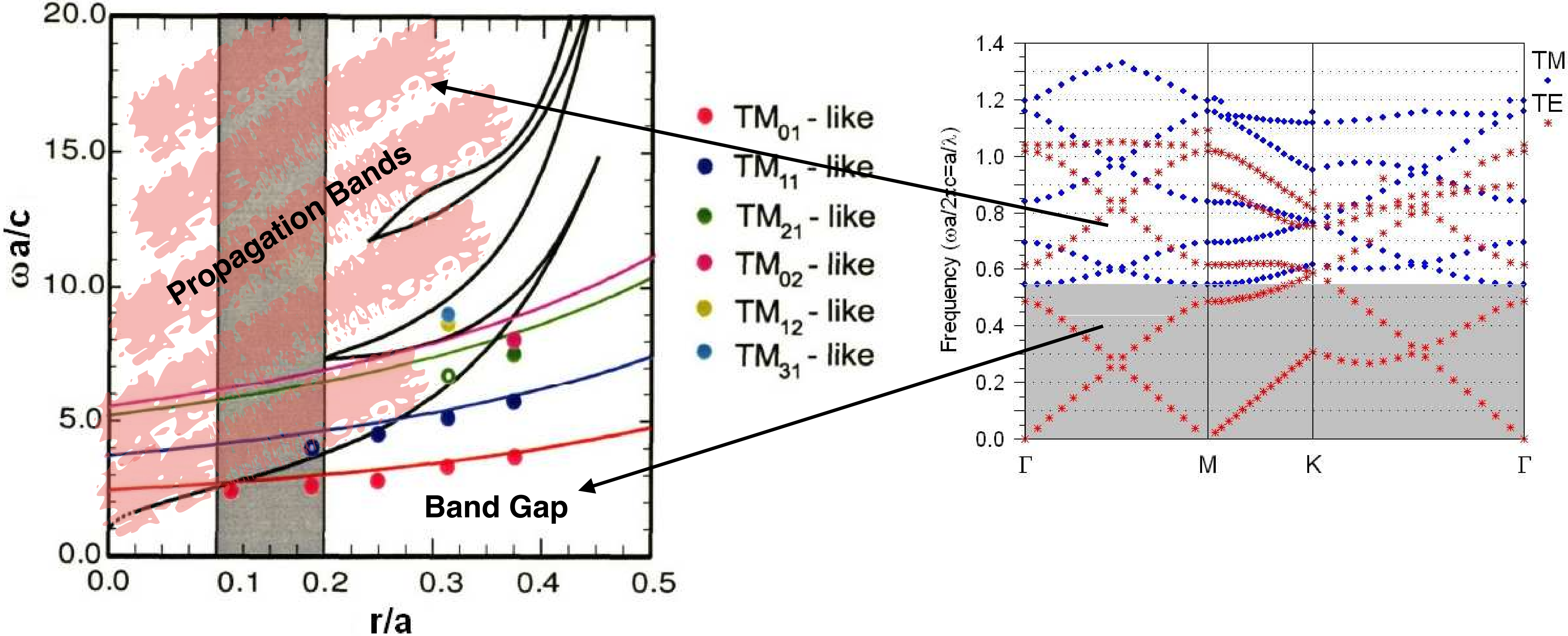
SMA stub coupler
Stub tuner



S11
1
0.8
0.6
0.4
0.2
0
9.45
9.5
9.55
9.6
Frequency (GHz)



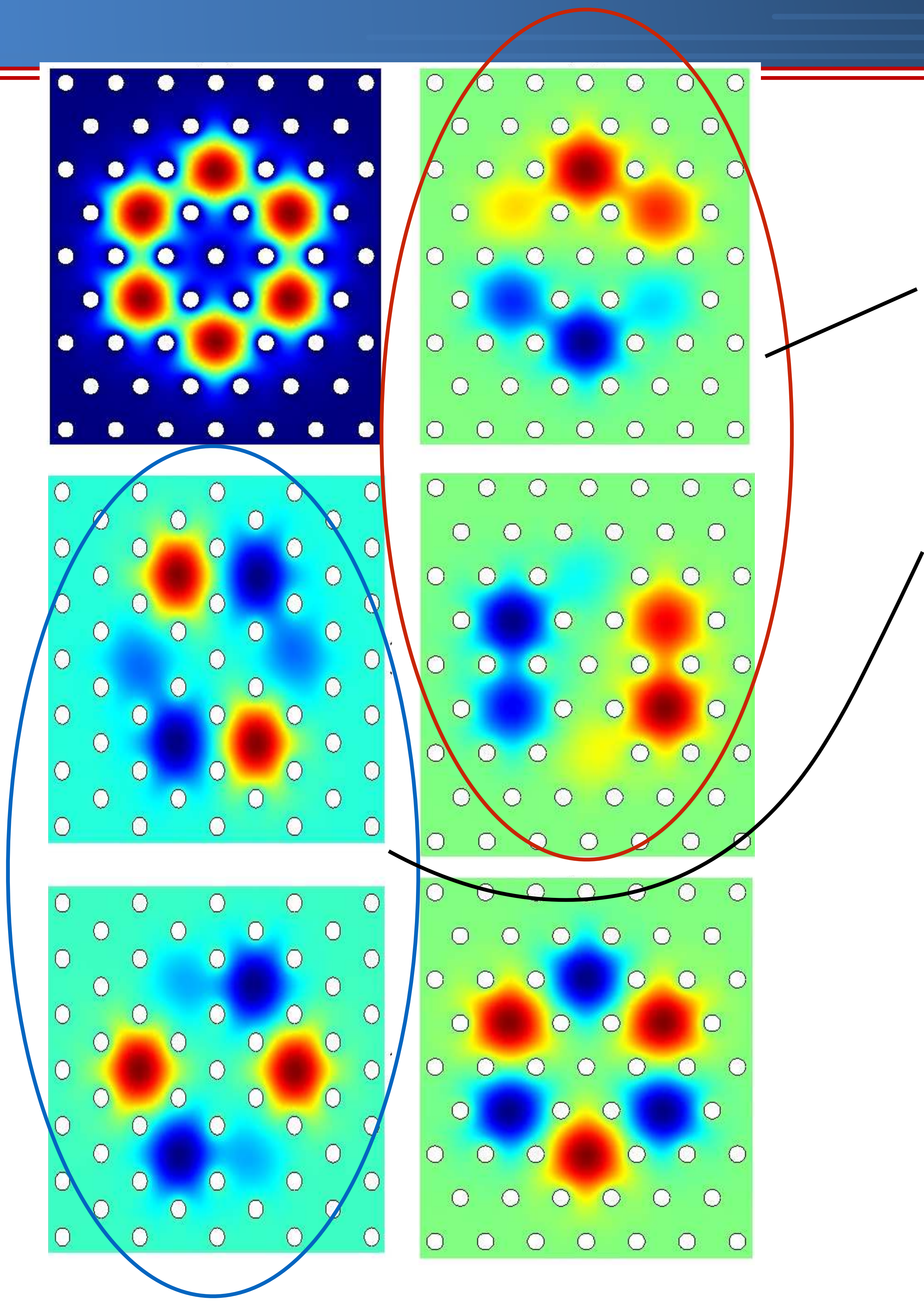
14 GHz Lattice parameters



r/a~0.15 —> 2.55 = wa/c

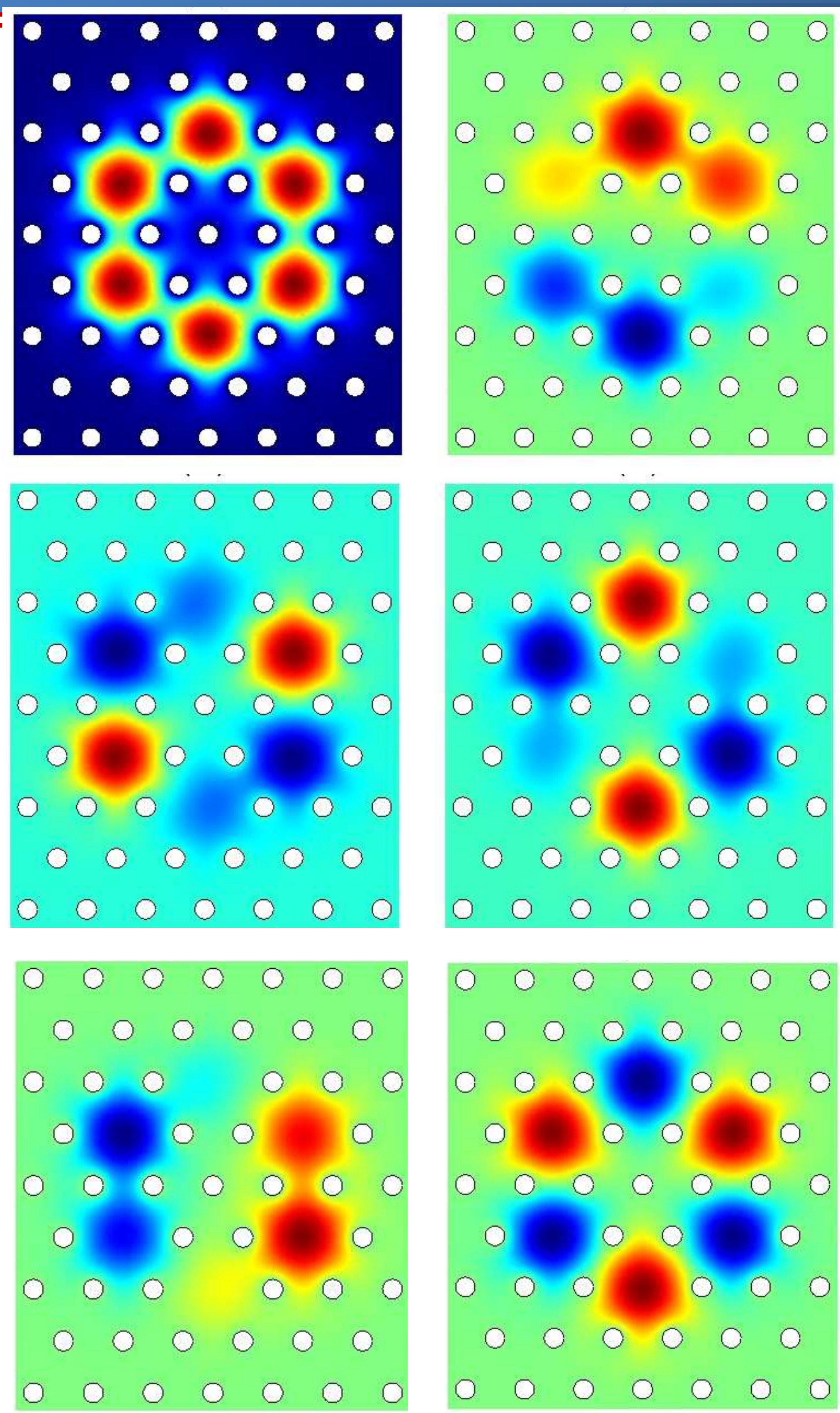
—> a =8.67 mm

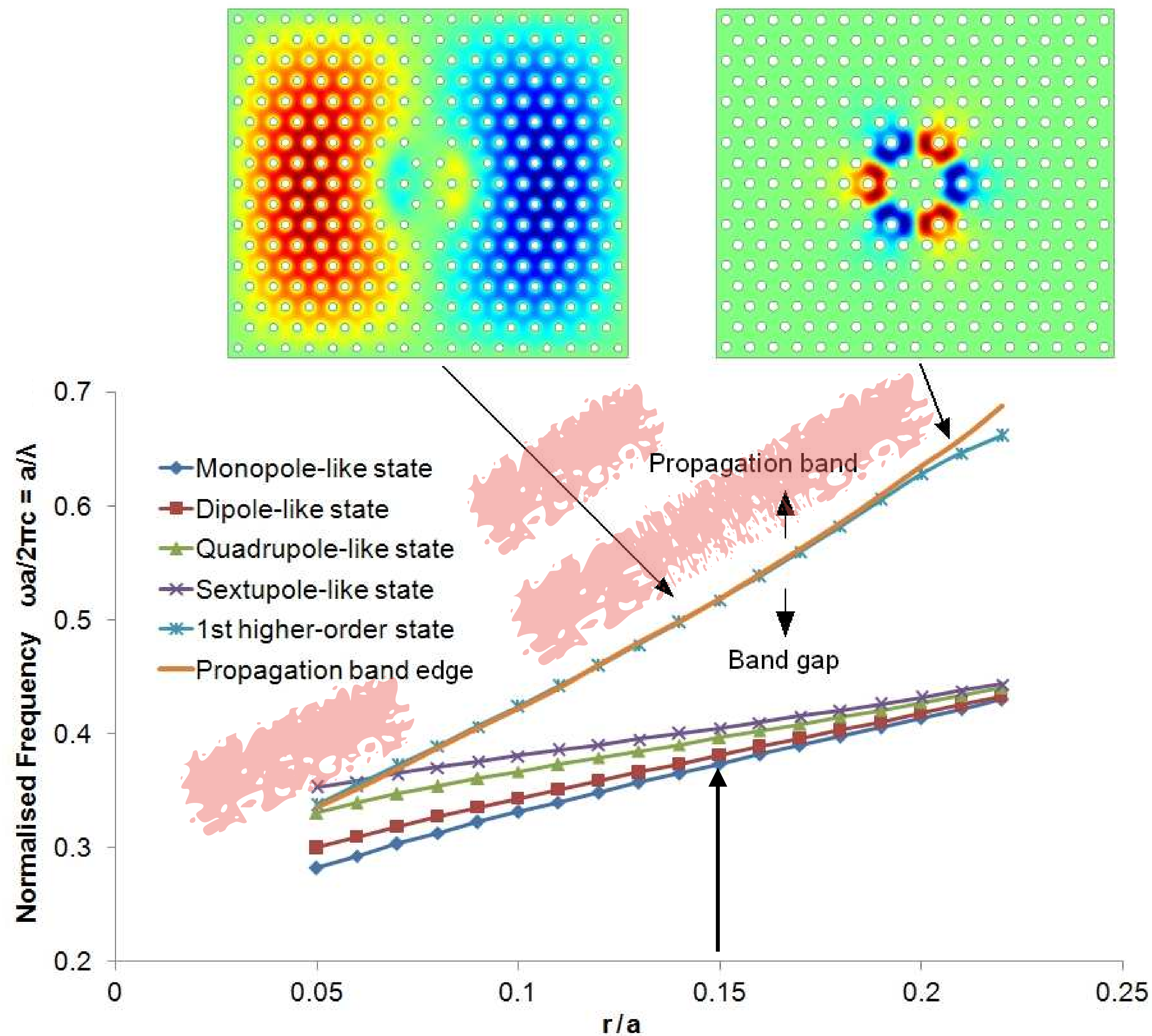
—> r=1.3 mm



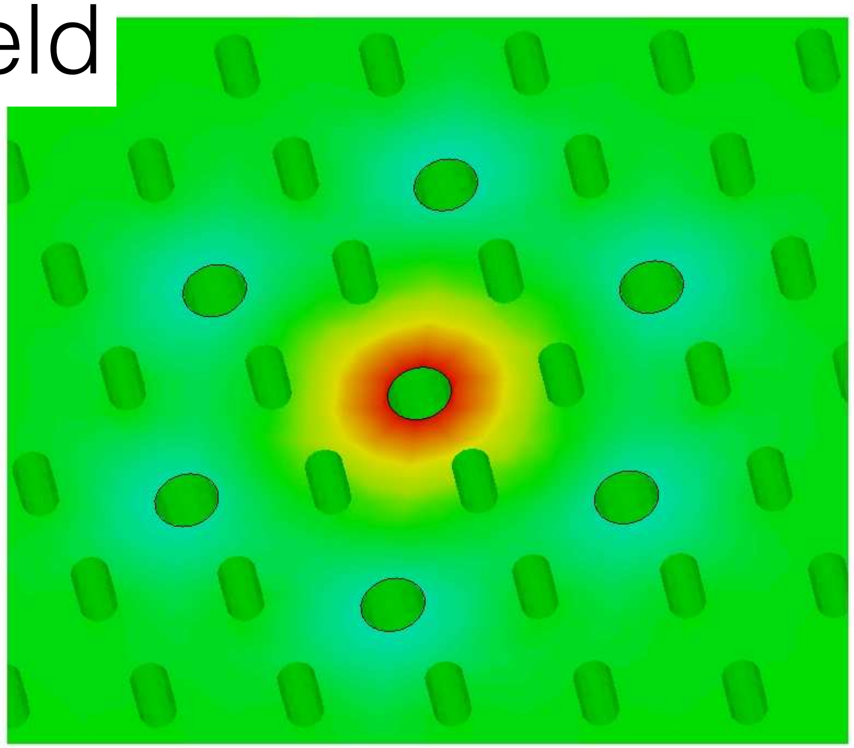
Monopole	14	GHz
Dipole	14.229 GHz	
	14.230 GHz	
Quad	14.733 GHz	
	14.734 GHz	
Sextupole	15.011 GHz	

Multi-defect lattice





E field

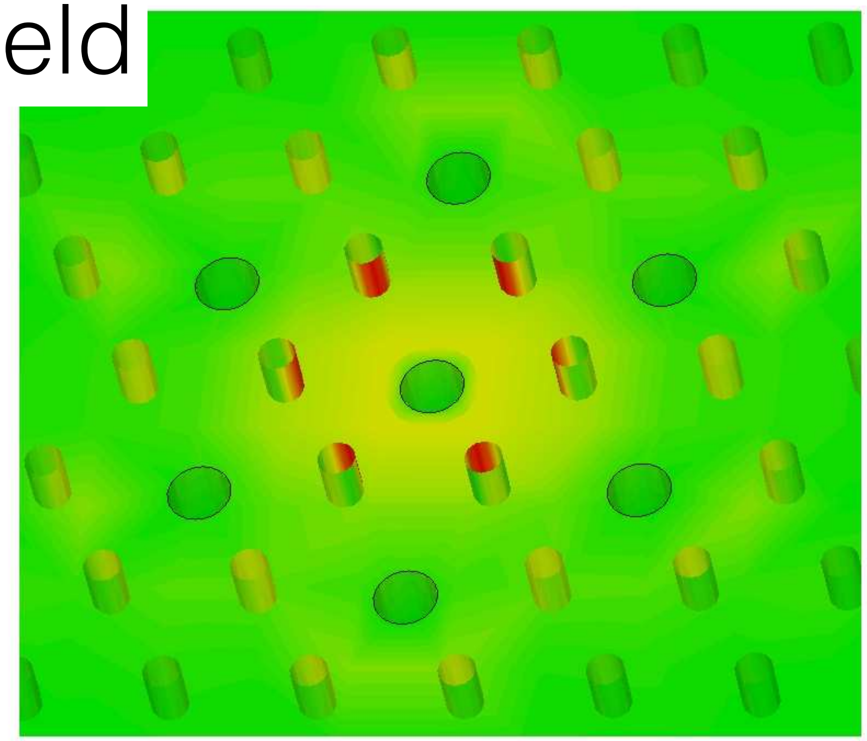


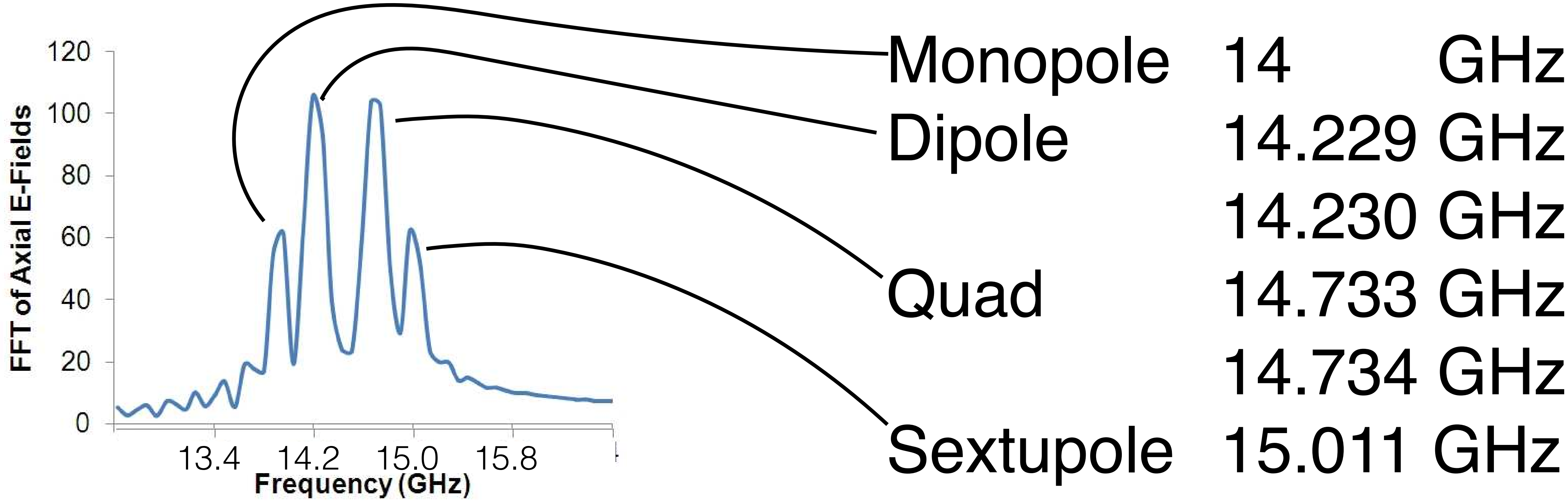
6 inputs 200 KV each

Peak E-field = 46 MV/m

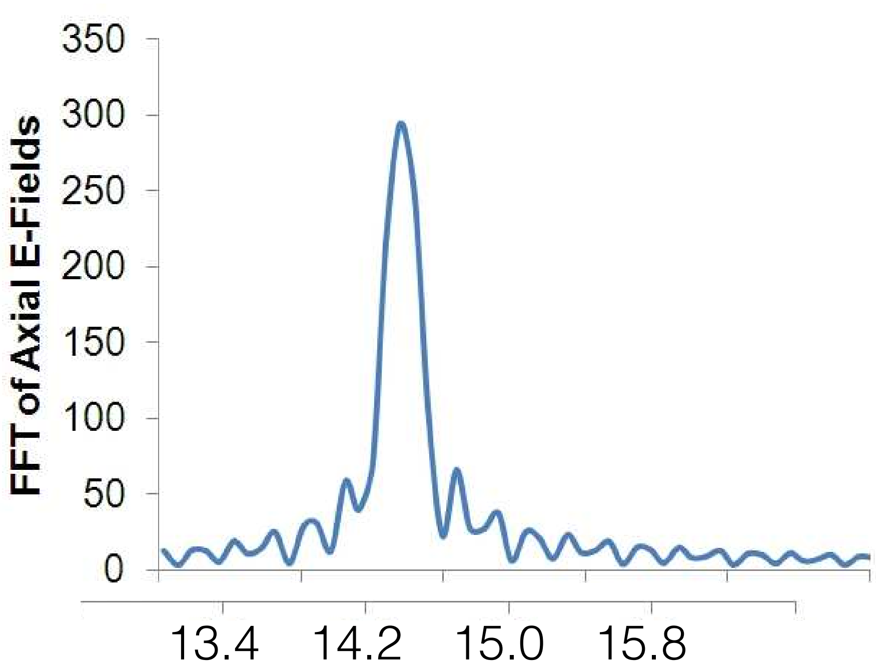
Peak B-field = 120 KA/m

B field

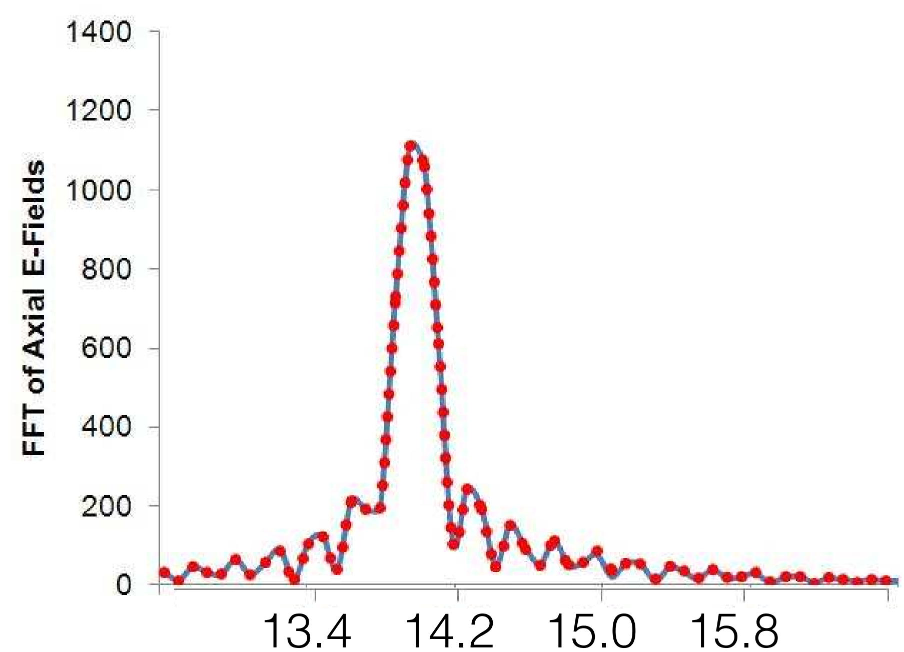




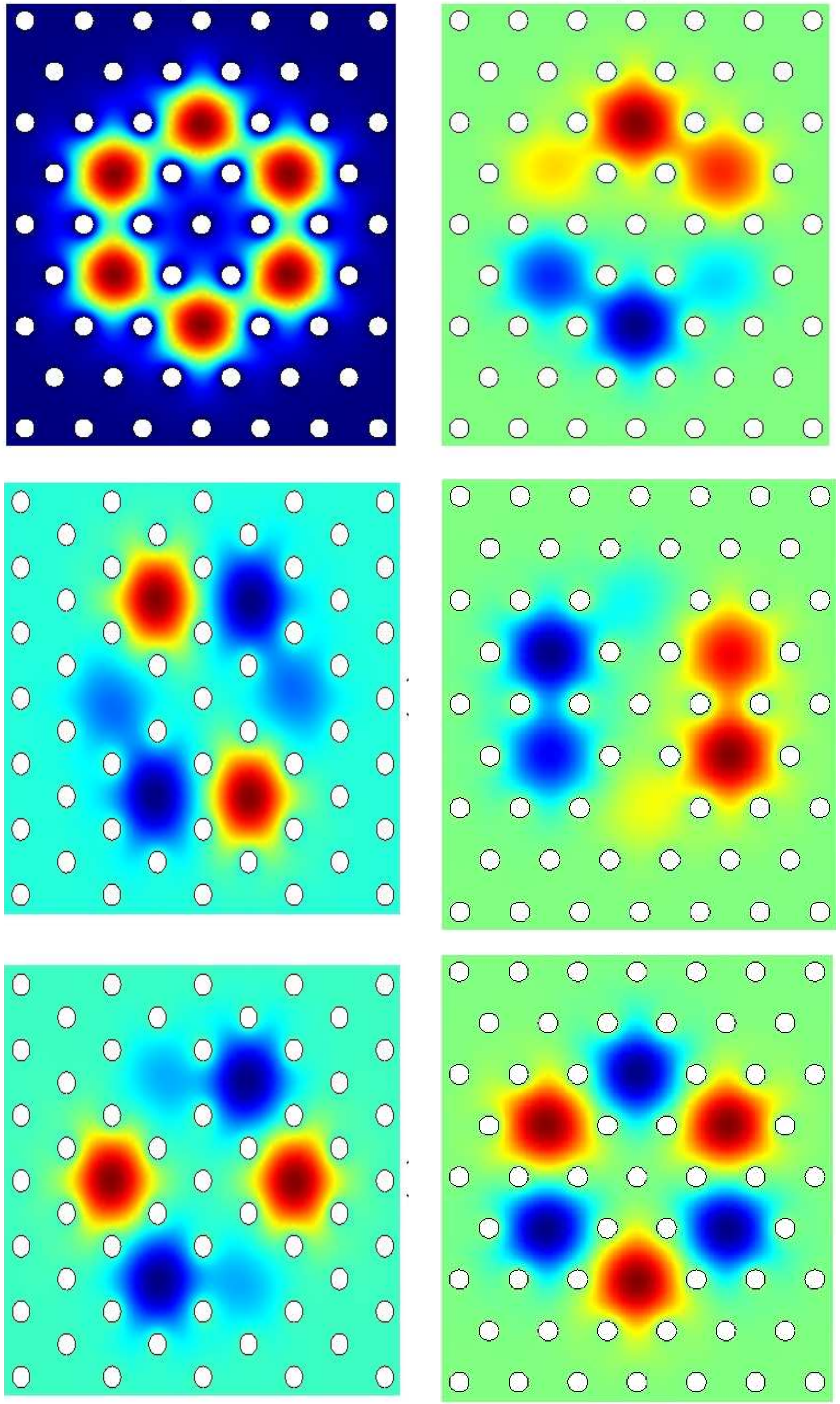
Excitation of one defect

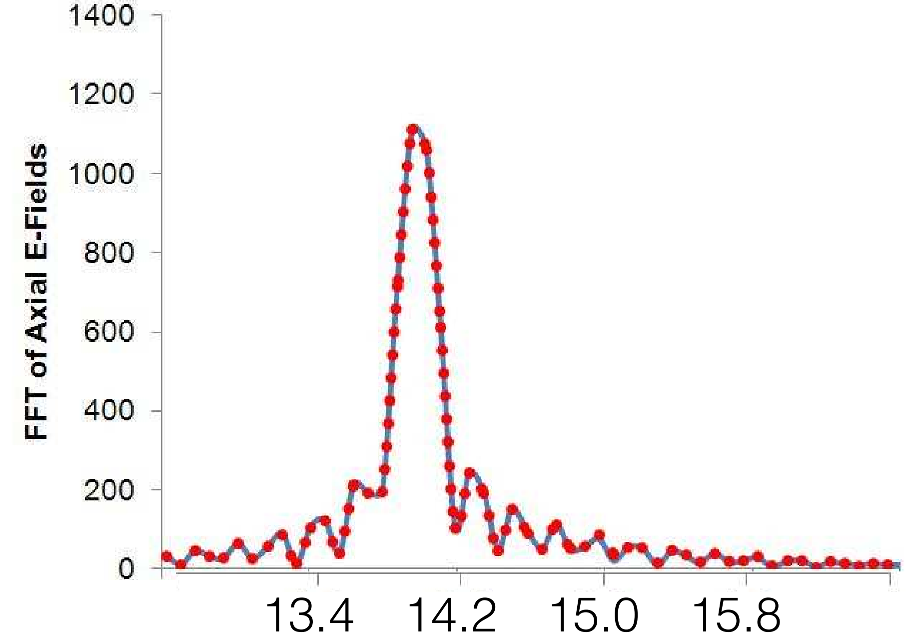


Synchronous excitation of all defect

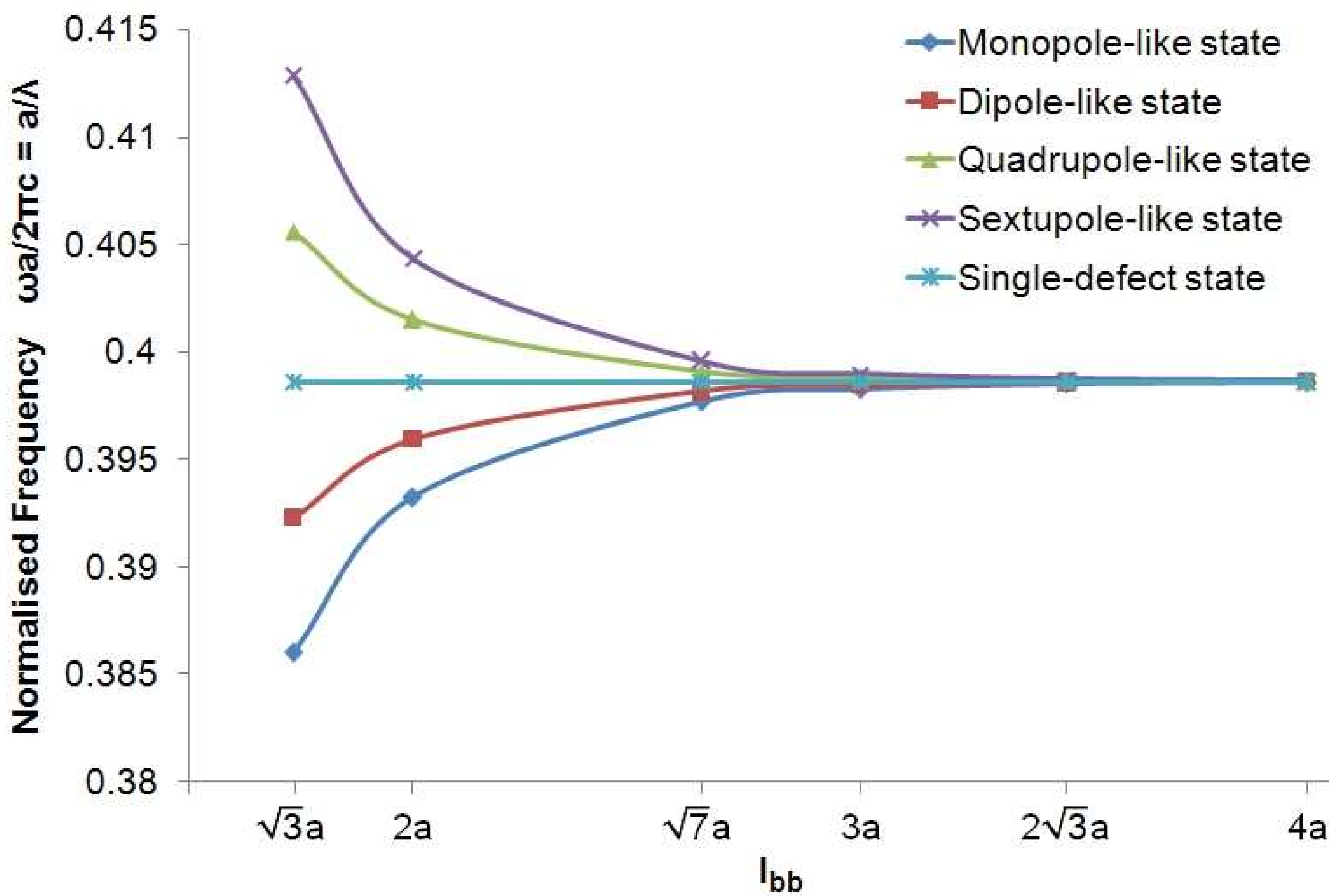


Excitation of all defect, 1% disorder in phase in each defect

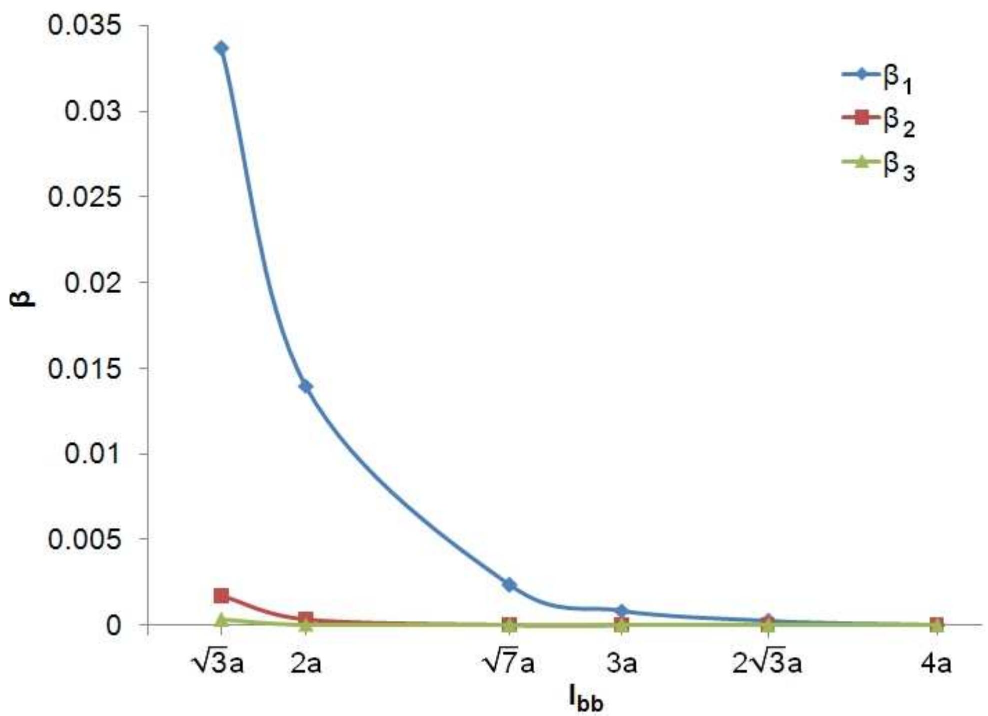




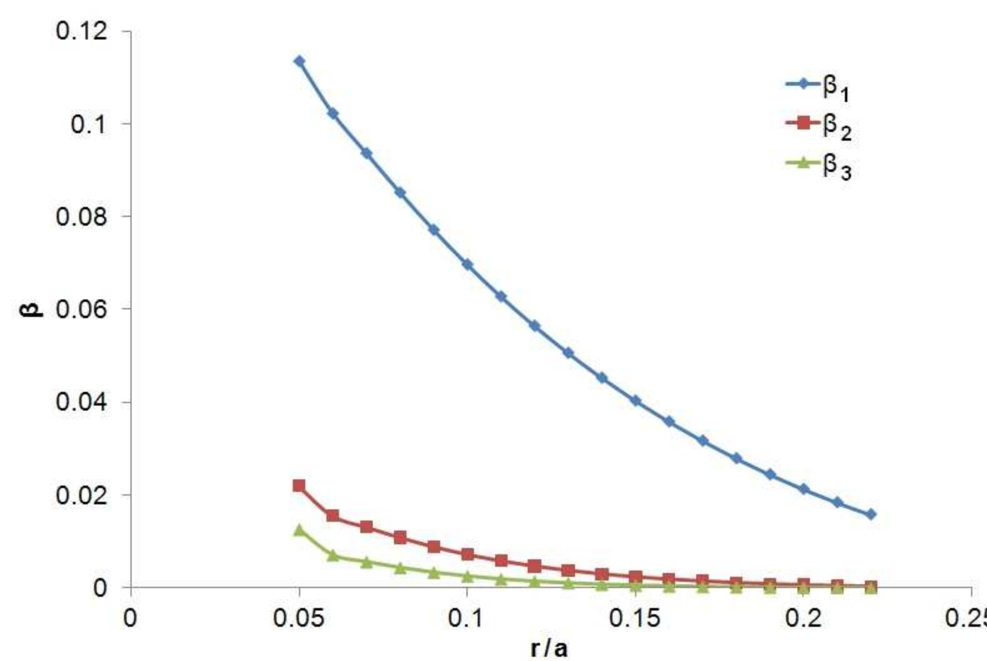
FFT of Axial E-Fields
1400
1200
1000
800
600
400
200
0
13.4
14.2
15.0
15.8



0.415
0.41
0.405
0.4
0.395
0.39
0.385
0.38
Normalised Frequency ωa/2πc = a/λ
Monopole-like state
Dipole-like state
Quadrupole-like state
Sextupole-like state
Single-defect state
√3a
2a
√7a
3a
2√3a
4a
l_{bb}

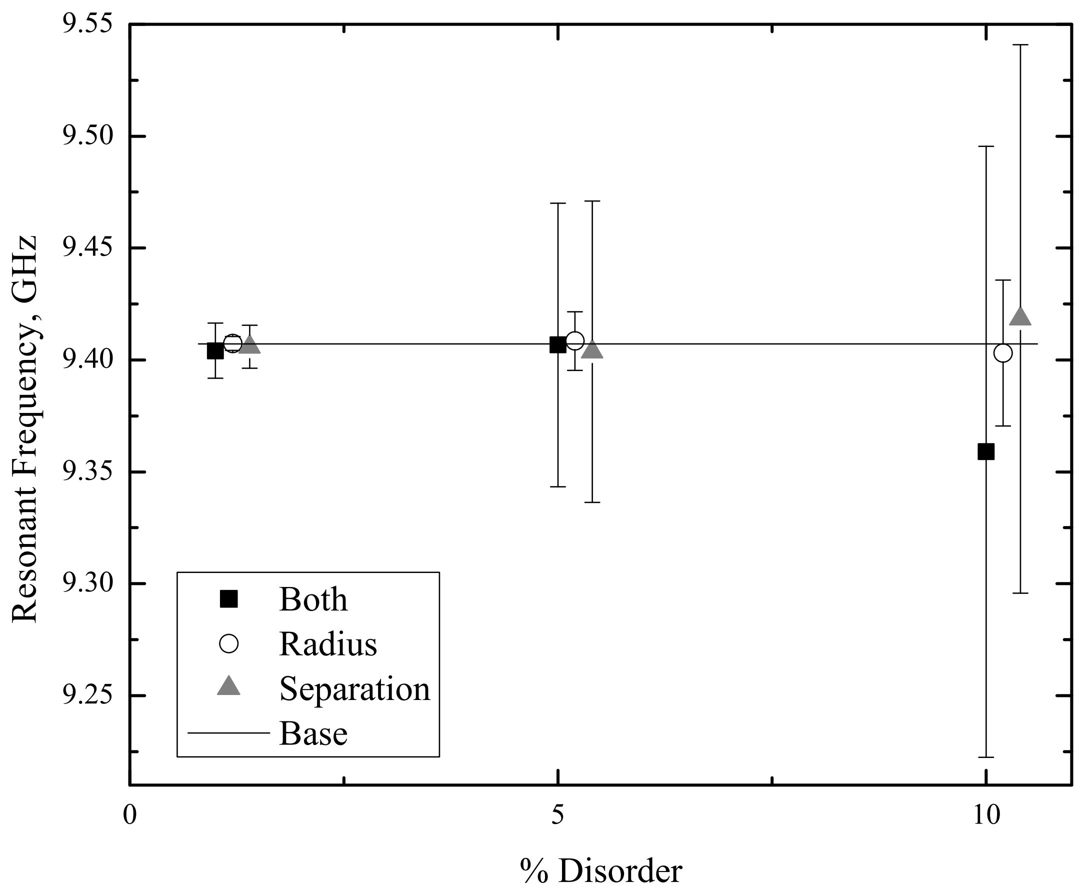


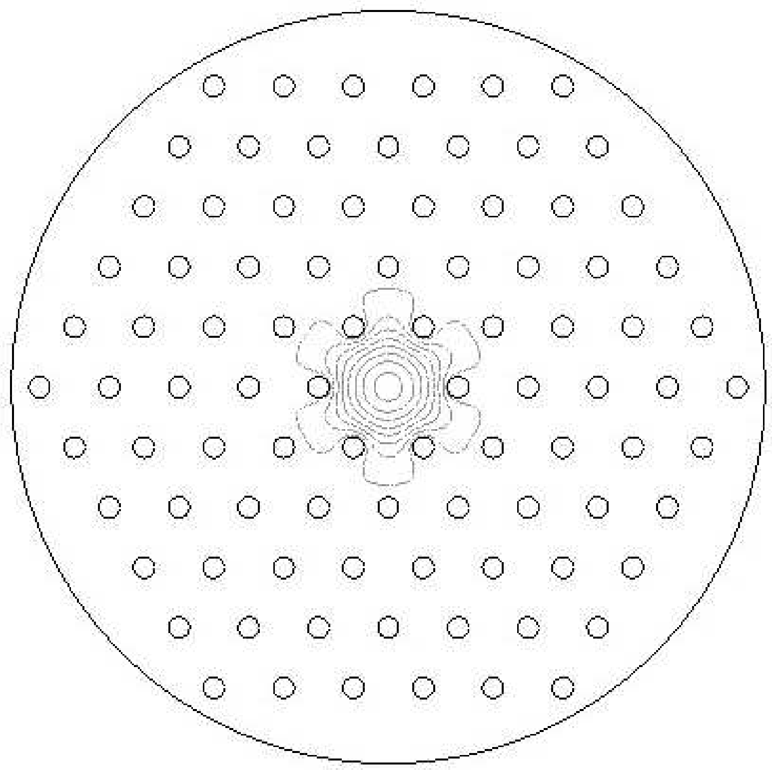
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
β
$β_1$
$β_2$
$β_3$
√3a
2a
√7a
3a
2√3a
4a
l_{bb}



0.12
0.1
0.08
0.06
0.04
0.02
0
β
$β_1$
$β_2$
$β_3$
0
0.05
0.1
0.15
0.2
0.25
r/a

Effects of Disorder on the Frequency and Field of Photonic Crystal Cavity Resonators.. / Matthews, C.; **Seviour, Rebecca**.
In: Applied Physics B: Lasers and Optics, Vol. 94, No. 3, 03.2009, p. 381-388

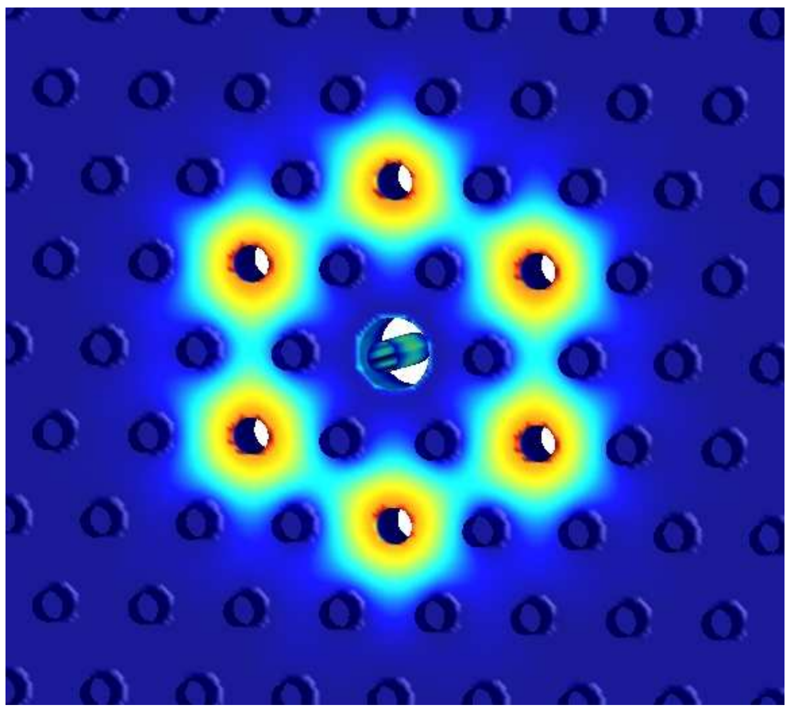


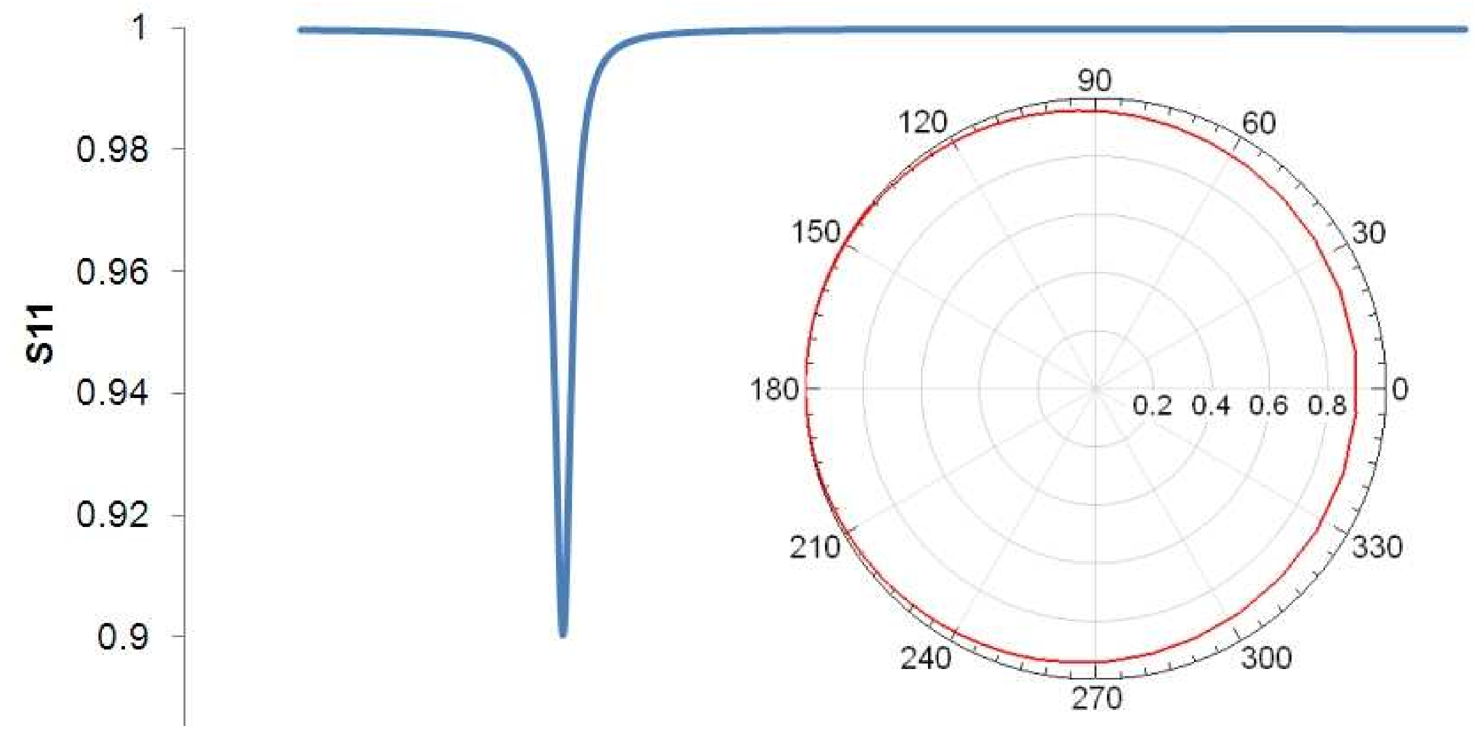


a =8.67 mm —> ± 80 micros
r=1.3 mm —> ± 50 micros

14 GHz ~ ± 29.7 MHz [although standard CnC has ± 5 Micro accuracy]

Output Coupling





Overview

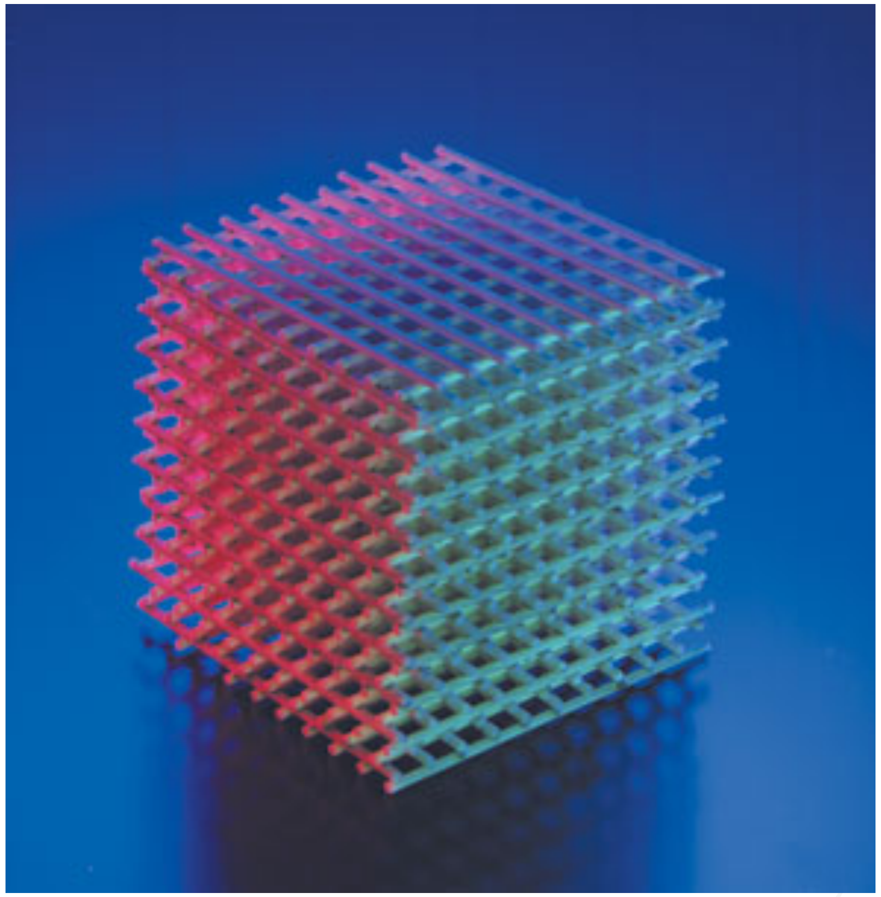
- Looks promising
- Preliminary work shows coupler is feasible at 14 GHz
- good input coupling
- good stability
- with stand high voltages

To do:

  - Wide lattice investigation
  - Improve output coupling
  - Improve modelling
  - Thermal modelling
  - Investigate HOM exploiting (band-width)
  - Investigate fabrication techniques
    - Cold-press extruded rods into a base
    - Al mandrel, plate, acid etch away
    - hollow rod for water cooling
  - Cold test
  - Consider transistor integration

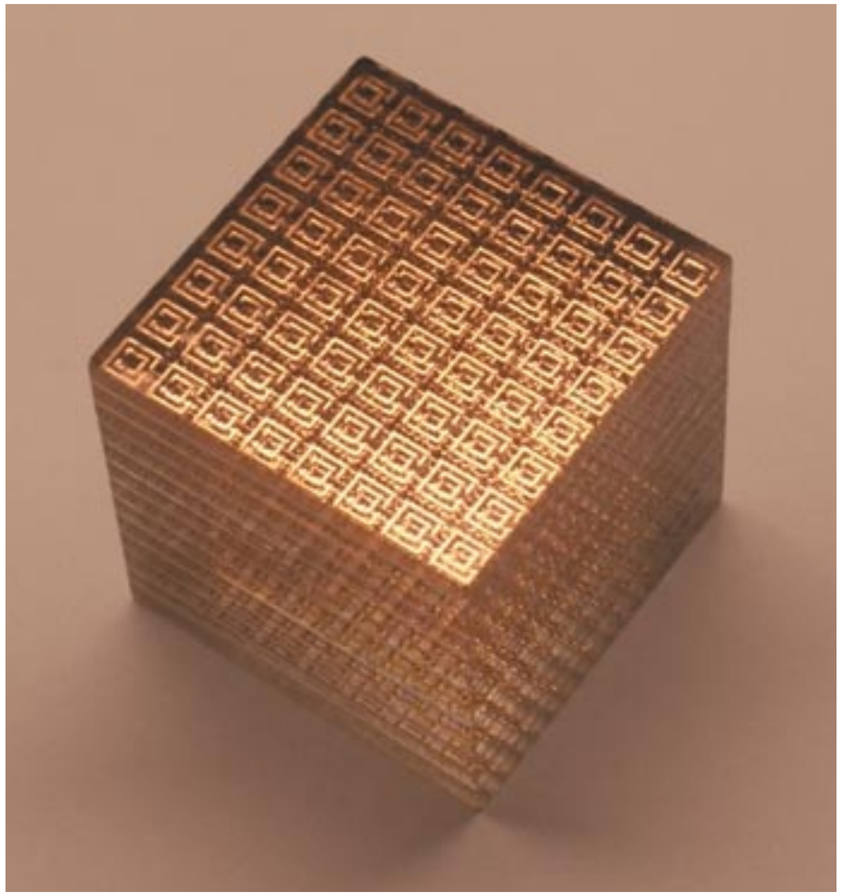
- way forward ?   [need effort (and money), phd or post-doc?]
  - STFC-case [next round may]
  - EPSRC [low probability of success]
  - TSB ?

Photonics

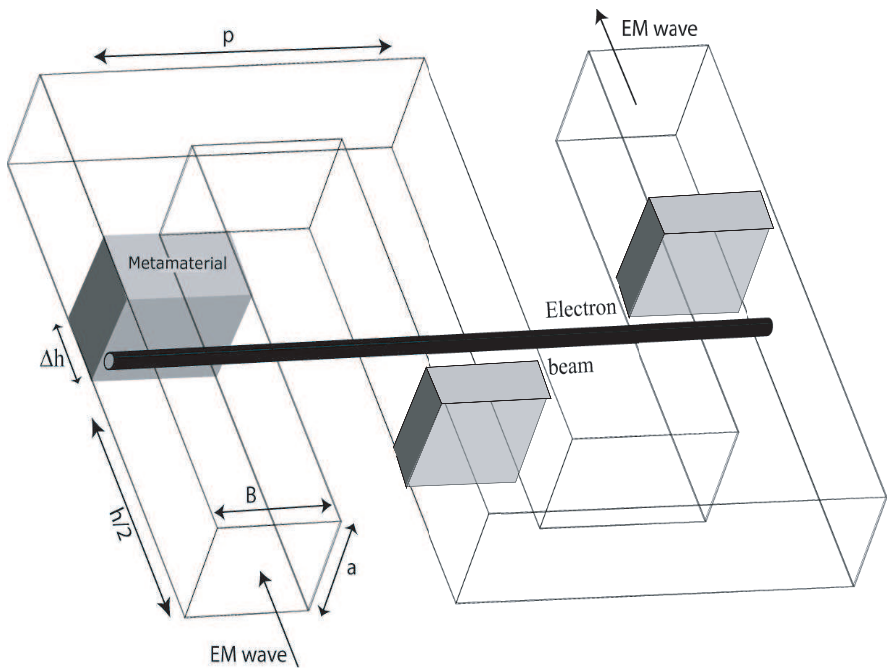


$a \sim \lambda$

Effective-Media



$a << \lambda$

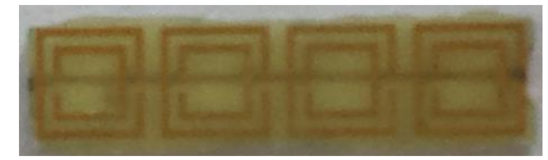


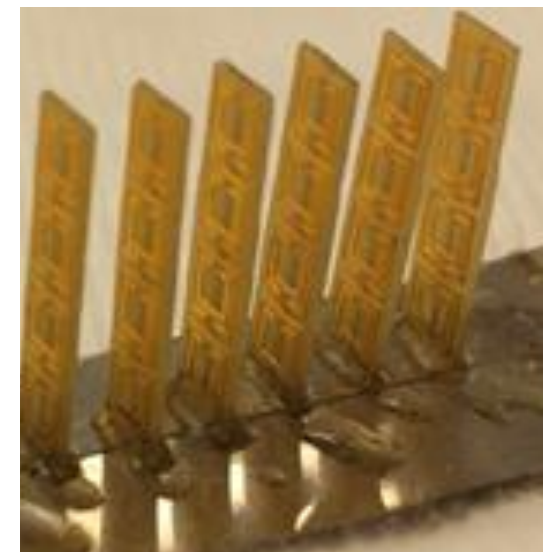
$$\omega = \sqrt{c^2\left(\gamma_n - \left(\frac{\pi(2n+1)}{p} + \beta_{mm}(f)\frac{\Delta h}{p}\right)\right)^2 \alpha + \omega_c^2}$$

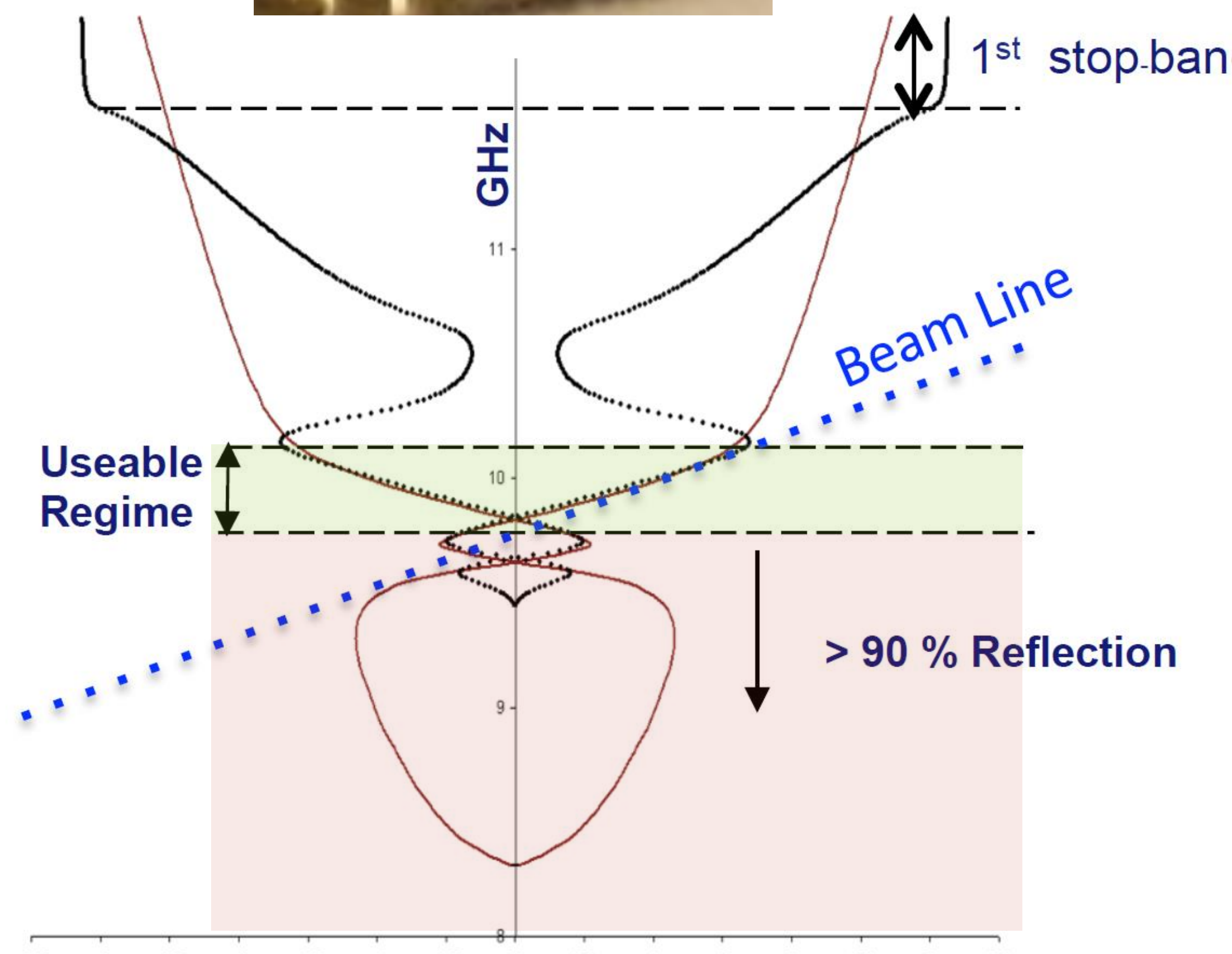
$$\gamma_n = \beta_0 \frac{p+h-\Delta h}{p} + \beta_{mm}(\omega)\frac{\Delta h}{p} + (2n+1)\frac{\pi}{p}$$

$$\alpha = \left(\frac{p}{p+h-\Delta h}\right)^2$$

$$\beta_{mm}(\omega) = c^{-1}\sqrt{\omega^2 \epsilon_r(\omega)\mu_r(\omega) - \omega_c^2}$$







Lorentz's Force Equation

$$m_0c^2\frac{d}{dt} = -\ \mathbf{E}$$

Time changing in $m_0c^2\gamma$ (DC and AC beam energy) is related by the E.v dot product in this equation. The DC beam energy γdc is given by (1+Vdc/511); Vdc is the DC beam accelerating potential. While the AC beam energy exchange (stimulated emission) is calculated through the Madey's theory.

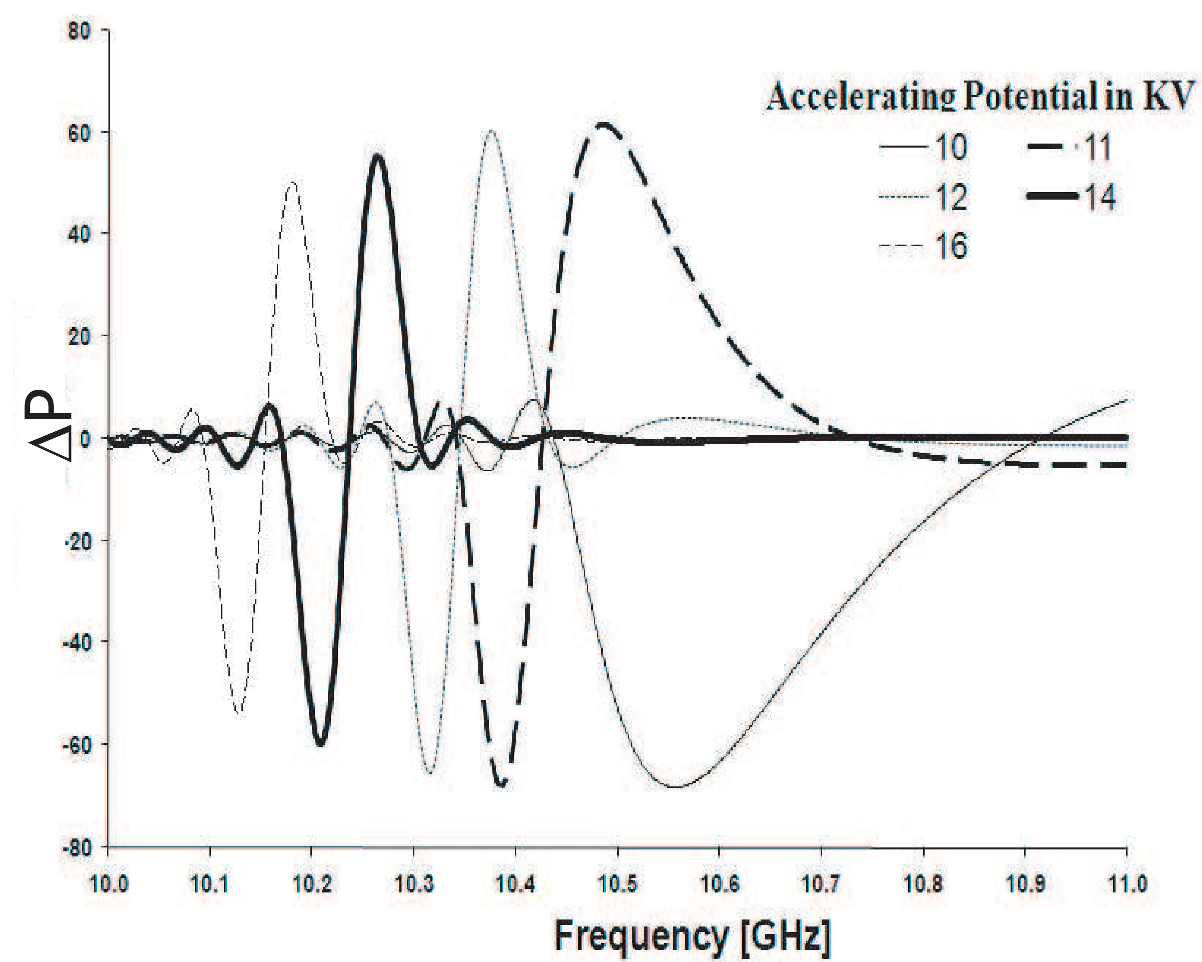
$$m_0c^2\frac{d}{dt}{}_1 = -\ \mathbf{E}{}_0$$

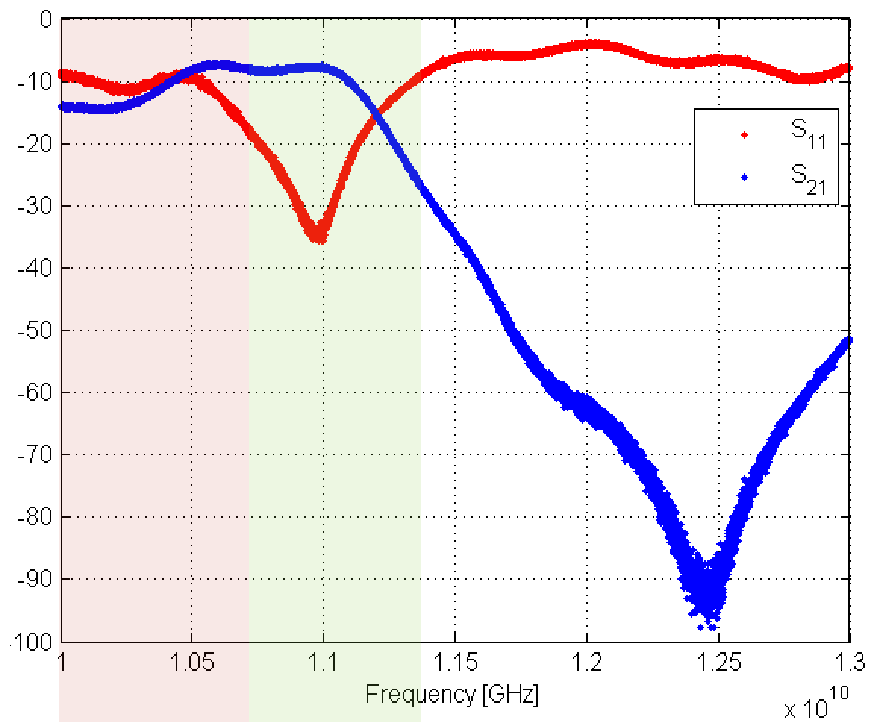
1^{st} order perturbation >> Spontaneous emission

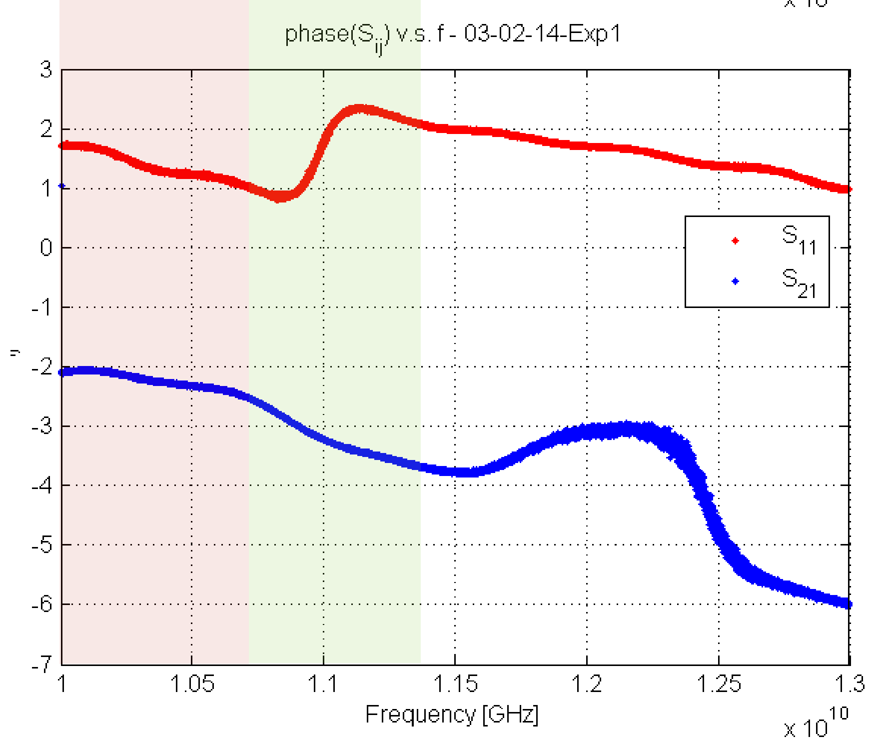
$$\langle\Delta\gamma_2\rangle = \frac{1}{2}\frac{d}{d}\langle\Delta\gamma_1{}^2\rangle$$

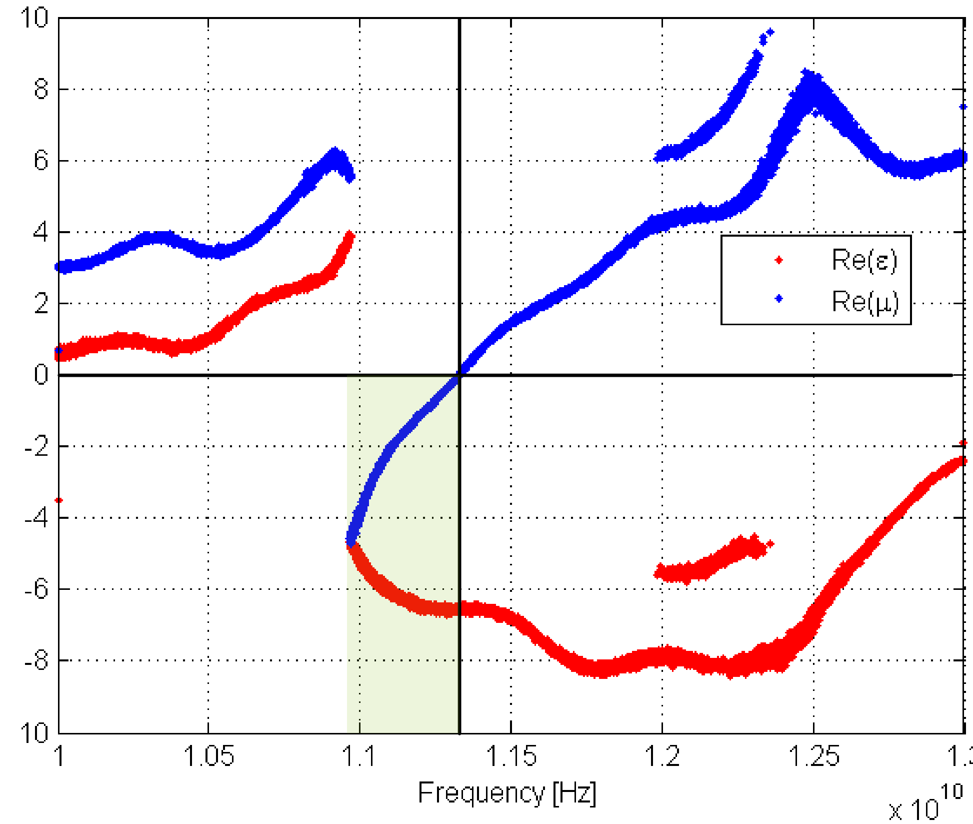
2^{nd} order perturbation >> Stimulated emission

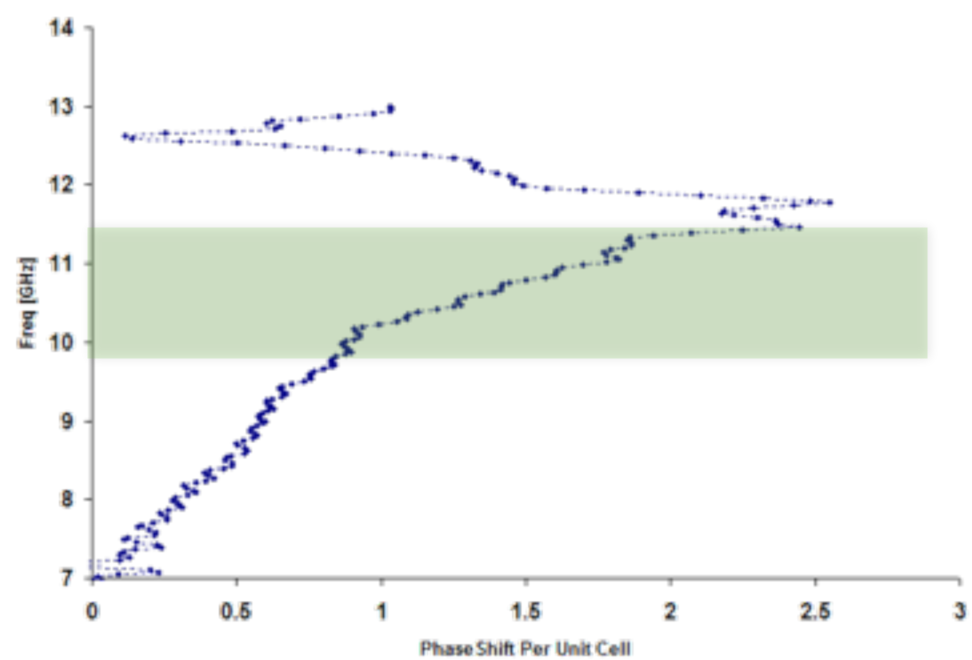
$$\frac{\Delta P_{out}}{P_{in}} = \frac{-\frac{1}{2}\frac{d}{d\gamma}\langle\Delta\gamma_1{}^2\rangle m_0c^2\frac{I}{e}}{P_{in}}$$

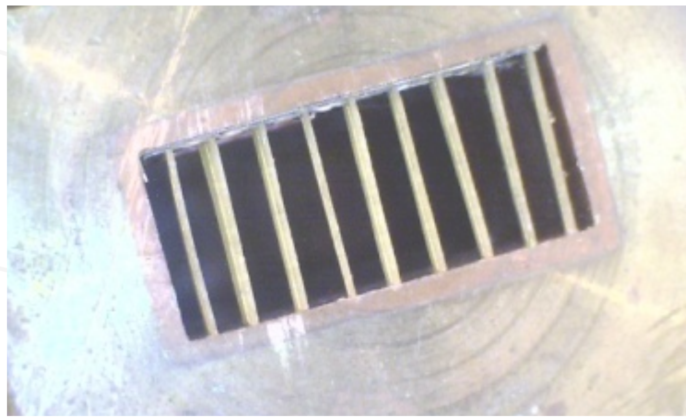


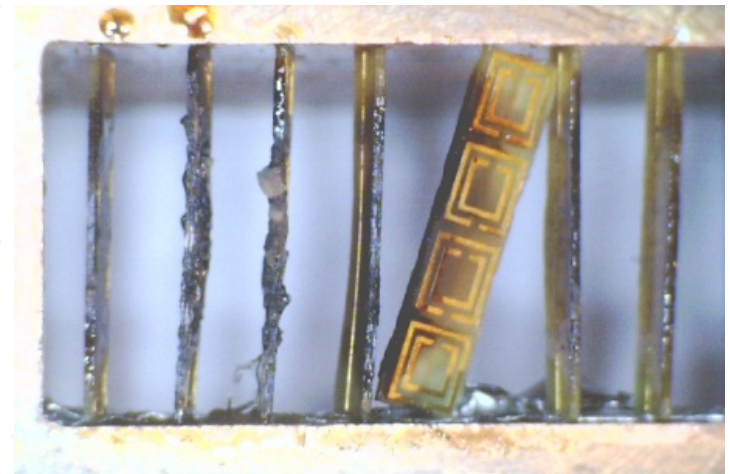

S11
S21
Frequency [GHz]
x 10^10

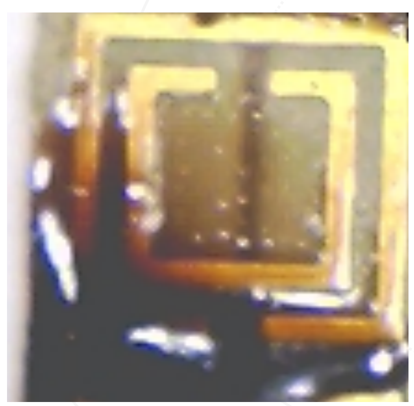

phase(Sij) v.s. f - 03-02-14-Exp1
S11
S21
Frequency [GHz]
x 10^10

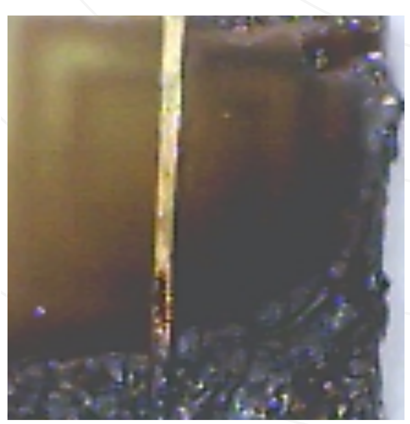

Re(ε)
Re(μ)
Frequency [Hz]
x 10^10

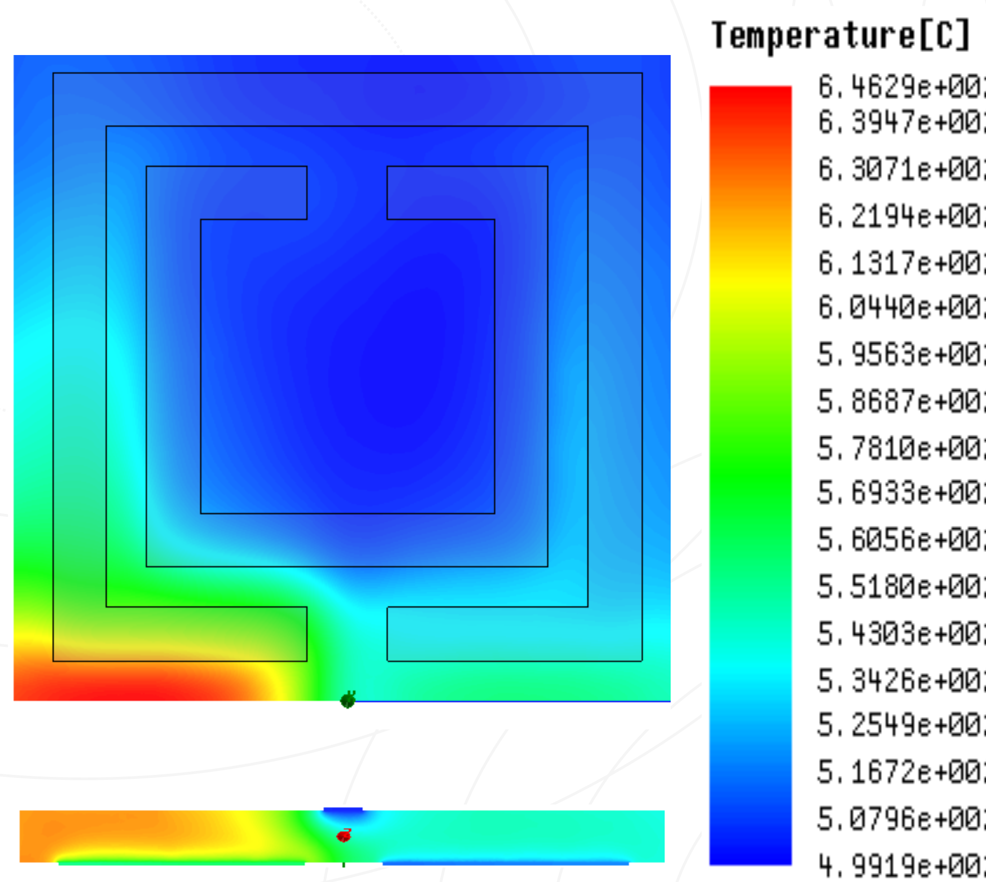

Freq [GHz]
Phase Shift Per Unit Cell










Temperature[C]
6.4629e+002
6.3947e+002
6.3071e+002
6.2194e+002
6.1317e+002
6.0440e+002
5.9563e+002
5.8687e+002
5.7810e+002
5.6933e+002
5.6056e+002
5.5180e+002
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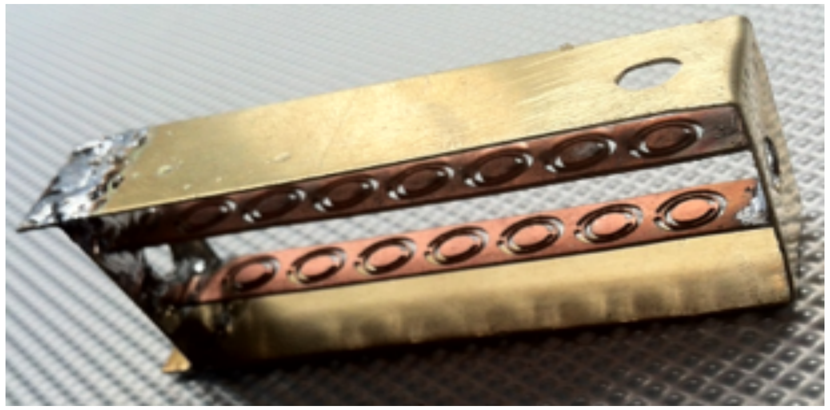
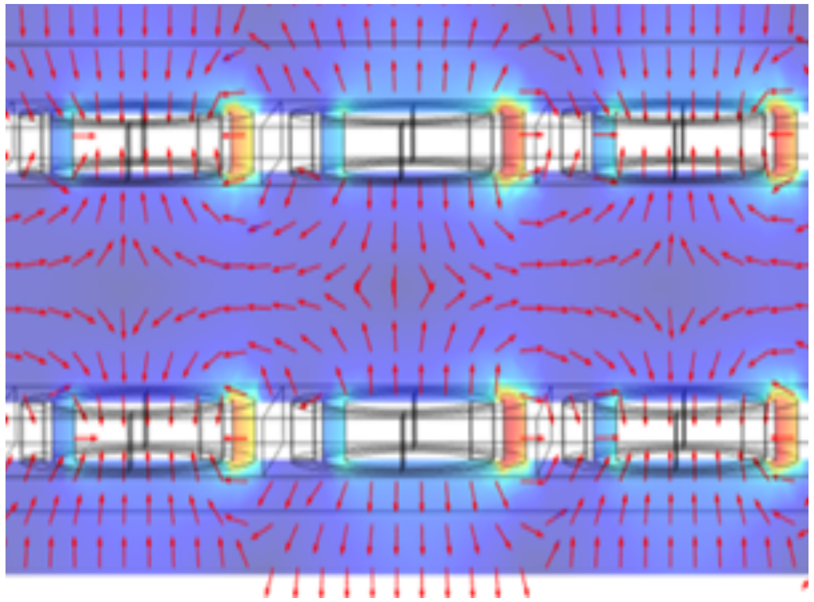
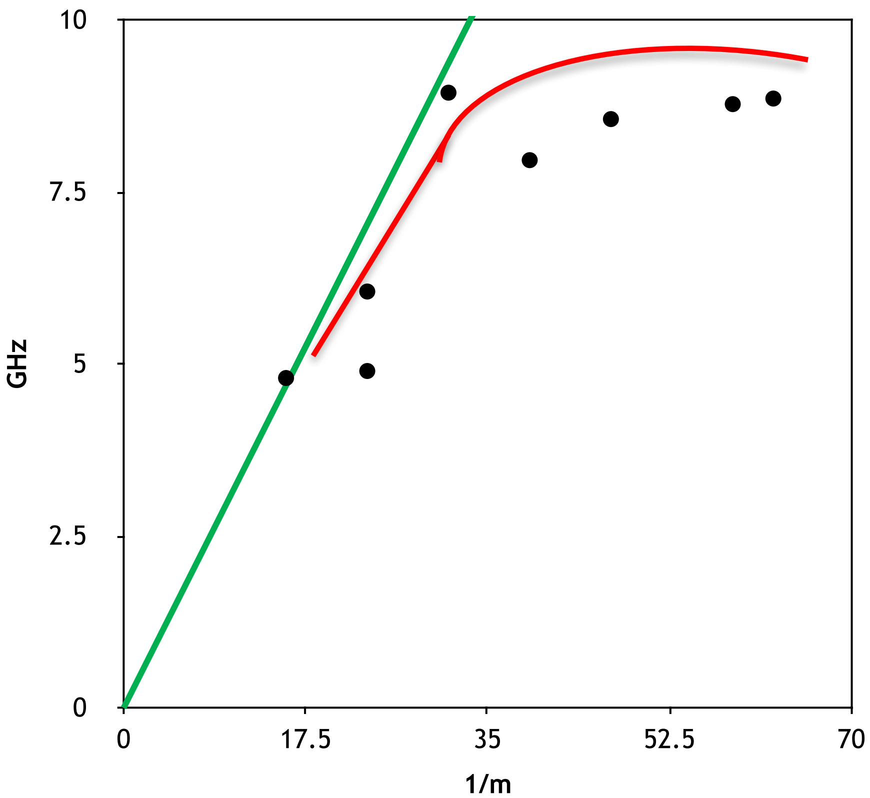
4.9919e+002





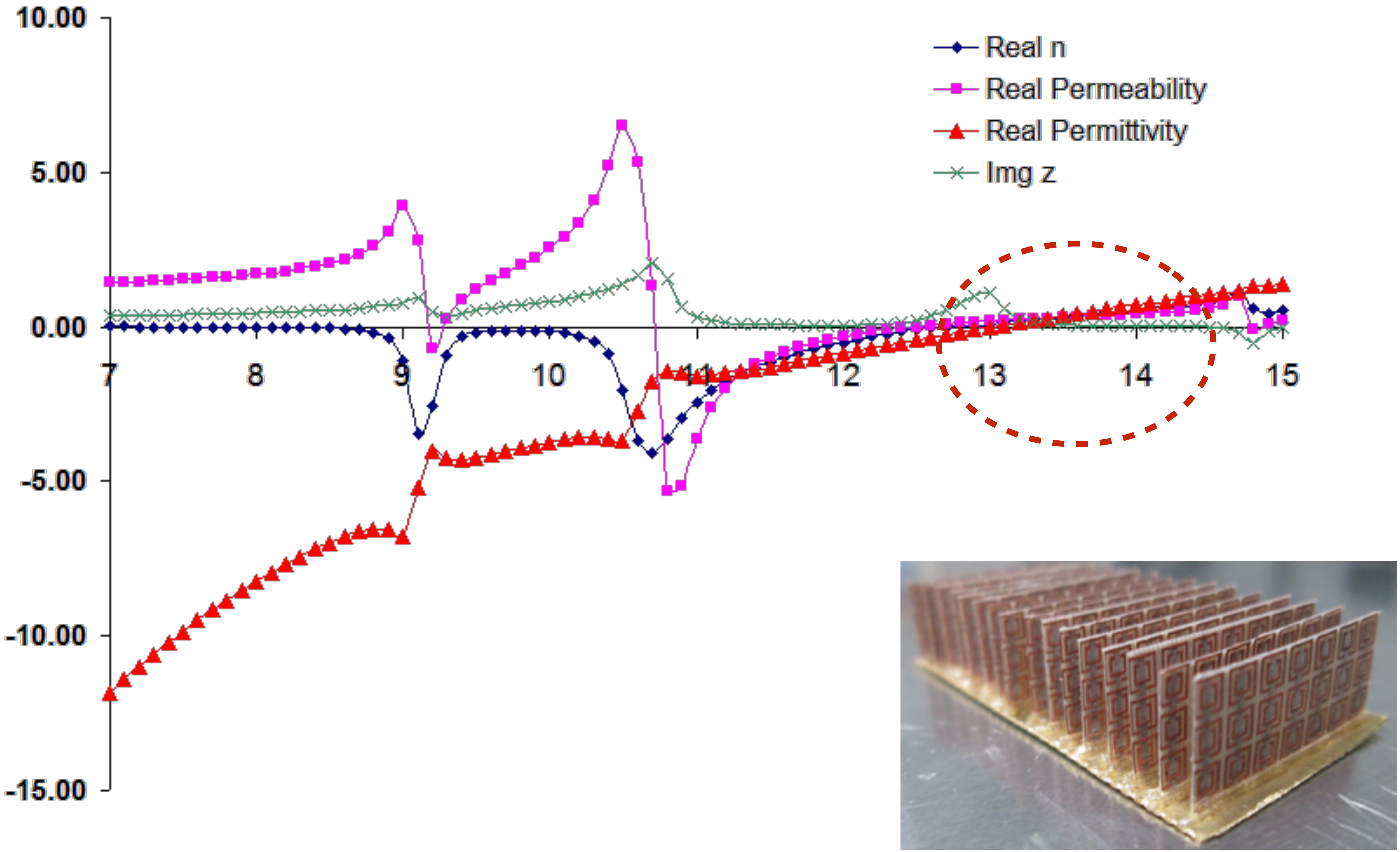
E field 9.6 GHz
π - Mode

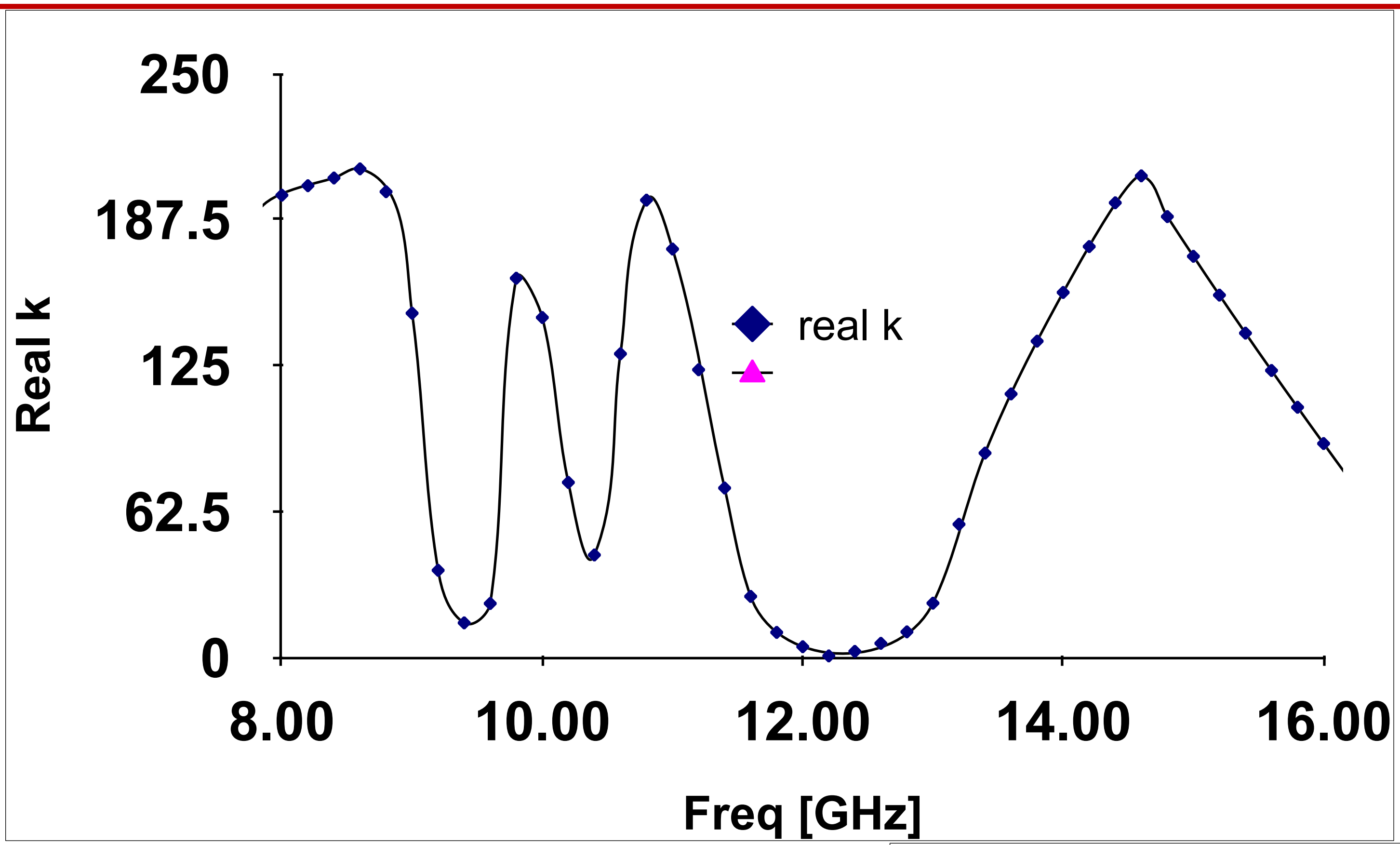
Dispersion relation extracted via bead pull, black dots, with the light line shown in green.



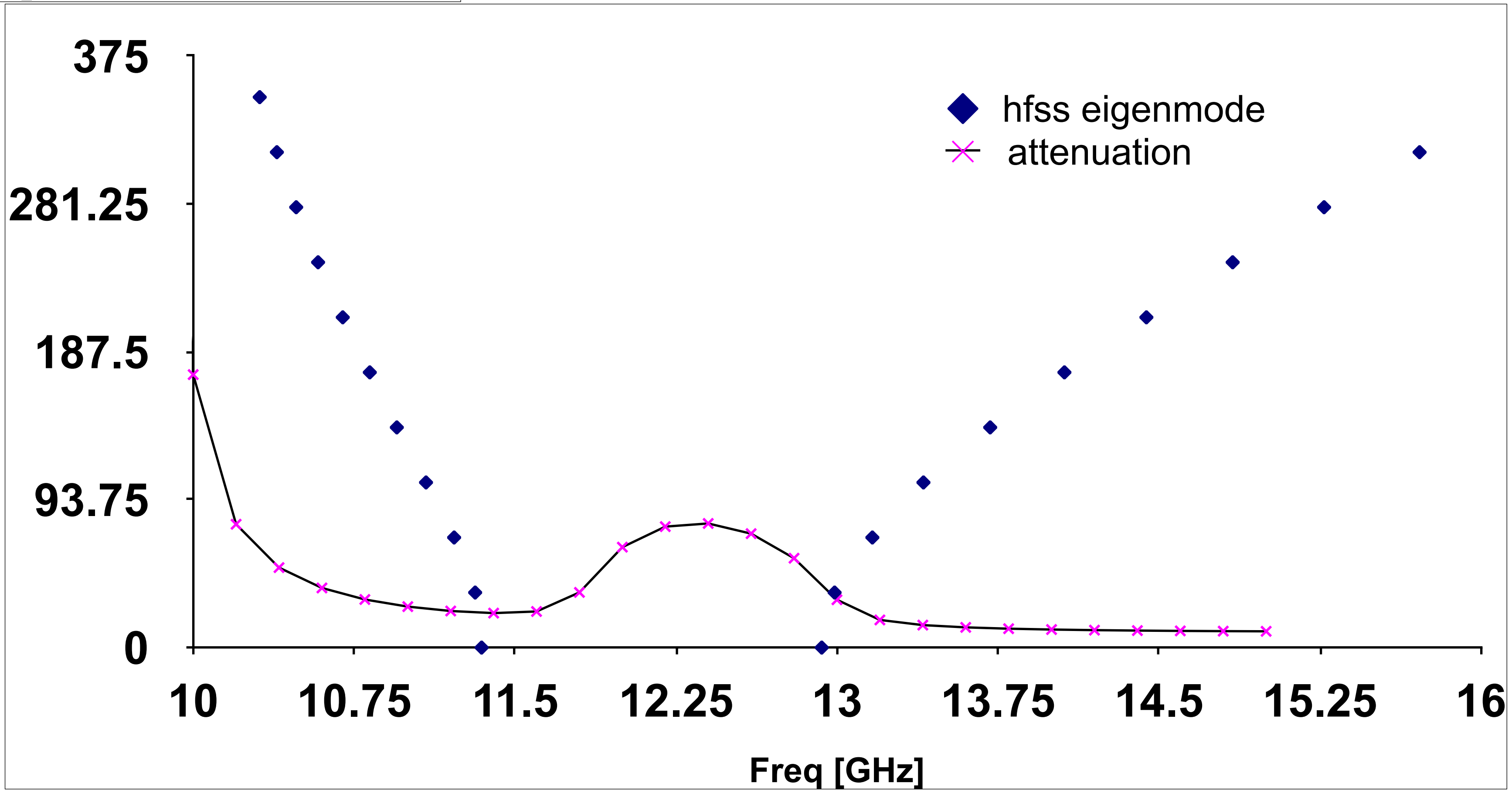
- 2 KeV/M gradient
- Redesign SRR at lower frequency to couple more effectively to slow-waves.
- increase beam voltage (30kev ->50Kev)
- Although CSRR breaks down @ 80W forward power

David French (Huddersfield 2013)

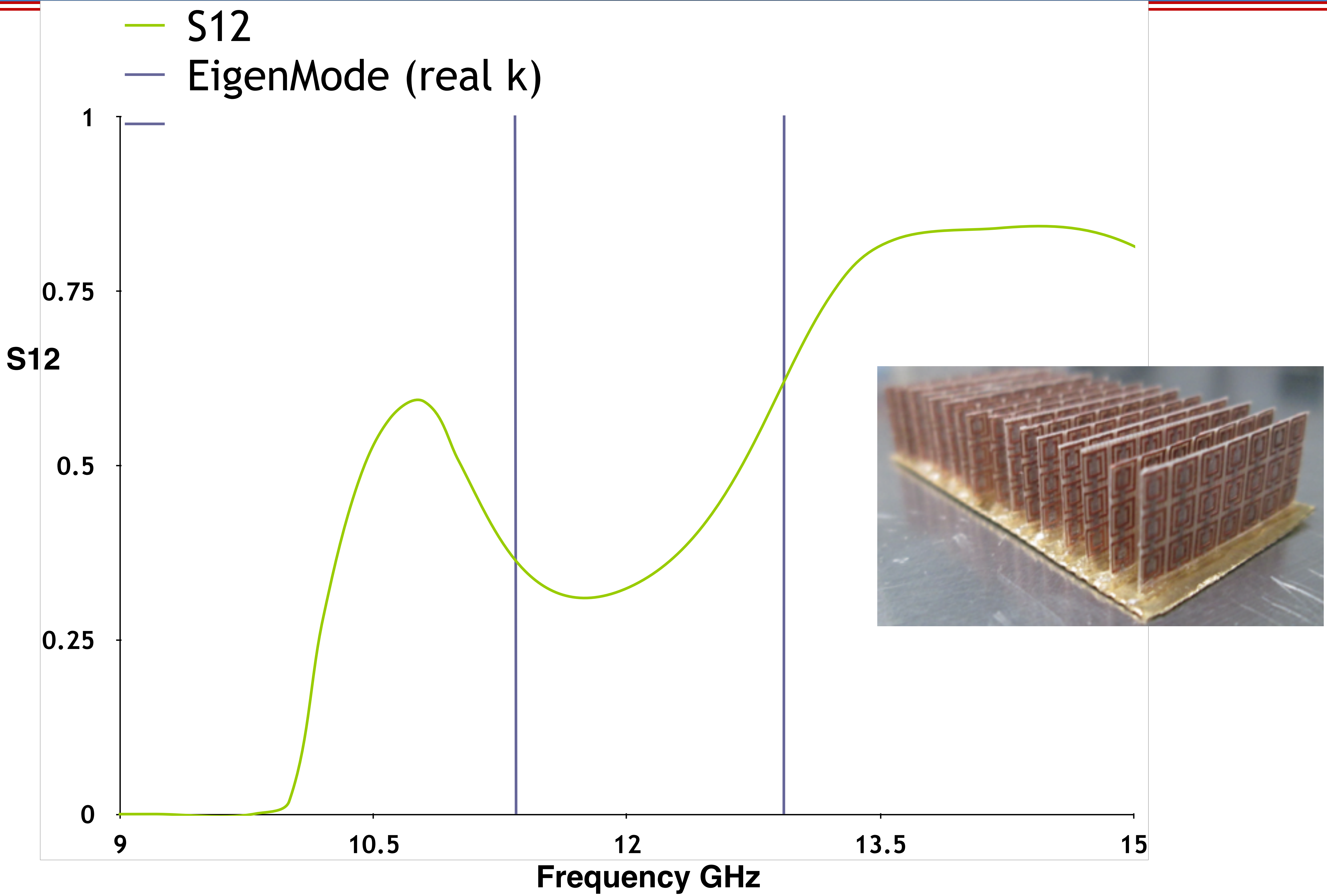

Real n
Real Permeability
Real Permittivity
Img z
10.00
5.00
0.00
-5.00
-10.00
-15.00
7
8
9
10
11
12
13
14
15



250
187.5
125
62.5
0
Real k
real k
8.00
10.00
12.00
14.00
16.00
Freq [GHz]



375
281.25
187.5
93.75
0
hfss eigenmode
attenuation
10
10.75
11.5
12.25
13
13.75
14.5
15.25
16
Freq [GHz]


S12
EigenMode (real k)
1
0.75
0.5
0.25
0
S12
9
10.5
12
13.5
15
Frequency GHz