Absorbing Materials for Beamline Absorbers: How good is good enough?

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Presentation Outline

- Beamline absorber benefits
- Example absorber materials
- Computer and theoretical models to determine acceptable EM absorber properties
- Conclusions

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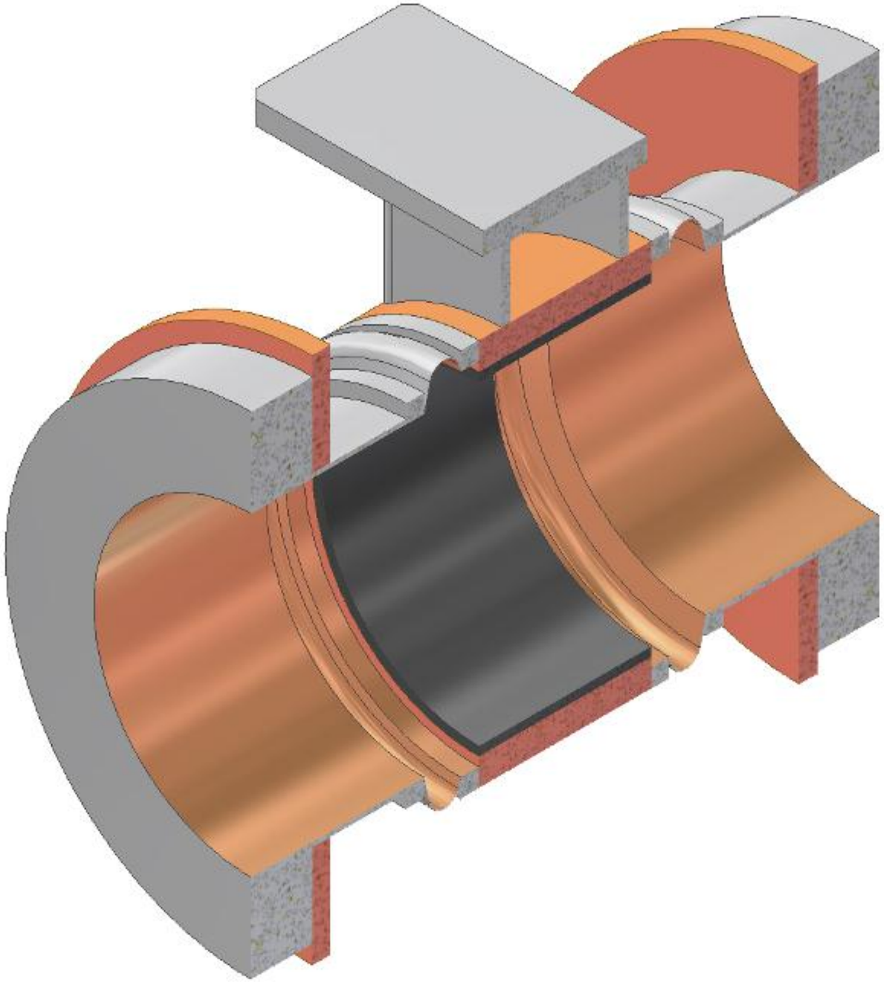
Beam Line Absorber Benefits

- Radial symmetry helps avoid beam kicks
- Radial symmetry ensures all HOM polarizations are damped
- Absorber length > λ/2 of lowest freq. HOM damps all non-trapped modes.
- Straightforward design → easier RF optimization.



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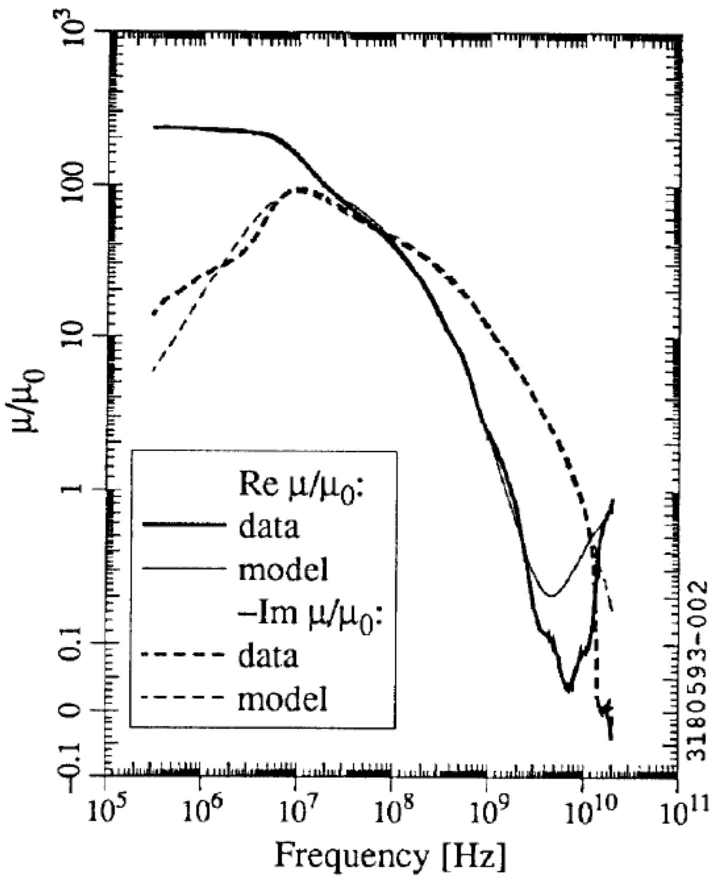
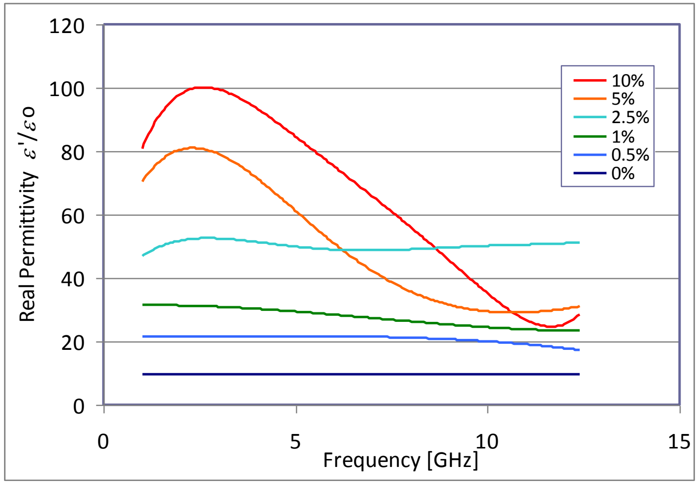
Absorber Properties

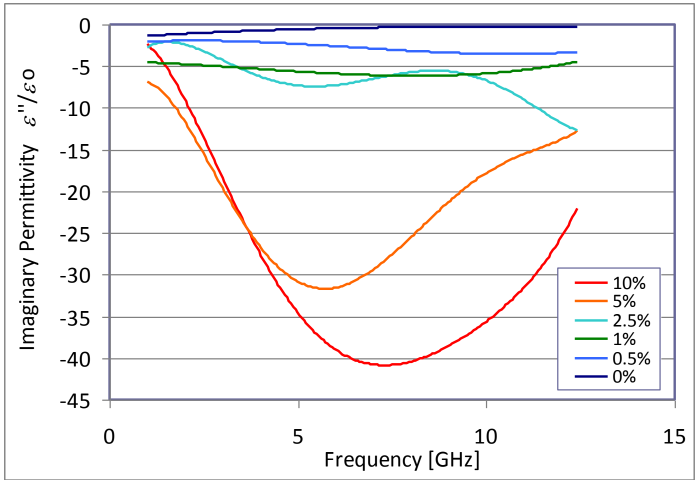
- CESR-III HOM load

  TT2-111V



- Carbon Nanotube





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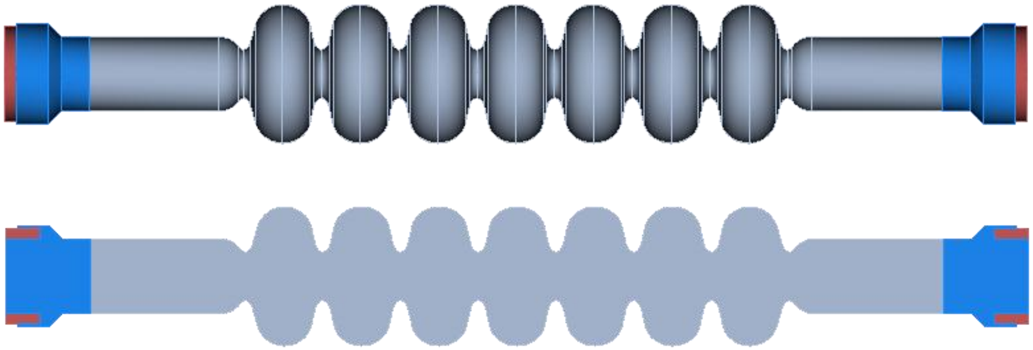
Optimal Absorber Properties

- We model a cavity damped by an absorber with frequency independent EM properties
- The cavity + HOM absorber geometry is simulated using CLANS, a 2D-finite-element code.
- CNT absorbers were modeled with $\mu = \mu_0$ and

$\mathrm{Real}\{\varepsilon\} = (5, \ldots, 25)\ \varepsilon_0$ $\mathrm{Imag}\{\varepsilon\} = -(1, \ldots, 10)\ \varepsilon_0$



Computer Simulation

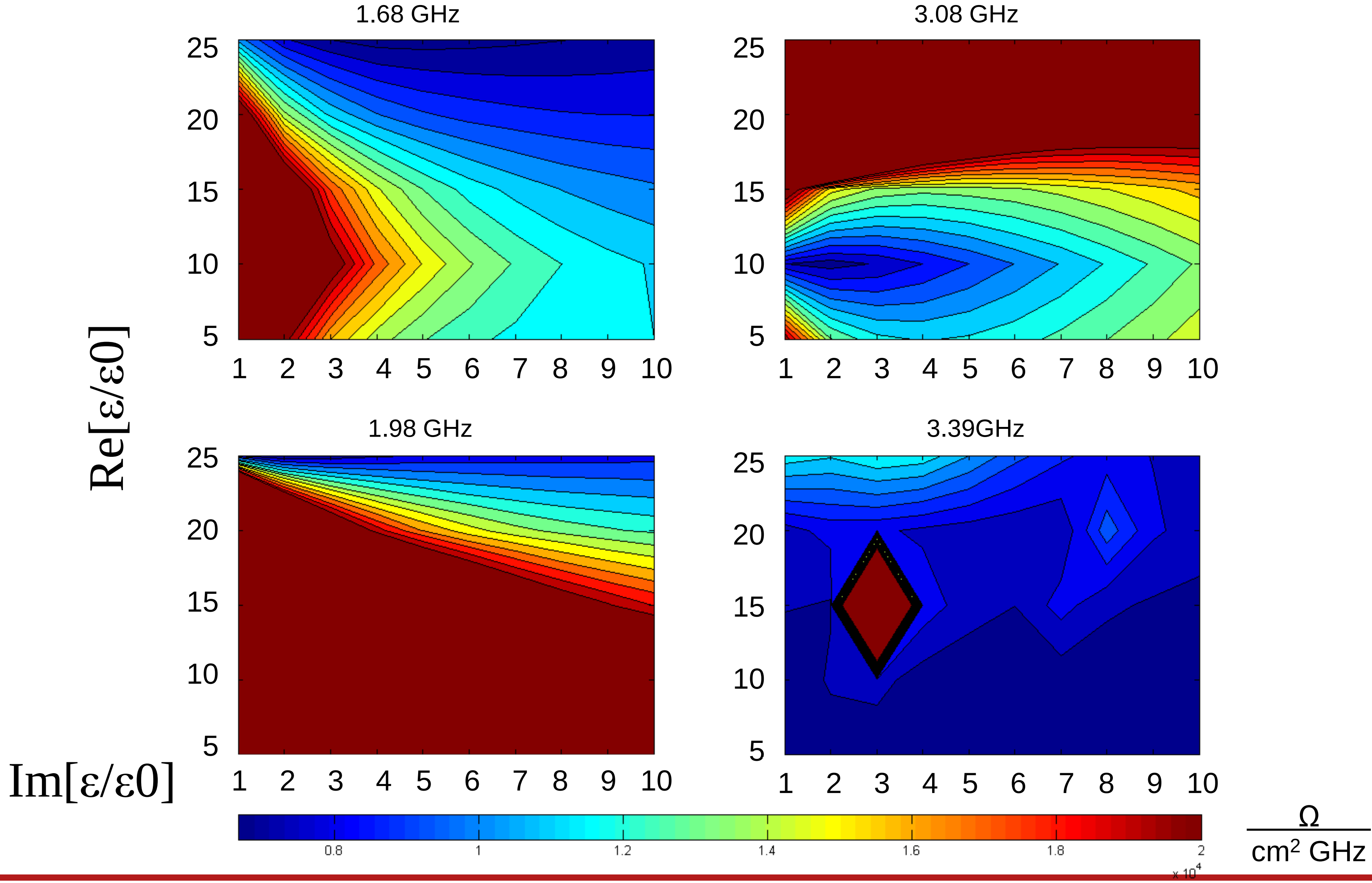
- Goal: Determine the relation between absorber properties and beam-break up current.
- Previous work shows the threshold current follows the empirical relation:

$$I_{th}^{-1} \propto \max\left[\left(\frac{R}{Q}\right)_{\lambda} \frac{\sqrt{Q_{\lambda}}}{f_{\lambda}}, \lambda \in \mathrm{Dipole\,HOM\,Spectrum} \right]$$

- Simulated dipole HOMs up to 10 GHz, (E-E and M-M B.C.s). Found the “worst” BBU parameters, and plotted vs dielectric constant.

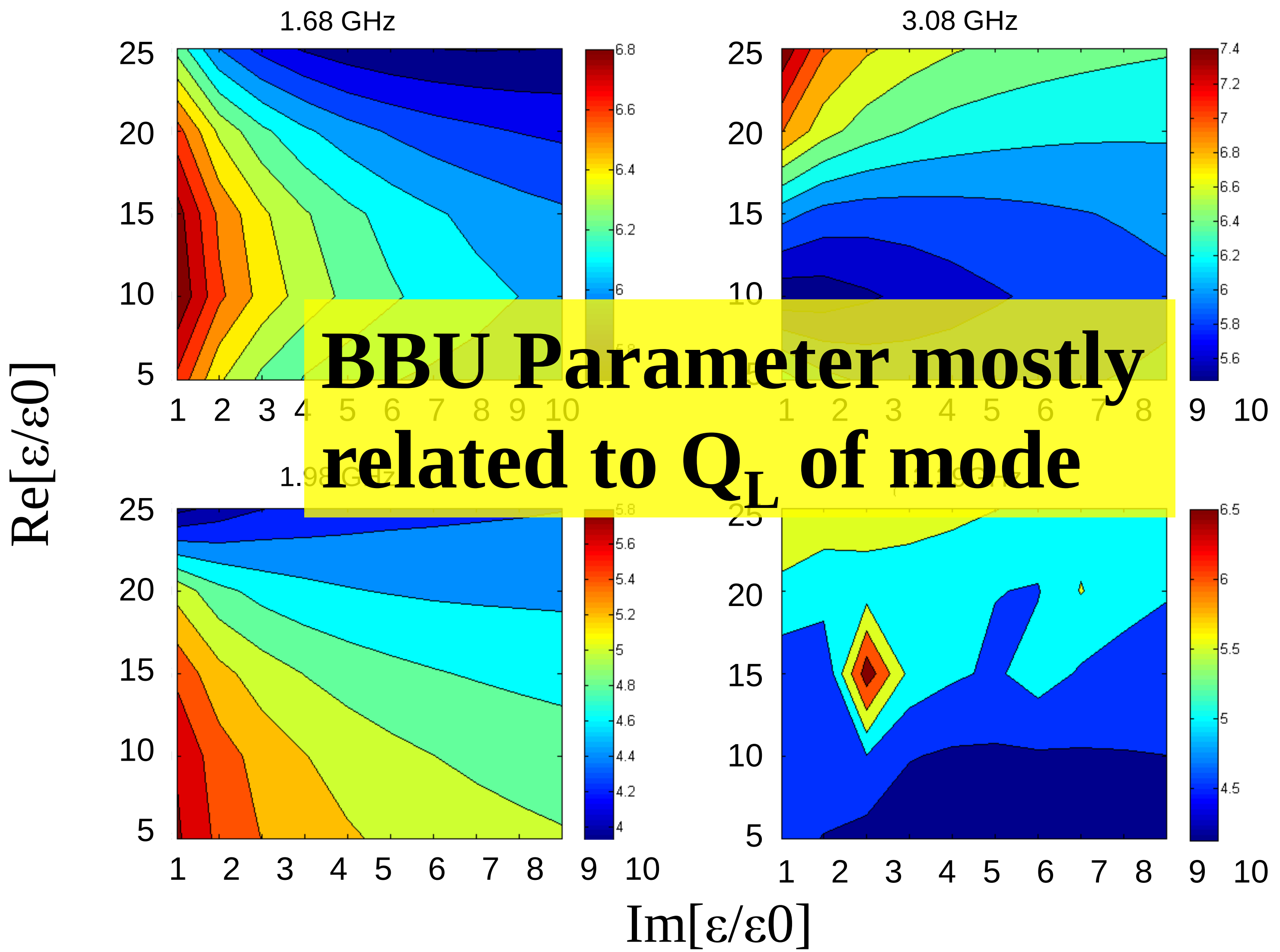
CLANS Simulation Results

BBU Parameter as a function of Dielectric Constant for 0.8 cm thick HOM Absorbers



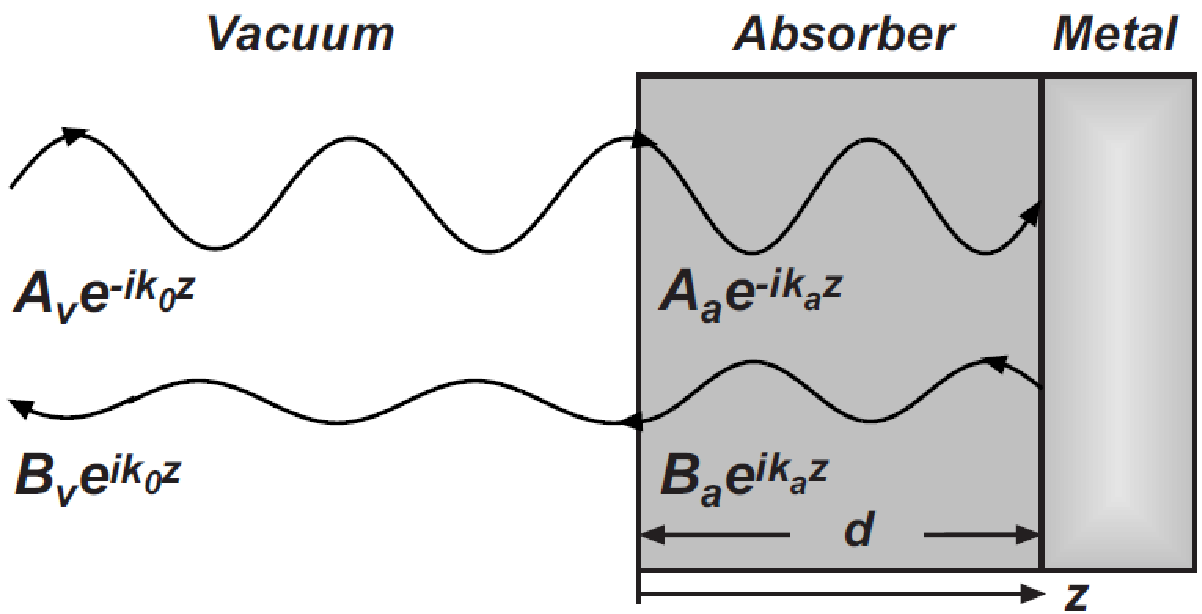
CLANS Simulation Results

Q_L as a function of Dielectric Constant for 0.8 cm thick HOM Absorbers



BBU Parameter mostly related to Q_L of mode

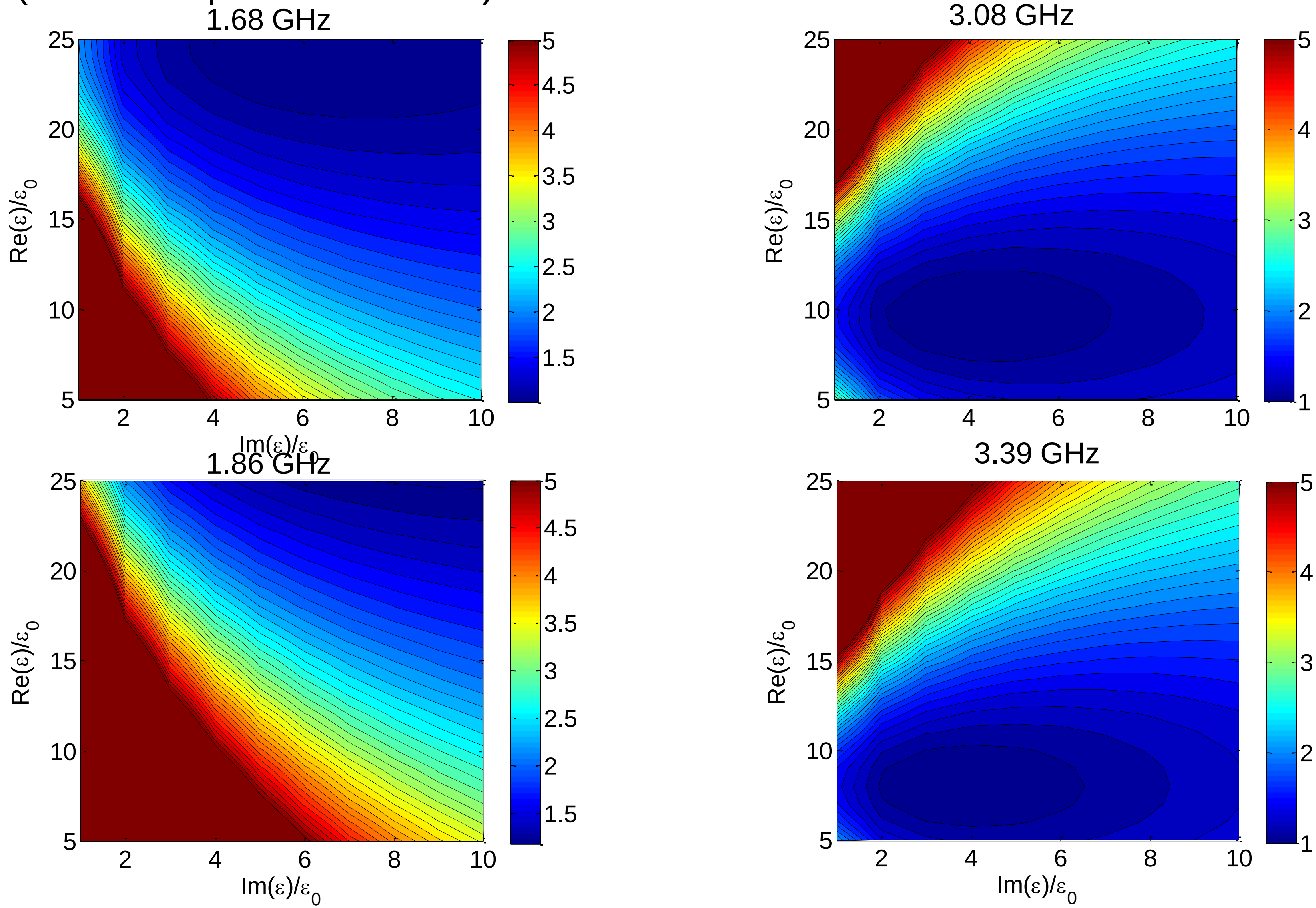
Analytic Solution



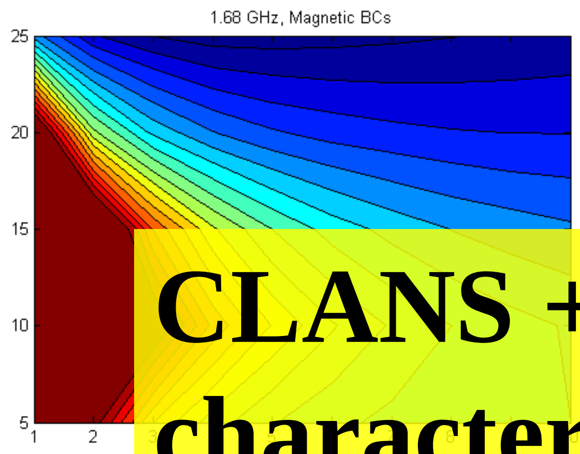
- Model a plane wave striking an absorber with thickness, d, (infinite in x-y extent) to and find power absorption.
- Figure of merit is absorber efficiency: $P_{incident}/P_{absorbed}$.

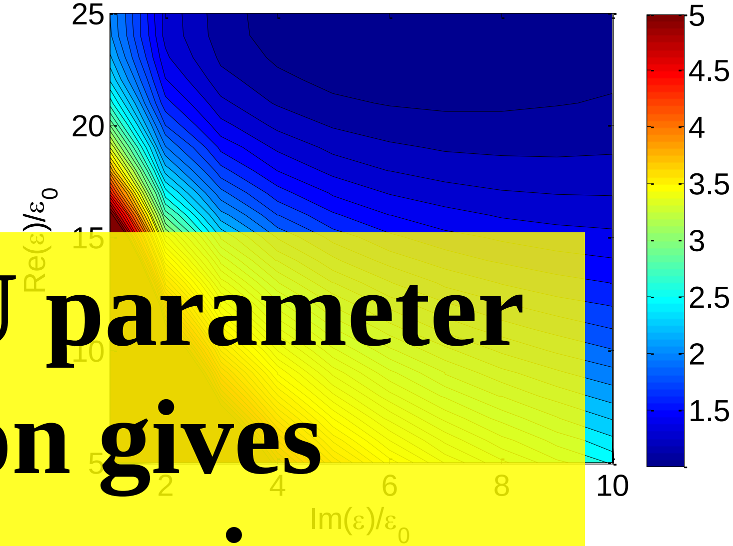
Plane Wave Model Power Absorption

1/(fraction of power absorbed) as function of dielectric constant for 0.8 cm absorber

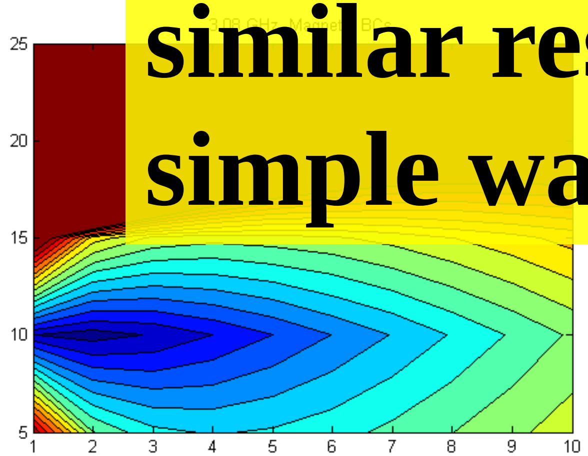


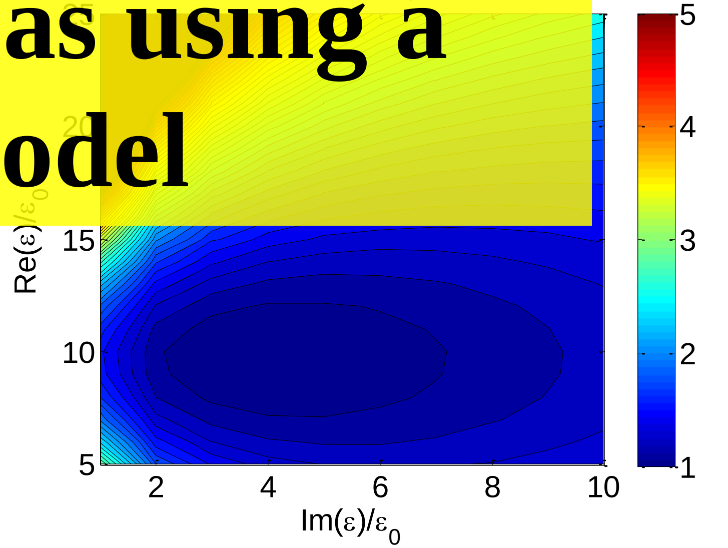
Theory-Simulation Correspondence





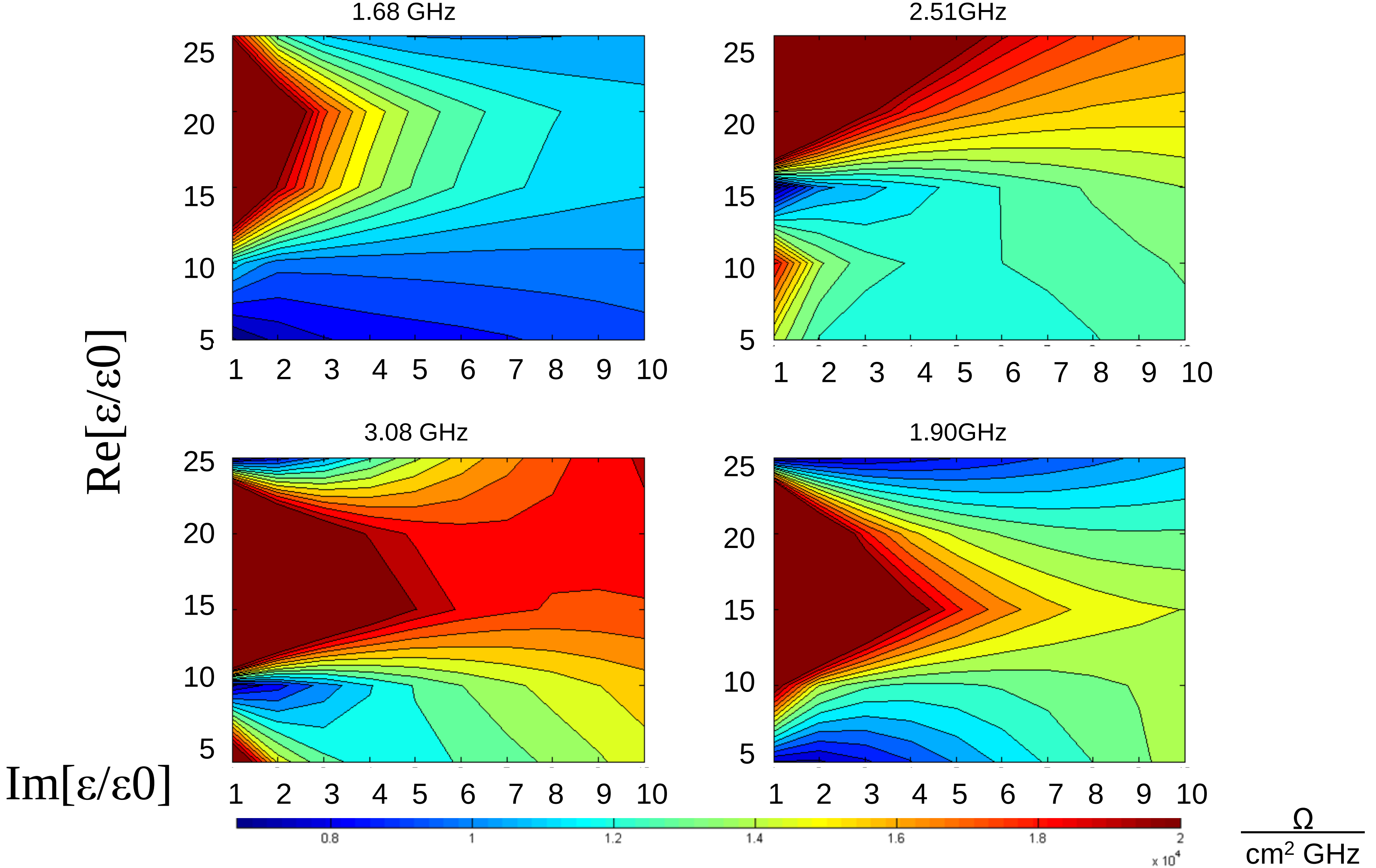
CLANS + BBU parameter characterization gives similar results as using a simple wave model





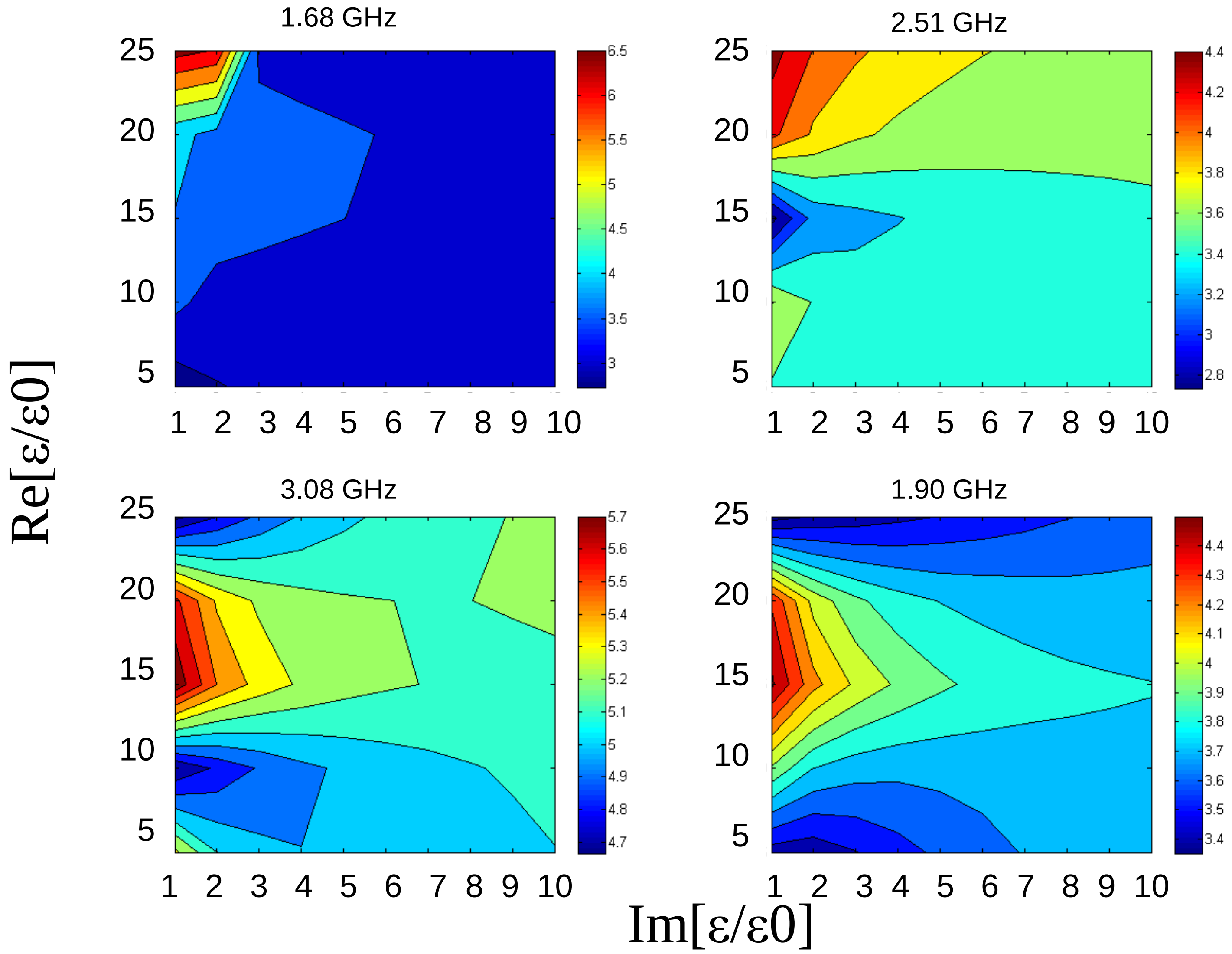
CLANS Simulation Results

BBU Parameter as a function of Dielectric Constant for 2.5 cm thick HOM Absorbers



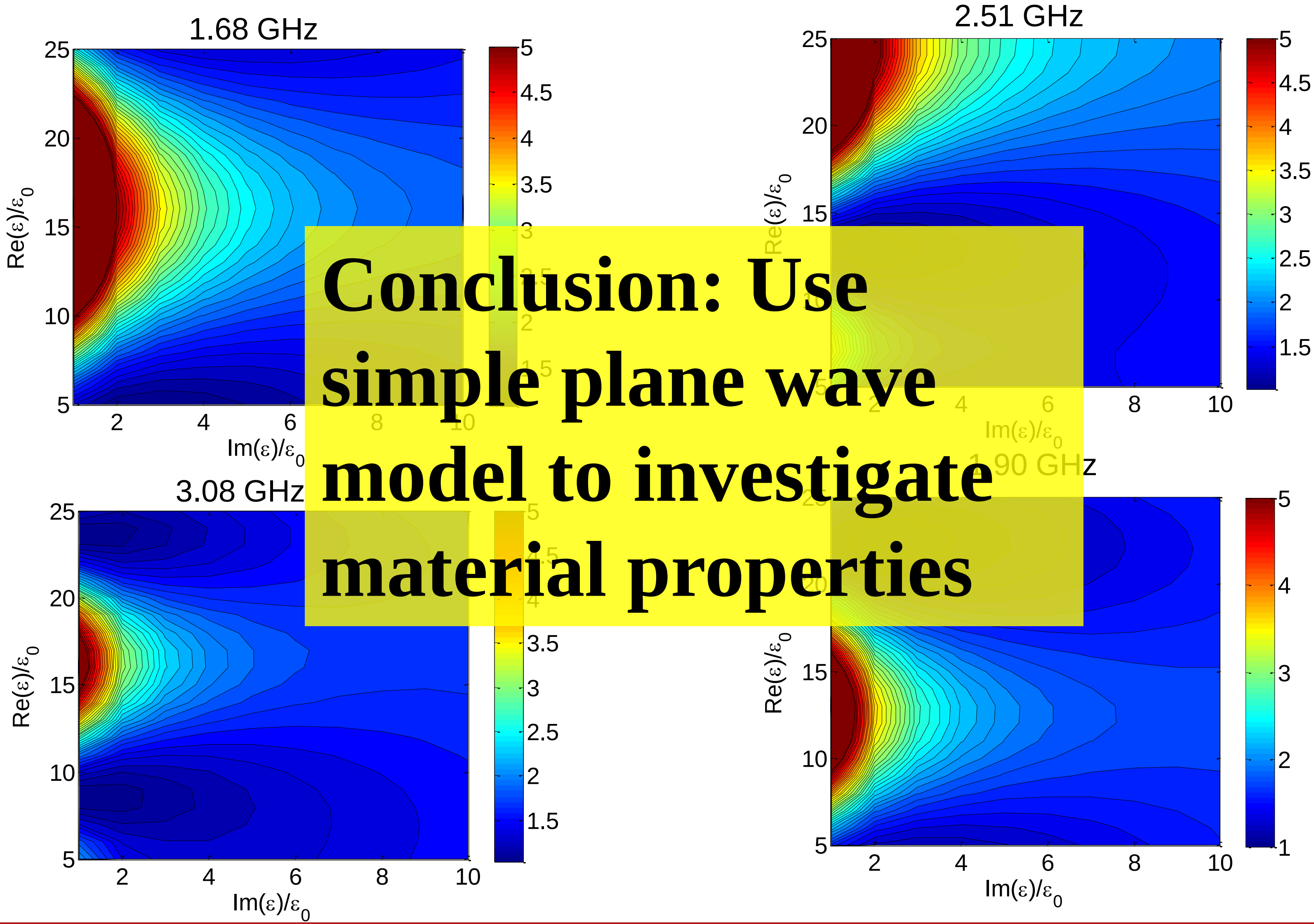
CLANS Simulation Results

Q_L as a function of Dielectric Constant for 2.5 cm thick HOM Absorbers



Plane Wave Model Power Absorption

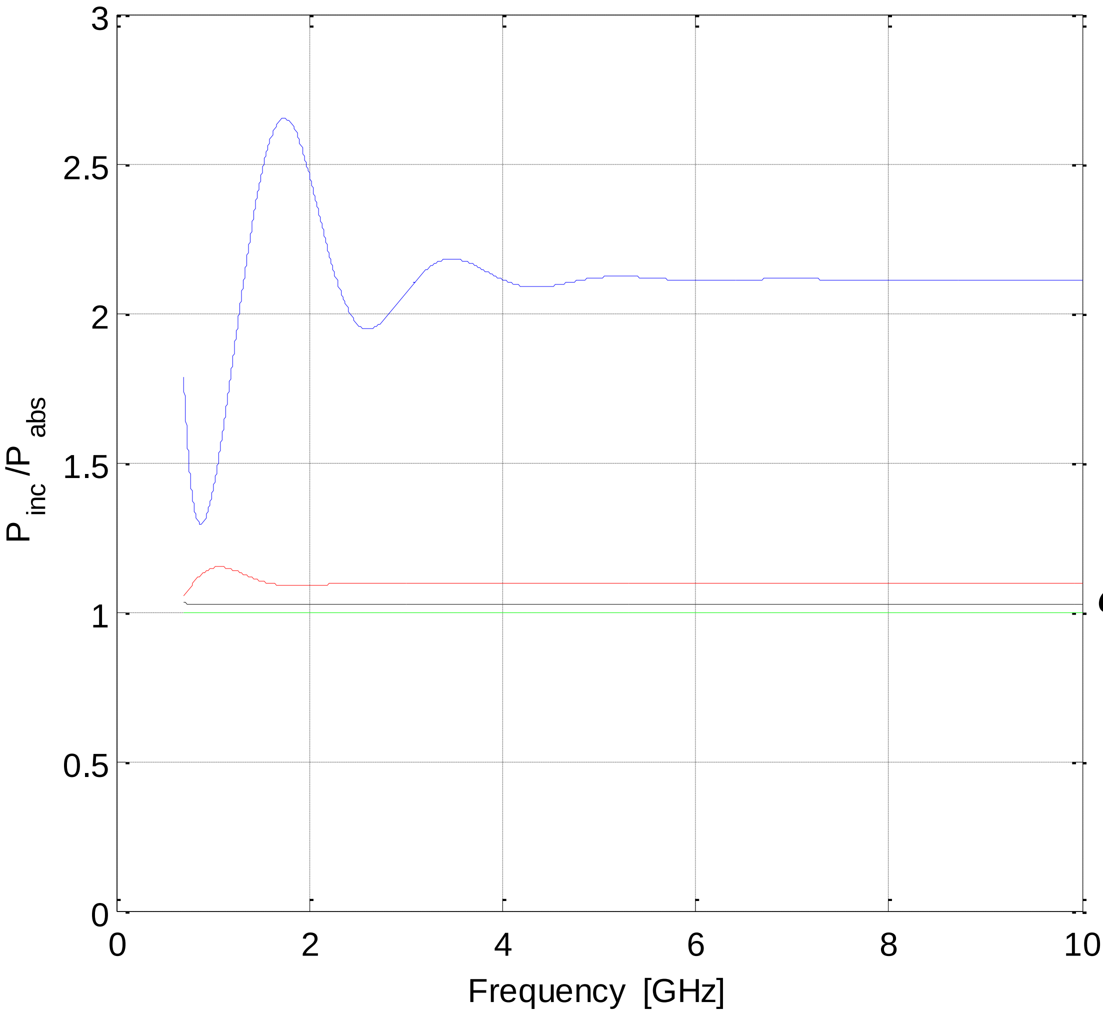
1/(fraction of power absorbed) as function of dielectric constant for 2.5 cm absorber



Conclusion: Use simple plane wave model to investigate material properties

Material Comparison: Power Absorbtion

Simple Plane Wave Model for Ideal Absorbers (1.5 cm thick)



CNT $\varepsilon = 30 - 20i$, $\mu = 1 - 0i$

Ferrite $\varepsilon = 10 - 0.1i$, $\mu = 3 - 5i$

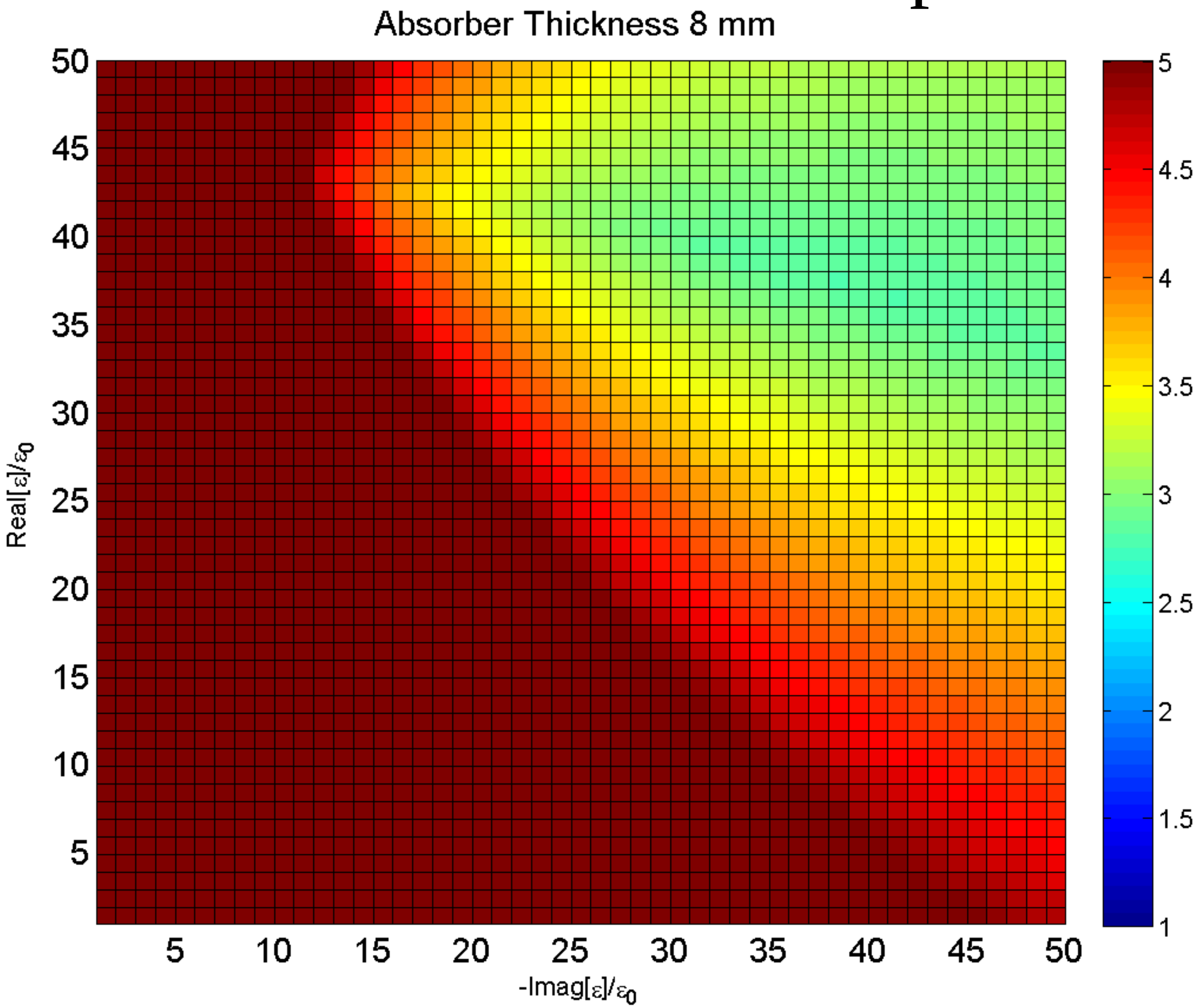
'Loaded' CNT

$\varepsilon = 30 - 20i$, $\mu = 30 - 0i$

Perfect Absorber

Epsilon Parameter Space

Plane wave model: Worst Case Absorption 1-50 GHz



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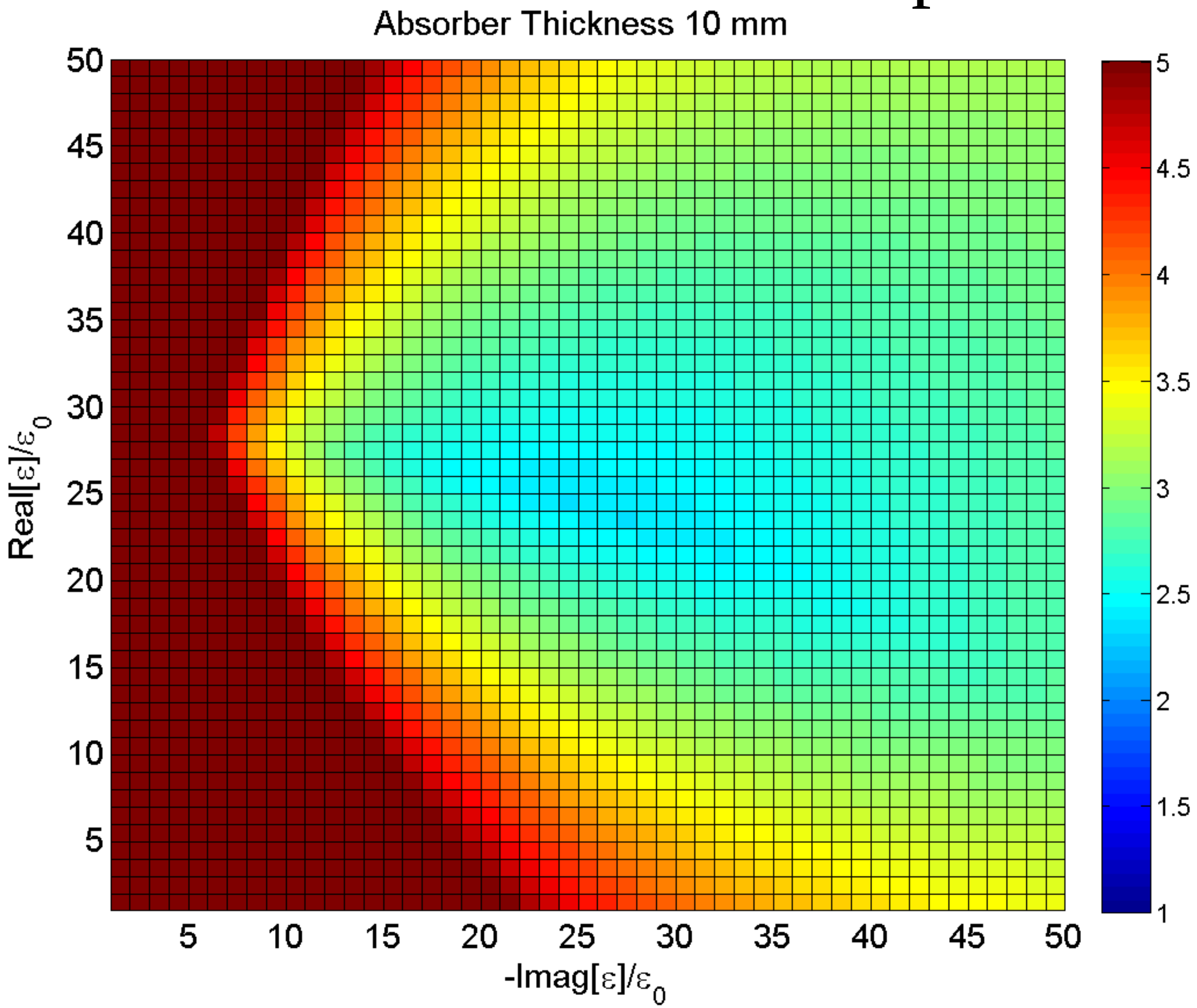

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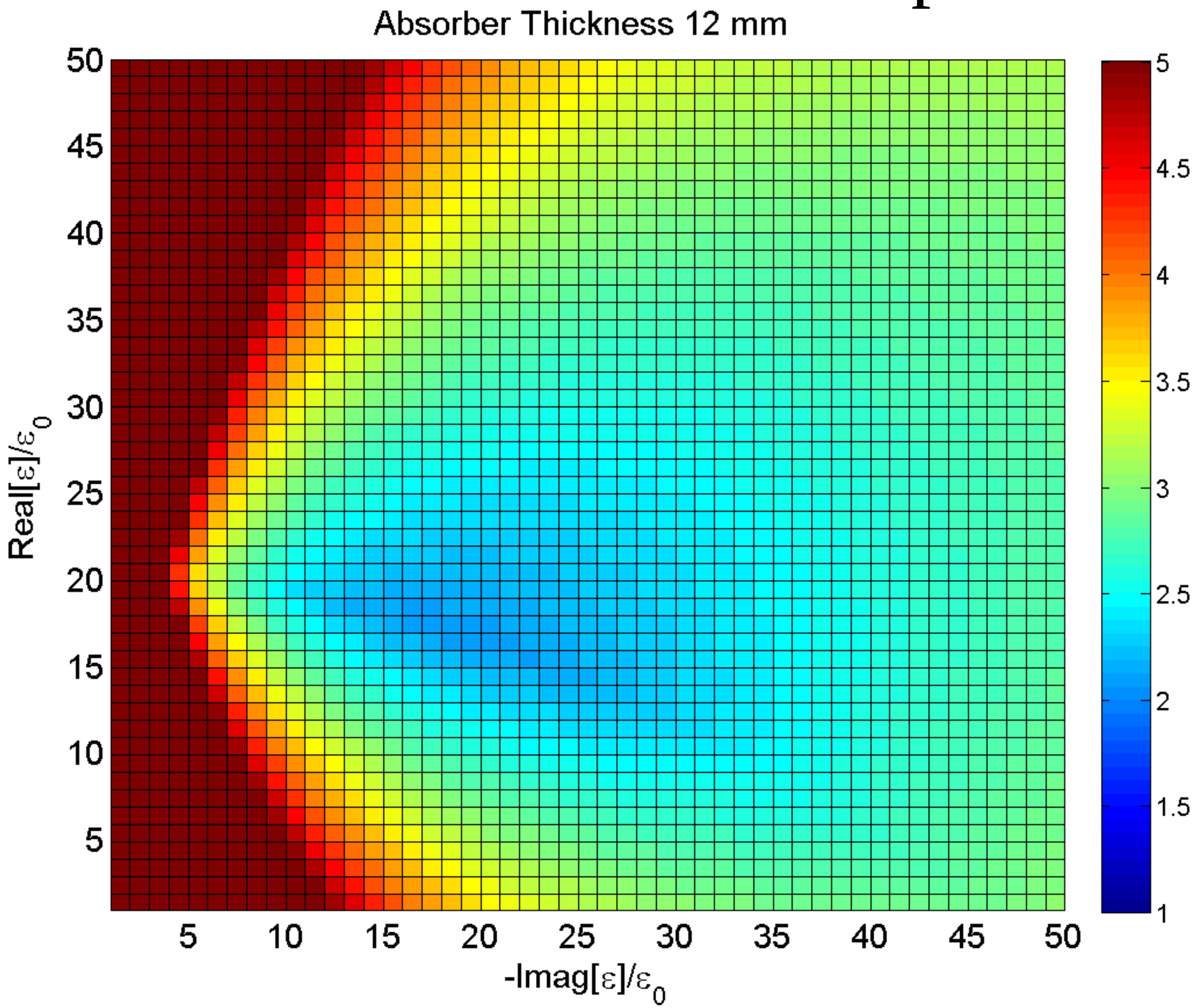

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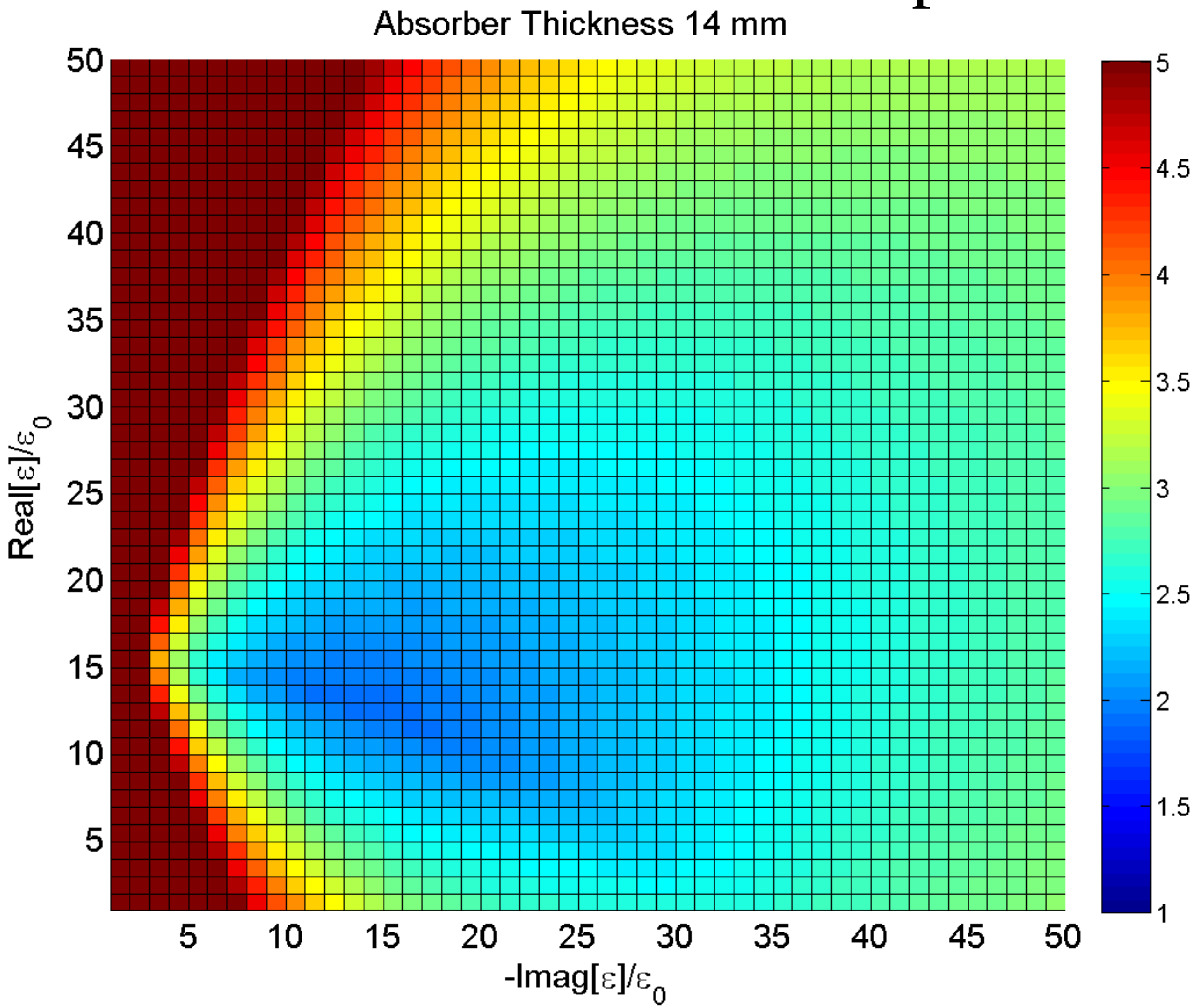

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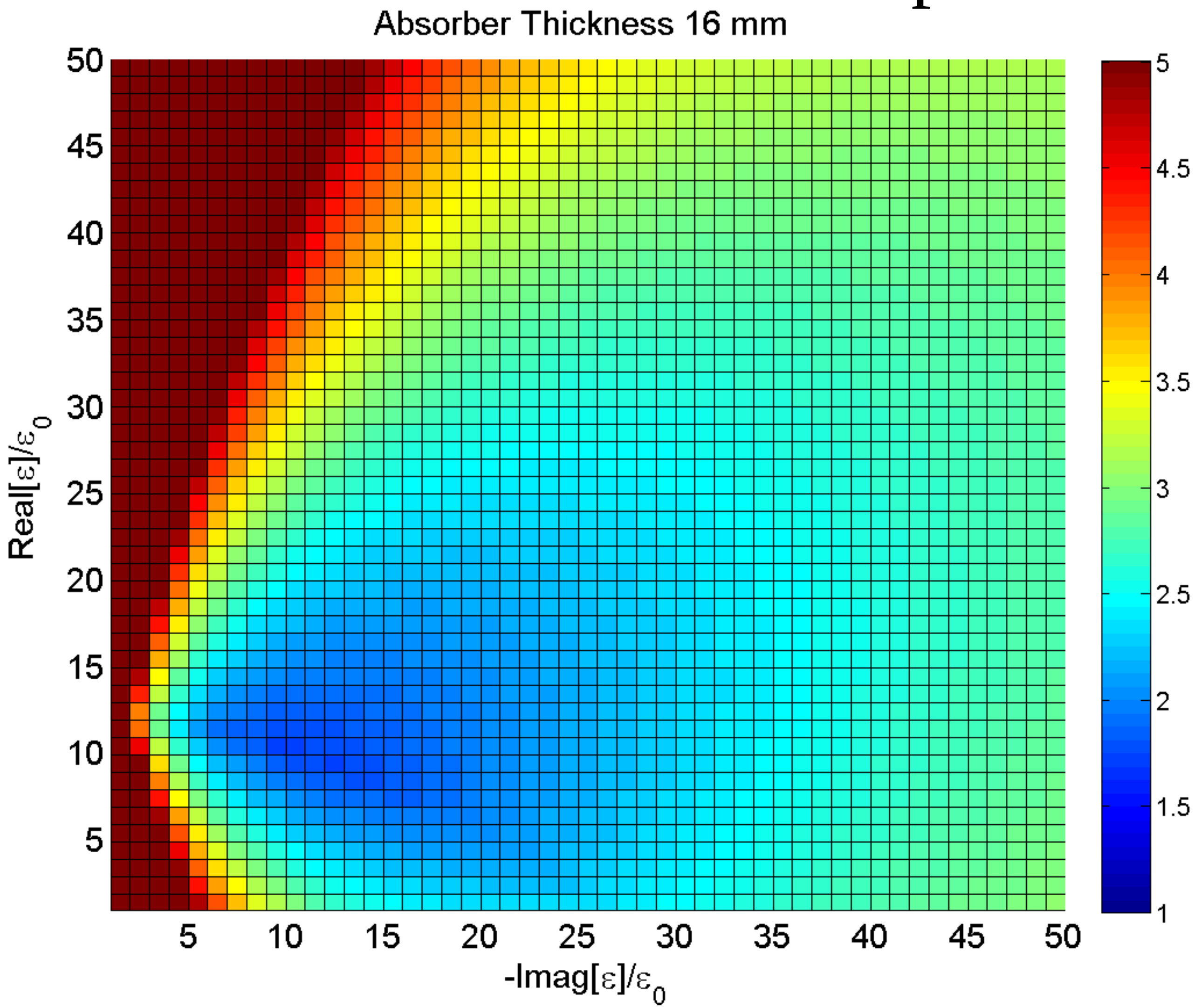

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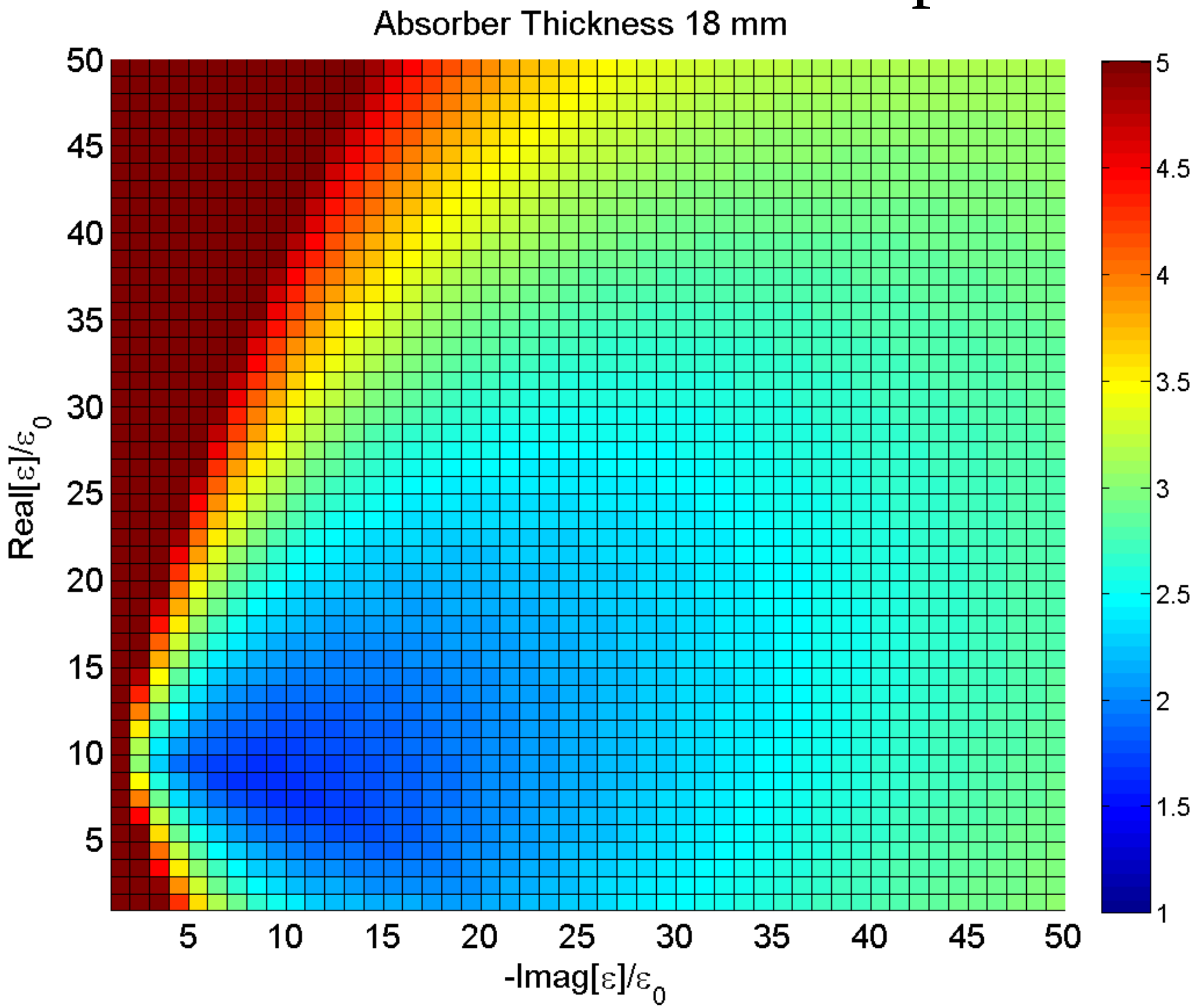

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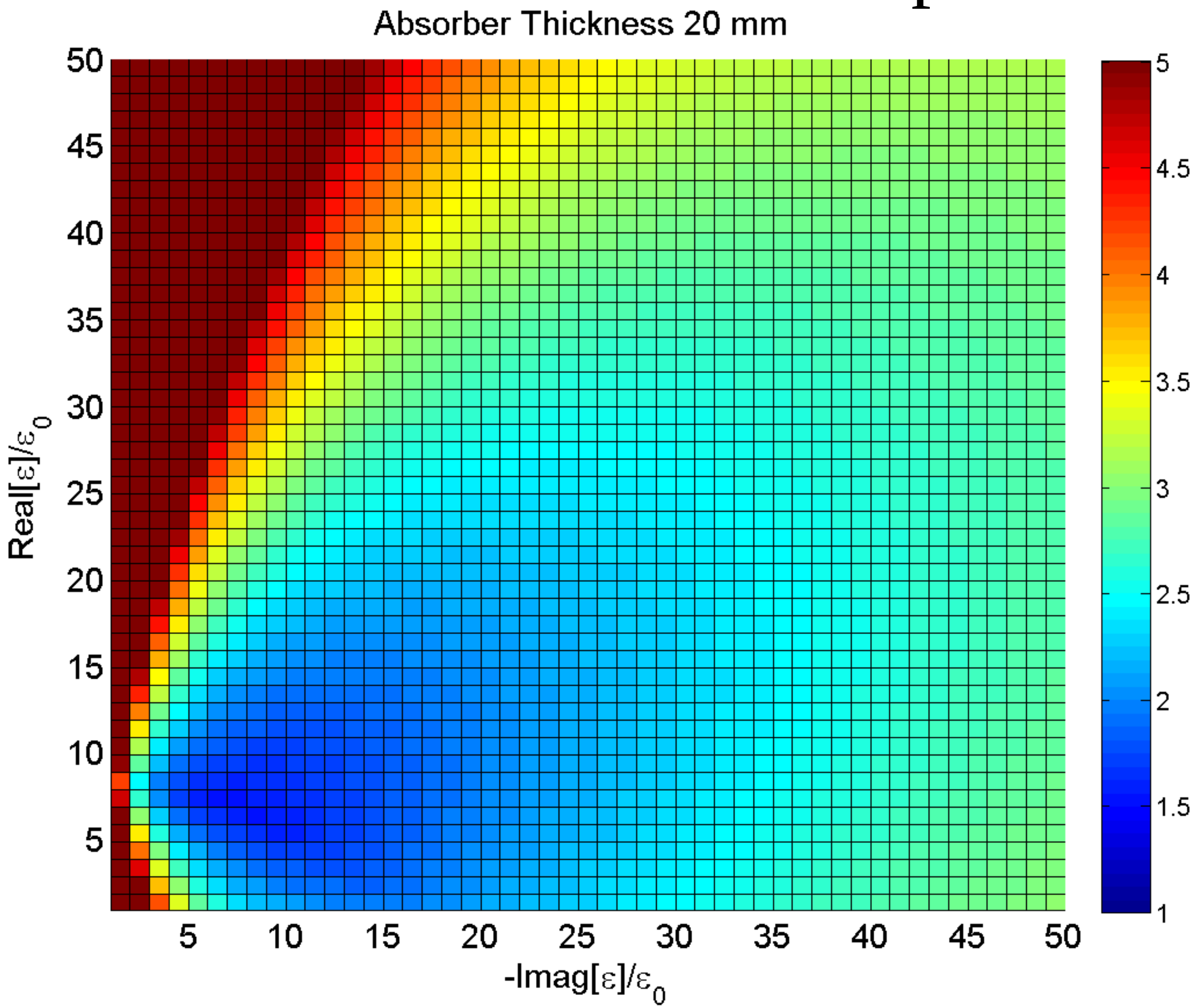

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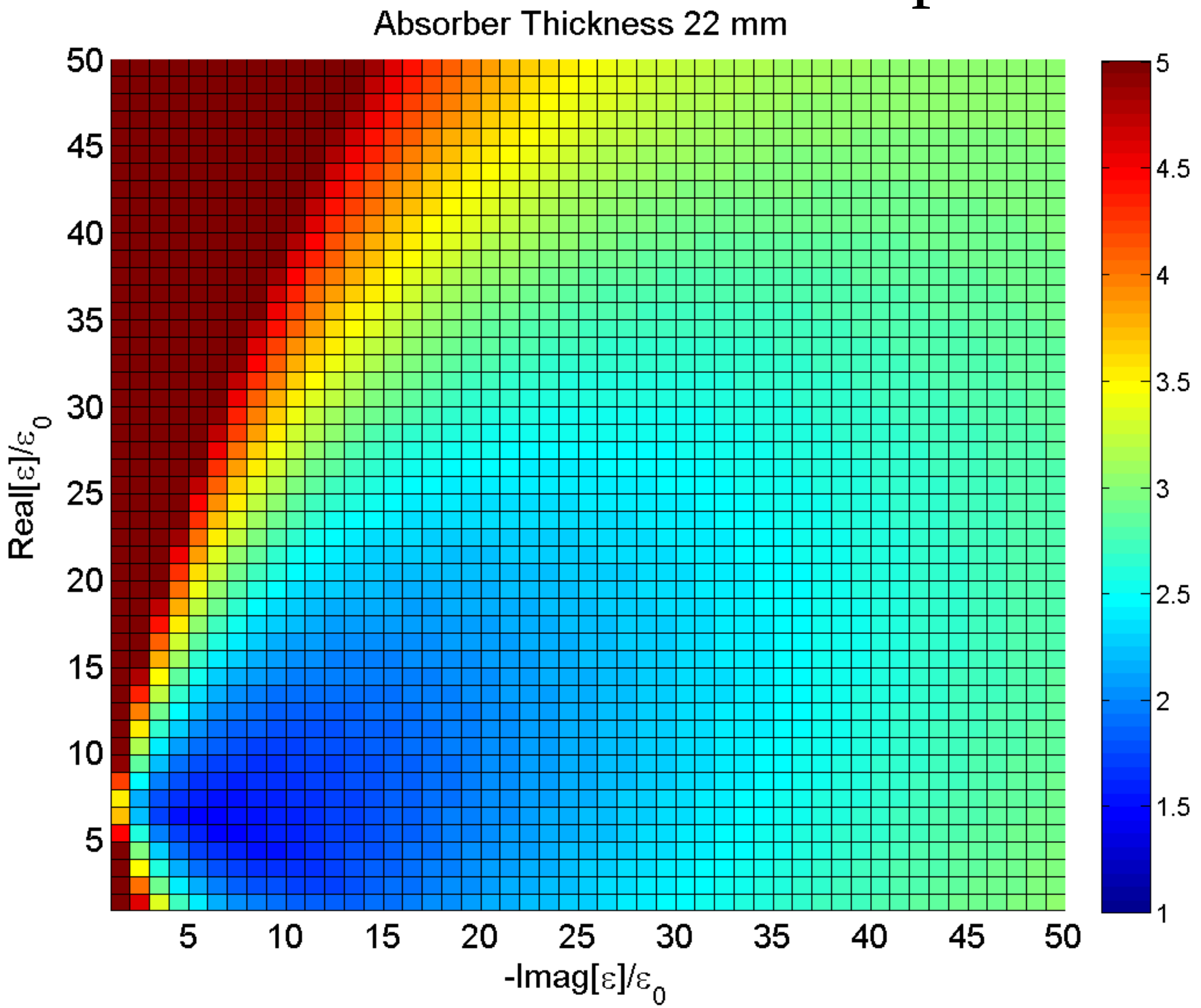

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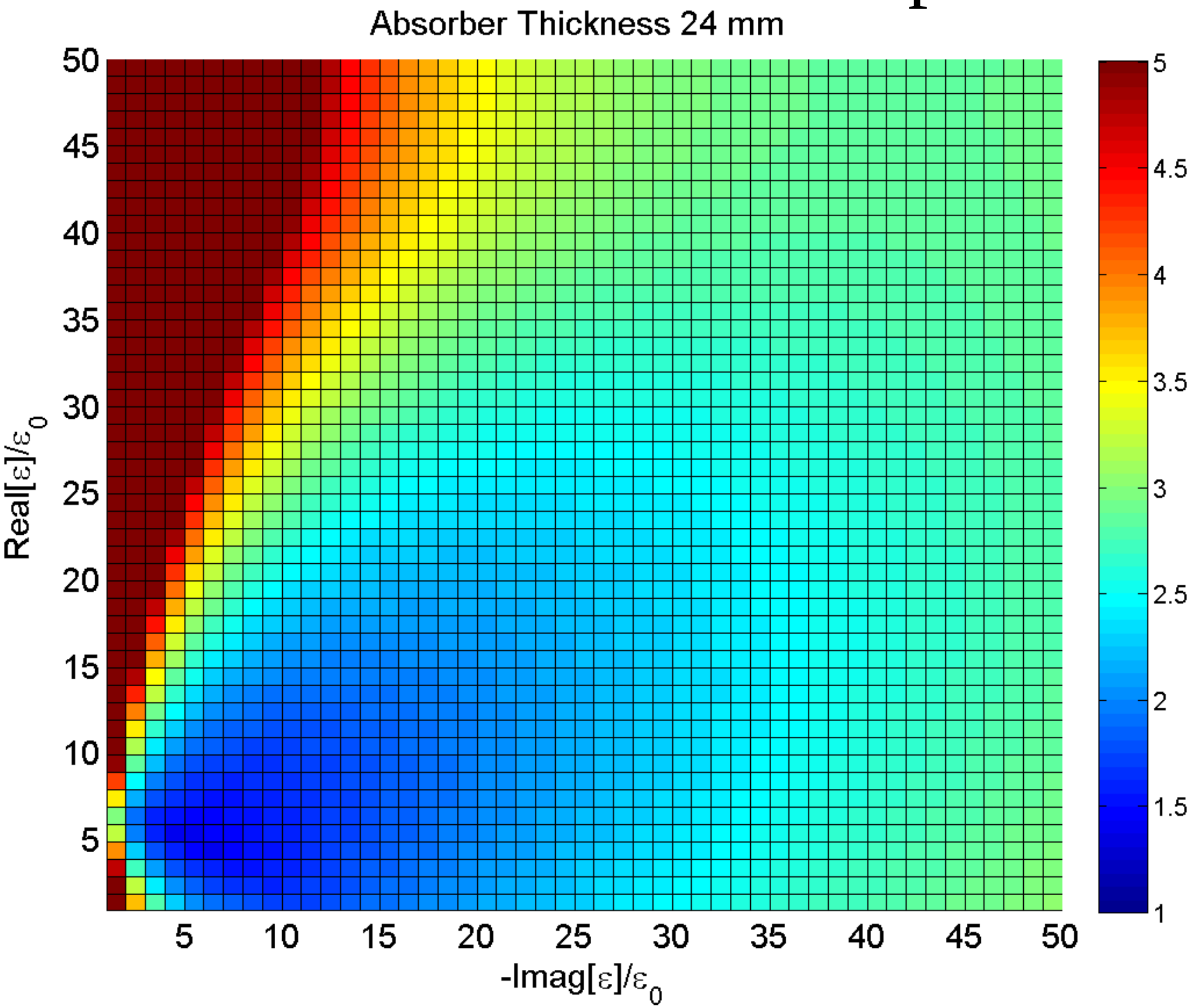

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- Simple plane wave model is a useful tool to determine absorber efficiency
- Q's are twice as large with real absorbers compared to perfect absorbers (matched ports)
- Effective broadband CNT dielectric absorbers should aim for ε/ε0 ~ [10…20] – [10…20]*i*, (dependent on absorber thickness). This is doable with current technology.
- The loss tangent isn't the most important item to consider for an absorber
  - To reduce reflections, absorber impedance, $Z_m = \sqrt{(\mu/\varepsilon)}$ should not be too large

Acknowledgements

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References:

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