‘MetaNETs’ - Accelerated Discovery and Design of Photonic Metamaterials using Artificial Neural Networks

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THE OBJECTIVE

This work reports a model to custom-design artificially designed composites known as ‘metamaterials’ which demonstrate highly engineerable electromagnetic (EM) properties. Typically, they comprise of 2D or 3D periodic arrays of sub-wavelength conducting elements.

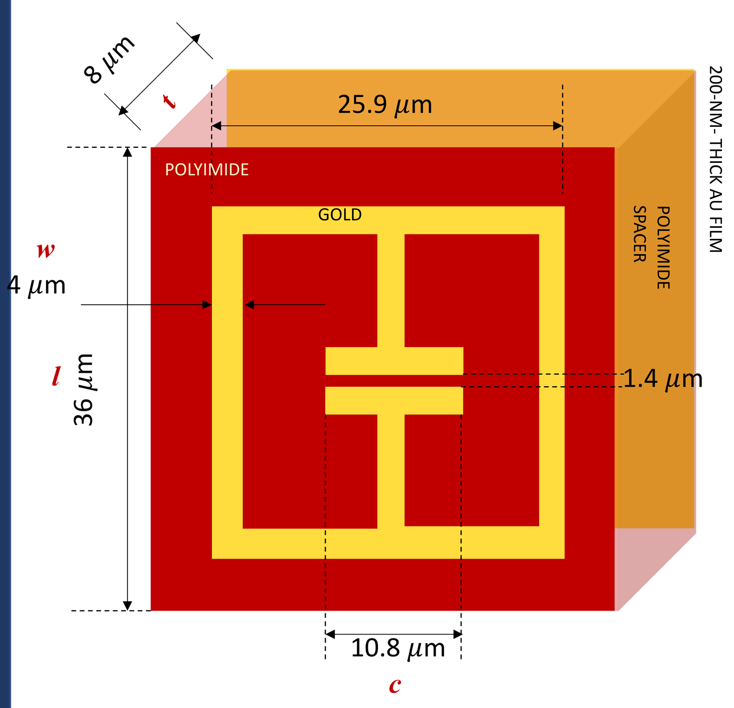
OUR APPROACH

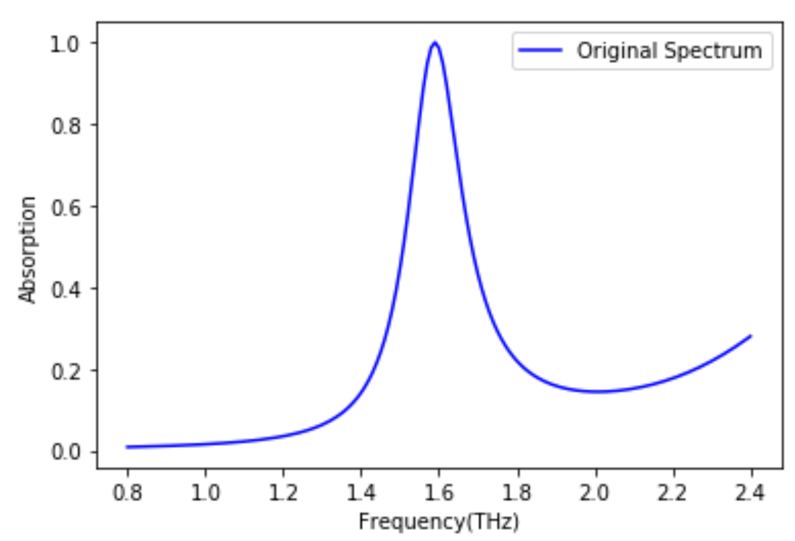
An efficient design scheme encompassing :

- The **forward** problem (predicting the EM response from a given design), and,
- The **inverse** problem (generating a design for a desired EM response)

We demonstrate that by treating the EM response data as a time-varying sequence and the inverse problem as a single-input, multiple-output (SIMO) model, we *force* our architecture to learn the geometry of the design parameters (from the training data) as opposed to abstract features.

Selected design: MM ‘perfect’ absorber@1.6 THz



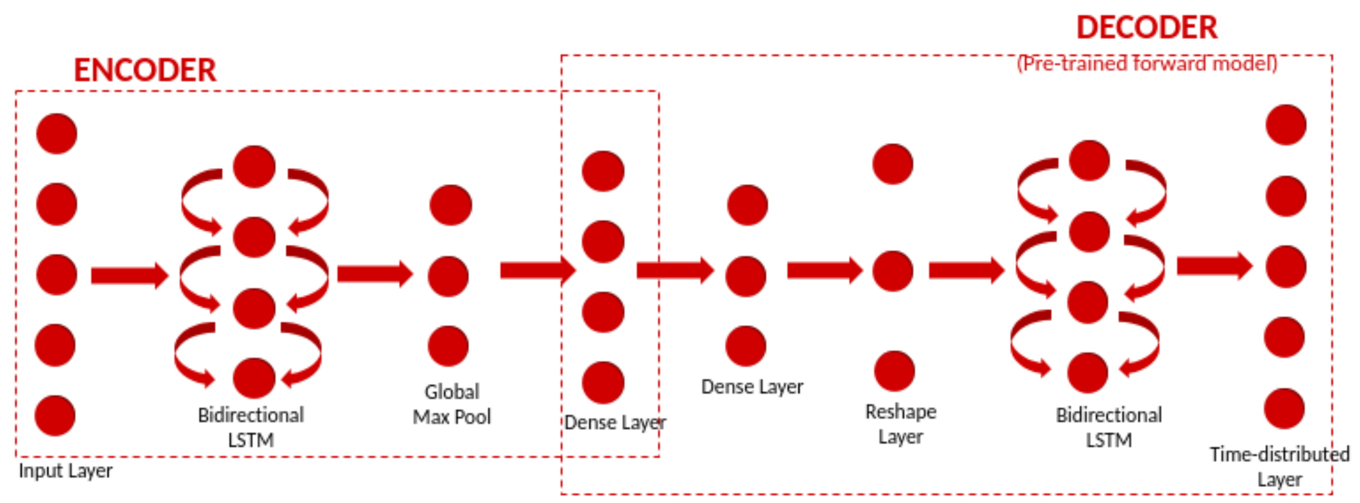


Annotated schematic of a split-ring resonator-based THz absorber (left) and its corresponding electromagnetic response as a function of frequency

Challenges

- Distinct geometries may yield near-identical EM response
- There may be no inverse solution for a given EM response

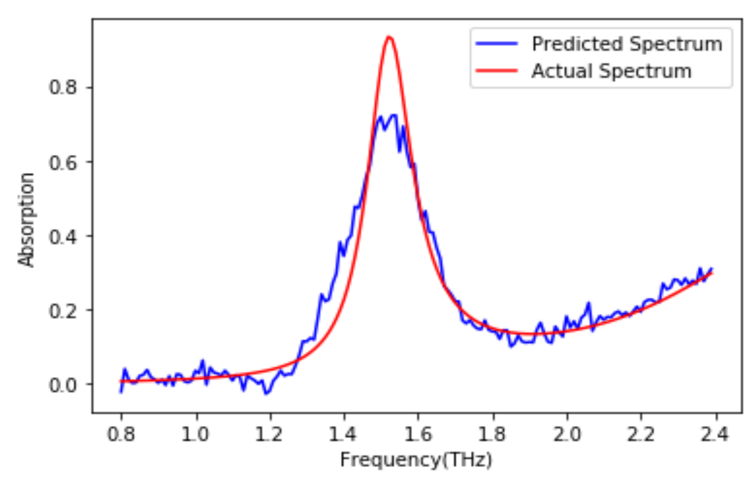
NETWORK ARCHITECTURE



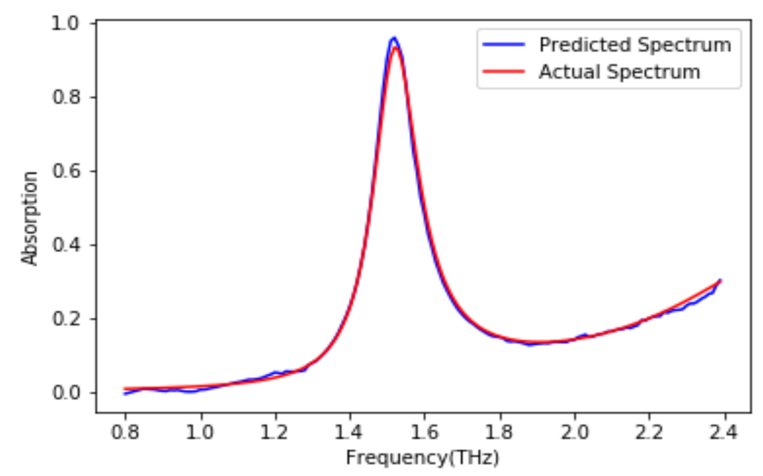
Our network has a tandem architecture with a pre-trained forward model (decoder) connected to an encoder for inversely predicting the design parameters.

- The input layer comprises of 16 expanded dimensions obtained by combining geometrical parameters (*l*, *w*, *t*, *c*)
- The 161-absorption values as timesteps for the sequential input to the bidirectional LSTM layer

Why LSTM?



Response prediction using a DNN-only baseline model



Response prediction using an LSTM model

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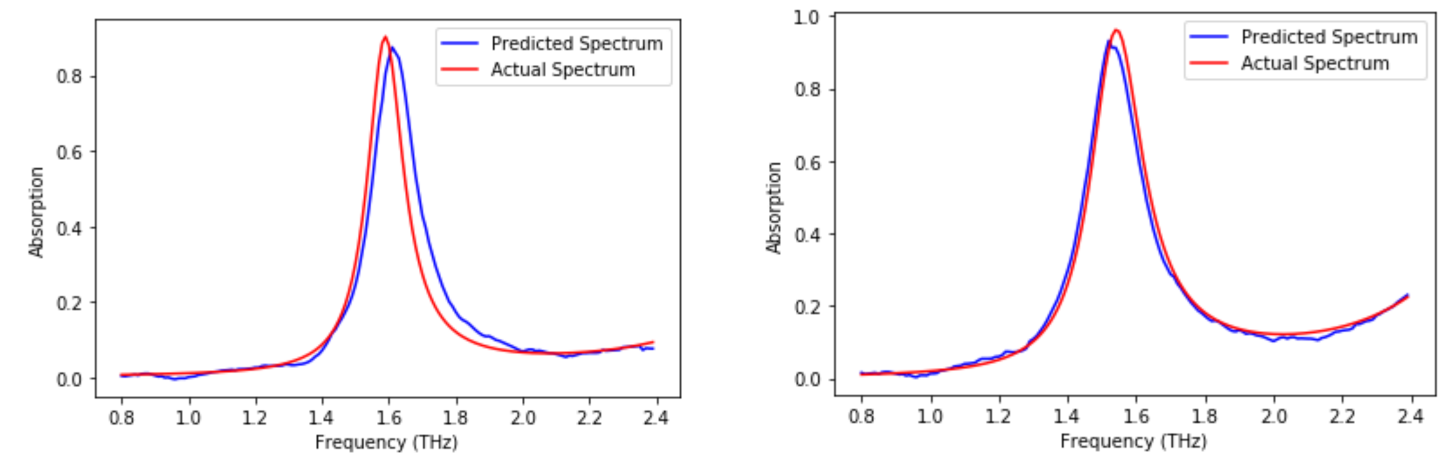
VALIDATION & RESULTS

- How the tandem architecture performs



Comparison of predicted (blue) and actual (red) EM responses from the tandem ‘MetaNETSs’ model on randomly selected samples from the test set

MetaNETS’ Losses

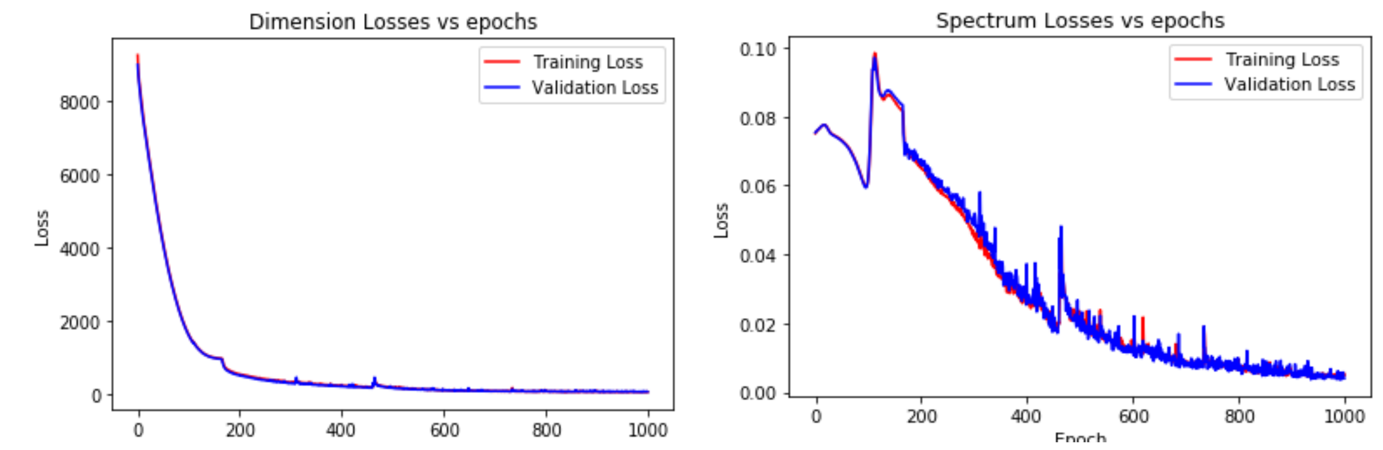
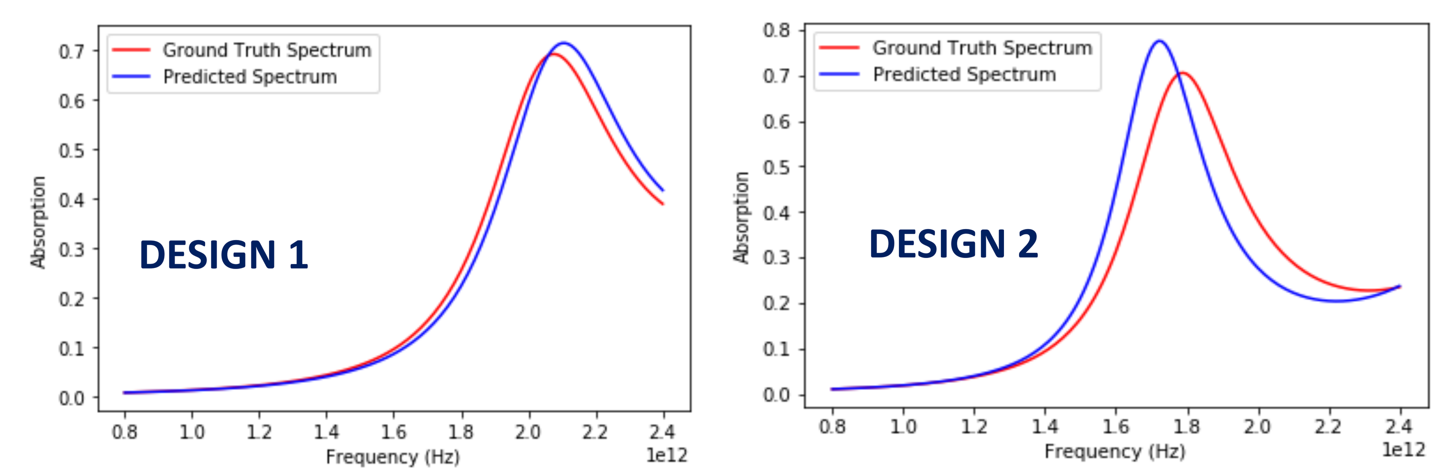


Table 1: Model evaluation (Average losses over 5 runs)

Model	Train	Validation	Test
Forward model	0.0056	0.0057	0.0056
Inverse model (spectrum)	0.004	0.0039	0.004
Inverse model (dimensions)	48.64	59.79	53.38

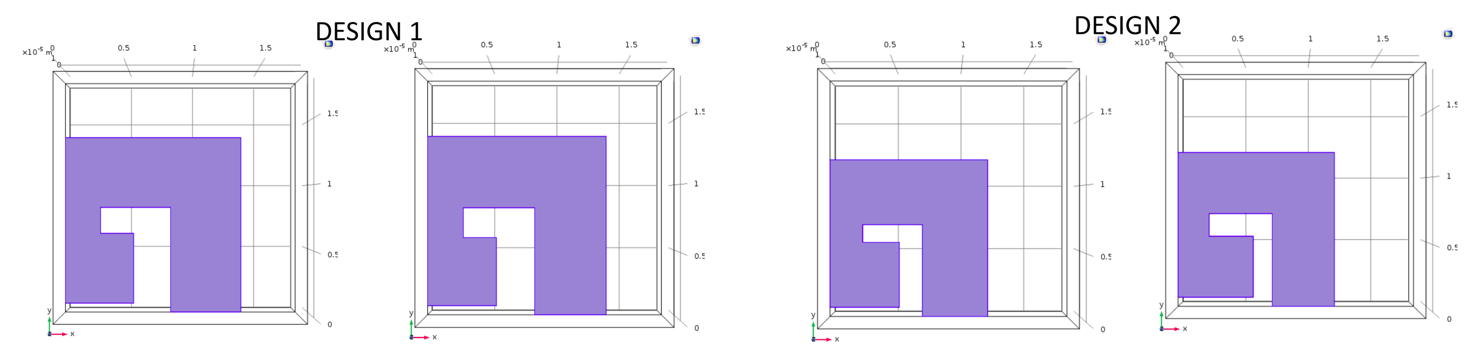
Predicted vs Actual

Electromagnetic Response prediction



Geometrical Design prediction

	D1				D2			
	l	*w*	*t*	*c*	*l*	*w*	*t*	*c*
Ground truth	23.95	4.96	9.43	10.52	27.49	5.50	8.31	10.69
Predicted	23.90	4.75	9.00	11.50	27.90	5.25	8.10	10.60



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