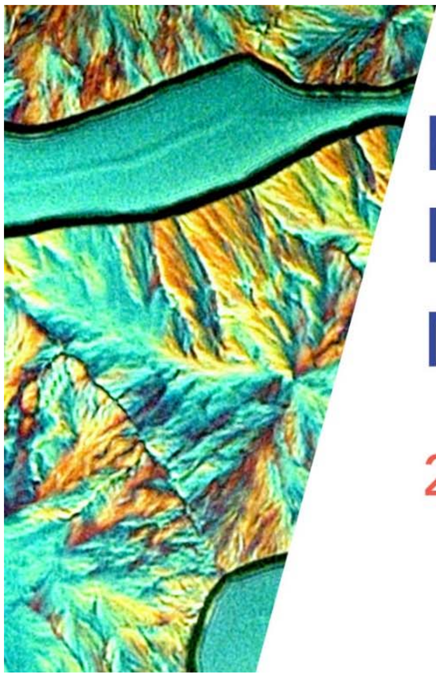
Electromagnetics & Photonics in the Age of Digital Manufacturing

Presented by:

OSA Photonic Metamaterials Technical Group

The OSA Photonic Metamaterials Technical Group Welcomes You!



ELECTROMAGNETICS & PHOTONICS IN THE AGE OF DIGITAL MANUFACTURING

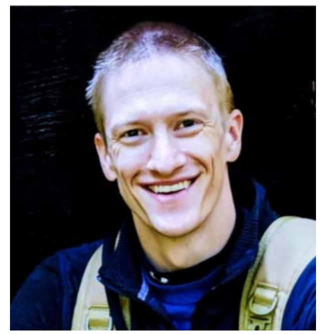
25 March 2019 • 10:00 EDT

OSA Photonic Metamaterials Technical Group

Technical Group Leadership 2019

Wei-Ting Chen
Chair
Harvard University

Shaimaa Azzam
Social Media Officer
Purdue University



Aaron Pung
Webinar Officer
Sandia National Laboratories

Technical Group at a Glance

- Focus
  - Fundamental and applied aspects of waves in random and periodically nanostructured materials
  - Nonconventional materials: Left-handed, negative index, photonic/plasmonic bandgap, metamaterials and metasurfaces etc.
- Mission
  - Total members: 1,516 members
  - To benefit *YOU* and to strengthen *OUR* community
  - Webinars, publications, technical/industrial events and outreach in OSA conferences
  - Interested in presenting your research? Have ideas for TG events? Contact us at TGactivities@osa.org.
- Find us here
  - Website: www.osa.org/OP

OSA Photonic Metamaterials Technical Group

Today's Webinar

OSA Photonic Metamaterials Technical Group

Electromagnetics & Photonics in the Age of Digital Manufacturing

Dr. Raymond Rumpf

Director, EM Lab
El Paso, USA
rcrumpf@utep.edu

Speaker's Short Bio:

Ph.D. in Optics from the University of Central Florida in 2006. Currently the Schellenger Professor of Electrical Research in the department of Electrical & Computer Engineering and Computational Science at University of Texas at El Paso.

The Optical Society

Pioneering 21st Century Electromagnetics & Photonics

LAB

New Concepts for Metamaterials & Photonic Crystals in the Age of Digital Manufacturing

Dr. Raymond C. Rumpf

Director, EM Lab

Schellenger Professor of Electrical Research

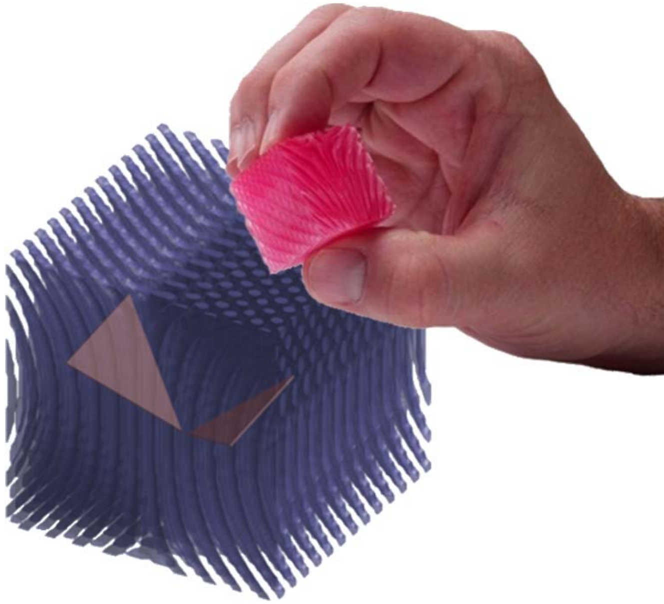
Department of Electrical & Computer Engineering + Computational Science

University of Texas at El Paso, El Paso, Texas 79968

rcrumpf@utep.edu ♦ (202) 64-EMLAB ♦ http://emlab.utep.edu

Outline

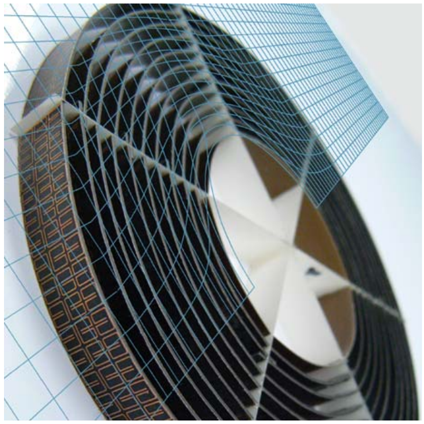
- Spatially-Variant Lattices
- 3D Electrical Circuits
- Spatially Variant Anisotropic Metamaterials (SVAMs)
- Spatially Variant Photonic Crystals (SVPCs)



Spatially-Variant Lattices

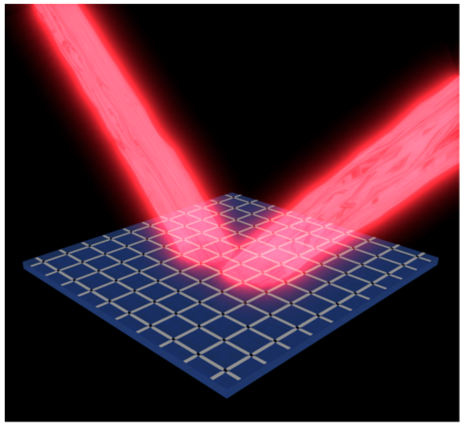
Periodic Structures in Electromagnetics

Metamaterials



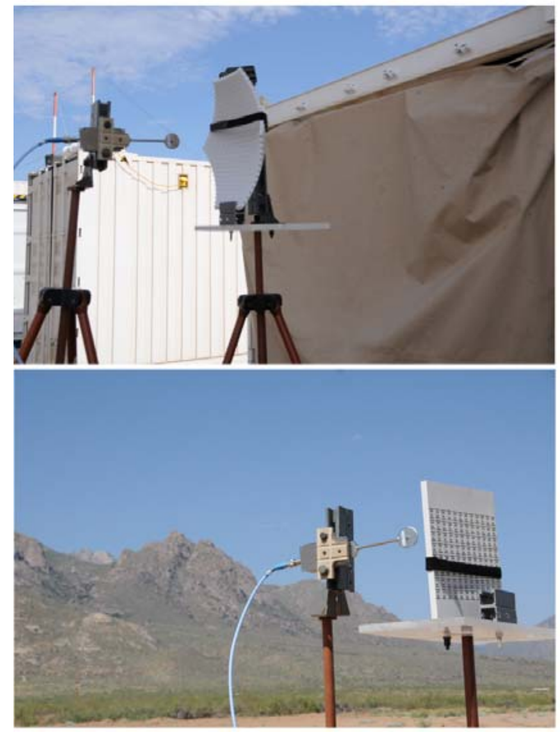
Duke University

Metasurfaces

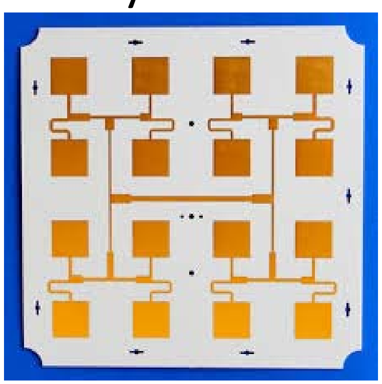


Photonic Crystals

Frequency Selective Surfaces

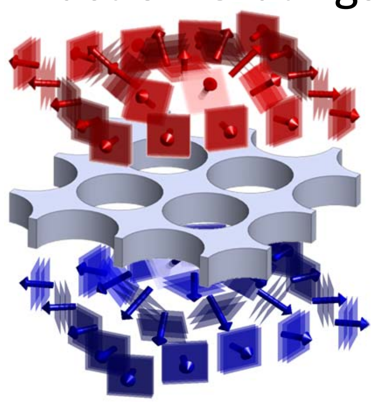


Array Antennas



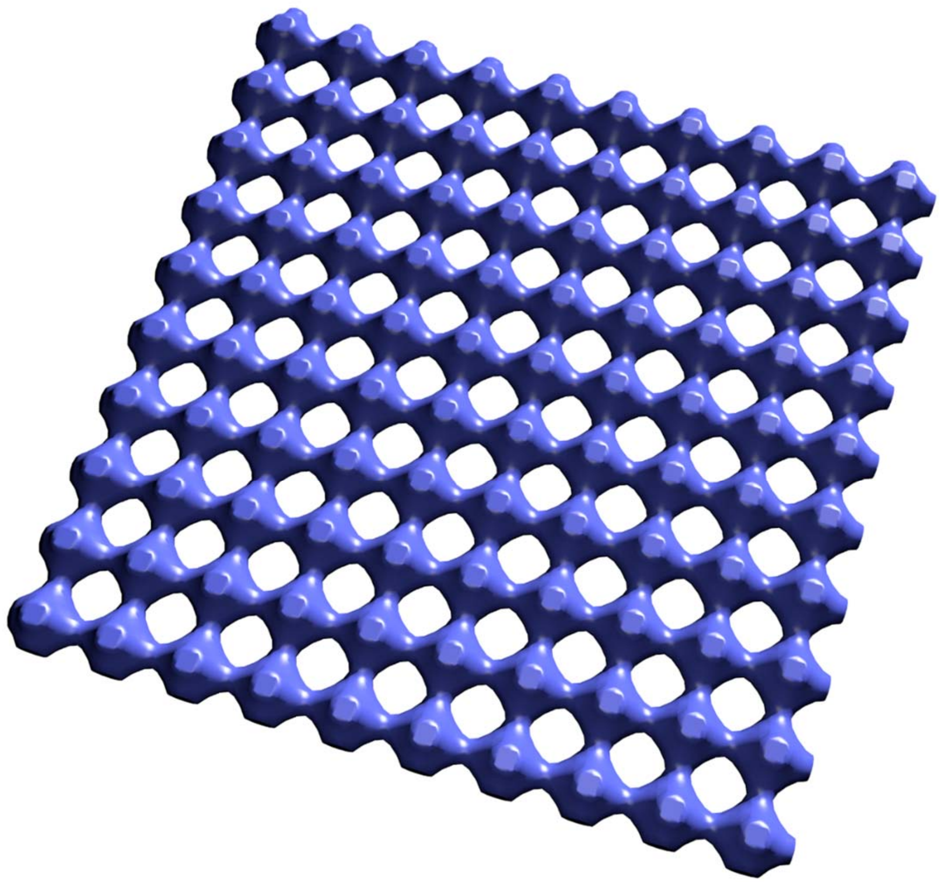
CST.com

Diffraction Gratings



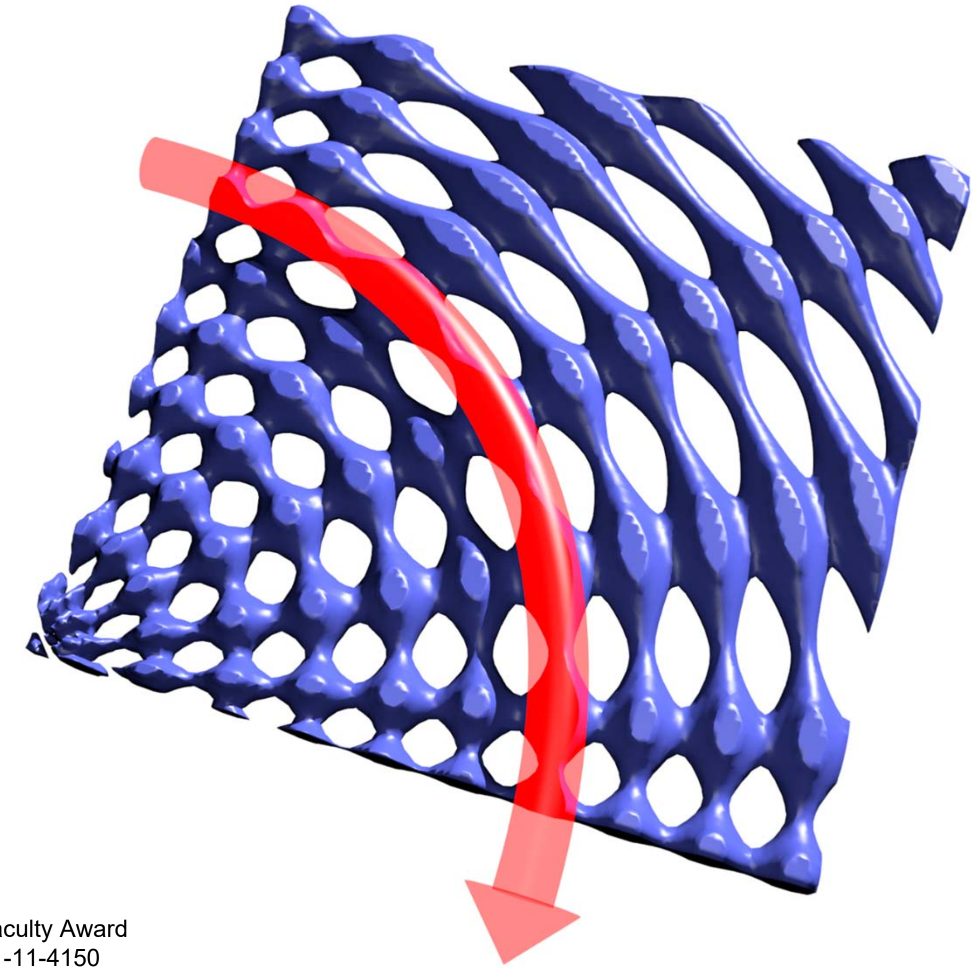
Unintentional

What is a Spatially Variant Lattice?



DARPA Young Faculty Award
Grant No. N66001-11-4150

What is a Spatially Variant Lattice?



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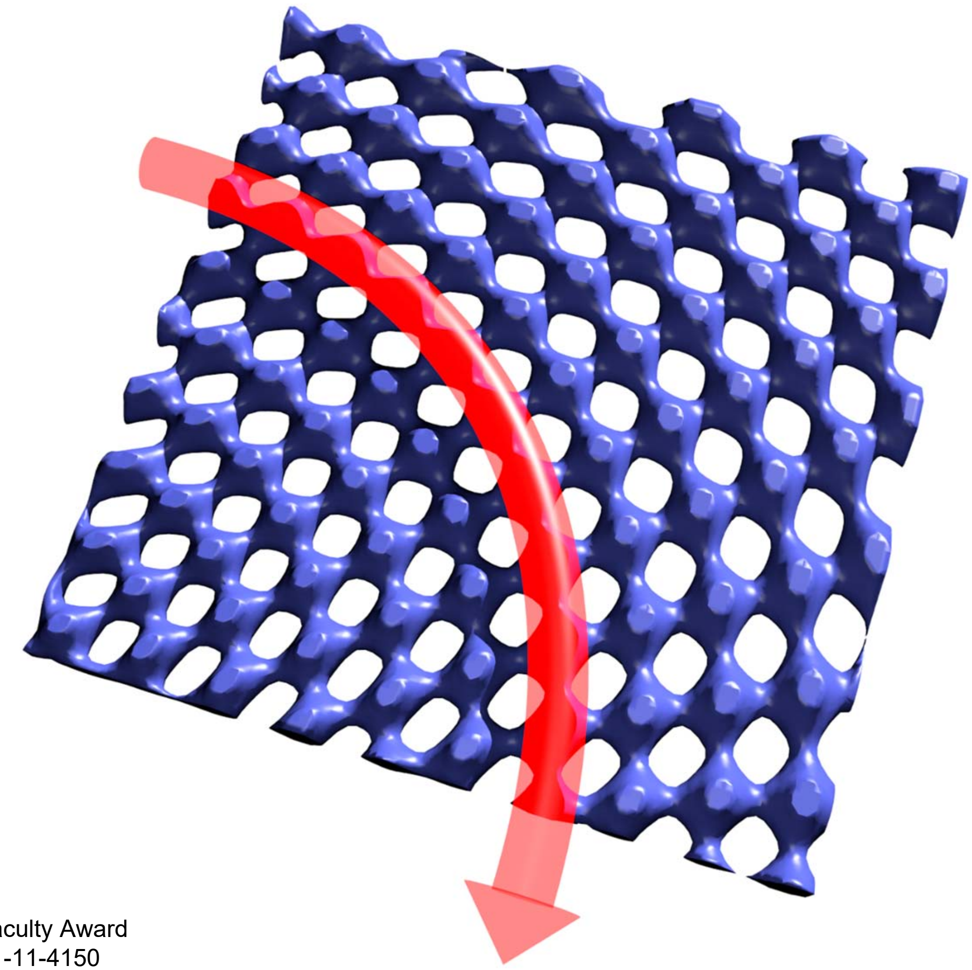

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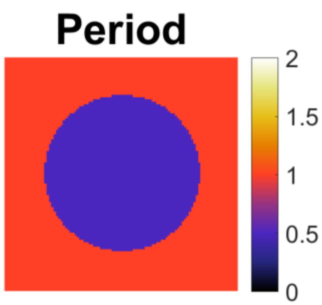
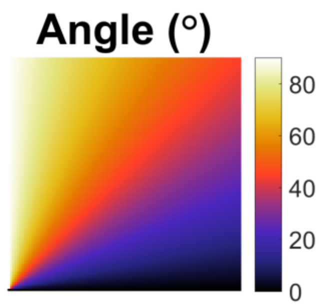
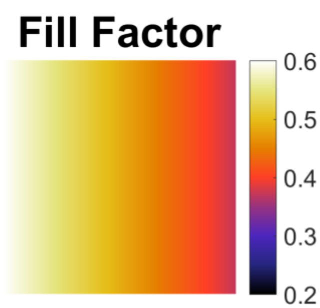
What Can Be Spatially Varied?







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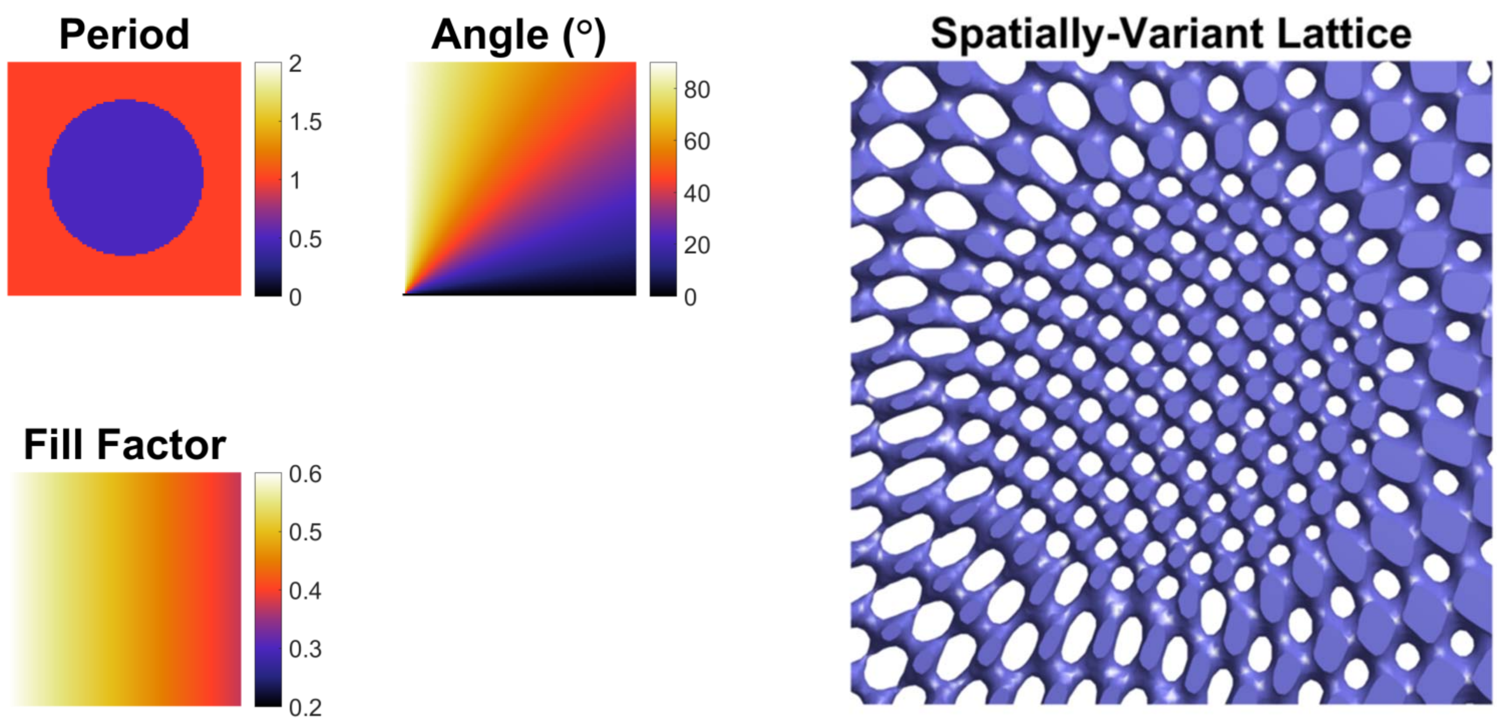

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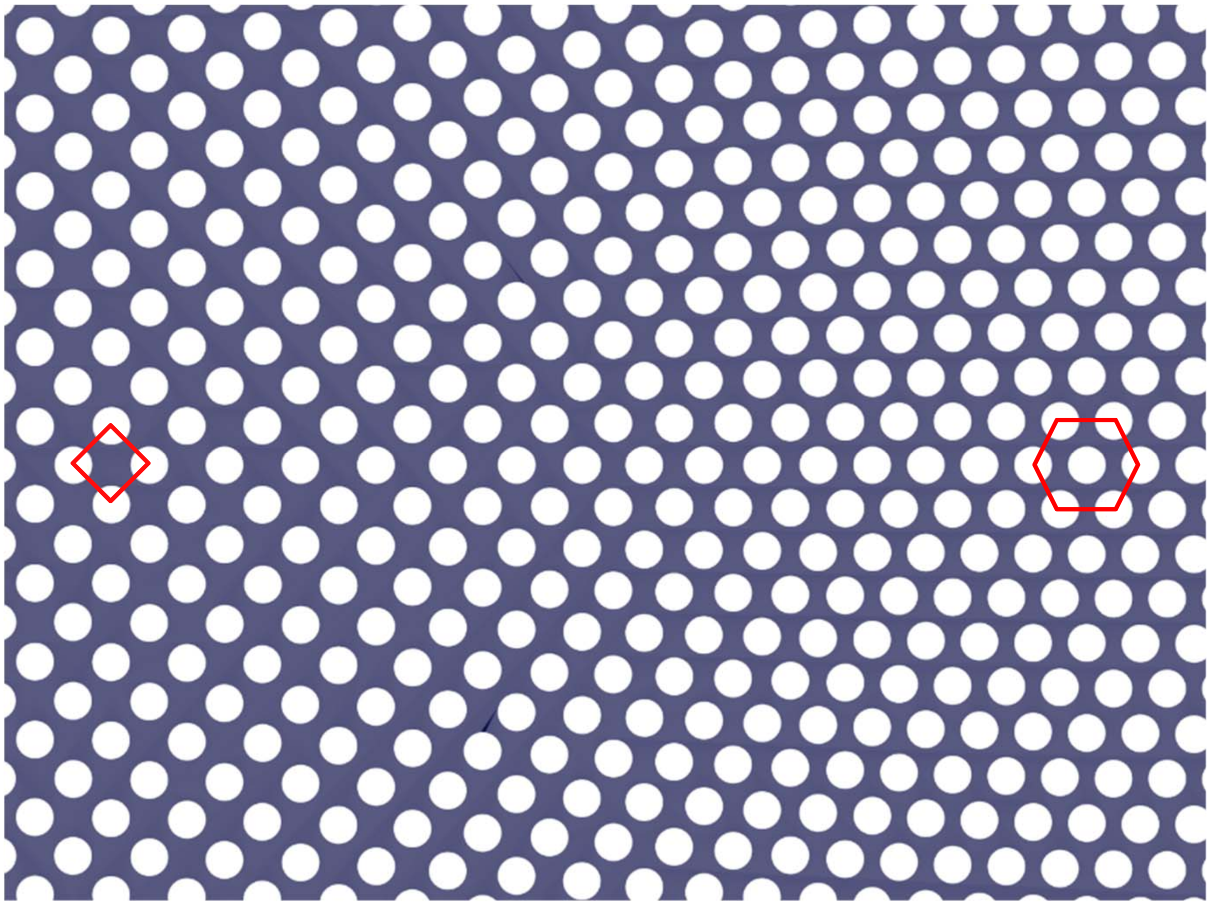
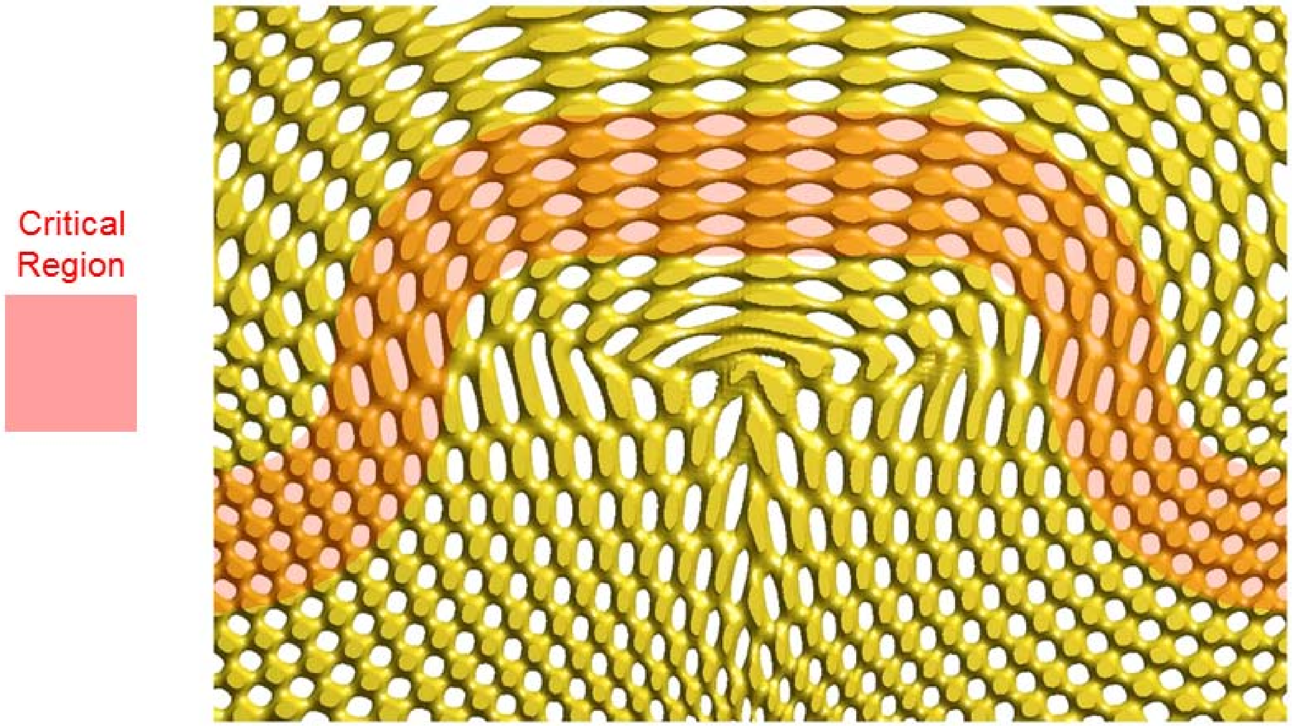
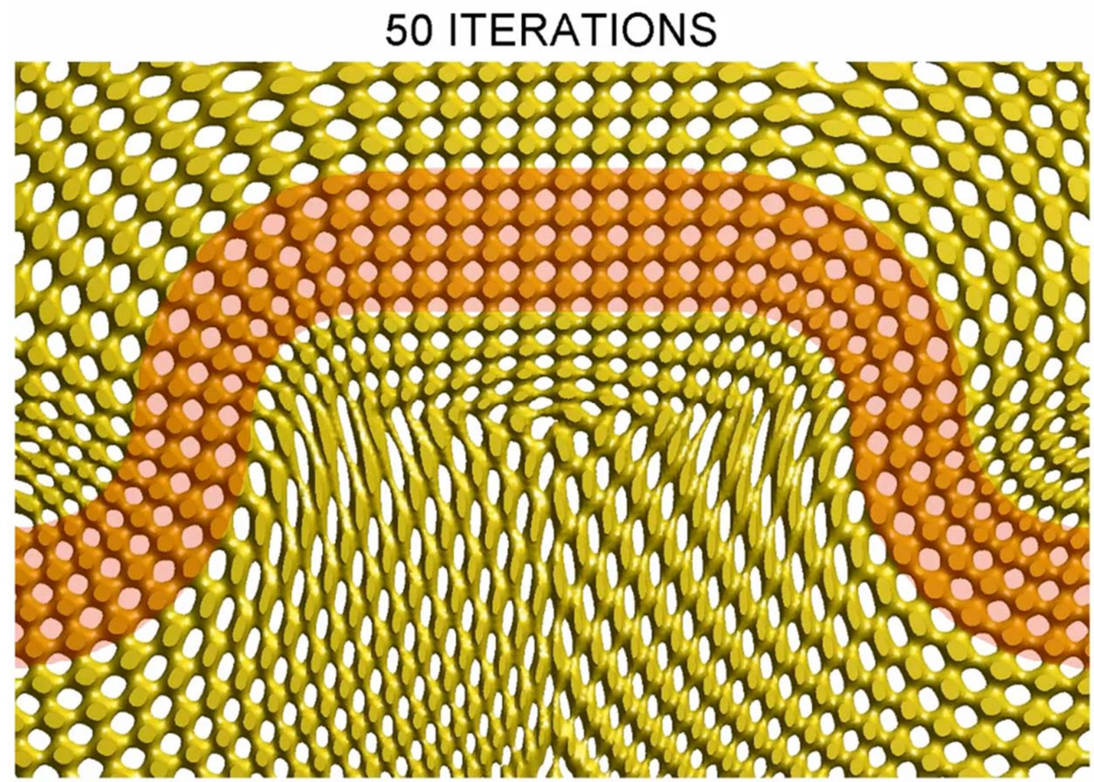


Controlling Deformations

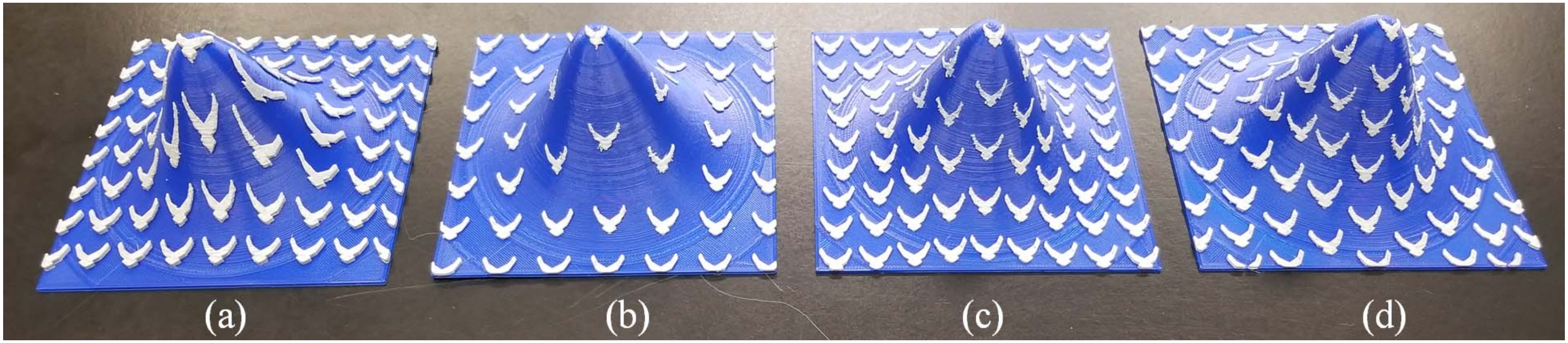


Controlling Deformations



Critical
Region

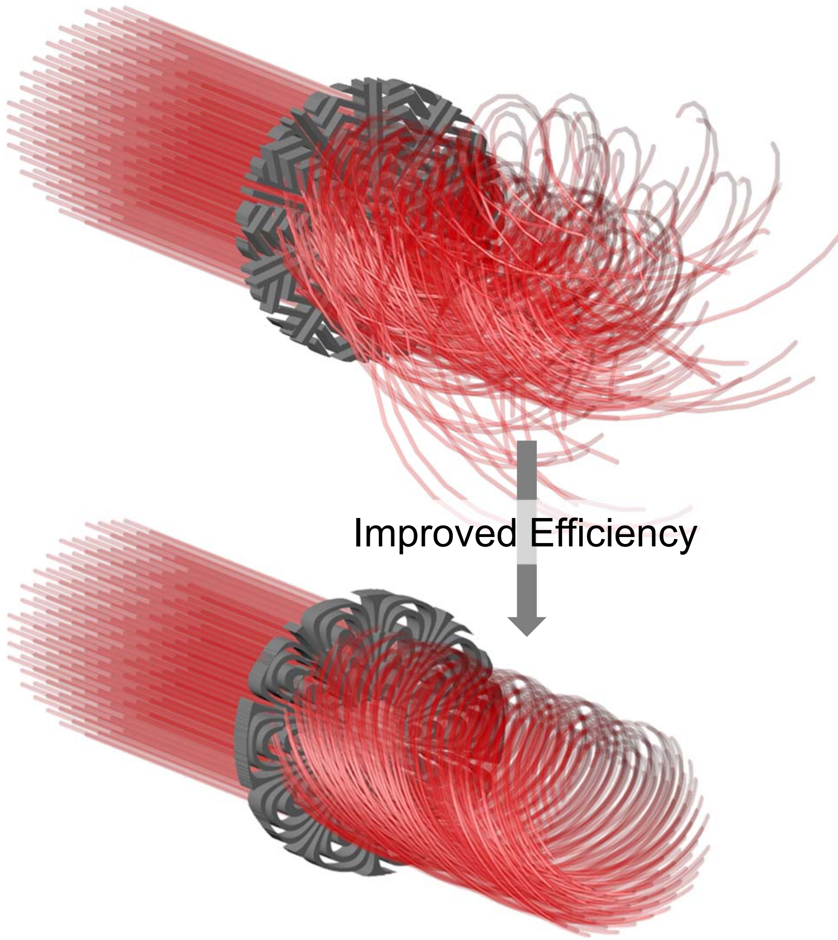
Lattices on Curved Surfaces

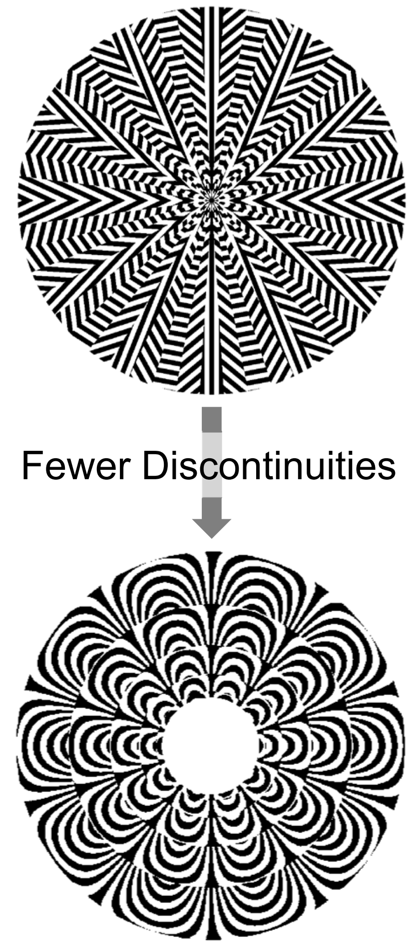


Standard projection	Standard projection + corrected element size	Spatially-variant lattice	Improved spatially-variant lattice

Grant No. FA8650-17-C-1011

Optical Vortex Lenses

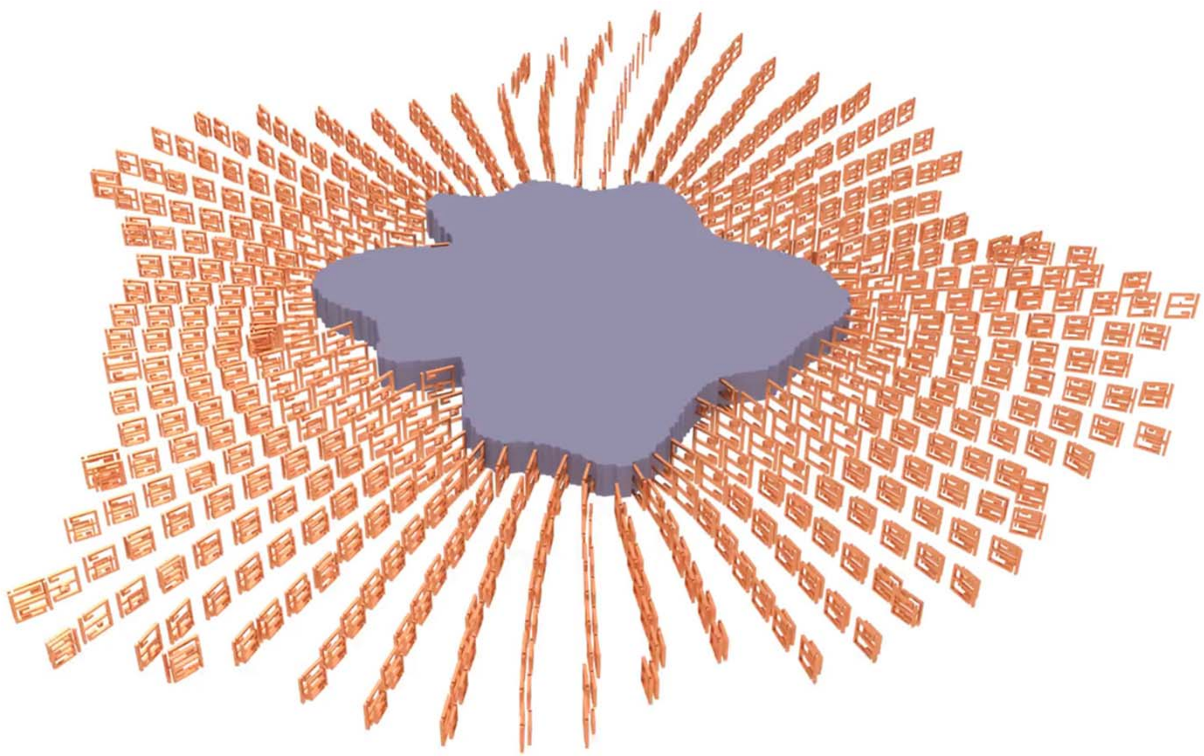




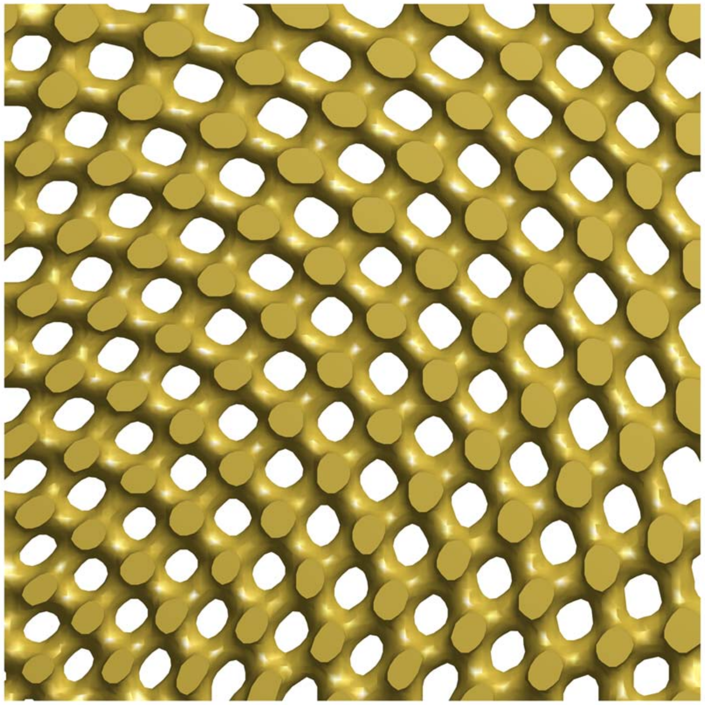
Beresna, Martynas, et al. "Geometric phase via stress induced birefringence." (2017).

Lattices Designed by Transformation Optics

- Accommodates any shape
- Smoother form factor
- Greater density of elements
- Prevents element overlap & dilution
- Minimizes deformations to the unit cells



Extraordinary Control Over Randomness



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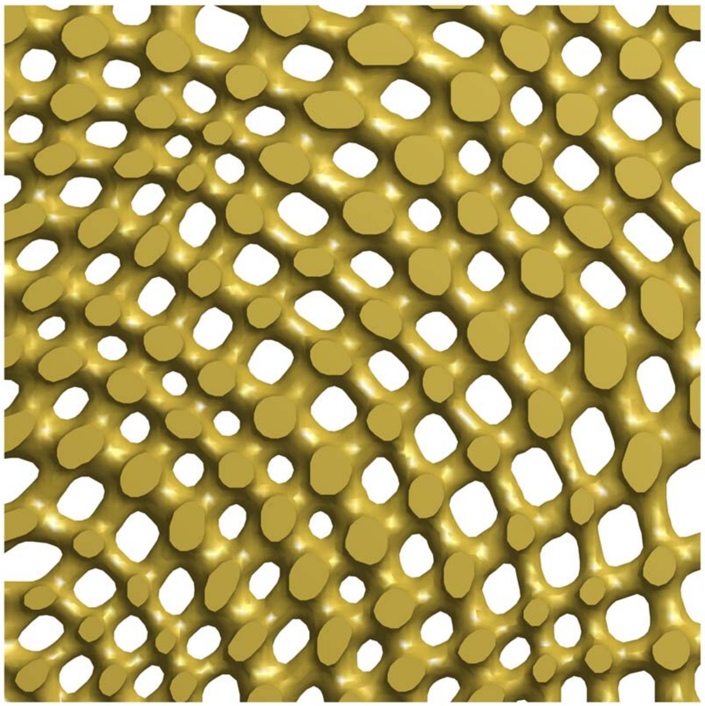

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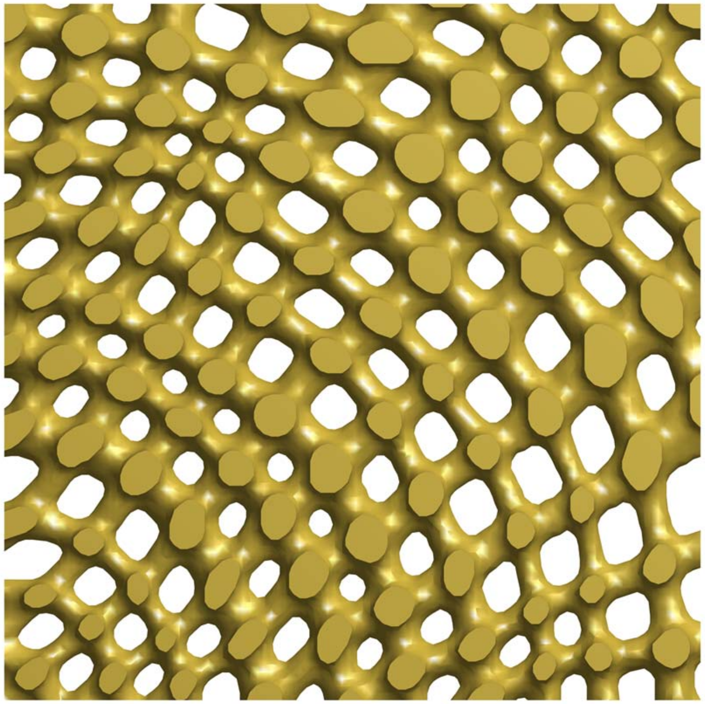

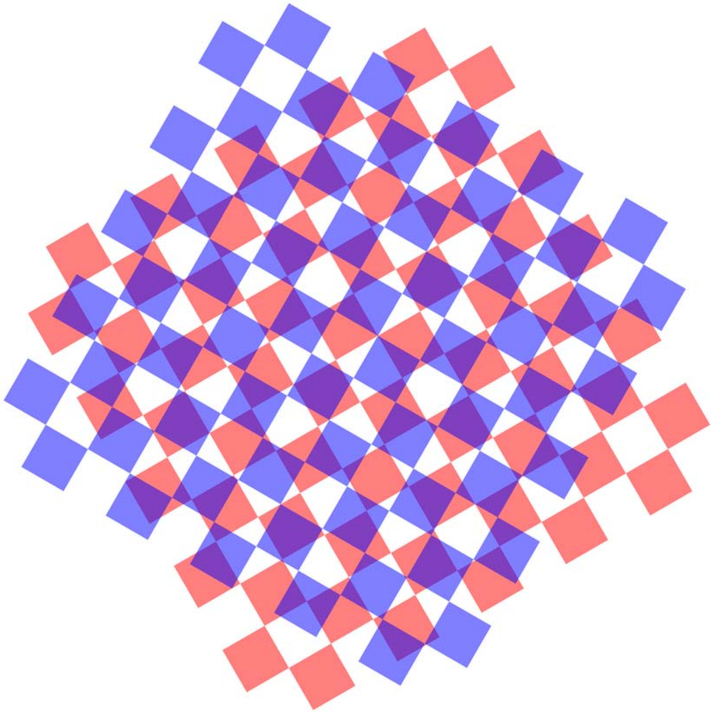

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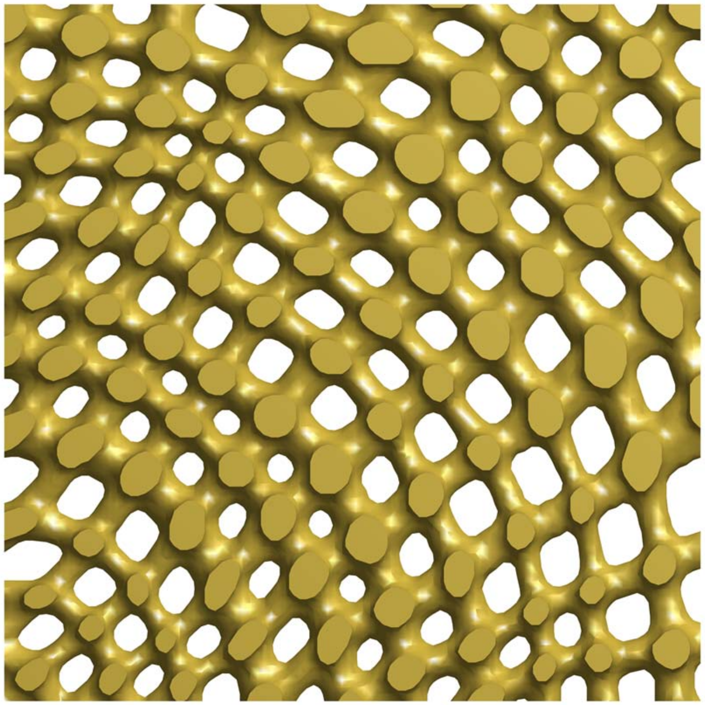
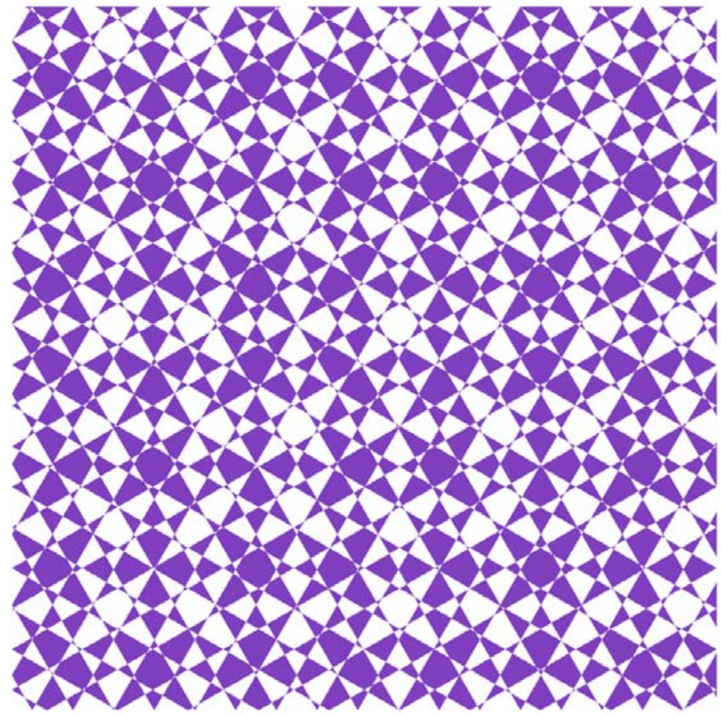
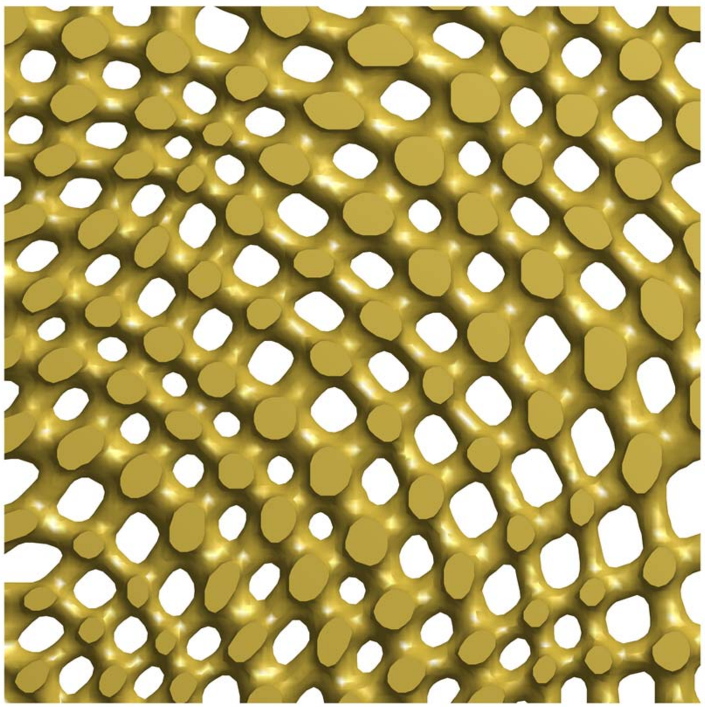
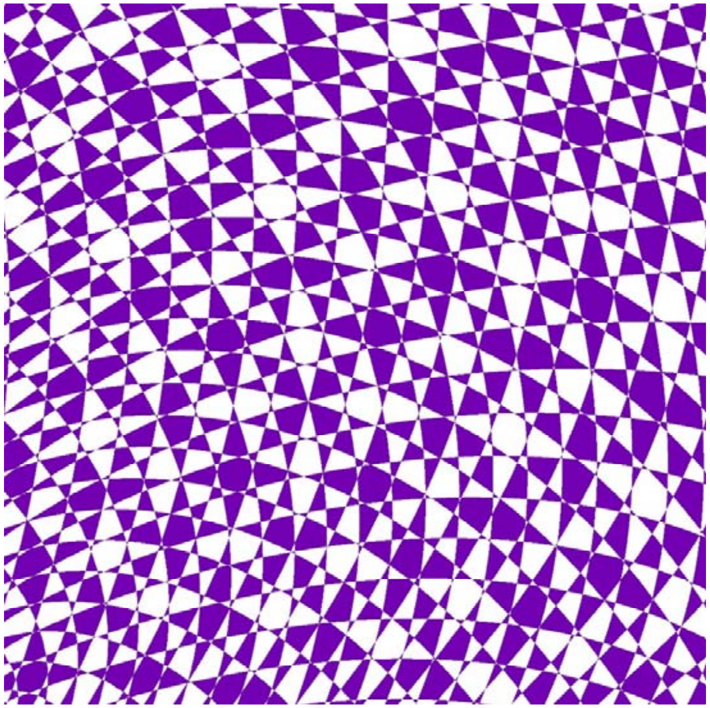




Extraordinary Control Over Randomness

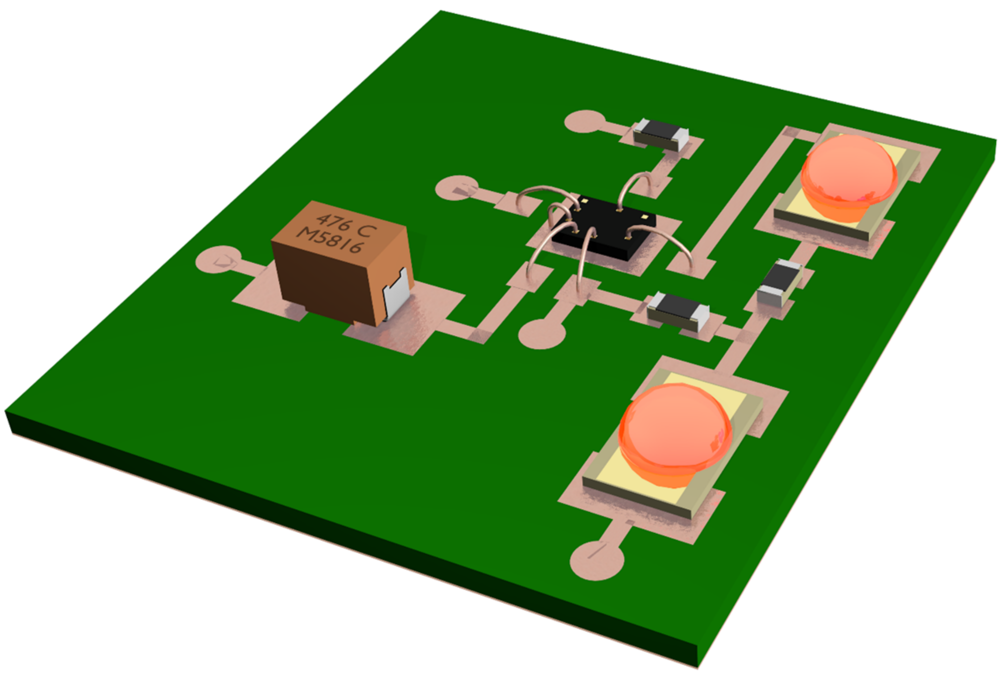




3D Electrical Circuits

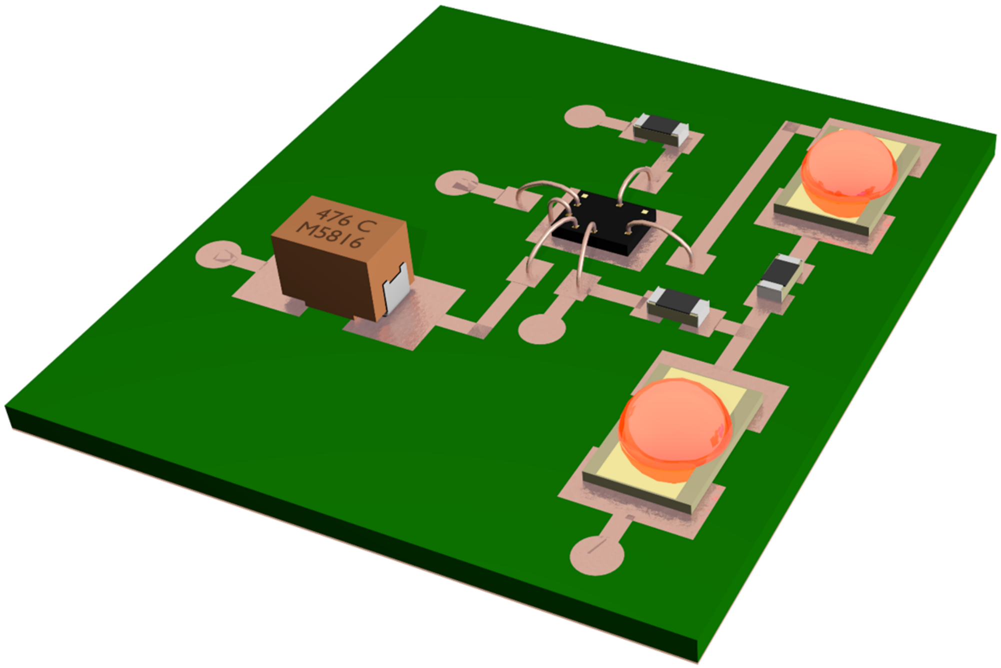
What is a 3D Circuit?

Conventional 2D Circuit



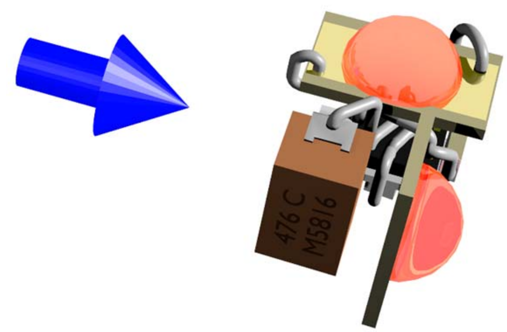
What is a 3D Circuit?

Conventional 2D Circuit

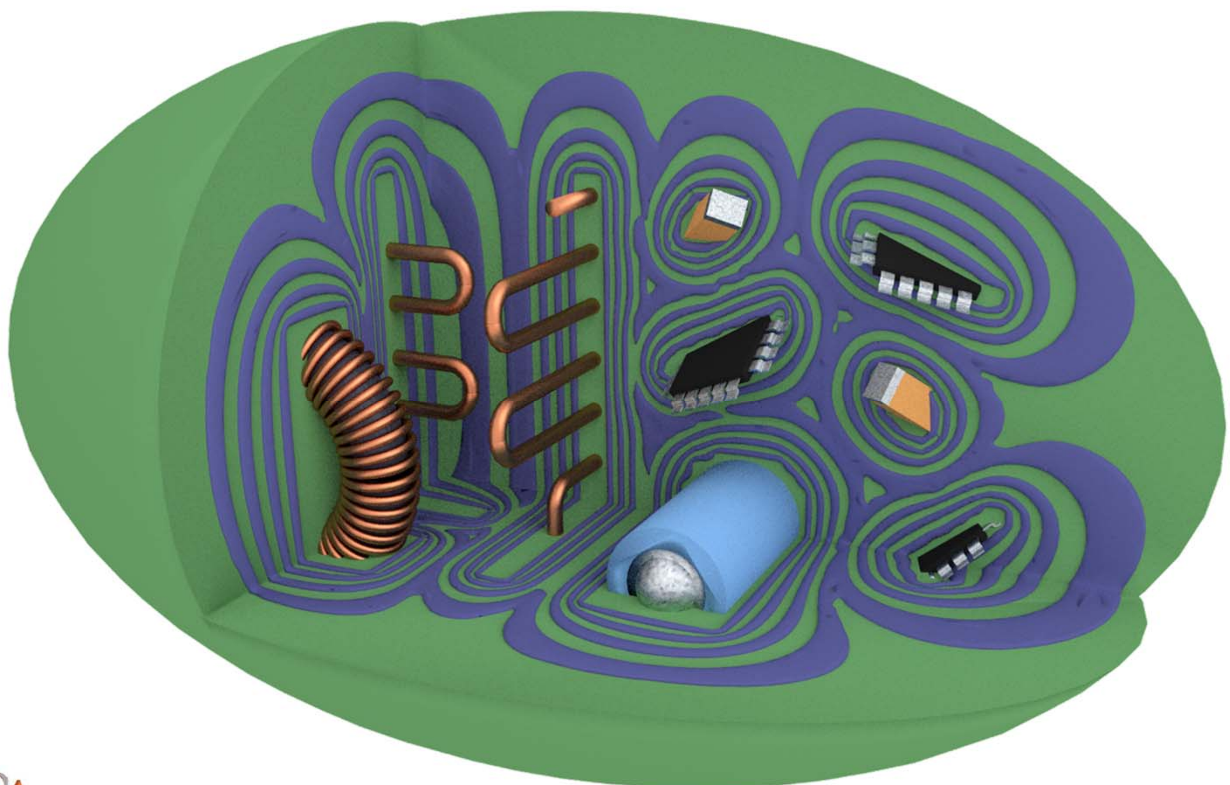


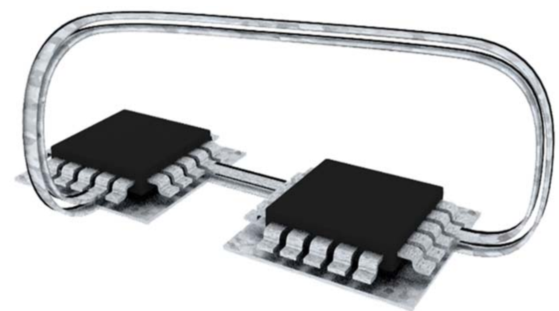
- Lower volume
- Lighter weight
- Shorter trace lengths
- Improved power efficiency
- Greater bandwidth
- Unconventional form factors
- New physical mechanisms

3D Circuit



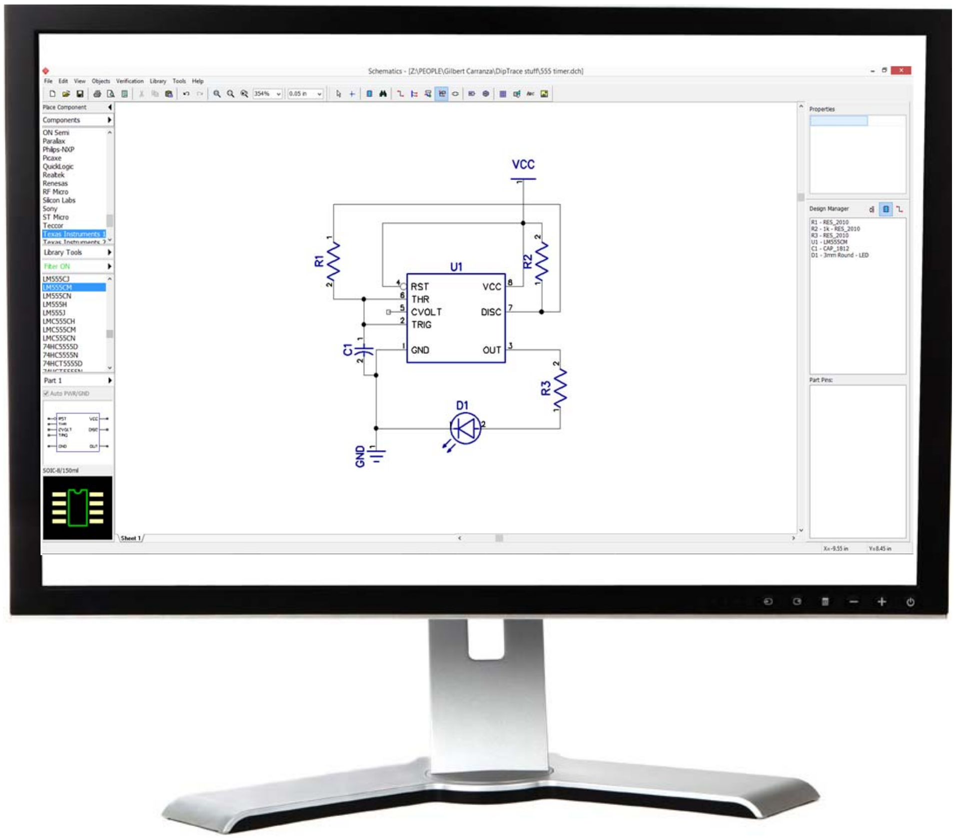
Vision for 3D Printed Circuits and Electromagnetic Systems





US Provisional Patent 62,016,478

Process Flow for 3D Circuits:
Step 1 – Schematic Capture



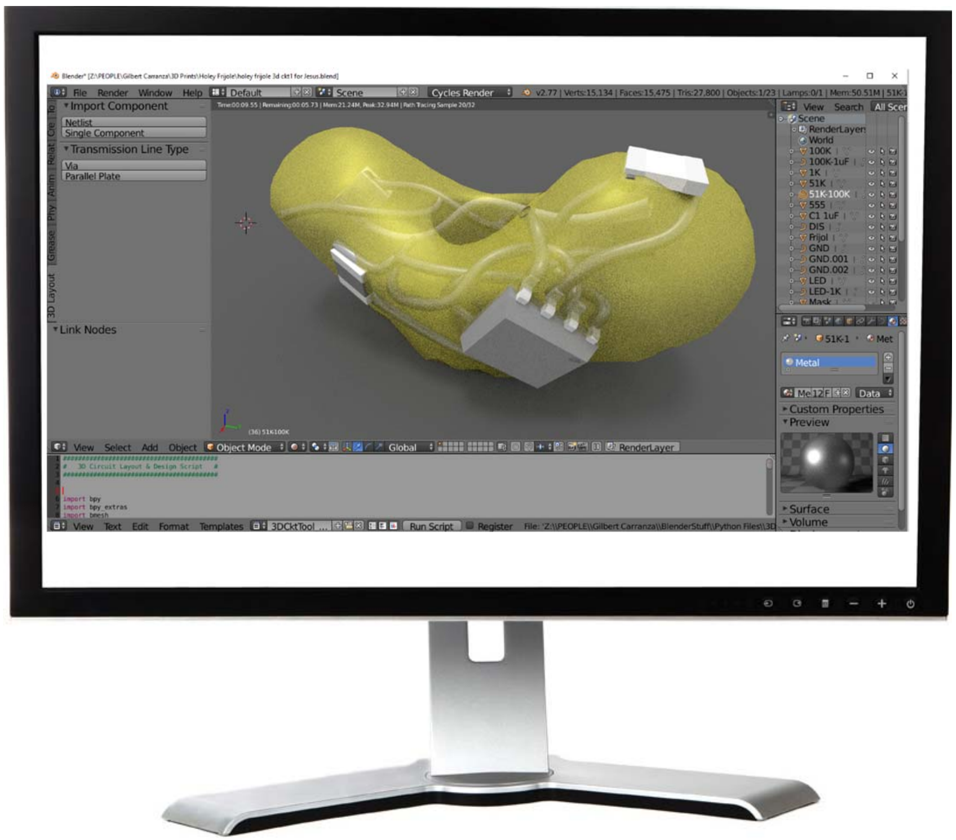
DIPTRACE

Schematic and PCB Design Software

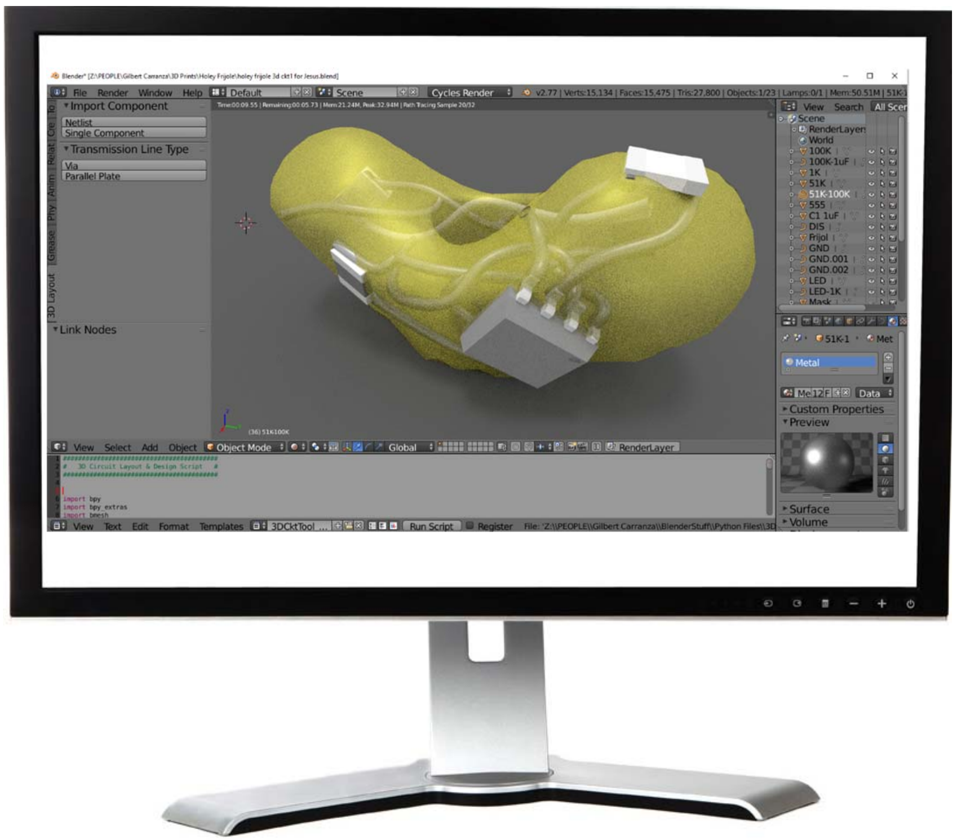
https://diptrace.com/

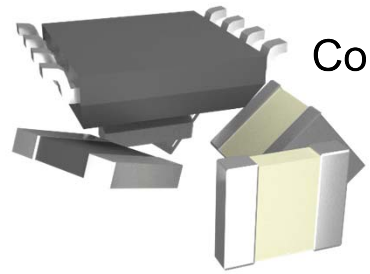
LAB

Process Flow for 3D Circuits:
Step 2 – Layout & Routing



Process Flow for 3D Circuits:
Step 2 – Layout & Routing





Process Flow for 3D Circuits:
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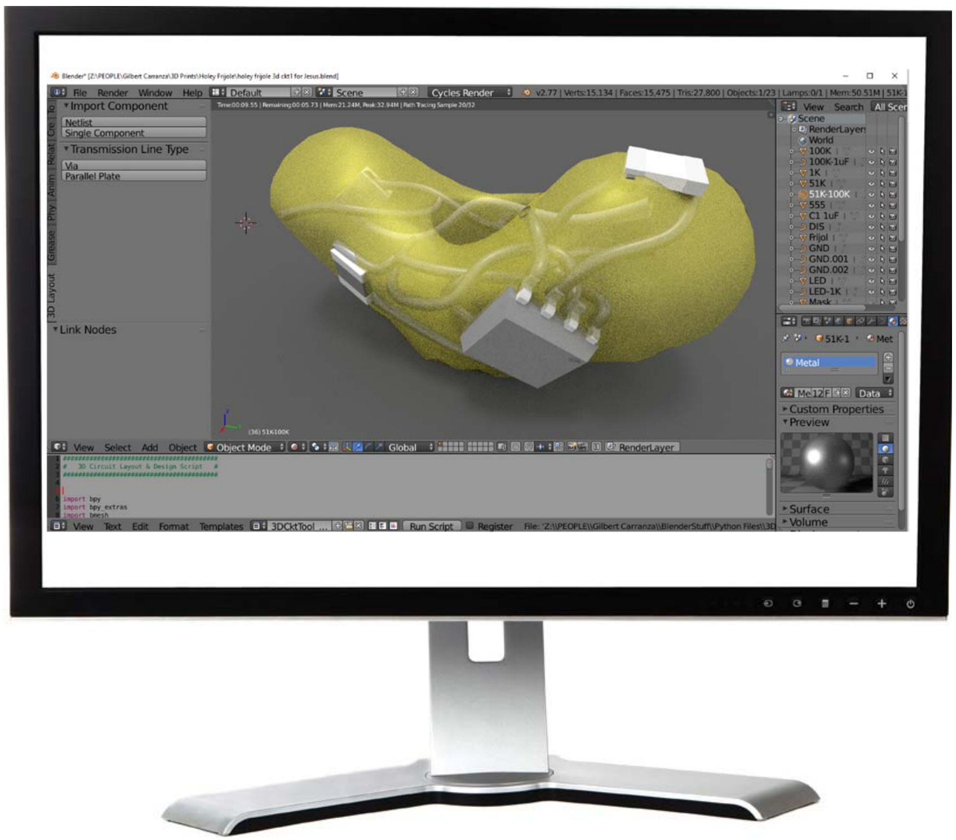
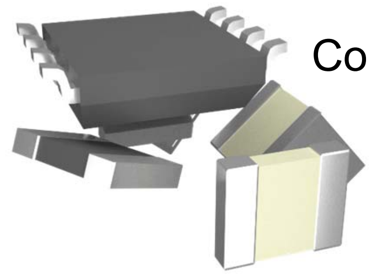
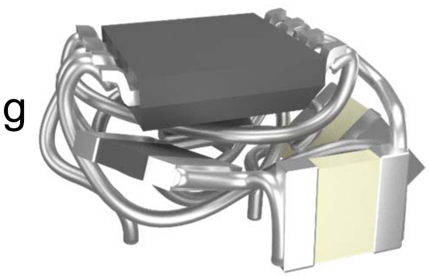


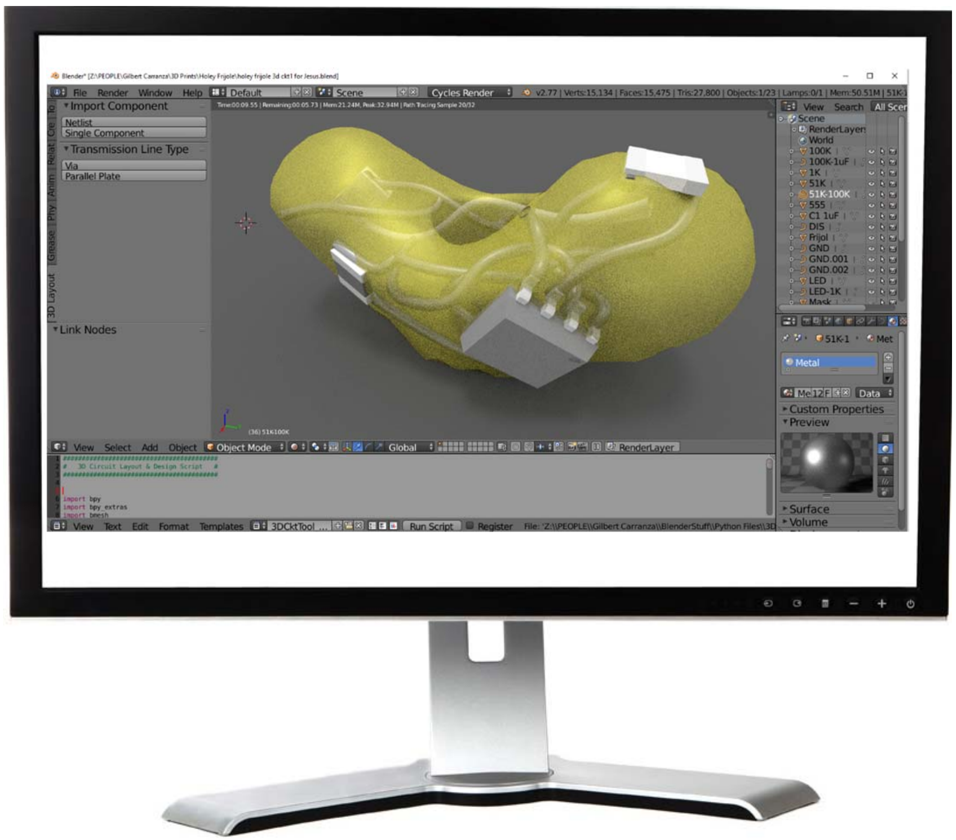


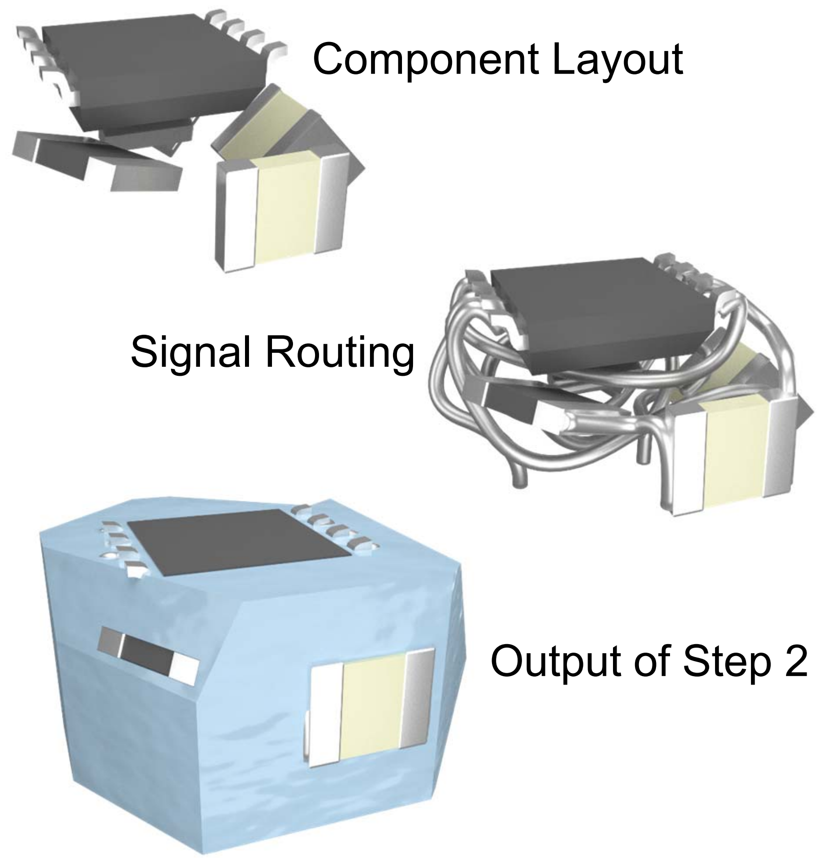
Component Layout



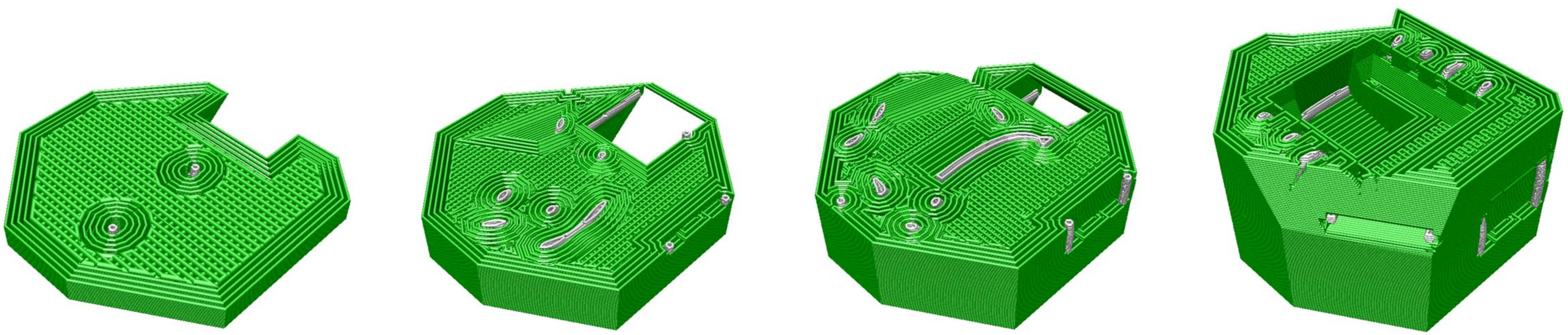
Signal Routing

Process Flow for 3D Circuits:
Step 2 – Layout & Routing



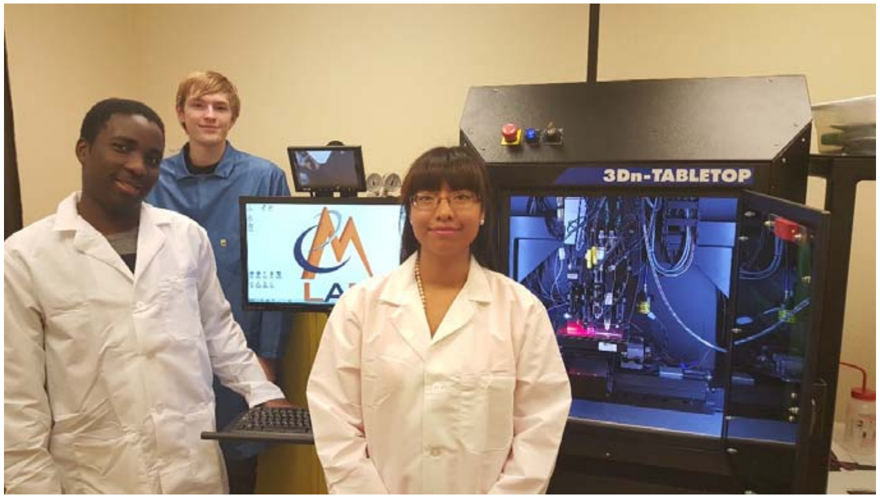


Process Flow for 3D Circuits:
Step 3 – Slicing for Hybrid 3D Printing

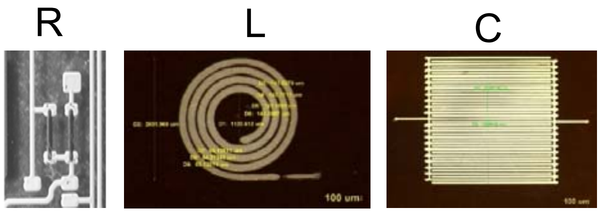


Grant No. FA8650-17-C-1011

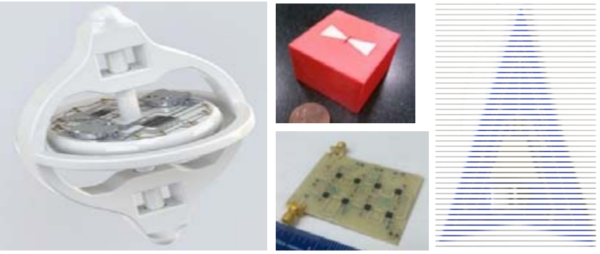
Process Flow for 3D Circuits:
Step 4 – Hybrid 3D Printing



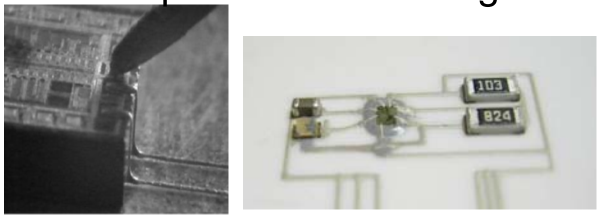
3D Printed Impedance Elements



3D Printed Circuits



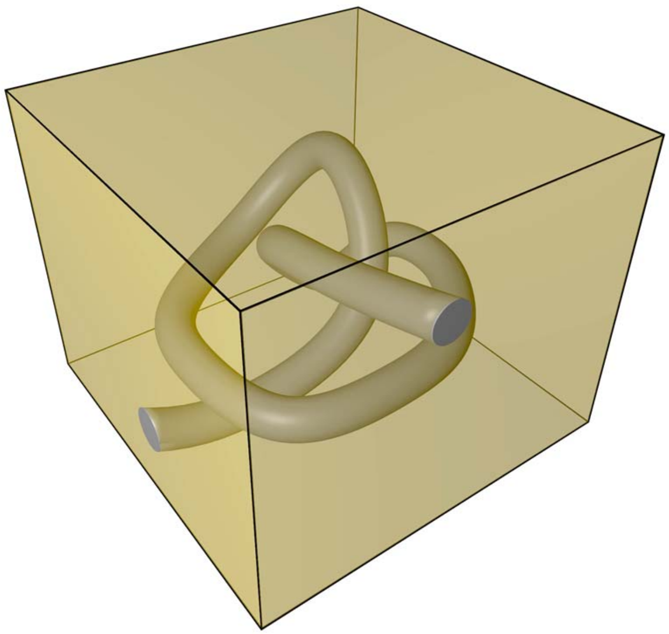
Chip Scale 3D Printing

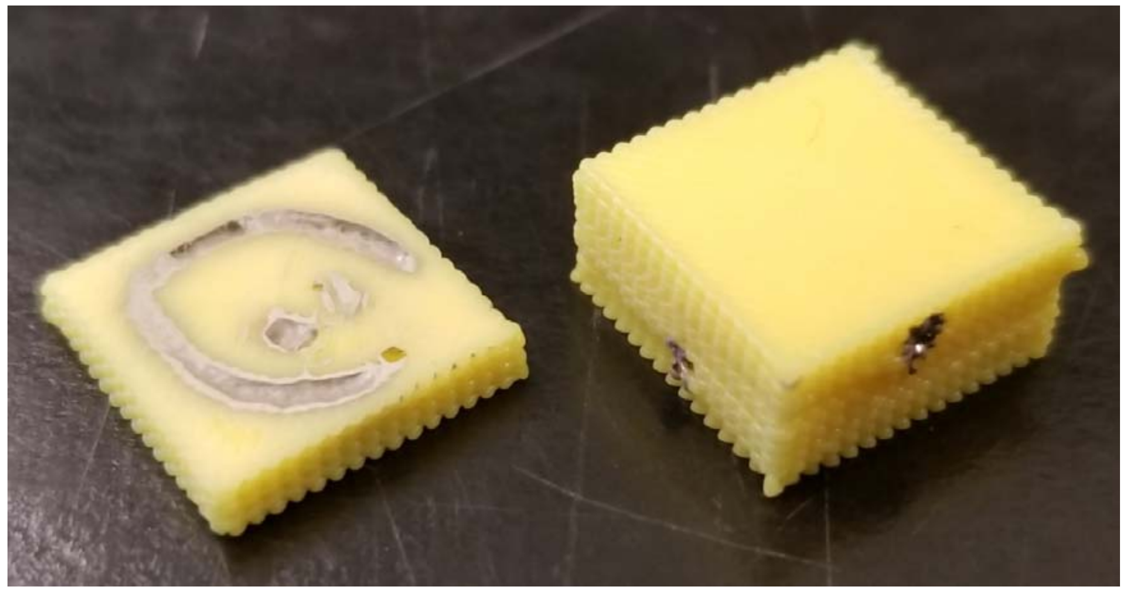


- Ultra-fine resolution for high frequencies
- Micro-dispensing for conductors (~25 μm)
- Micro-FDM for dielectrics (~50 μm)
- Pulsed laser for trimming, cutting, and drilling
- CW laser for curing and sintering

LAB Sciperio A Science Revelation

First-Ever Automated CAD-to-Print for Direct-Write Hybrid 3D Printing

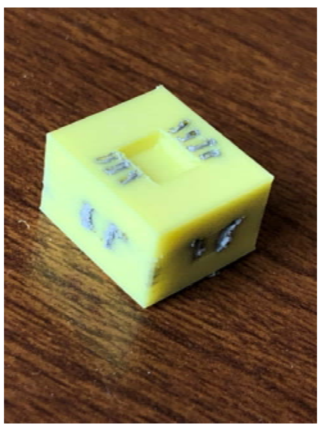


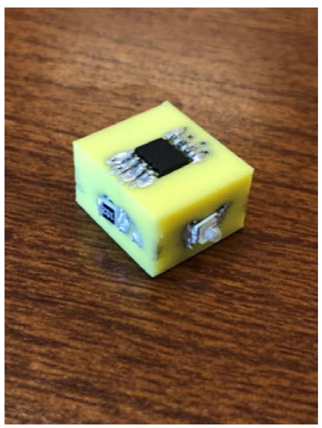


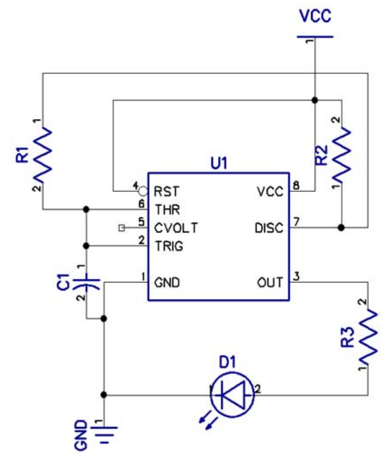
"One small step for electronics,
one giant leap for digital manufacturing."

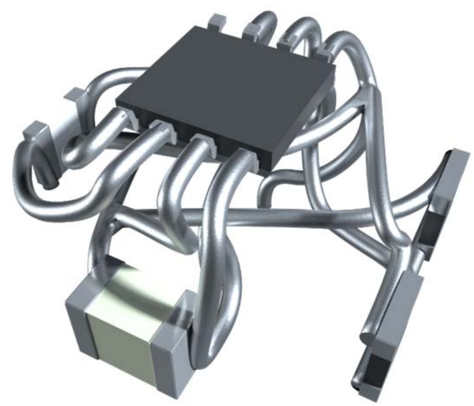
Grant No. W911NF-16-2-0019

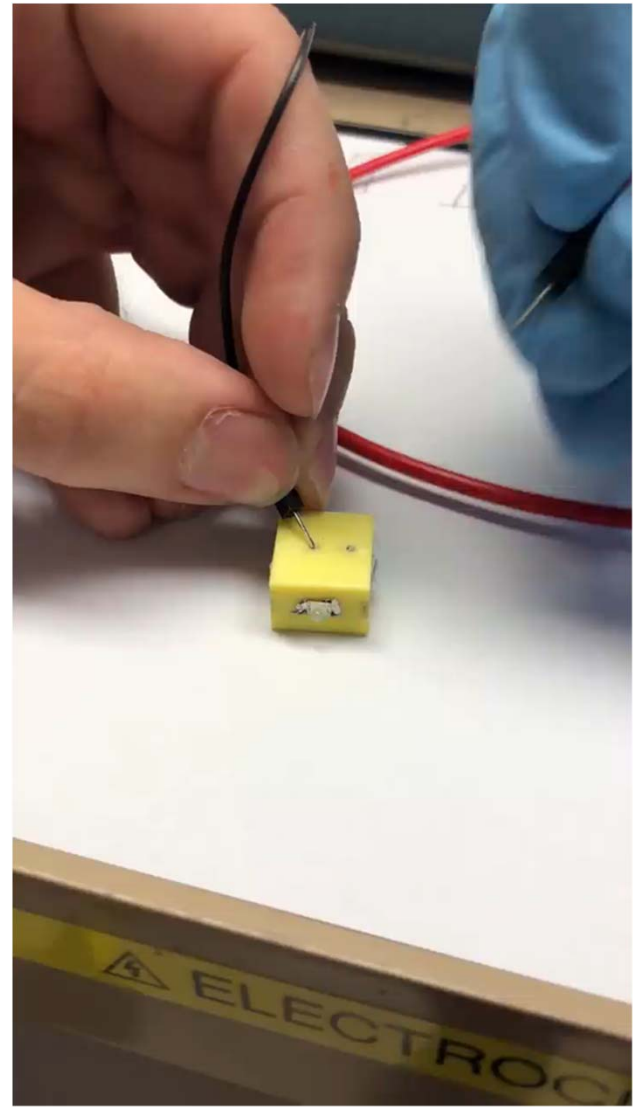
Manufactured Device



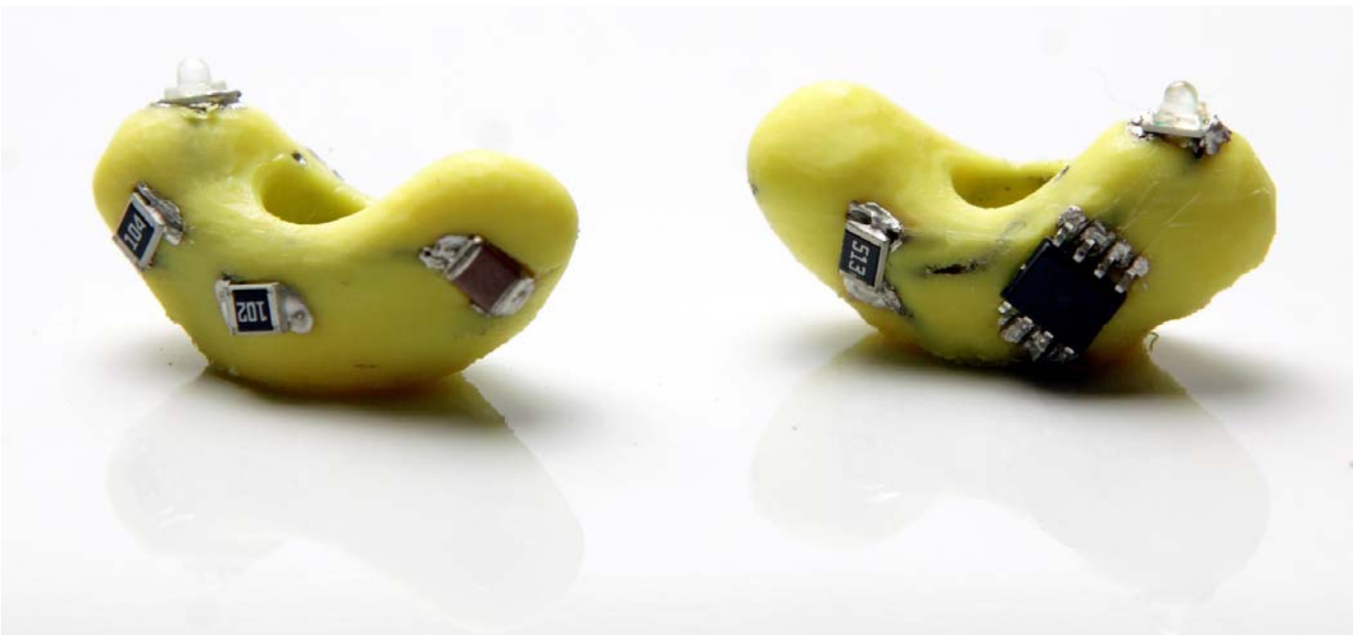






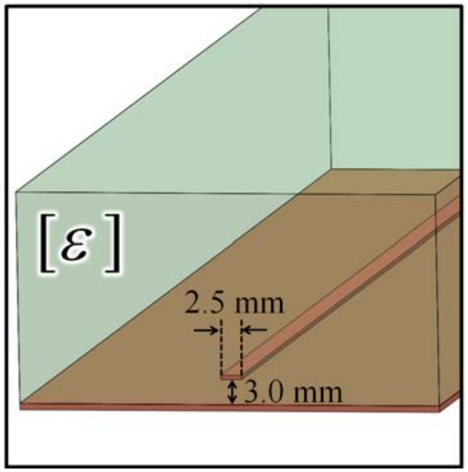


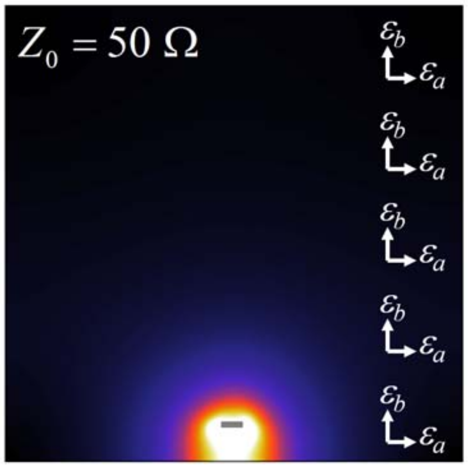
The Holey Frijoles



Spatially-Variant Anisotropic Metamaterials

Field Sculpting

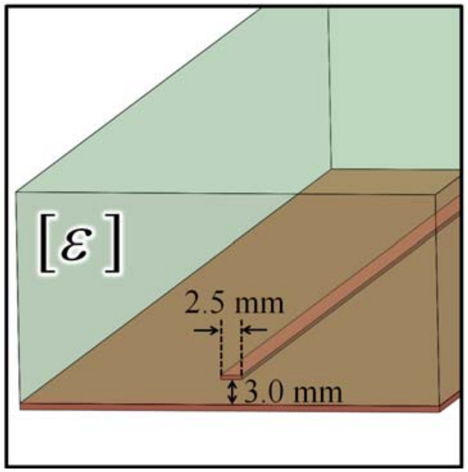


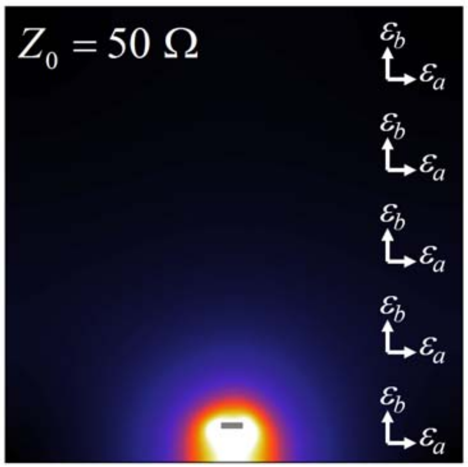


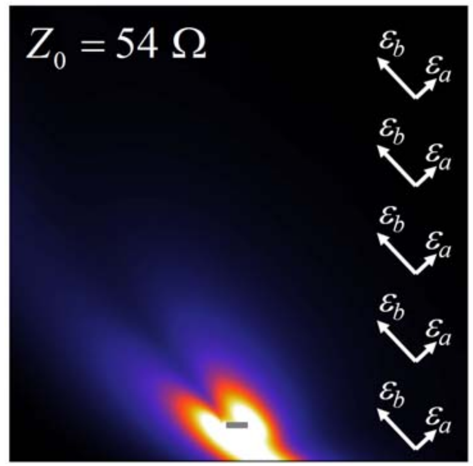
DARPA Young Faculty Award
Grant No. N66001-11-4150

Raymond C. Rumpf "Engineering the Dispersion and Anisotropy of Periodic Electromagnetic Structures," Solid State Physics, Vol. 66, pp. 213-300, 2015.

Field Sculpting







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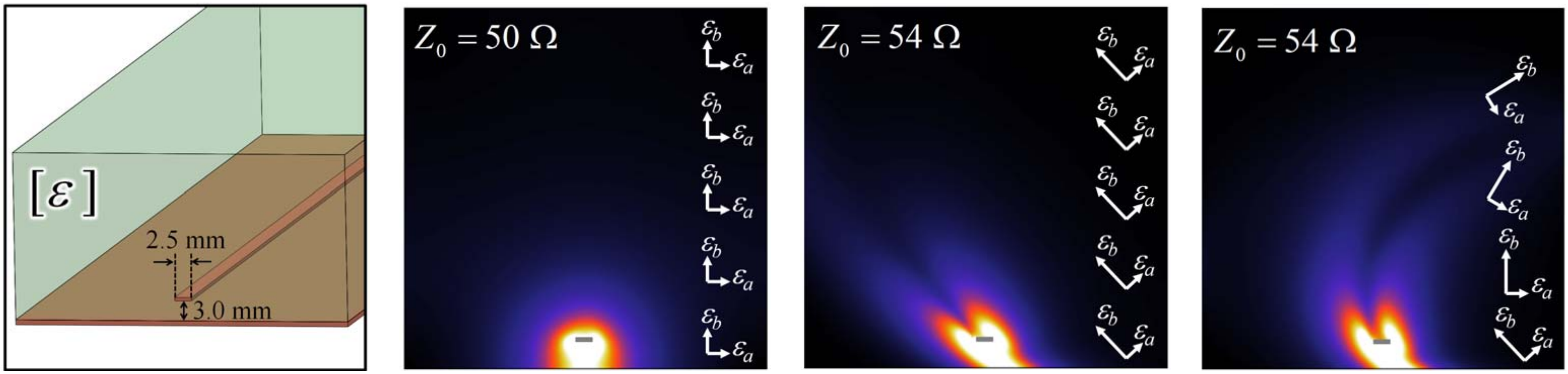
Grant No. N66001-11-4150

Raymond C. Rumpf "Engineering the Dispersion and Anisotropy of Periodic Electromagnetic Structures," Solid State Physics, Vol. 66, pp. 213-300, 2015.

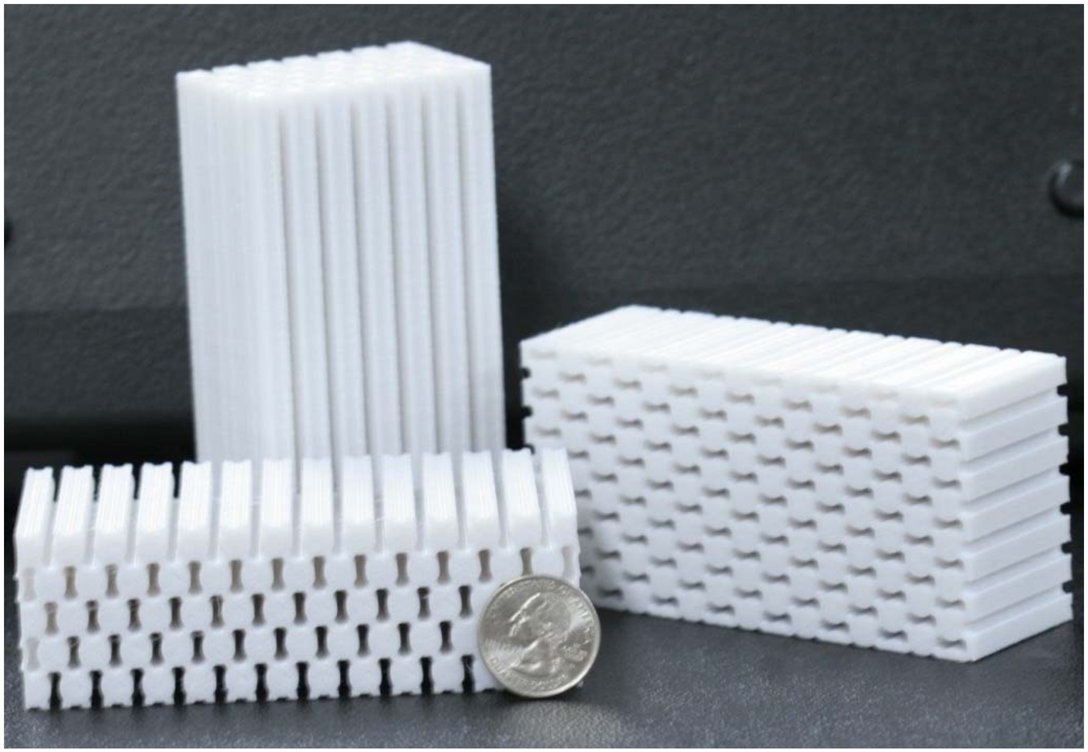
Field Sculpting



DARPA Young Faculty Award
Grant No. N66001-11-4150

Raymond C. Rumpf "Engineering the Dispersion and Anisotropy of Periodic Electromagnetic Structures," Solid State Physics, Vol. 66, pp. 213-300, 2015.

All-Dielectric Anisotropic Metamaterials

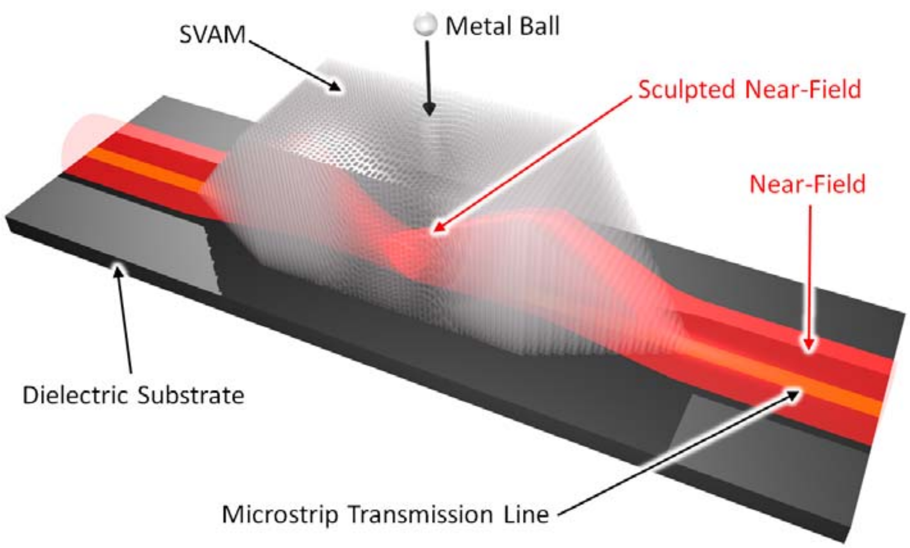


- Strong anisotropy
- All-dielectric
- Nonresonant
- Very low loss
- Ultra broadband
- Can be spatially varied

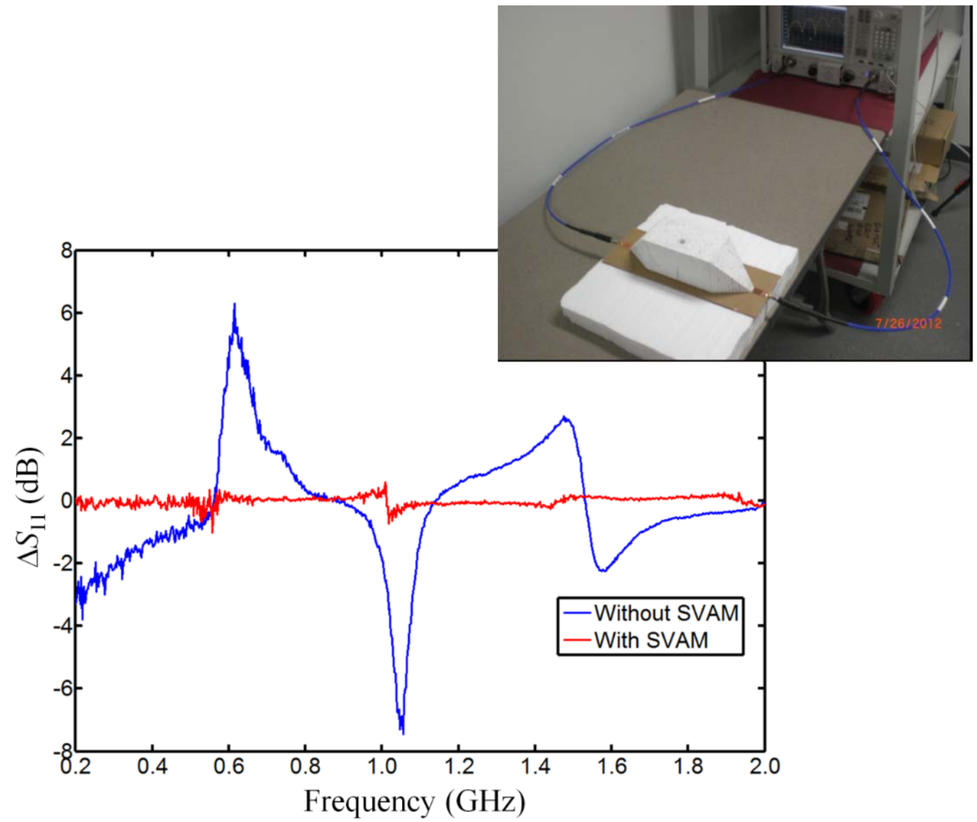
DARPA Young Faculty Award
Grant No. N66001-11-4150

C. R. Garcia, J. Correa, D. Espalin, J. H. Barton, R. C. Rumpf, R. Wicker, V. Gonzalez, "3D Printing of Anisotropic Metamaterials," PIER Lett, Vol. 34, pp. 75-82, 2012.

Microstrip Decoupled From Metal Object in Close Proximity



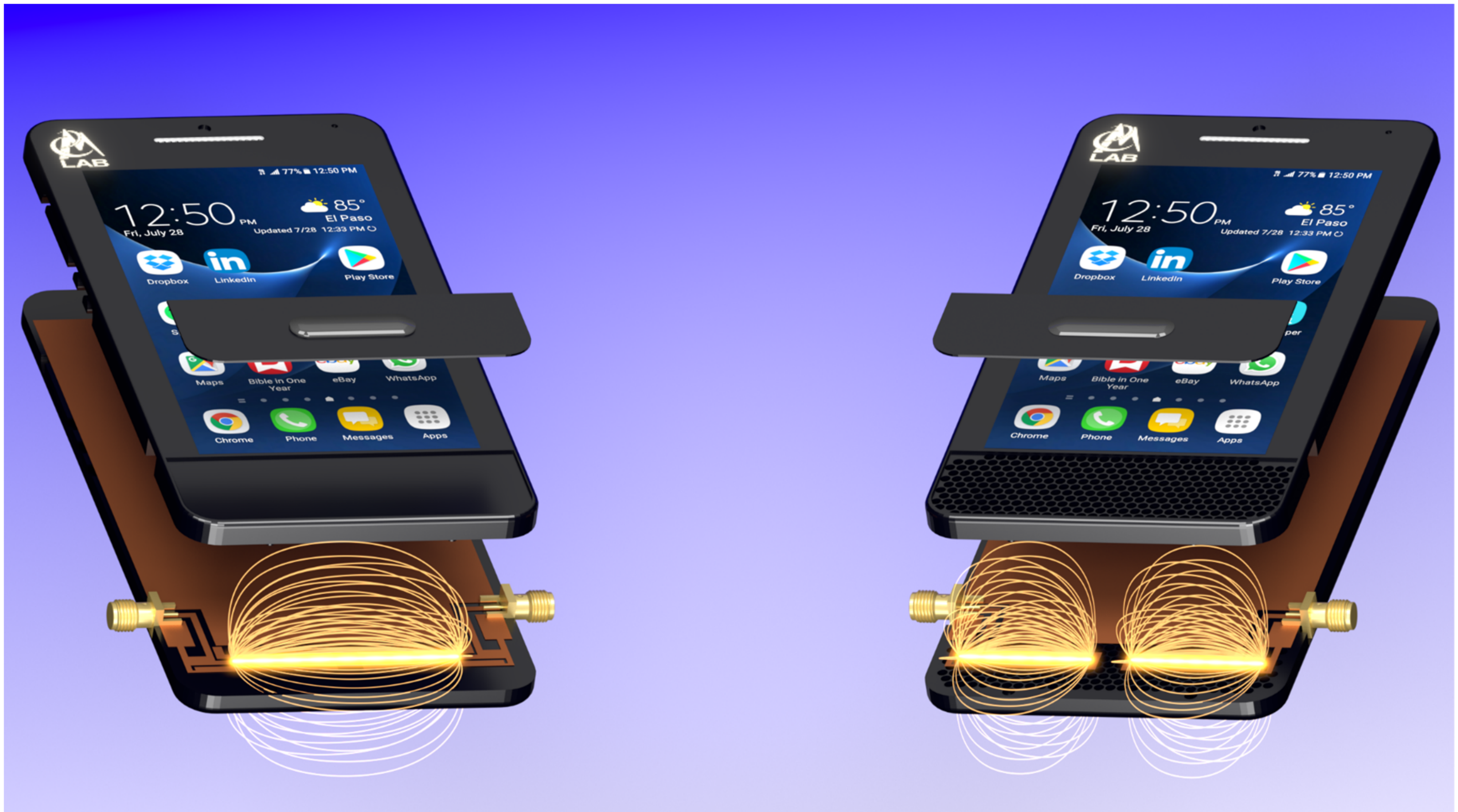
US Provisional Patent 62,016,478



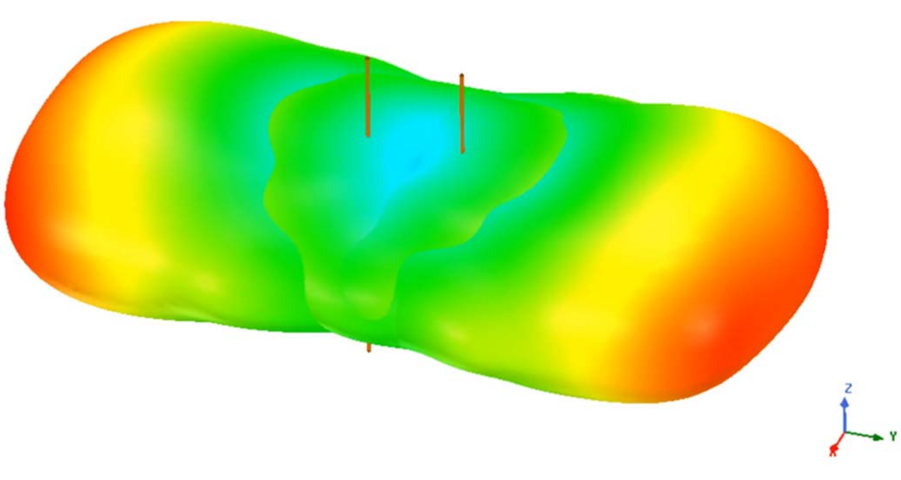
DARPA Young Faculty Award
Grant No. N66001-11-4150

R. C. Rumpf, C. R. Garcia, H. H. Tsang, J. E. Padilla, M. D. Irwin, "Electromagnetic Isolation of a Microstrip by Embedding in a Spatially Variant Anisotropic Metamaterial," PIER, Vol. 142, pp. 243-260, 2013.

Artist Concept of Antenna Decoupling by SVAM

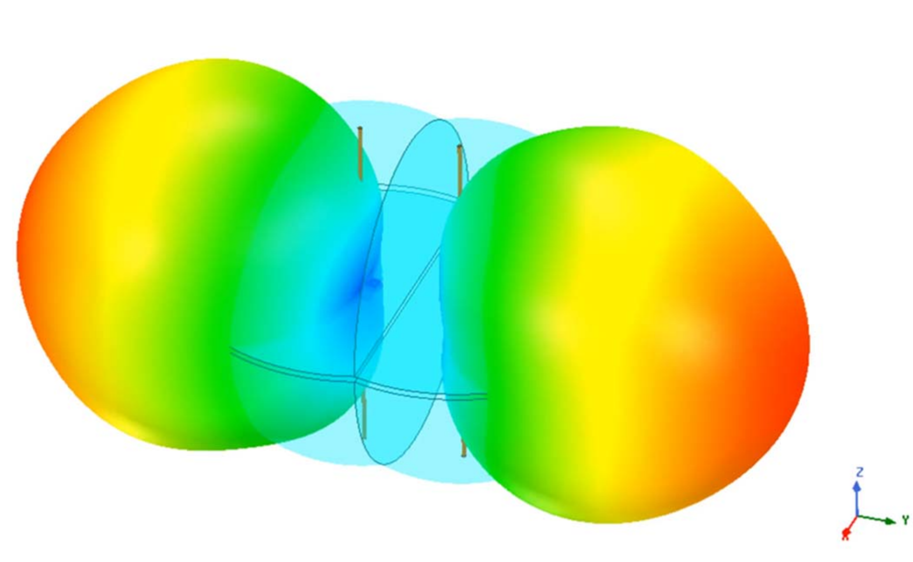


Simulated Decoupling of Two Dipole Antennas



No SVAM

Separation: $0.135\lambda_0$
Frequency: 810 MHz
Wavelength: λ_0 = 37 cm
ECC: 0.14
S_{21}: -5.5 dB

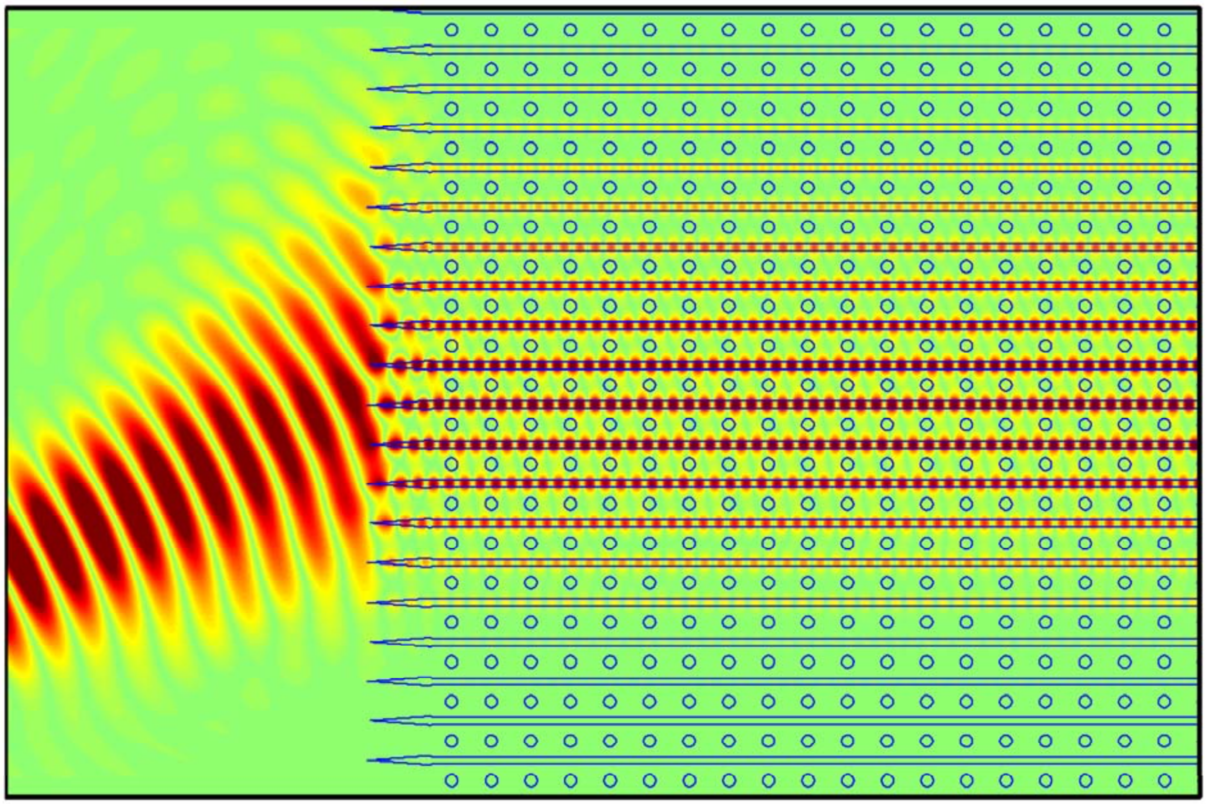


With SVAM

Separation: $0.096\lambda_0$
Frequency: 575 MHz
Wavelength: λ_0 = 37 cm
ECC: 0.016
S_{21}: -42 dB

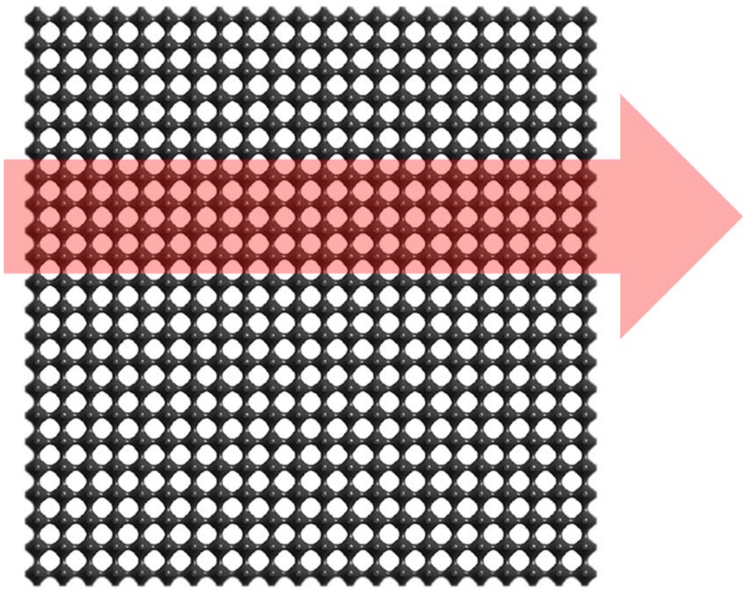
Spatially-Variant Photonic Crystals

Self-Collimation

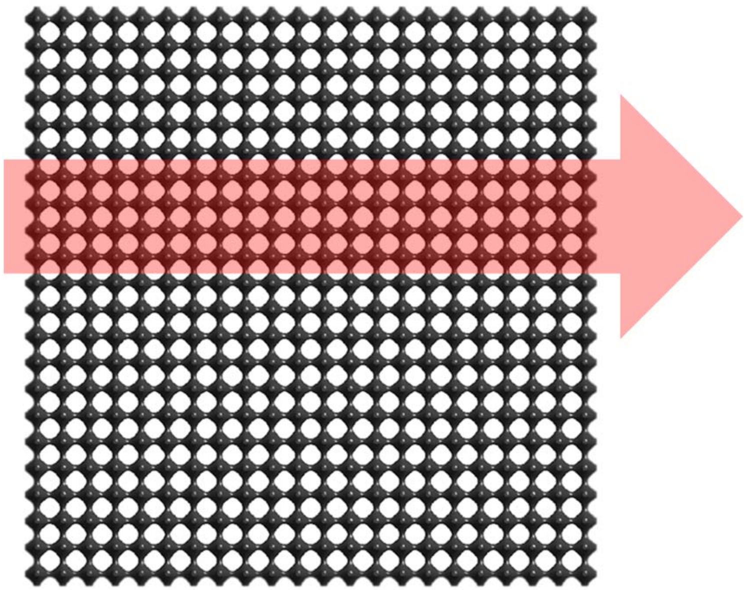


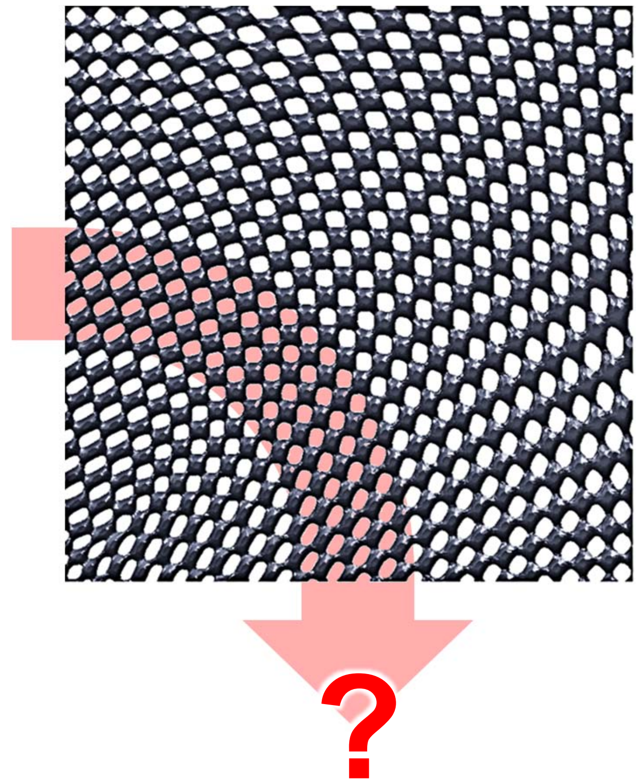
Raymond C. Rumpf "Engineering the Dispersion and Anisotropy of Periodic Electromagnetic Structures," Solid State Physics, Vol. 66, pp. 213-300, 2015.

Spatially-Variant Self-Collimation

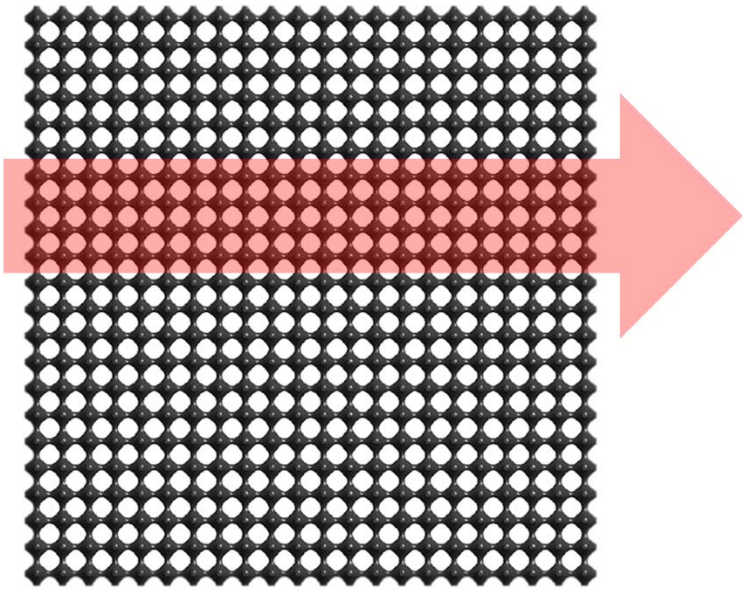


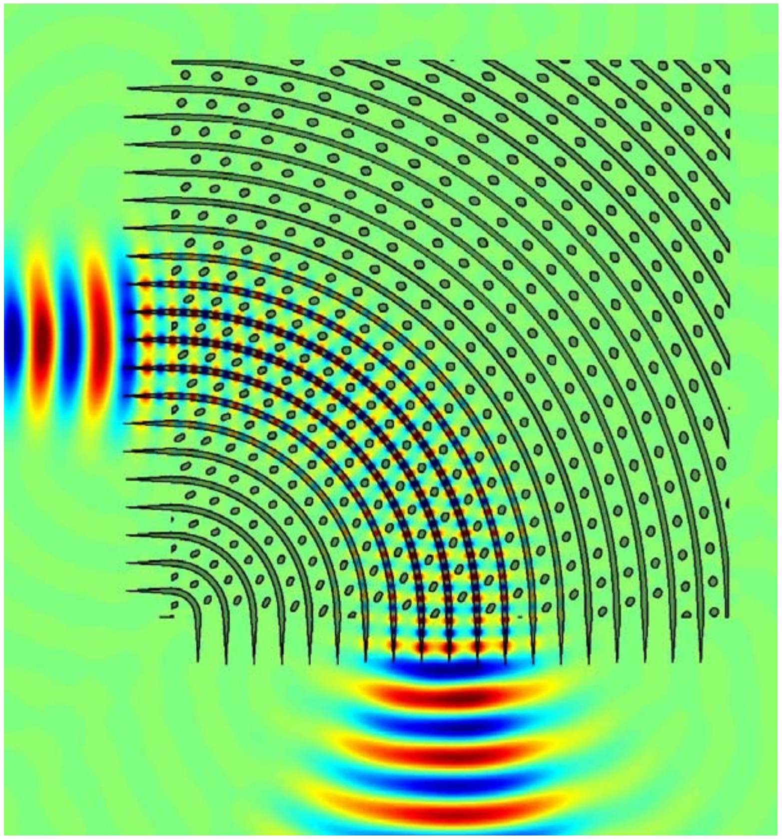
Spatially-Variant Self-Collimation



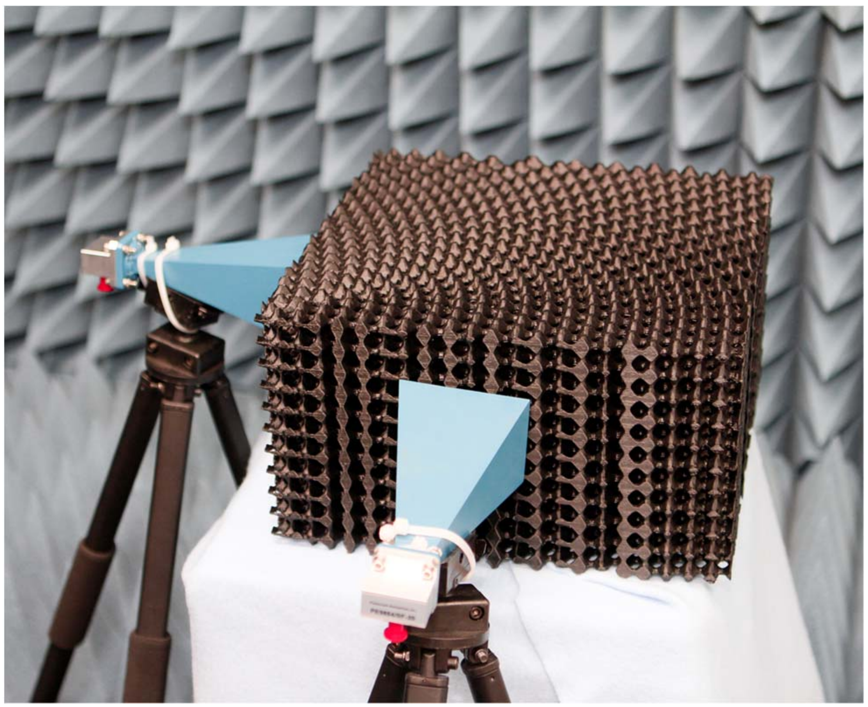


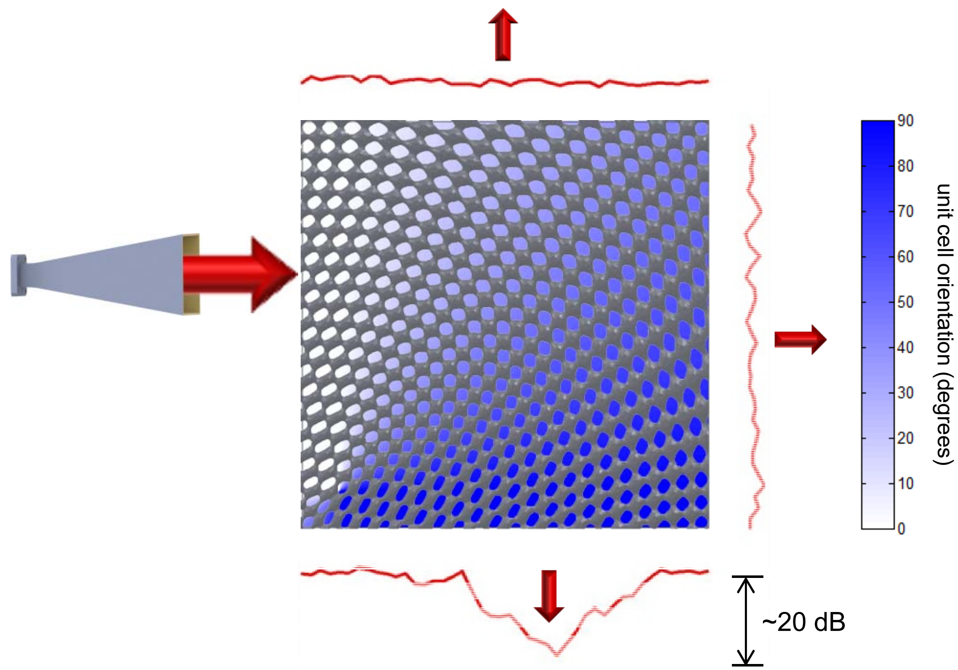
Spatially-Variant Self-Collimation





First Demonstration of Spatially-Variant Self-Collimation





DARPA Young Faculty Award
Grant No. N66001-11-4150

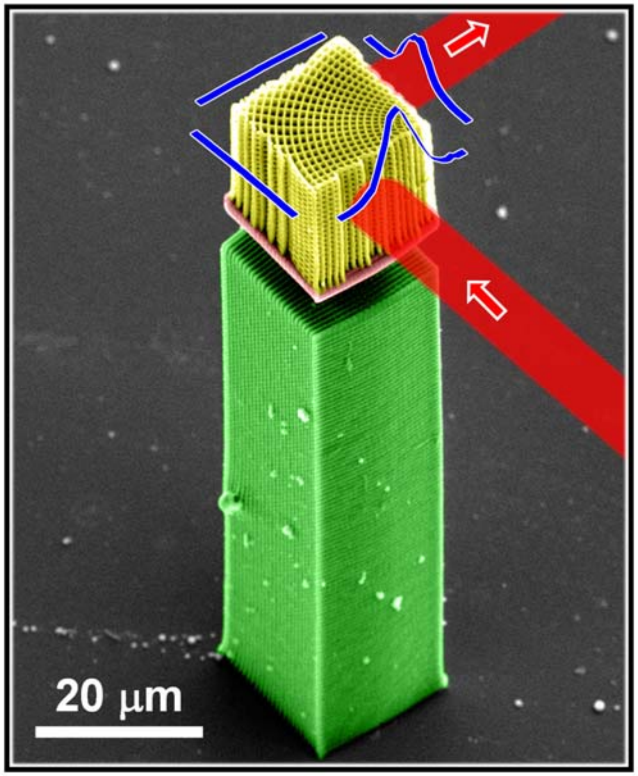
R. C. Rumpf, J. Pazos, C. R. Garcia, L. Ochoa, and R. Wicker, "3D Printed Lattices with Spatially Variant Self-Collimation," PIER, Vol. 139, pp. 1-14, 2013.

Tightest Bend of an Unguided Optical Beam

- Bend radius was $6.7\lambda_0$.
  World Record!

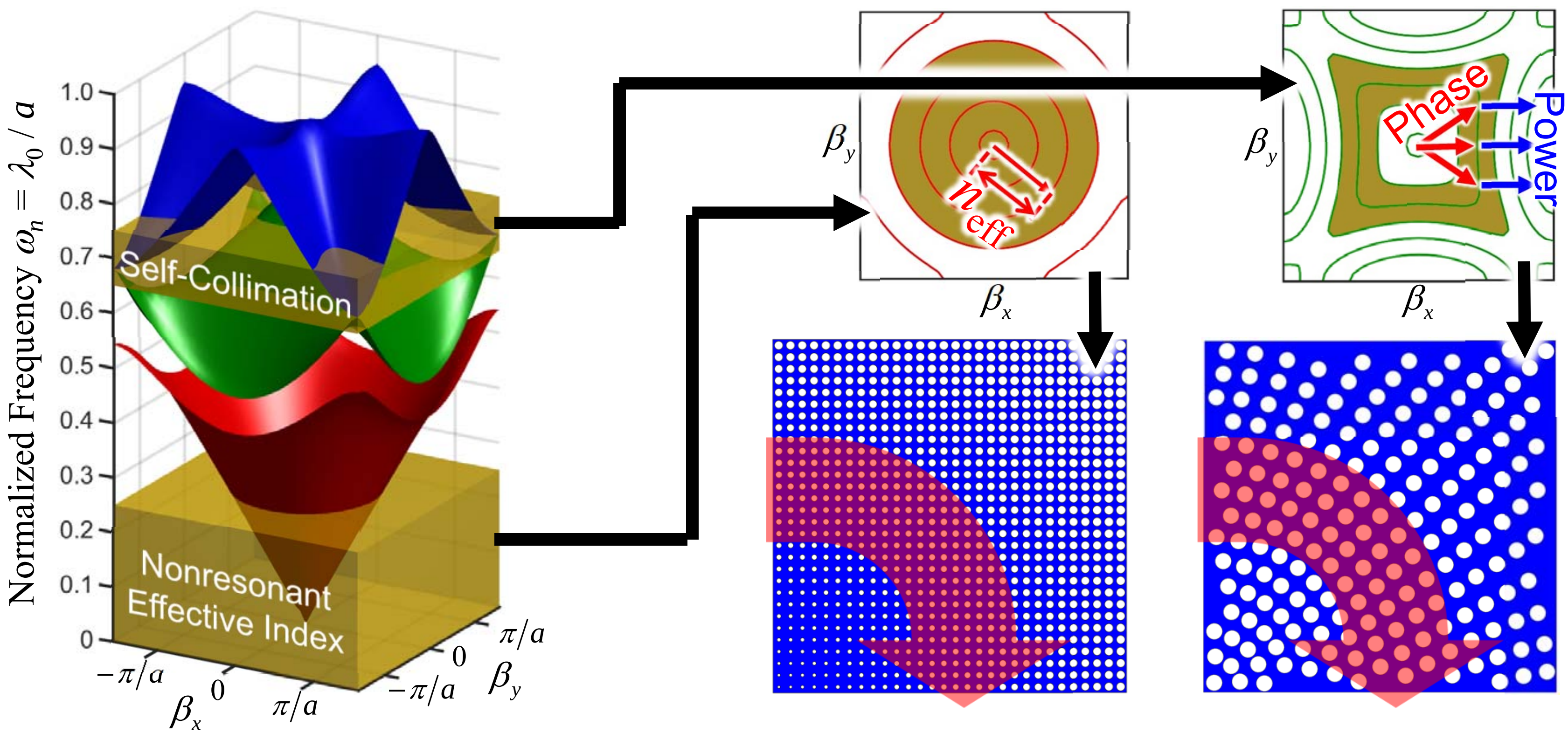
- Low refractive index
  ($n \cong 1.59$).

- Operated at λ_0 = 1.55 mm.

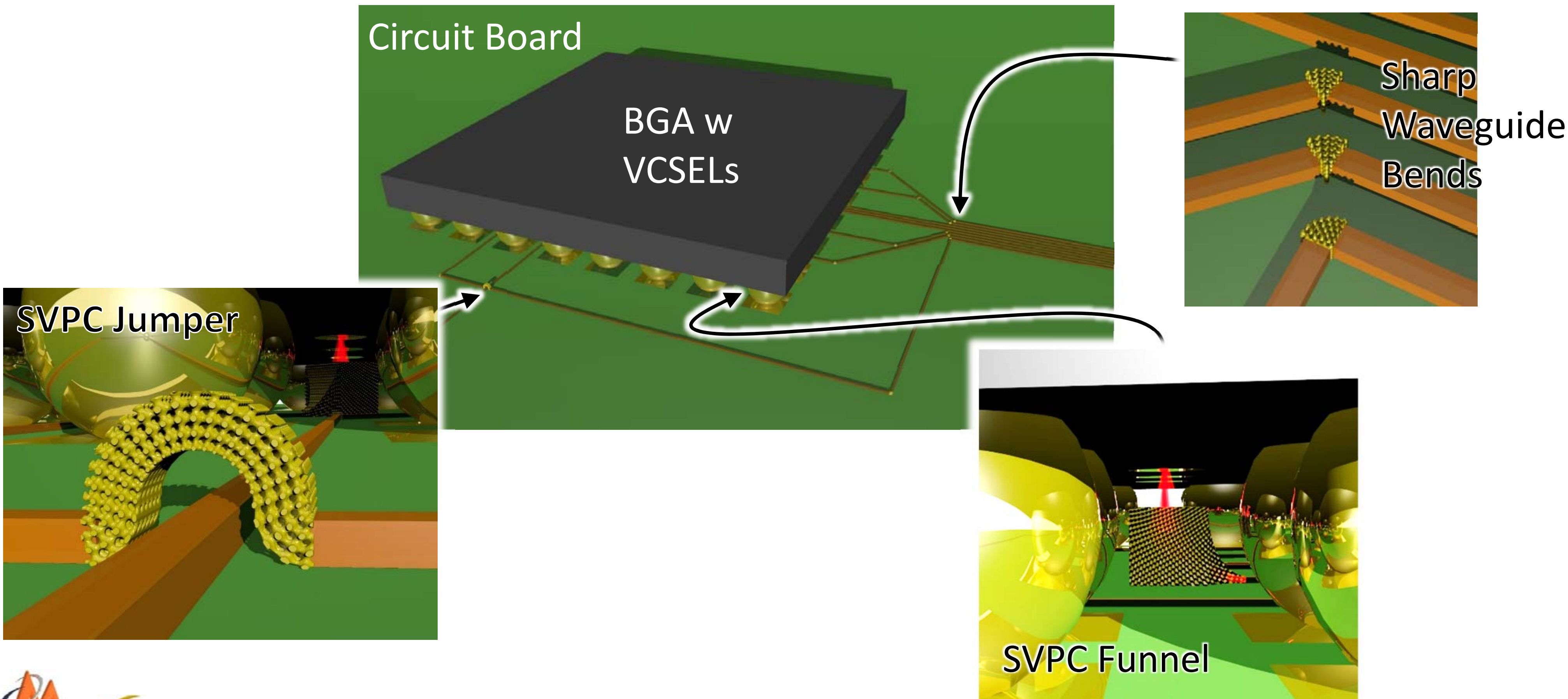


J. L. Digaum et al "Tight Control of Light Beams in Photonic Crystals with Spatially-Variant Lattice Orientation," Optics Express, Vol. 22, Issue 21, pp. 25788-25804, 2014.

SVPC Vs. Graded-Index

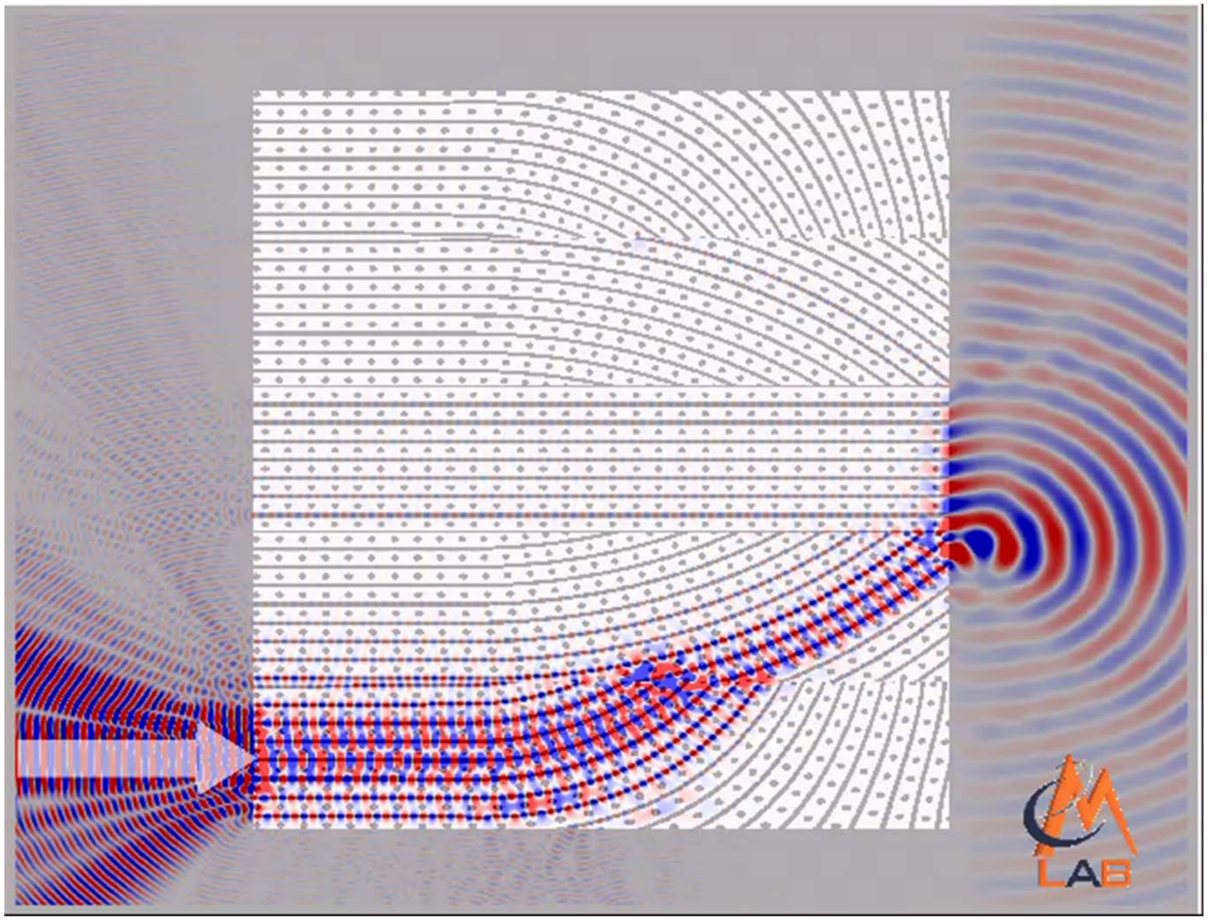


High-Speed Optical Interconnects



US Provisional Patent 62,351,565

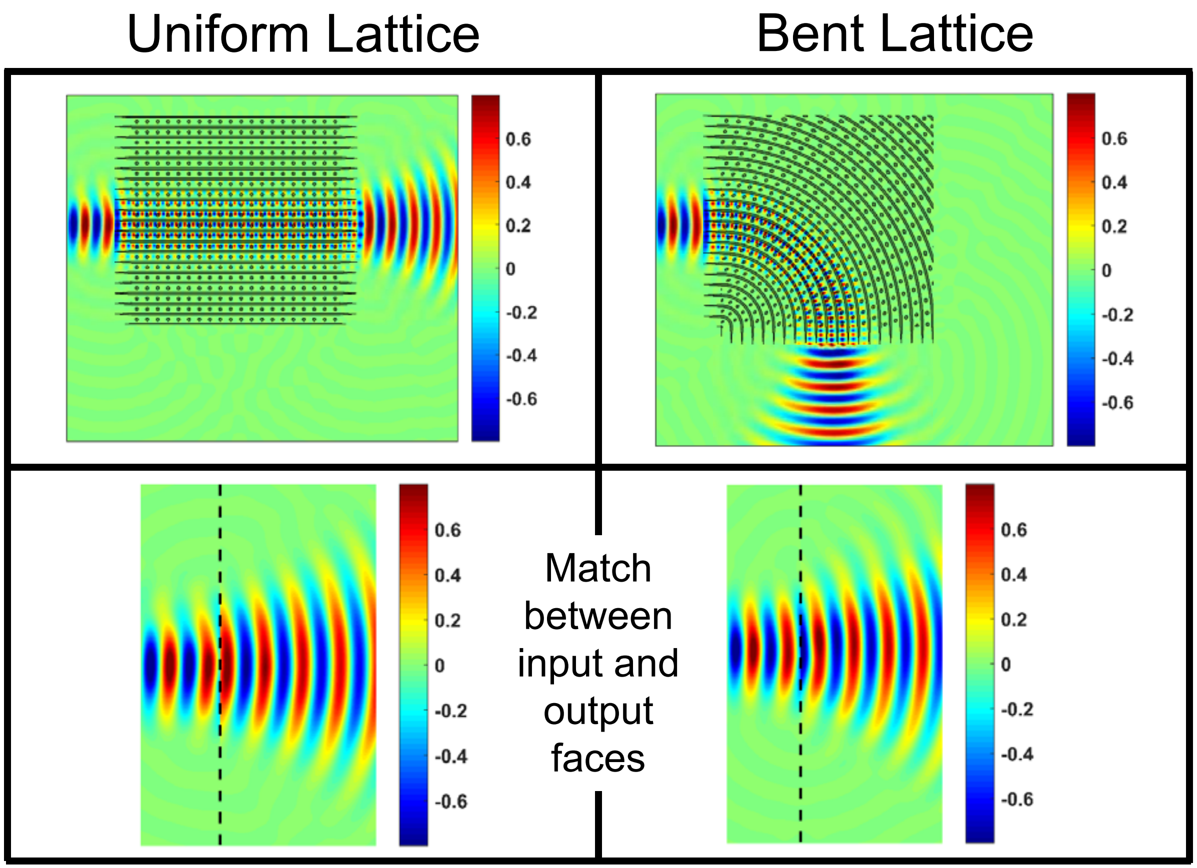
Preliminary Photon Funnel



Grant No. 1711529

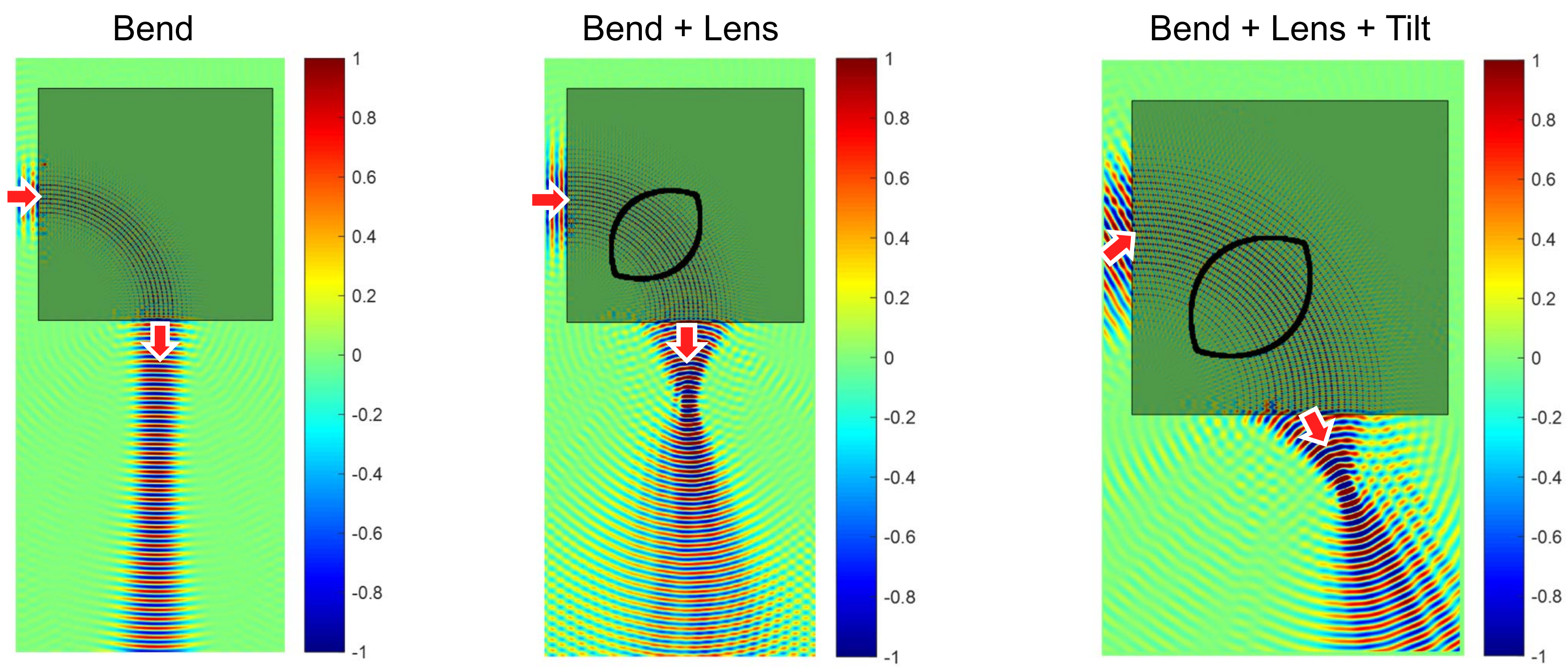
US Provisional Patent 62,351,565

Beams Through an SVPC



US Provisional Patent 62,351,565

Multiplexed Lattices



US Provisional Patent 62,351,565

THANK YOU!!

http://emlab.utep.edu