Semiconductor Plasma Phased Arrays with Integrated System Performance-to-Radiator Mapping

Project IDs: 2434019, 2434020

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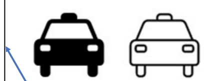
Project Summary

Spectrum Era 4:

Third-Party Coordination and Enforcement (SSMS):

In congested environments, SSMSs coordinate users, adaptively coordinate/modify rights for coexistence, and enforce penalties on violations to encourage judicious spectrum use.



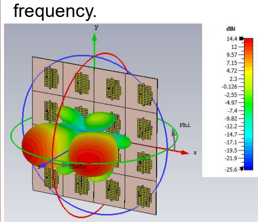
Spectrum Sharing Rights/Obligations:

Adaptive sharing is autonomous in simple cases and third-party coordinated in complex ones, but rules must be followed.

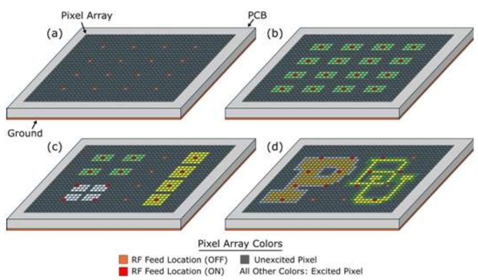
User Systems and Circuits:

Users share directly under rules in simple cases. In complex scenarios, third-party coordination is required. Systems optimize performance within prescribed limits to maximize their application needs.

PPA Algorithm demonstrates a 2-tiered optimization with interval halving and 2-D directional modulation to realize a custom radiation pattern well-match at the TX frequency.



Plasma Pixel Array (PPA) 'paints' unique conductive patch configurations, enabling reconfigurable pattern transmission and a stealth, non-conductive state.



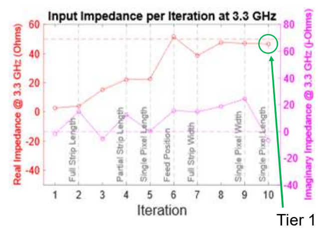
Project Progress

A two-tiered algorithm and a plasma pixel cell is being developed to realize/control the PPA's layout for a unique customizable transmit (TX) pattern.

PPA Algorithm has a two-tier approach: **Tier 1.) Layout ↔ Tier 2.) Excitation**

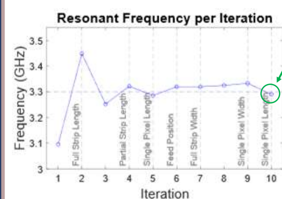
Tier 1: Optimizes PPA pixel configuration: in future will incorporate the active element pattern (AEP) to capture inter-patch coupling for a high-performance array.

Tier 2: Computes 2-D directional modulation to realize custom TX patterns by setting unique patch feed excitations.

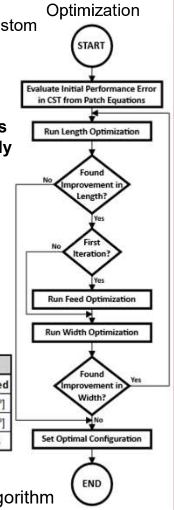


Good RF performance is achieved in only 10 iterations.

Tier 1 Optimized RF Performance



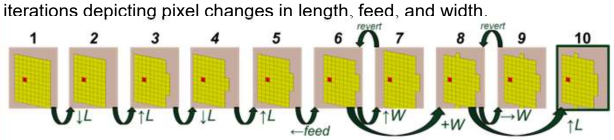
PPA Tier 1 Optimization



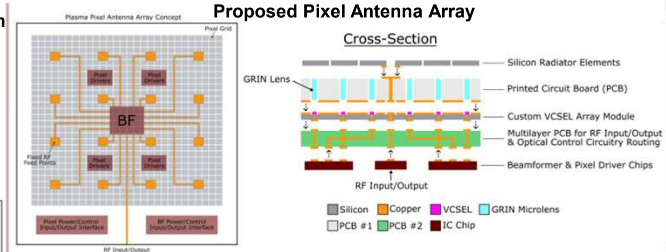
PPA Dual-Main Beam Metrics

	Desired	Simulated
Azimuth (ϕ)	[0°, 180°]	[0°, 180°]
Zenith (θ)	[25°, 25°]	[25°, 25°]
Array $S_{11,AVG}$	-10 dB	-8.3 dB

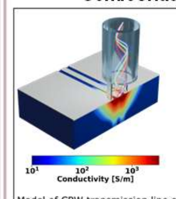
Step-by-step evolution of patch shape across algorithm iterations depicting pixel changes in length, feed, and width.



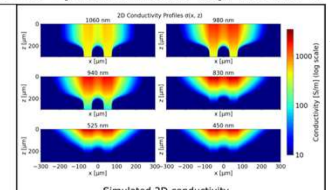
Proposed Pixel Antenna Array



Semiconductor Optimization for Improved RF Performance



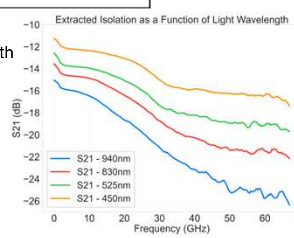
Model of CPW transmission line on silicon under focused laser illumination.



Simulated 2D conductivity profiles σ(x, z) for various wavelengths

A coplanar waveguide (CPW) microwave transmission line structure is used to optimize the silicon radiator element performance for the plasma pixel array integration.

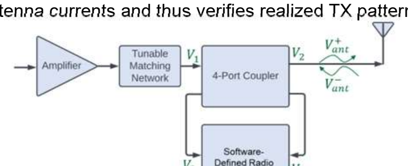
- Investigated the impact of light wavelength on carrier and conductivity profiles.
- Measured photoconductive response across the light spectrum.
- Extracted depth-dependent carrier generation and diffusion profiles.
- Identified optimal conditions for forming high-conductivity regions in Si.



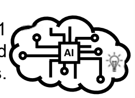
Future Directions and Broader Impacts

PPA Algorithm Future Improvements

In-situ measurement replaces CST for real-time hardware pattern reconfiguration. In-situ uses coupling to calculate antenna currents and thus verifies realized TX pattern.



AI / ML advancements can improve Tier 1 optimizations by achieving an improved PPA layout configuration in fewer iterations.



PPA Structure and Design Future Directions

- Analyze Optical Crosstalk Between Pixels
- Model lateral carrier diffusion in Si with varying lifetime properties
- Quantify crosstalk impact on adjacent pixel performance
- Assess trade-offs between conductivity and spatial resolution in array design

PPA Project Design Objectives

- Build up to a 4x4 plasma patch array hardware demonstration of the PPA in measurement.
- Incorporate an algorithm to control the PPA utilizing in-situ measurements and AI/ML intelligence for fast and accurate optimizations of the pixel layout and feed excitations enabling custom TX pattern generation.
- **We plan to visit local Texas and Indiana area high schools to discuss research results.**
- **2023-2028 SMART Hub/NSF Undergraduate "Spectrum Sizzle" Workshops**
- **Discuss this technology in academic courses and technical conferences.**

References

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