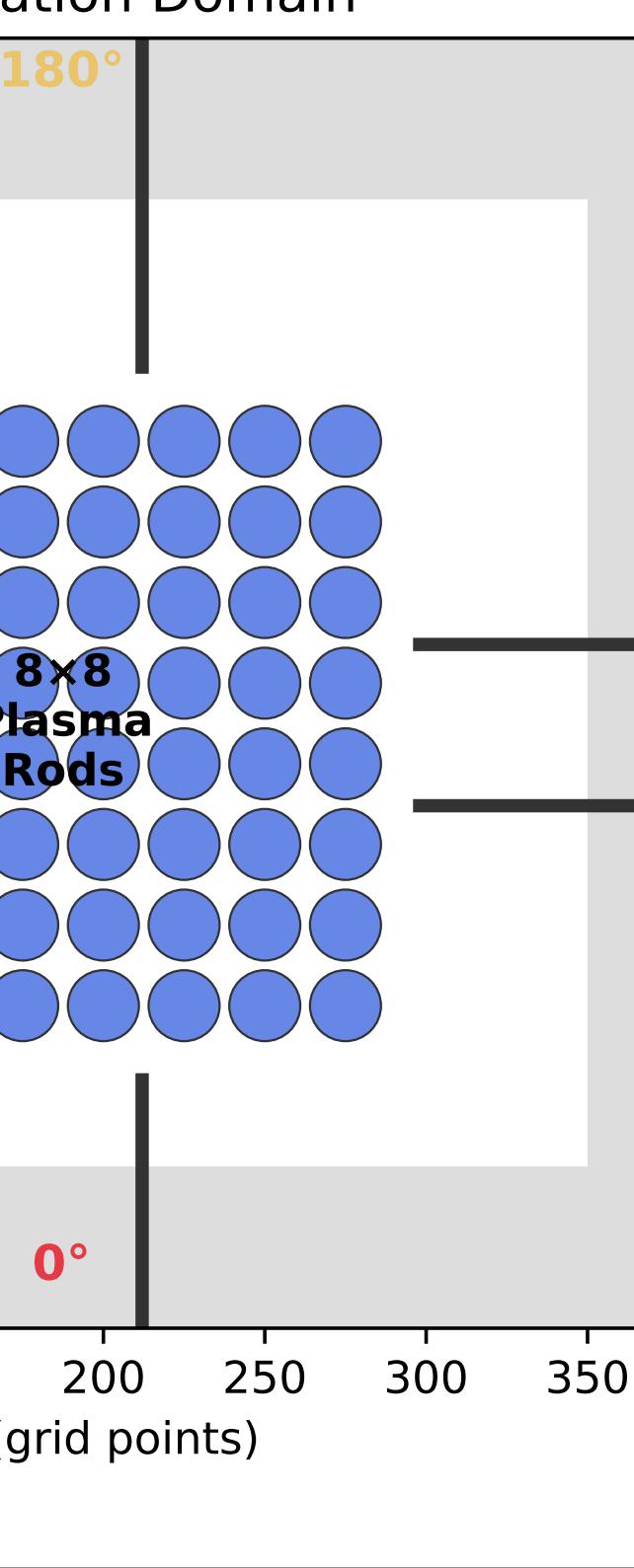


Conditional Beam Steering in Plasma Photonic Crystals via Evolution Strategies

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System

ent-free optimization match gradient-based methods for inverse EM design?



Plasma rods: $\varepsilon(\rho) = 1 - (\rho \cdot \omega_p^{\max}/\omega)^2$, $\varepsilon \in [-5.25, 1]$
Design space: $\rho \in [0, 1]^{64}$ (64 rod densities)

Simulation: FDFD solver, 400×400 grid, 6 GHz

Methods

ES-Single: Separate designs for each $\theta^* \in \{0^\circ, 90^\circ, 180^\circ\}$

$$R = P_{\theta^*} - 0.5 \sum_{\theta \neq \theta^*} P_\theta$$

ES-Multi: One design for all angles

$$R = \sum_\theta P_\theta - 0.5 \cdot \text{Var}(P_\theta)$$

ES+NN: Neural network $f_\phi: [\sin \theta, \cos \theta] \mapsto \rho_{8 \times 8}$

ES Algorithm

1. Sample $N = 100$ perturbations $\epsilon_i \sim \mathcal{N}(0, I)$

2. Evaluate $R_i = R(\theta + \sigma \epsilon_i)$ in parallel

3. Estimate gradient: $\hat{\mathbf{g}} = \frac{1}{N\sigma} \sum w_i \epsilon_i$

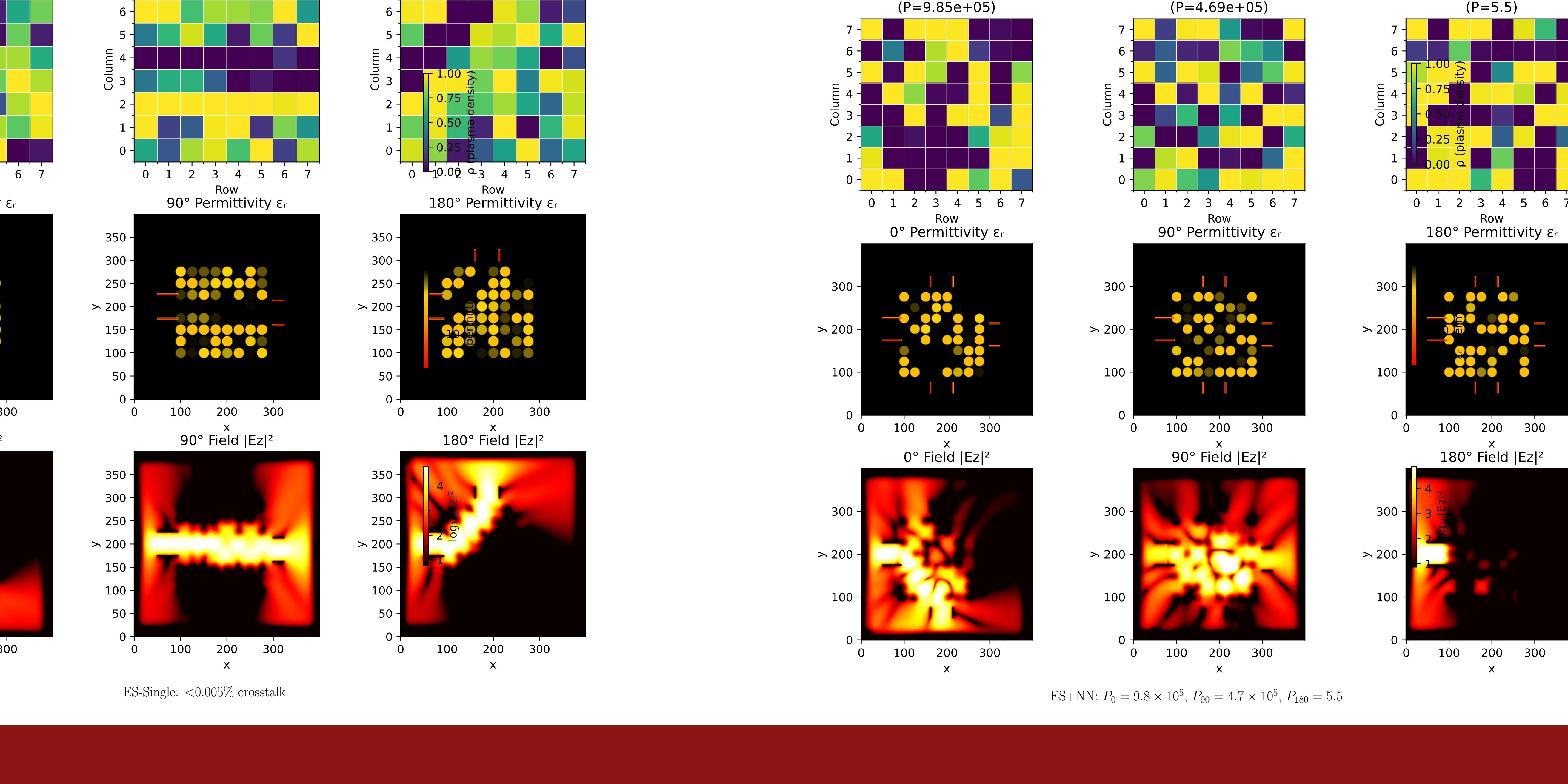
4. Update with Adam ($\eta = 0.02$, $\sigma_0 = 0.3$)

ES+NN: Same procedure, but θ are NN weights (20,928 params). Network: 4-layer MLP, 128 units per layer.

Conclusions

- ES-Single achieves <0.005% crosstalk
- ES-Multi confirms no universal design
- ES+NN reveals: $0^\circ/90^\circ$ compatible, 180° not
- Gradient-free approach is **viable**

Coder: github.com/szertan/cs229-beam-steering



ES-Single: <0.005% crosstalk

ES+NN: $P_0 = 9.8 \times 10^5$, $P_{90} = 4.7 \times 10^5$, $P_{180} = 5.5$