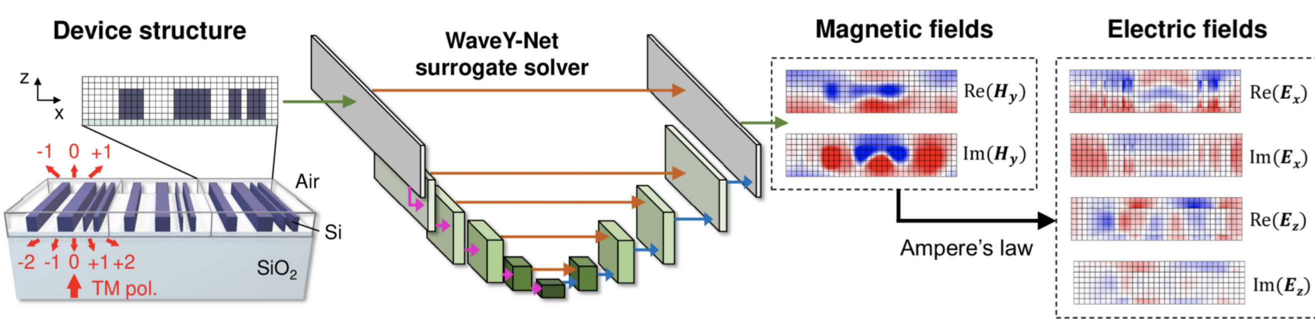
Docket #: S22-445

Denoising WaveY-Net: An ultra-fast, auxiliary neural network enhanced surrogate field solver

The Fan Lab at Stanford University has developed an ultra-fast, physics-augmented, deep learning enhanced surrogate field solver for high-speed electromagnetic simulation and optimization. Denoising WaveY-Net uses a two-stage approach to target different field error sources. The conditioned surrogate solver architecture also uses a two-stage approach to generate fullwave field solutions for a given dielectric structure. The solver generates a solution for a given set of parameters, such as wavelength of illumination, angle of incident light, polarization, and material permittivity. Denoising WaveY-Net consistently optimizes topology greater than three orders-of-magnitude faster than a finite-difference frequency-domain (FDFD) solver. Adding physics into the training process qualitatively improves outcomes beyond those obtained by adding more training data. This ultra-fast and accurate field solver can save time and money for a wide range of design and modelling applications including meta-optical devices, photonics integrated circuits, RF components, additive manufacturing, and computational fluid dynamics.



(Image courtesy the Fan Lab)

Figure 1 Schematic of a metagrating EM field evaluation with Denoising WaveY-Net. The device layout is used as the input image for the neural network, which predicts the real and imaginary part of the magnetic field Hy, which is then used to calculate the electric field components.

Stage of Development – Prototype

Applications

- **Meta-optical elements design** - design of high-performance and/or large-scale optical components, such as metagratings, metalens, metapolarizers, etc.
- **Photonic integrated circuits design** - used in fiber-optic communication, biomedical sensing, photonic computing, autonomous driving, etc.
- **RF component design** - commonly used for communication and imaging, such as 5G wireless telecommunications and magnetic resonance imaging.
- Freeform mechanical structure design, **additive manufacturing, 3D printing** – the Denoising WaveY-Net ultrafast surrogate solver can accelerate the iterative optimization based on adjoint-variable method used for the freeform inverse design process.
- **Computational fluid dynamics (CFD)** - Denoising WaveY-Net can bring orders of magnitude speed-up with high fidelity in simulation accuracy compared to existing CFD methods based on finite difference used for complex flow simulations, such as **aircraft aerodynamic simulations and complicated heat transfer processes** thermal analysis.

Advantages

- **Orders of magnitude faster and much cheaper** to solve than conventional finite element method (FEM) and finite difference frequency domain (FDFD) algorithms.
- **High speed, high accuracy, and robust functionality** compared to alternative surrogate solvers based on the use of neural networks.

Publications

- Chen, M., Lupoiu, R., Mao, C., Huang, D. H., Jiang, J., Lalanne, P., & Fan, J. A. (2022, March). WaveY-Net: physics-augmented deep-learning for high-speed electromagnetic simulation and optimization. In *High Contrast Metastructures XI* (Vol. 12011, pp. 63-66). SPIE. https://doi.org/10.1117/12.2612418
- Chen, M., Lupoiu, R., Mao, C., Huang, D. H., Jiang, J., Lalanne, P., & Fan, J. (2021). Physics-augmented deep learning for high-speed electromagnetic simulation and optimization.https://doi.org/10.21203/rs.3.rs-807786/v1

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