Docket #: S18-558

Fast, Accurate Large-Scale Metasurface Optimization

Researchers in Stanford's Nanoscale and Quantum Photonics Lab have developed a fast and accurate method to analyze large area metasurfaces. Since traditional simulation techniques (e.g., finite difference time domain, finite element method) take too long and are prohibitively expensive, metasurface designers typically use approximations - optimizing each meta-atom in isolation from the others. To design metasurfaces with higher efficiencies, Stanford researchers developed software to quickly analyze the full metasurface. Using the transfer matrix method, a system of equations based on each meta-atom's input-output relationship is used to solve for electromagnetic fields capturing the interaction between meta-atoms (figure 1). The adjoint method optimizes the full metasurface. GPU nodes accelerate solving the matrix, and decrease simulation time and cost (figure 2). Quick gradient-based optimization iterations significantly improve overall device performance (figure 3). Stanford's quick, accurate and cost effective metasurface simulation facilitates the design of efficient metasurfaces for applications ranging from virtual and augmented reality devices to other imaging, sensors, and flat optical components.

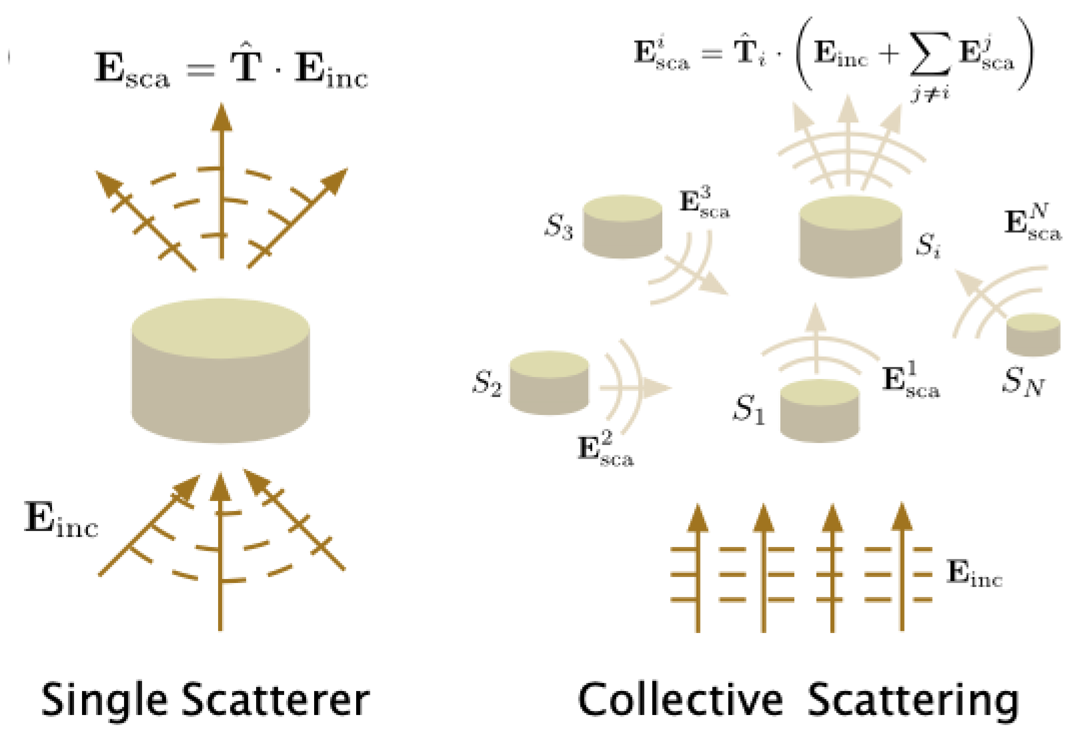

Figure 1 Schematic of a single scatter T-matrix formulation (left) and collective scattering from multiple scatterers (right).
(Images courtesy of Stanford's Nanoscale and Quantum Photonics Lab)

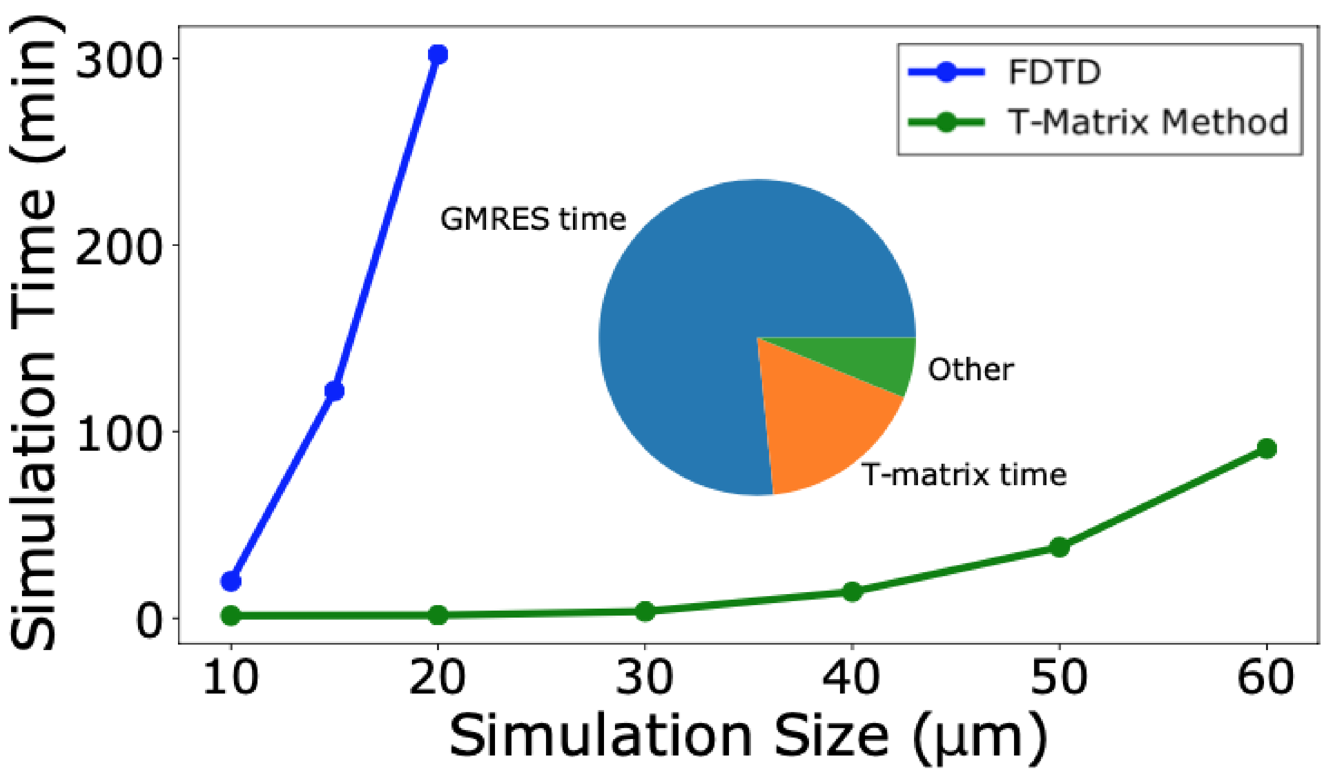

Figure 2 Simulation time versus simulation size for single GPU T-matrix method and for FDTD.
(Images courtesy of Stanford's Nanoscale and Quantum Photonics Lab)

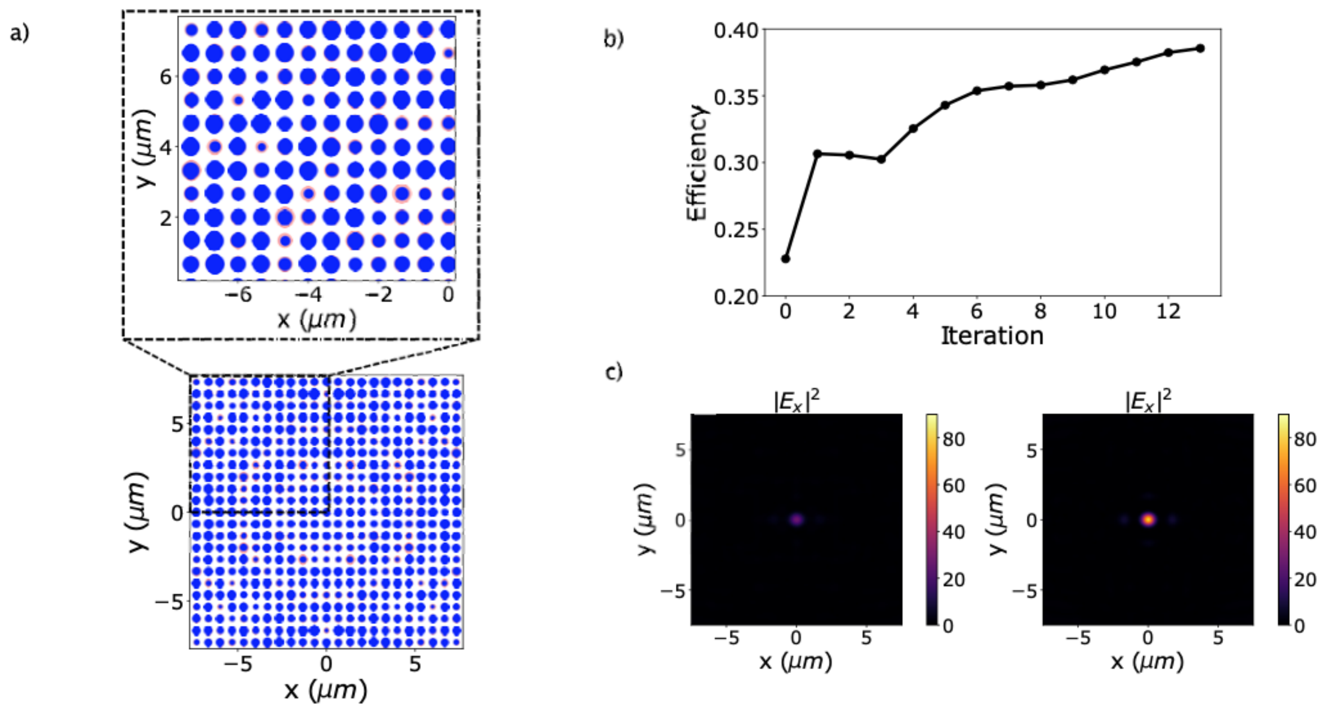

Figure 3 Optimization improvement of metalens design. (a) Metasurface scatterers before optimization (red) and after optimization (blue). (b) Lens efficiency versus optimization iteration. The metalens efficiency is nearly doubled in 15 iterations. (c) X-component of the electric field in the focal plane before optimization (left) and after optimization (right).
(Images courtesy of Stanford's Nanoscale and Quantum Photonics Lab)

Stage of Development –Prototype Software

Applications

- **Metasurface design** for:
  - **Augmented** and **virtual reality** devices (e.g. near-eye displays, AR glasses).
  - Smaller, light weight and low cost **flat optical components** to replace conventional lenses, mirrors, and prisms.
  - **Imaging, sensors, and computer vision.**

Advantages

- **Fast** and **cost-effective**
- **More accurate** - able to design more efficient metasurfaces

Publications

- Skarda, J., Trivedi, R., Su, L. et al. Low-overhead distribution strategy for simulation and optimization of large-area metasurfaces. *npj Comput Mater* 8, 78 (2022). https://doi.org/10.1038/s41524-022-00774-y
- Skarda, J., Trivedi, R., Su, L., Ahmad-Stein, D., Kwon, H., Han, S., ... & Vu?kovi?, J. (2021). "Simulation of large-area metasurfaces with a distributed transition matrix method." *arXiv preprint arXiv:2107.09879*. https://arxiv.org/abs/2107.09879

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