



Centre for Metamaterial
Research and Innovation

EPSRC Centre for
Doctoral Training
in Metamaterials

XM^2



Engineering and
Physical Sciences
Research Council

The first of these is the fact that the system is not a simple one. It is a complex system, and as such, it is not possible to understand it by looking at its parts in isolation. The system is a whole, and its behavior is determined by the interactions between its parts. This is a fundamental principle of systems thinking, and it is one that is often overlooked in traditional engineering and science.

The second of these is the fact that the system is not a static one. It is a dynamic system, and its behavior changes over time. This is another fundamental principle of systems thinking, and it is one that is often overlooked in traditional engineering and science.

The third of these is the fact that the system is not a linear one. It is a non-linear system, and its behavior is not predictable by simple linear models. This is another fundamental principle of systems thinking, and it is one that is often overlooked in traditional engineering and science.

The fourth of these is the fact that the system is not a closed one. It is an open system, and it interacts with its environment. This is another fundamental principle of systems thinking, and it is one that is often overlooked in traditional engineering and science.

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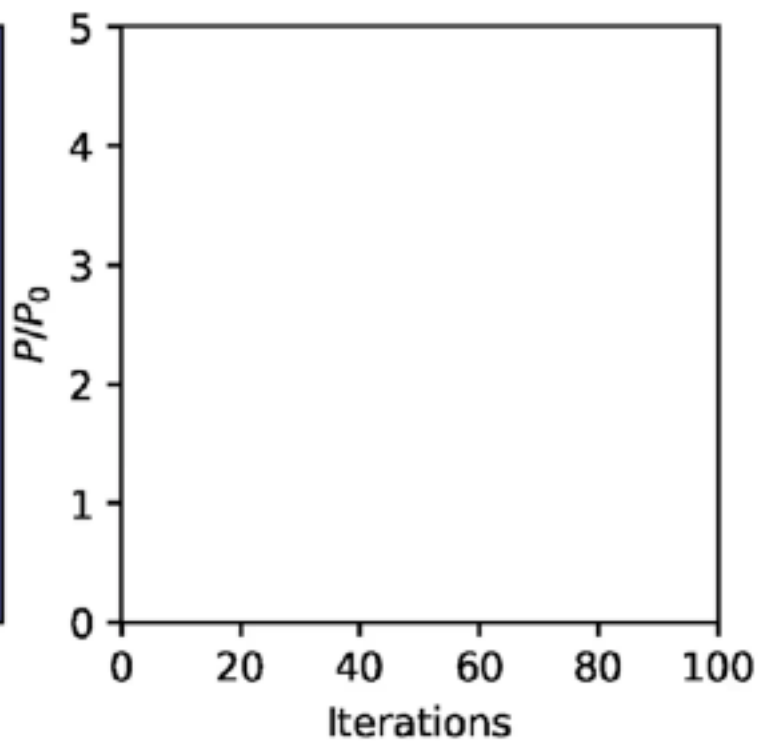
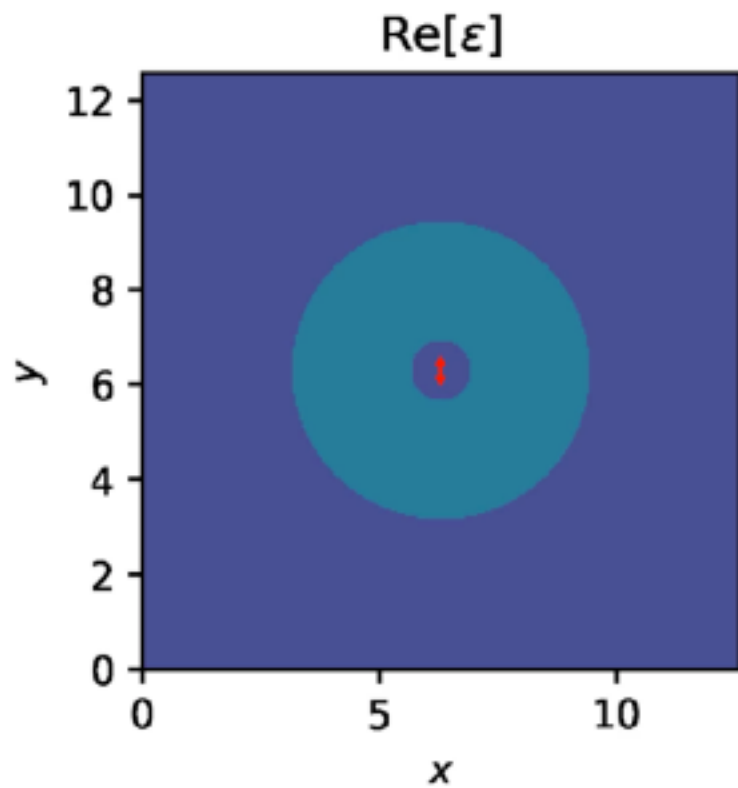
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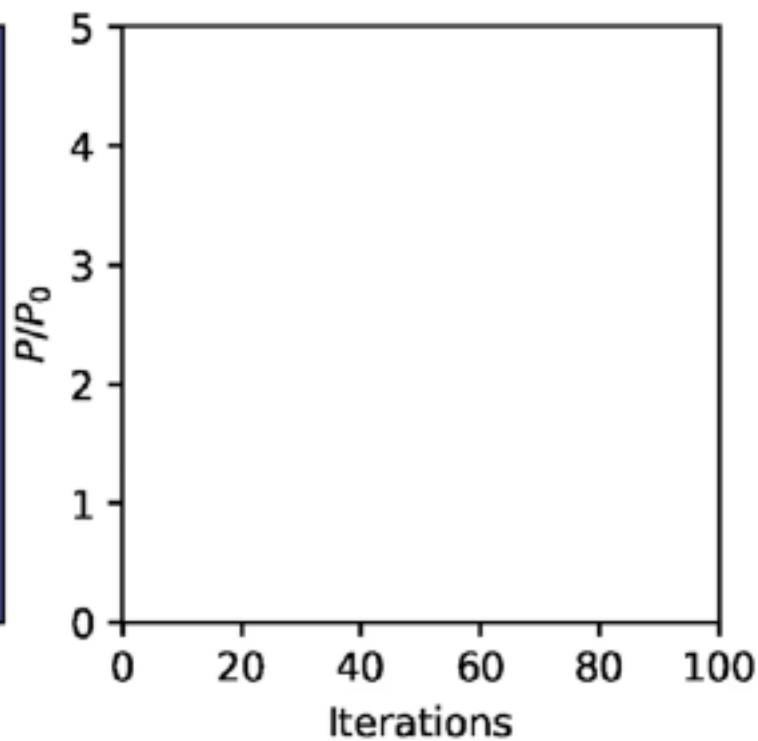
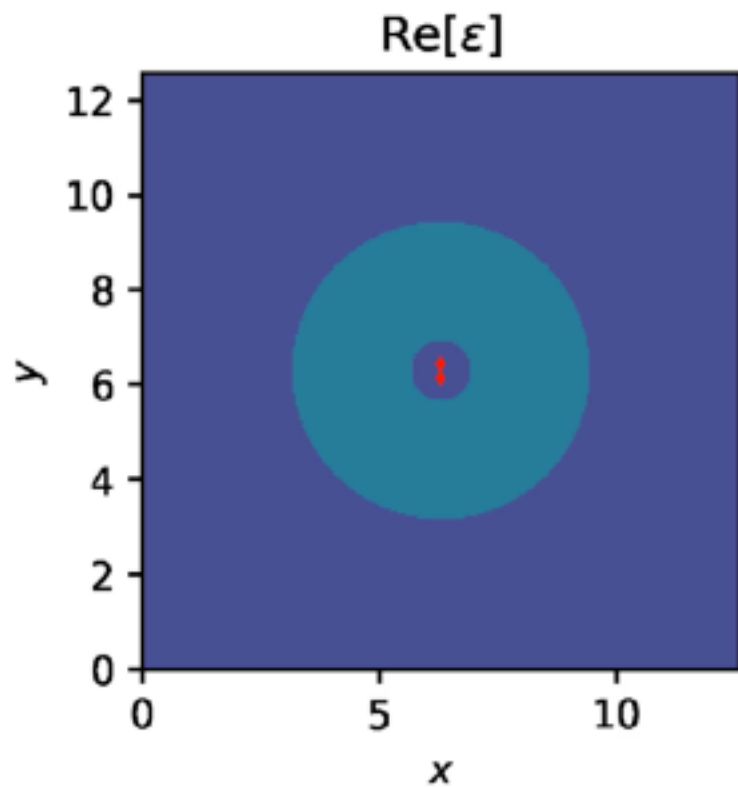
The Adjoint Method

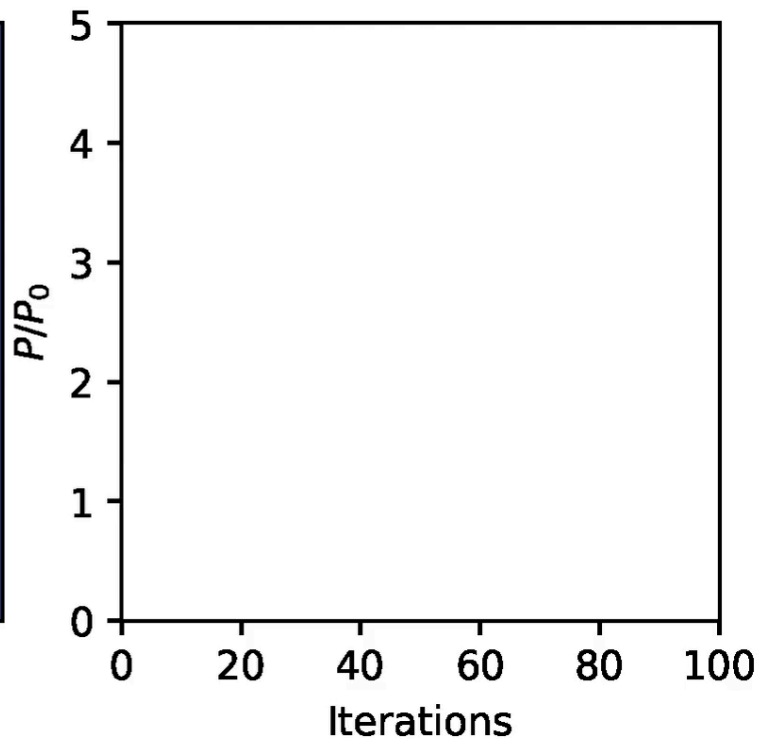
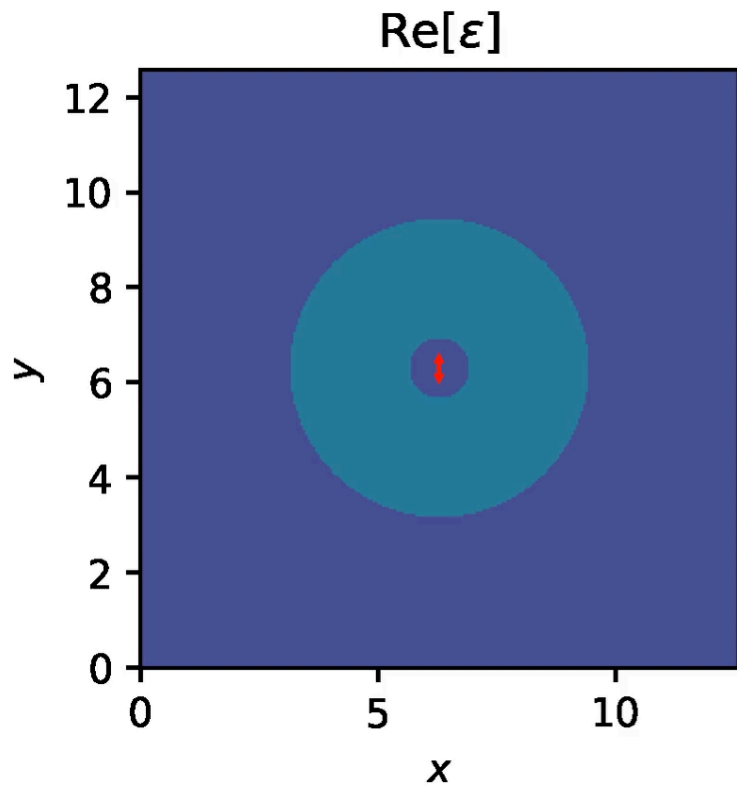


- Sandro Mignuzzi, Stefano Vezzoli, Simon A. R. Horsley, William L. Barnes, Stefan A. Maier, and Riccardo Sapienza “Nanoscale Design of the Local Density of Optical States”, Nano Lett. 19, 3, 1613–1617 (2019)
- Owen Miller, “Photonic Design: From Fundamental Solar Cell Physics to Computational Inverse Design”, PhD thesis (2012)



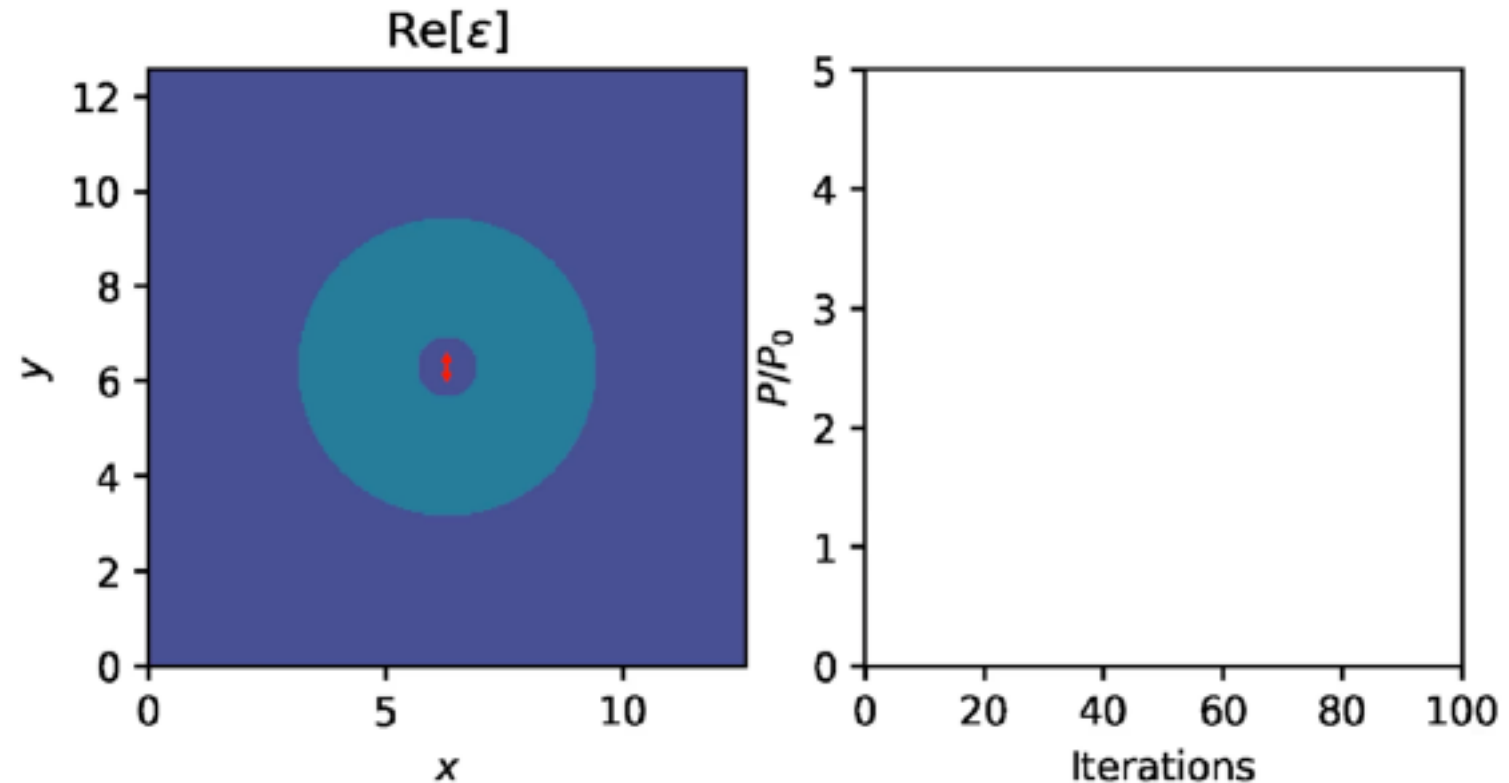
$$\delta P = \frac{1}{2} \operatorname{Im} \left[\boldsymbol{E}_*(\boldsymbol{r}) \cdot \boldsymbol{E}(\boldsymbol{r}) \right] \delta \varepsilon$$





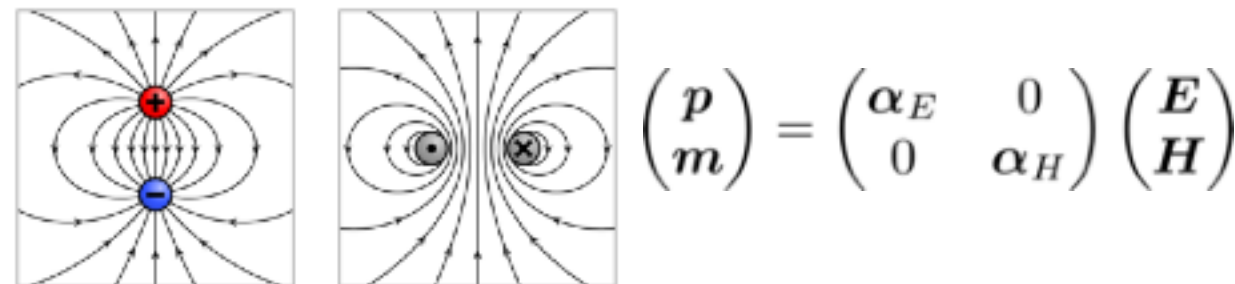
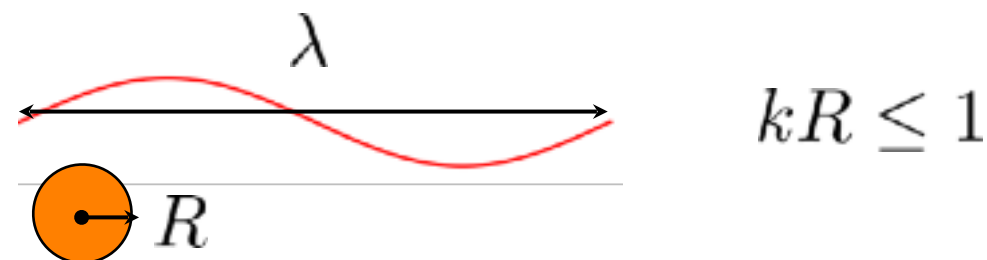
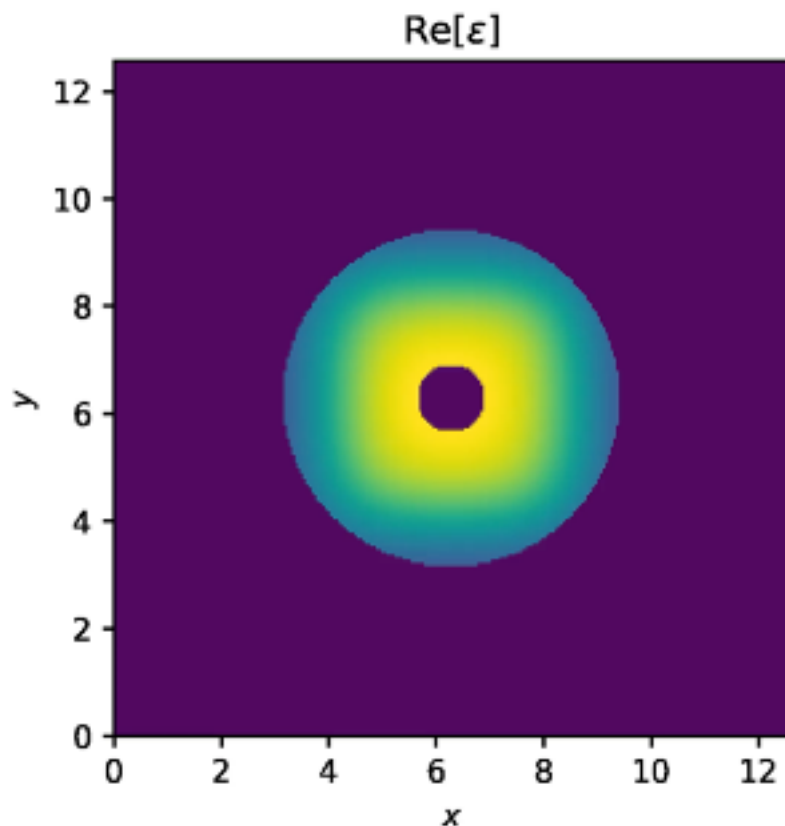
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Continuous \rightarrow Discrete



$$\begin{pmatrix} \mathbf{E}(\mathbf{r}) \\ \mathbf{H}(\mathbf{r}) \end{pmatrix} = \begin{pmatrix} \mathbf{E}_s(\mathbf{r}) \\ \mathbf{H}_s(\mathbf{r}) \end{pmatrix} + \sum_n \begin{pmatrix} \xi^2 \vec{\mathbf{G}}(\mathbf{r}, \mathbf{r}_n) \alpha_E & i\xi \vec{\mathbf{G}}_{EH}(\mathbf{r}, \mathbf{r}_n) \alpha_H \\ -i\xi \vec{\mathbf{G}}_{EH}(\mathbf{r}, \mathbf{r}_n) \alpha_E & \xi^2 \vec{\mathbf{G}}(\mathbf{r}, \mathbf{r}_n) \alpha_H \end{pmatrix} \begin{pmatrix} \mathbf{E}(\mathbf{r}_n) \\ \mathbf{H}(\mathbf{r}_n) \end{pmatrix}$$

$$\delta \mathbf{E}(\mathbf{r}) = - \left[\xi^2 \mathbf{G}(\mathbf{r}, \mathbf{r}_n) \alpha_E \nabla \mathbf{E}(\mathbf{r}_n) + i\xi \nabla \times \mathbf{G}(\mathbf{r}, \mathbf{r}_n) \alpha_H \nabla \mathbf{H}(\mathbf{r}_n) \right] \delta \mathbf{r}_n$$

- Purcell, E. M. and Pennypacker, C. R., "Scattering and absorption of light by nonspherical dielectric grains" Astrophysical Journal 186 705 (1973)