# Separating light in time and space – fully resolving partial coherence

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With lasers, we are used to working with coherent light. Recent programmable interferometer meshes in silicon photonics [1] now allow us to work with coherent fields in quite arbitrary ways [2], including manipulating coherent fields in a full modal description [3]. However, most light in the environment is at best partially coherent. For sensing in particular, being able to measure such fields could be important. Here we show [4] how we could use modal views of optics and such meshes to work with partially coherent light in a modal way, and to perform measurements and operations on it that previously were difficult or even apparently impossible. Constructing such meshes from cascades of self-configuring layers of interferometers allows particularly powerful architectures and algorithms.

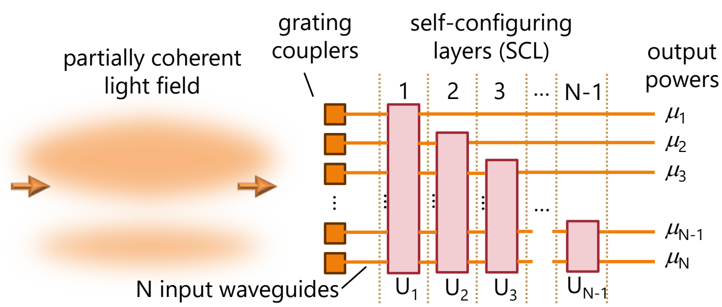


Fig. 1. An interferometer mesh made from successive self-configuring layers to separate an incoming partially coherent light field into its mutually incoherent and orthogonal modal components, which emerge from the outputs as the corresponding modal powers $\mu_1$, $\mu_2$, …. Layer settings $U_1$, $U_2$, etc., give the modal components, so also measuring the partially coherent field.

The mesh architecture in Fig. 1, working by successive layer-by-layer power optimizations at each layer output, effectively both measures the full coherency matrix of the partially coherent input light and separates it physically into its mutually incoherent orthogonal components (the "natural mode" or "Karhunen-Loève" expansion), a function not apparently previously possible. This approach can also be used to measure the full single-photon density matrix of the light [4] and an extension with two meshes can analyze entanglement of bipartite photon states [5].

Such an approach can also be used backwards to generate desired partially coherent fields [4]. Related recent insights and results now also mean we understand how to generate arbitrary volume light fields [6].

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[2] D. A. B. Miller, "Self-configuring universal linear optical component," *Photon. Res.* **1**, 1 (2013), doi: 10.1364/PRJ.1.000001.

[3] D. A. B. Miller, "Waves, modes, communications, and optics: a tutorial," *Adv. Opt. Photon.* **11**, 679 (2019), doi: 10.1364/AOP.11.000679.

[4] C. Roques-Carmes, S. Fan, and D. A. B. Miller, "Measuring, processing, and generating partially coherent light with self-configuring optics," *Light Sci Appl* **13**, 1 (2024), doi: 10.1038/s41377-024-01622-y.

[5] C. Roques-Carmes, A. Karnieli, D. A. B. Miller, and S. Fan, "Automated modal analysis of entanglement with bipartite self-configuring optics," (2024) doi: 10.48550/arXiv.2407.16849.

[6] V. S. de Angelis, A. H. Dorrah, L. A. Ambrosio, D. A. B. Miller, and F. Capasso, "Optimal structured light waves generation in 3D volumes using communication mode optics," (2024), doi: 10.48550/arXiv.2411.10865.