Self-configuring spectral filters by mapping time to space

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Meshes of integrated Mach-Zehnder interferometers (MZIs) have shown an impressive range of programmable and self-configuring optical functions for light in different spatial modes [1,2]. Though we have had many interesting and useful integrated optical spectral filters based on concepts like unbalanced interferometers, resonators, and recirculating meshes that enable programmable rings, the simple programming and self-configuration possible with "forward-only" meshes has not so far been available for spectral filtering. Now we show, both theoretically [3] and in first experiments [4], a flexible and powerful way of exploiting such meshes for fully programmable and self-configuring spectral filters.

The key concept is to use an array of waveguides of different lengths, and so of different time delays, to map different frequencies into different spatial patterns or input vectors for a self-configuring MZI mesh (Fig. 1). This time-space or frequency-space mapping allows the many interesting and powerful ideas demonstrated with such meshes for spatial beams to be transferred into time and/or frequency.

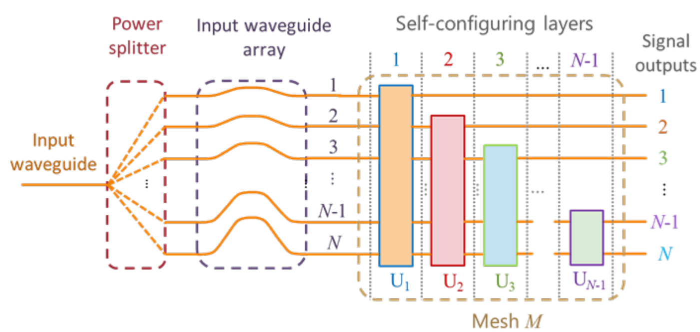

Fig. 1. Block diagram of a programmable and self-configuring spectrometer formed by adding a power splitter and a waveguide array in front of a Mach-Zehnder interferometer mesh.

In addition to conventional and fully programmable filtering operations, the approach offers self-configuring filters that tune themselves to the wavelength of interest, filters that can reject multiple arbitrarily chosen frequencies automatically, and filters that simultaneously and separately perform multiple filter functions. Proposed extensions allow very narrow line filtering without resonators (and without limitations from resonator Q-factors) with relatively small meshes and measurement and separation of partially coherent light into its mutually incoherent components. The key underlying principle of mapping time to space suggests many other interesting spectral devices may be possible even with optical structures that are not themselves intrinsically dispersive.

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4. C. G. Valdez, A. R. Kroo, M. Vlk, C. Roques-Carmes, S. Fan, D. A. B. Miller, and O. Solgaard, "Programmable Optical Filters Based on Feed-Forward Photonic Meshes," (2025). http://arxiv.org/abs/2509.12059