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Microsphere Resonators: a route to enhanced functionality in planar lightwave circuits

James S. Wilkinson, G. Senthil Murugan, Yuwapat Panitchob and Mikhail N. Zervas
Optoelectronics Research Centre, University of Southampton, Highfield,
Southampton, SO17 1 BJ, United Kingdom

Microspheres coupled to planar optical waveguides through evanescent field interaction offer compact high-Q resonators combined with a flexible choice of resonator material for lasing, sensing, filtering or all-optical switching devices. Coupling on a planar optical circuit results in robust construction, straightforward alignment of multiple and concatenated resonators, direct access to evanescent fields, high compatibility with optical fiber applications and low cost of fabrication [1].

Resonant cavities are key components in photonic circuits, providing feedback, wavelength selectivity, and energy storage to allow dispersion control and enhanced nonlinearity [2], resonant filtering [3,4], waveguiding with low bend radius [5,6] and ultra-low threshold lasing [7-9]. Silica microspheres and microcylinders with diameters ranging from a few microns to a hundred microns or more have been shown to exhibit high Q's (quality factors) of order 10^9 when an appropriate whispering-gallery mode (WGM) is excited [10], and lend themselves to evanescent coupling to optical waveguides to provide integrated resonant functions in an optical circuit. Integrated optics is a field of rapid growth in telecommunications, miniature lasers, and sensing, and planar lightwave circuits (PLCs) can potentially offer low-cost mass-manufacturable solutions for complex optical circuit requirements. Conventional optical waveguide technologies suffer from two related problems which limit dense integration. The first is that exploitation of many optical phenomena requires long optical path lengths to achieve, for example, sufficient delay in dispersion compensation, or sufficient growth of power in a nonlinear interaction. Coupling of waveguides to arrays of microresonators potentially allows energy storage, long delays and high-efficiency nonlinear interactions. The second problem is in producing tight waveguide bends with low loss to enable interconnection of multiple waveguide components in a small area. Conventional high-index waveguides and photonic crystal circuits promise solutions to this problem but coupled-resonator optical waveguides [5] provide a fascinating alternative.

The vast majority of demonstrations of microsphere resonators to date have employed light delivery by tapered optical fibres where the modes evanescently couple to WGMs of the spheres. Planar lightwave circuits offer a platform for the stable placement of individual microspheres or arrays of microspheres, with evanescent coupling to single or multiple waveguides, to realise highly functional circuits in a much more robust configuration than fibre devices. In this paper, progress in microsphere resonator photonic circuit functions will be reviewed, and potential device configurations discussed.

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