Introduction to the Issue on Microresonators

IT is widely known that whispering-gallery-mode (WGM) resonators were introduced by Rayleigh nearly a hundred years ago, in connection with the study of propagation of sound waves. Nearly 50 years later, and after the advent of the laser, optical waves in WGM resonators were first studied in the 1960s. Interestingly, these first studies with optical waves involved WGM modes in solid-state lasers. In the seventies, the dye laser had arrived and liquid dye provided an attractive system for application of WGM resonators, and many linear and nonlinear optical properties of these droplet geometries were studied. The challenging problem of efficient coupling to spherical glass microresonators found an effective solution in fiber tapers in the eighties, and advances in microfabrication techniques led to the demonstration and study of WGM microrings, which were produced in batch with semiconductor fabrication processes in the nineties. This process also allowed the realization of coupled microrings, and the engineering of the modal shapes other than Lorentzian that coupled structures made possible.

During this 40-year period, applications of optical WGM resonators were limited by the connection between the achievable quality (Q) factors on the one hand, and the ease and efficiency of in and out coupling of the resonator on the other. While Qs in the range of 10^9 were achievable with silica microspheres, coupling light in and out of the spheres still represented a challenge. Ring resonators, on the other hand, were readily coupled to waveguides that could be fabricated *in situ* with the same process by which the resonators were fabricated; yet the Qs of these batch fabricated structures remained a few orders of magnitude smaller than microspheres.

In the past five years, several new and important developments in coupling, fabrication, and materials have expanded the range of properties and applications of optical WGM resonators. As described in the two invited papers by A. B. Matsko and V. S. Ilchenko, batch fabrication of silica resonators with Qs in the range of 10^8, fabrication of crystalline resonators with Qs greater than 10^{10}, and polymer waveguides are but a few of these new developments that promise a vast array of applications—ranging from cavity quantum electrodynamics, microwave photonics, and biological sensing—to be realized. Nevertheless, the current state of the field still remains open to investigations of the fundamentals of WGM resonators: modal structures, input–output coupling, resonator geometry, coupled resonators, absorption/emission properties, and new techniques of fabrication.

This issue of the IEEE JOURNAL OF SELECTED TOPICS IN QUANTUM ELECTRONICS presents some of the latest developments in theoretical, experimental, and numerical modeling of optical WGM resonators. The two invited papers provide a summary of the field up to the current state, and contain comprehensive references. They are followed by 15 additional papers that report on recent studies in many of the areas mentioned above, ranging from the study of chaotic modes, to proposals for fabrication based on recent progress in silicon-on-insulator processes. Also included are papers that investigate new and more efficient lasers based on WGM, and studies of new coupling schemes for multiple resonators. The fact that the papers are predominantly theoretical or describe numerical modelings is indicative of the current state of the field: while it is widely believed that optical WGM resonators are poised to revolutionize the study and application of linear, nonlinear, and integrated optics and will have significant impact on many applications in science and technology, new investigations of various aspects of these structures are key to the realization of this belief. I hope that this issue of special topics provides information and inspiration that will help accelerate the already rapid pace of developments in the exciting field of optical WGM resonators.

I would like to thank the many reviewers who gave of their time to make this issue a success. I would also like to thank the authors for their contributions and their patience with the review process. This issue would not have been possible without assistance of my colleague, A. Matsko, the expert help of A. Beatrice, and invaluable assistance and support of Janet Reed and the Editorial Staff of the IEEE/LEOS.

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