On-chip Whispering Gallery Optical Resonators and Microlasers: A tool for detecting and measuring single particles and single molecules

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Abstract. Whispering-Gallery-Mode (WGM) optical microresonators, with their microscale mode volumes and ultra-high-quality factors, have shown great promise for applications in various fields of science, spanning from optomechanics and frequency combs to on-chip microcavity lasers and label-free bio-chemical sensing. In this talk, after briefly introducing the physical concepts behind these resonators, I will highlight some of the milestone applications with an emphasis on bio-chemical sensing with ultra-high-resolution. Then I will report a new sensing method that we have developed for the detection and measurement of individual nanoparticles. Contrary to the conventional approach of monitoring spectral changes in a single resonance, this new technique rely on the splitting of a single resonance mode into two resonances upon perturbations within close proximity of the resonator. I will first present the results of experiments using passive WGM microtoroid resonators, with which polystyrene nanoparticles down to 20nm and individual Influenza virions could be detected and measured one-by-one with a single shot measurement [1]. Then, I will show how the detection limit can be improved to reach down to 15nm for polystyrene, 10nm for gold nanoparticles, by incorporating a gain medium (rare earth ions such as erbium and ytterbium) into the resonator and using it as a microlaser [2]. I will end the talk with a discussion on some of the opportunities and challenges.

[1] J. Zhu, S. K. Ozdemir, Y.-F. Xiao, L. Li, L. He, D.-R. Chen & L. Yang, Nature Photonics 4, 46 - 49 (2010).
[2] L. He, S. K. Ozdemir, W. Kim, J. Zhu, & L. Yang, Nature Nanotechnology 6,428–432 (2011).