Side-pumped WGM Milled Microstub Resonator Laser

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Whispering Gallery Mode (WGM) resonators are promising candidates for realization of ultra-small micro lasers. Conventional 3D resonators such as micro toroids [1], micro spheres [2, 3] and microbottles [4] are well studied as both passive and active devices. The excitation and signal collection are mostly done using evanescently coupled micro-sized fibers [5], integrated waveguides [3] and\or collecting the scattered light [6]. As the spectrum and coupling efficiency highly depend on the excitation position, the coupling system requires precise alignment, and packaging is complex. Here, we demonstrate a completely new micro laser based on WGM generated in an Yb^{3+}-doped stub resonator side-pumped at 976nm wavelength.

The device is fabricated based on material ablation by a pulsed CO_2 laser. Micro grooves are initially milled by a CO_2 laser around a 240µm-thick fiber with 200µm-thick doped core to form the desired length of the stub resonator, then the structure is fire-polished by electrical arcs in a fusion splicer in order to improve the surface quality. The quality factor of the fabricated resonator exceeds 10^6. As illustrated in Fig. 1a, the device is separated in three regions where the first section shapes the pump mode before entering the resonator acting as a lens or multimode interferometer, then, WGMs are generated in the resonator section, and finally, pump residuals and generated signals are coupled out through the fiber stem. The efficiency and selection of WGMs as well as the output coupling can be controlled by precisely engineering the micro grooves shape. This is an advantage over our previous work [7] which involved time consuming cleaving and splicing separate piece of fibers to form the cavity. The pump, from a single mode fiber, is coupled through free space into the resonator, hence, it is possible to optimize the coupling condition in order to reach a wide range of azimuthal WGMs by offsetting the launch fiber along the doped fiber facet. Figure 1b shows the scattered light when the device is pumped almost from the center of the coupling section. The scattered light shows the formation of WGMs close to the surface of the resonator. The spectra of the collected signals guided through the fiber stem are plotted in Fig. 1c. Lasing peaks corresponding to WGMs of the resonator are observed at 1060nm-1110nm wavelength range. The threshold, efficiency and spectra of the laser can be further enhanced and controlled by varying the length of the resonator.

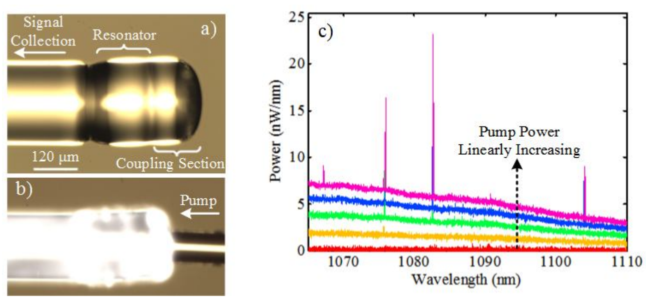

Fig. 1 a) Milled microstub resonator, b) optical image showing scatter light from the device, and c) power spectra of the collected signal as a function of pump power.

This is a fundamental step towards development of stand-alone, robust and unified WGM microresonator lasers where the pump launching and signal collection are achieved through the same fiber stem in order to eliminate all the concerns about conventional coupling and launching optics in WGM microresonators. Moreover, by using CO_2 laser milling, the fabrication time is significantly shortened, as well as improved control on the geometrical parameters of the resonator. Furthermore, having fiber stems linked to the sides of the resonator, makes the structure intriguing for sensing applications.

References

[1] D. K. Armani, T. J. Kippenberg, S. M. Spillane, and K. J. Vahala, “Ultra-high-Q toroid microcavity on a chip,” Nature 421, 925–928 (2003).

[2] V. Sandoghdar, F. Treussart, J. Hare, V. Lefèvre-Seguin, J.-M. Raimond, and S. Haroche, “Very low threshold whispering-gallery-mode microsphere laser,” Phys. Rev. A 54(3), R1777–R1780 (1996).

[3] G. S. Murugan, M. N. Zervas, Y. Panitchob, and J. S. Wilkinson, “Integrated Nd-doped borosilicate glass microsphere laser,” Opt. Lett. 36, 73–75 (2011).

[4] G. Senthil Murugan, J. S. Wilkinson, and M. N. Zervas, “Selective excitation of whispering gallery modes in a novel bottle microresonator,” Opt. Express 17, 11916-11925 (2009).

[5] M. Cai, O. Painter, K. J. Vahala, and P. C. Sercel, “Fiber-coupled microsphere laser,” Opt. Lett., 25(19) 1430-1432 (2000).

[6] G. S. Murugan, J. S. Wilkinson, and M. N. Zervas, “Optical microdiscus resonators by flattening microspheres,” Appl. Phys. Lett. 101, 071106 (2012).

[7] G. S. Murugan, S. Bakhtiari-Gorajoobi, C. A. Codemard, M. N. Mohd Nasir, G. Y. Chen, A. Langner, and M. N. Zervas, “Optical microstub resonator lasers,” Proc. SPIE 8960, Laser Resonators, Microresonators, and Beam Control XVI, 896018 (2014).

Separate 35-word abstract to be uploaded:
A new Yb^{3+}-doped silica high Q WGM microstub resonator laser fabricated by CO_2 laser milling is demonstrated. Fabrication time is short, and unique structure of the resonator allows realization of robust lasers and sensors.