Performance Parameter Decoupled High Efficiency Micro Ring Laser Cavity for Biosensing

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High quality (Q) factor micro resonators have shown many promising biosensing applications during recent years[1-5]. A higher Q means a narrower resonant peak, thus, in principle, a smaller resonant wavelength shift can be detected which corresponding to a lower detection limit. One way to dramatically increasing the Q of a micro cavity is to provide gain inside the cavity and transform it into a laser. Recently, a Yb^{3+} doped Al_2O_3 micro ring laser sensor has been demonstrated[6]. However, design and optimize the performance of an optically pumped micro ring laser sensor is very difficult with the typical ring structure. This is due to the fact that every physical parameter (such as waveguide width, thickness, ring radius, and gap size) is entangled with multiple performance parameters (such as sensitivity, free spectral range and laser threshold). We proposed a design methodology in our previous work[7] to overcome this difficulty by decoupling the performance parameters into several regions in the cavity as shown in Fig. 1. (a). In this work, we describe the fabricated device and shown its preliminary experimental results.

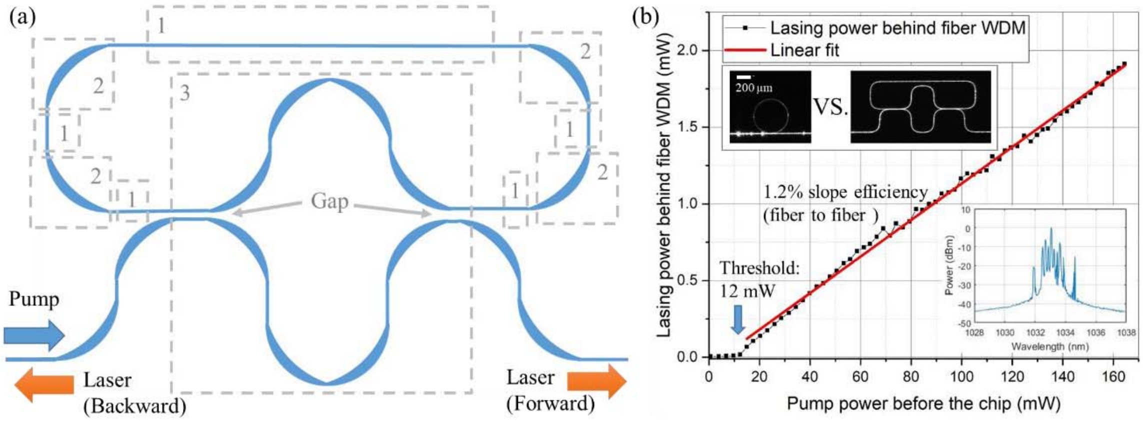

Fig. 1. (a) The proposed micro ring laser cavity. Blue lines are the waveguides. The regions 1 (indicated with dashed gray boxes) are used for sensitivity (the waveguide width and thickness) and free spectral range (length) design. The regions 2 are adiabatic bends, with negligible bending loss and straight to bend coupling loss. Region 3 is a Mach-Zehnder interferometer based Wavelength Division Multiplexing (WDM) for coupling strength tuning of the pumping and lasing wavelength. (b) Backward lasing power vs. pump power. The top inserts are top view images of a typical ring laser and a proposed device lasing in H_2O. The bottom insert is a typical multimode lasing spectrum of the proposed device.

The proposed cavity design has been fabricated on a Si wafer. The bottom cladding is 8 μm thick thermal SiO_2 layer. The core is Yb^{3+} doped Al_2O_3 waveguide with a thickness of 400 nm. The top cladding is H_2O. A fiber to fiber slope efficiency of 1.2% has been measured. The typical lasing power of this design is a factor 10~30 higher than the typical simple ring structure at the same external pump power. This is due to the fact, as shown in the top insert of Fig. 1. (b), that much more pump power (ideally 100%) is coupled into the cavity through the WDM compare with the coupling between a straight waveguide and a ring, which is typically less than 1% for high Q rings. A typical multimode lasing spectrum of the proposed device is shown in the bottom insert of Fig. 1. (b). The sensitivity characterization of these devices will be performed in the near future.

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