Gas Flow Sensor using a Hollow WGM Microlaser

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1. Introduction

Hollow microcapillary and microbubble whispering gallery resonators have the unique feature of allowing a (gain) medium to fill their inner volume as already demonstrated in the case of the dye-filled microbubble laser, capillaries, and on-chip micro fluidic channels [1]. A desired feature of any laser is the ability to tune the frequency of the laser output. Tuning a micron-sized WGR in a fashion that does not add to the footprint of the device or require significant fabrication is a nontrivial task. The main approaches thus far are external heaters, applying stress/strain via an external clamp or aerostatic tuning [2], electric fields or thermo-optic tuning [3]. Each of these methods has its own advantages and disadvantages.

Here, we experimentally explore, for the first time, the idea of silica microbubble or microcapillary resonators coated with a layer of laser glass, in this case Yb:Er doped phosphate glass (Kigre, Inc). This is realized by the fact that the two glasses have different melting points. The Er:Yb doped glass outer layer is pumped at 980 nm and lasing is observed at 1535 nm. Thermal tuning of the lasing mode over 70 GHz is achieved by flowing air through the cavity. The cavity can also be passively probed at 780 nm. In this passive regime gas flow sensing using the concept of a “hot cavity” is discussed and preliminary measurements and characterization of the system is presented.

2. Experiment

A microcapillary with an OD of 350 μm and an ID of 250 μm was tapered, using a CO_2 laser, to a uniform waist with an OD of approximately 80 μm. Next, a glass wire was drawn from a bulk piece of Yb:Er doped phosphate glass (Kigre). The diameter of the doped glass wire was typically a few tens of microns. The doped glass wire was then placed on top of and in contact with the microbubble and the CO_2 laser beams were applied again. The CO_2 laser power was increased until the doped glass wire was melted onto the capillary. At this point the doped glass wire was removed and the CO_2 laser power was controlled to allow the remaining doped glass to flow onto and around the capillary. When the doped glass completely covered the capillary, the CO_2 laser was turned off. The resulting geometry is a hollow microbottle shaped resonator, see inset of Fig. 1.

A tapered fiber with a diameter of 1 μm was connected to a 980 nm diode laser. The tapered fiber was placed into contact with the equator of the doped glass microbottle resonator. The output end of the tapered fiber was connected to an optical spectrum analyser and lasing was observed at 1535 nm, see Fig. 1.

In the passive mode, the optical modes of the microcavity were probed using a tuneable 780 nm laser. At this wavelength the Q factor of the WGMs was estimated to be in excess of 10^5.

One end of the capillary was connected to a source of pressurized air via a pressure regulator. The input pressure to the capillary was increased and the position of the WGMs in the transmitted signal was recorded. As the pressure was increased the WGMs were observed to shift towards shorter wavelengths. This shift is assumed to be due to the cooling effect of the air flow through the capillary.

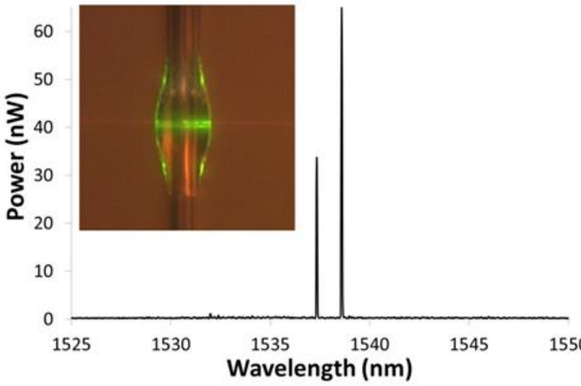

Fig. 1. The lasing spectrum from an Er:Yb doped glass microcavity formed on the outer surface of a microcapillary with a diameter of 70 μm. Inset: image of the microlaser.

The output end of the capillary was connected to a mass flow sensor. The shift rate of the WGMs as a function of output flow rate and laser power was measured.

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References

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