# Flow sensor based on heated-FBG by multiple pump lasers

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**Abstract:** This paper presents the preliminary results of a novel flow sensor constructed by a FBG and six Cobalt-doped fibers. The grating can be heated up by the $Co^{2+}$-doped fiber pumped with lasers.
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## 1. Introduction

Fiber Bragg gratings (FBGs) have been demonstrated to be good fiber-optic sensors due to their detection accuracy, fast response, EM immunity and simple interrogation [1]. In recent work, we have demonstrated that Cobalt-doped fiber can be heated up by laser. A short length of $Co^{2+}$-doped fiber with an inscribed FBG can be used as flow sensor based on the principle of hot-wire anemometry [2,3]. Similarly, FBG in close proximity to $Co^{2+}$-doped fibers can also be heated up by launching laser light to the $Co^{2+}$-doped fiber, and corresponding wavelength shift in the FBG should be observed. The flow speed of oil in down-holes is important information and thus there is the need to measure the flow velocity of oil up to 10 km away from the data logger. To measure the flow rate, thermal flow sensors are widely used [4] based on the effect of thermal convection. However, conventional electrical sensors typically cannot operate at more than several 10's of meters away from the data loggers. This limits their applications in down-holes environment, and fiber-optic sensors offer many other advantages such as spark-free and small size.

In this paper, we present a novel flow sensor based on FBG surrounded by six $Co^{2+}$-doped fibers. FBG can be heated up to very high temperature by pumping laser light to $Co^{2+}$-doped fibers. Temperature increase of 80˚C is maintained after placing the sensor in the water, which is high enough to measure the flow rate of the water flowing in a pipe.

## 2. Fabrication of the flow sensor

To fabricate the flow sensor, an FBG was inscribed in single mode fiber (SMF) using phase mask technique by scanning a 213-nm laser beam. The grating length is less than 3 mm to avoid the chirp effect after heated up. A capillary with outer diameter (OD) of ~600 µm and ID/OD=0.76 was prepared and tapered down to ID=385 µm. A certain inner diameter was chosen so as to stack seven fibers in a hexagonal structure. The schematic figure of the fabrication is illustrated in Fig. 1.

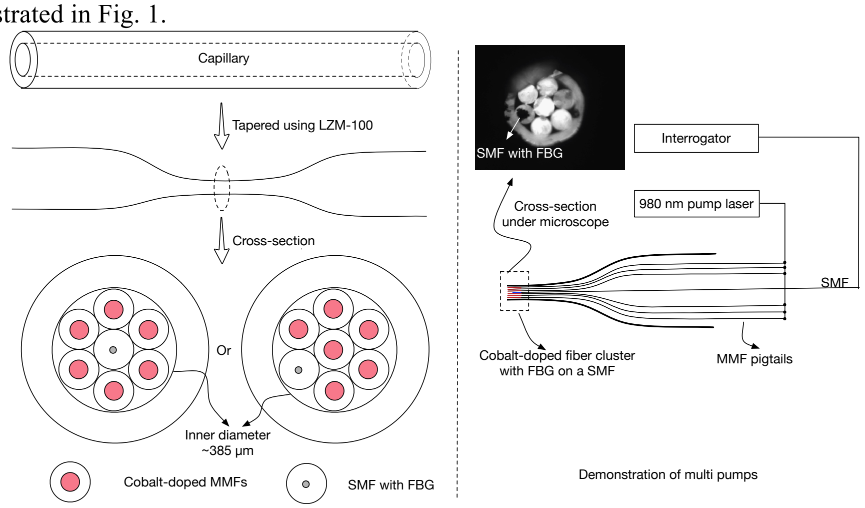


Fig. 1 Schematic figure of the fabrication of the flow sensor and the demonstration of multi-pumping scheme

Six $Co^{2+}$-doped multimode fibers with core diameter of 50 µm and cladding diameter of 125 µm were spliced to 50/125 µm standard MMFs. The length of $Co^{2+}$-doped MMFs is less than 7 mm. Careful alignment was conducted to ensure that the FBG fiber and six $Co^{2+}$-doped MMFs are at the same position during staking in the capillary, as shown in Fig. 1. Seven fibers were combined tightly due to the matched inner diameter of the tapered-capillary. It has to stress that the single mode fiber with FBG may be placed outside instead of in the center, and its position makes very small difference due to the compact size. The advantage of the proposed flow sensor is that six $Co^{2+}$-doped fibers with MMF pigtails can be pumped simultaneously to attain higher temperature to measure flow-rate of heated oil. MMF pigtails and SMF can be designed with longer length to implement long-distance measurement.

## 3. Experimental results

Fig. 2 shows the wavelength shift of the FBG heated by the $Co^{2+}$-doped fiber where only one MMF pigtail was pumped by 980 nm laser in the air and water, respectively. It can be observed that wavelength shift of about 6.2 nm is obtained when pumping one $Co^{2+}$-doped fiber in air, corresponding to an increase of over 600 ˚C in temperature. The wavelength shift is about 0.4 nm, indicating that the grating is heated to 40˚C in the water. It should be noted that by increasing pump power, higher temperature in the water has been achieved, which is over 80˚C.

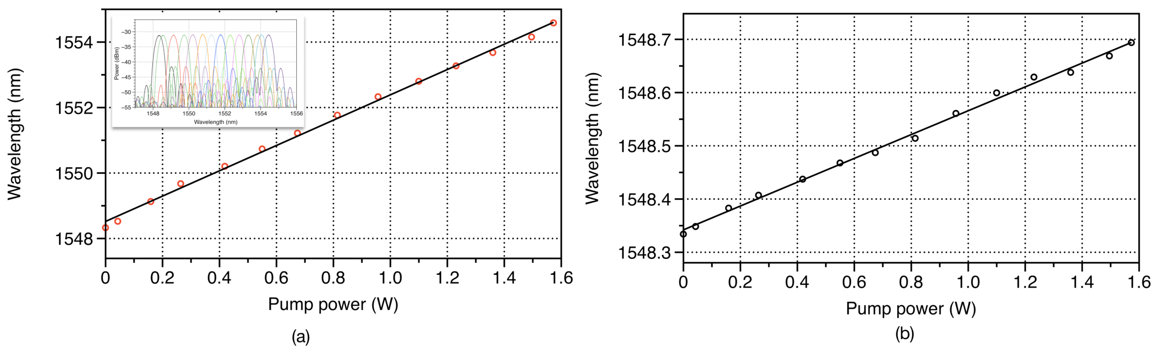


Fig. 2 Wavelength shift of the flow sensor with only one MMF pumped by 980 laser when placed (a) in the air and (b) in the water. Inset shows the spectrum shift

Fig. 3 plots the spectrum shifts of the flow sensor when only one $Co^{2+}$-doped fiber was pumped, and two $Co^{2+}$-doped fibers were pumped. About two times higher temperature was obtained by pumping two $Co^{2+}$-doped fibers. This demonstrated the capability of using multiple lasers to pump all the $Co^{2+}$-doped fibers so that even higher temperature can be achieved, especially when placed in the water.

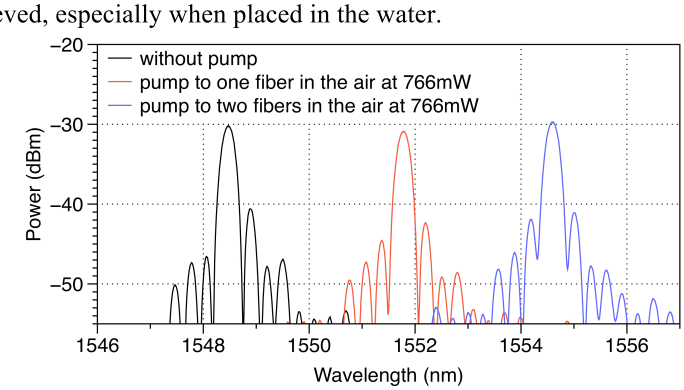


Fig. 3 Spectrum shift of the FBG when only one and two Co-doped fibers were pumped by 980 nm laser, respectively

## 4. Conclusion

In this paper, we presented a novel flow sensor based on FBG and $Co^{2+}$-doped MMFs. FBG function as the sensing head while the $Co^{2+}$-doped MMFs combined close to FBG were the heating elements. Higher temperature can be heated up in the air and in the water, however, no chirp effect was observed due to the short grating length. The capability of multiple-pumping scheme was demonstrated, which is very useful to get enough heating temperature in the water. Further experiments of measuring the flow speed using the proposed sensor will be conducted and presented at the conference.

## 5. References

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