Fibre-optic Sensors for Flow Rate Monitoring

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Background and Motivation

Flow rate measurement is important in the industry process and daily life, different kinds of sensing applications based on mechanical and electrical methods have been reported.

Fibre optic sensors have many unique advantages such as small size, anti-electromagnetic interference, anti-corrosion and the possibility of distributed monitoring over a long range. This project is to utilise fibre-optic techniques in fluid dynamic measurement.

Aims

- To develop a novel fibre-optic flow meter, which is
  - Sensitive & cost-efficient
  - Robust & easy to implement
- To assess the performance of the designed structures

Method I – Target Flow Meter

Fibre Bragg gratings (FBGs) + Bending Cantilever Beam(BCB) as transducer

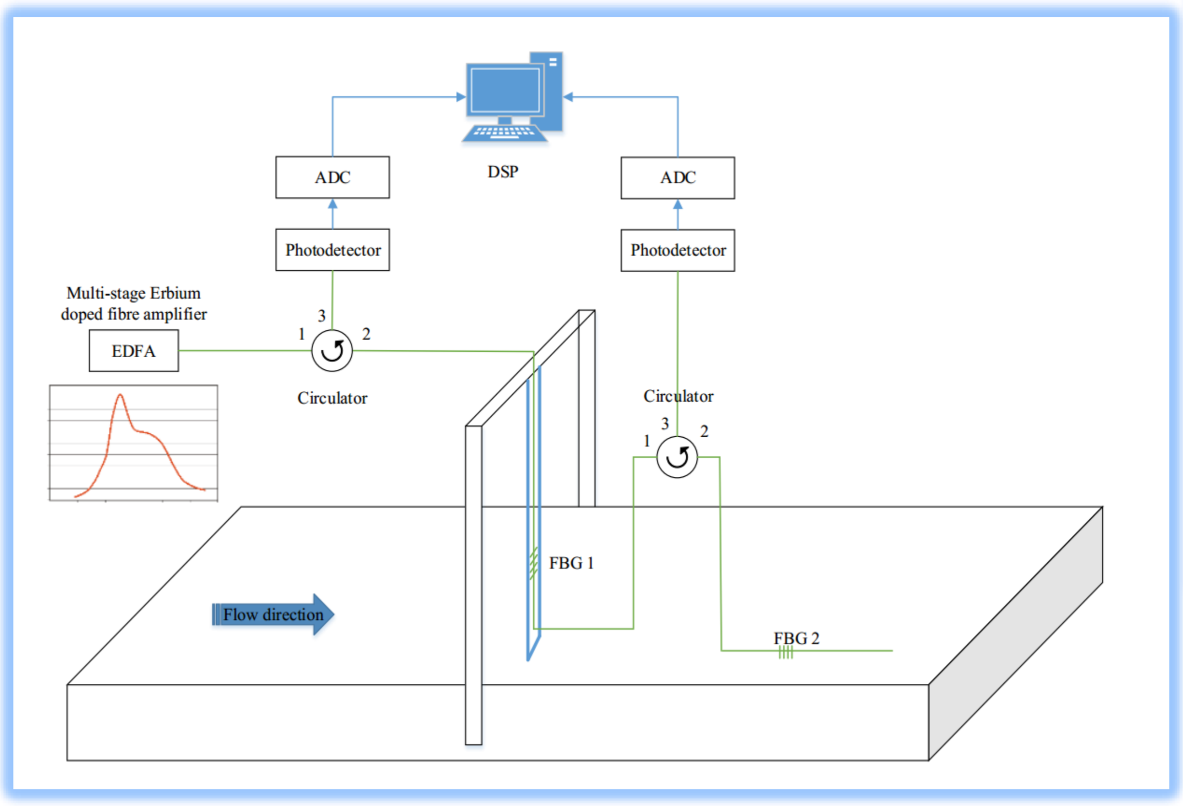

Fig 1. Schematic diagram for flow rate and temperature simultaneously sensing

There are two FBG sensors are used in this structure

- One is located on the bending cantilever beam, it is used for flow rate sensing, according to the liquid fluids pressure on the bending cantilever beam
- The other is attached at the bottom of the water channel with one end free to move, no strain/pressure change will apply on it, so it is only temperature sensitive

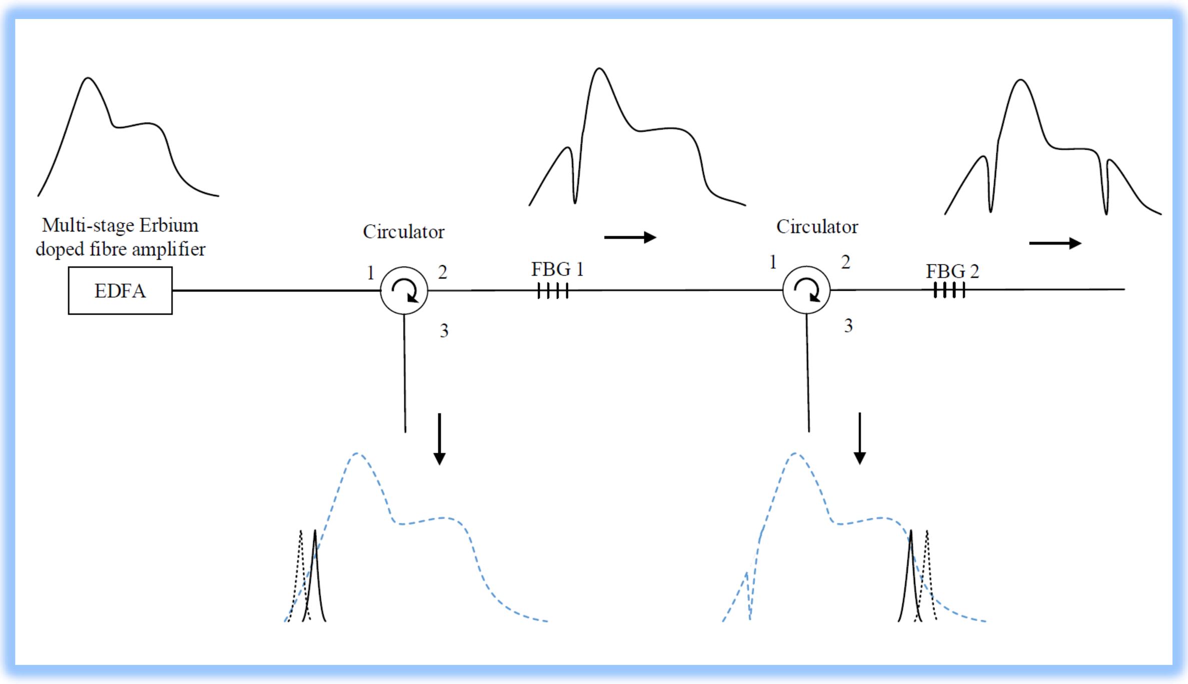

Fig 2. Operating principle for EDFA interrogation detection

About Passive interrogation detection for fibre grating sensors

This passive interrogation scheme is based on the multistage erbium doped fibre amplifier (EDFA), the operating principle can be found in **Fig 2**.

- Working as 'edge filter', convert wavelength shift to intensity change
- Using 'trapezoid' response shape to achieve flow rate and temperature simultaneous measurement

Compare to optical spectrum analyser (OSA) method, it is much cheaper, faster and possible to sense real-time data.

Method II – Vortex Flow Meter

Flow rate monitoring based on the floating fibre ring vortex sensor

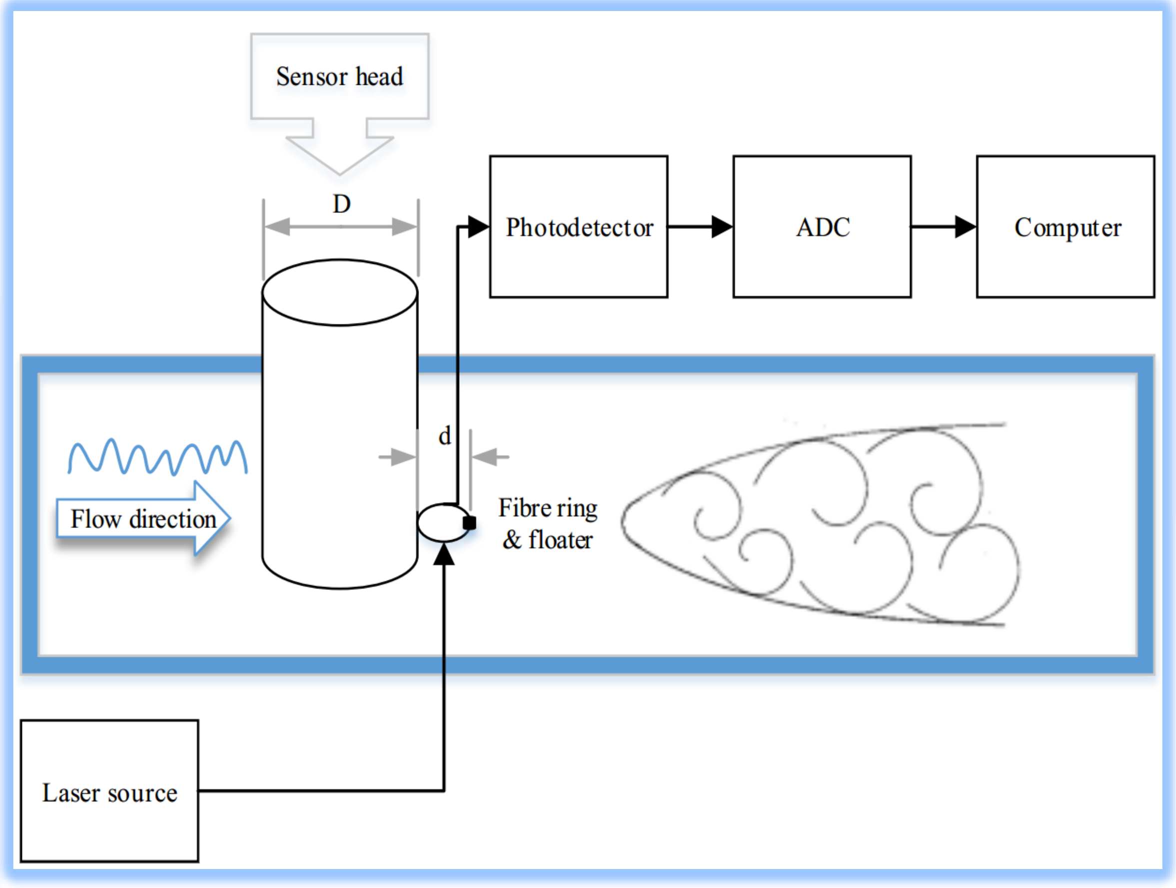

Fig 3. Schematic diagram for vortex flow meter

Von Karman vortex street

If one bluff cylinder body is inserted in the liquid flow, it will induce the vortex after the bluff body, the vortex shedding frequency is proportional to the flow velocity before the cylinder body

$$V = \frac{f \cdot D}{S_t} \quad (1)$$

Fibre-optic bending loss sensor

Optical fibres constructed from silica glass act as the waveguide for light to travel through.

The basic operating principle for the bending loss sensor is to bend the fibre in order to reduce the amount of light in the waveguide.

Working principle for vortex flowmeter

A laser light is emitted into the fibre, the shedding vortex generated after the liquid passing through the inserted bluff cylinder, it drags the fibre ring, and the output power is changing because the vortex is generated periodically. Apply signal processing method to get shedding frequency, then using equation (1) to calculate the flow velocity.

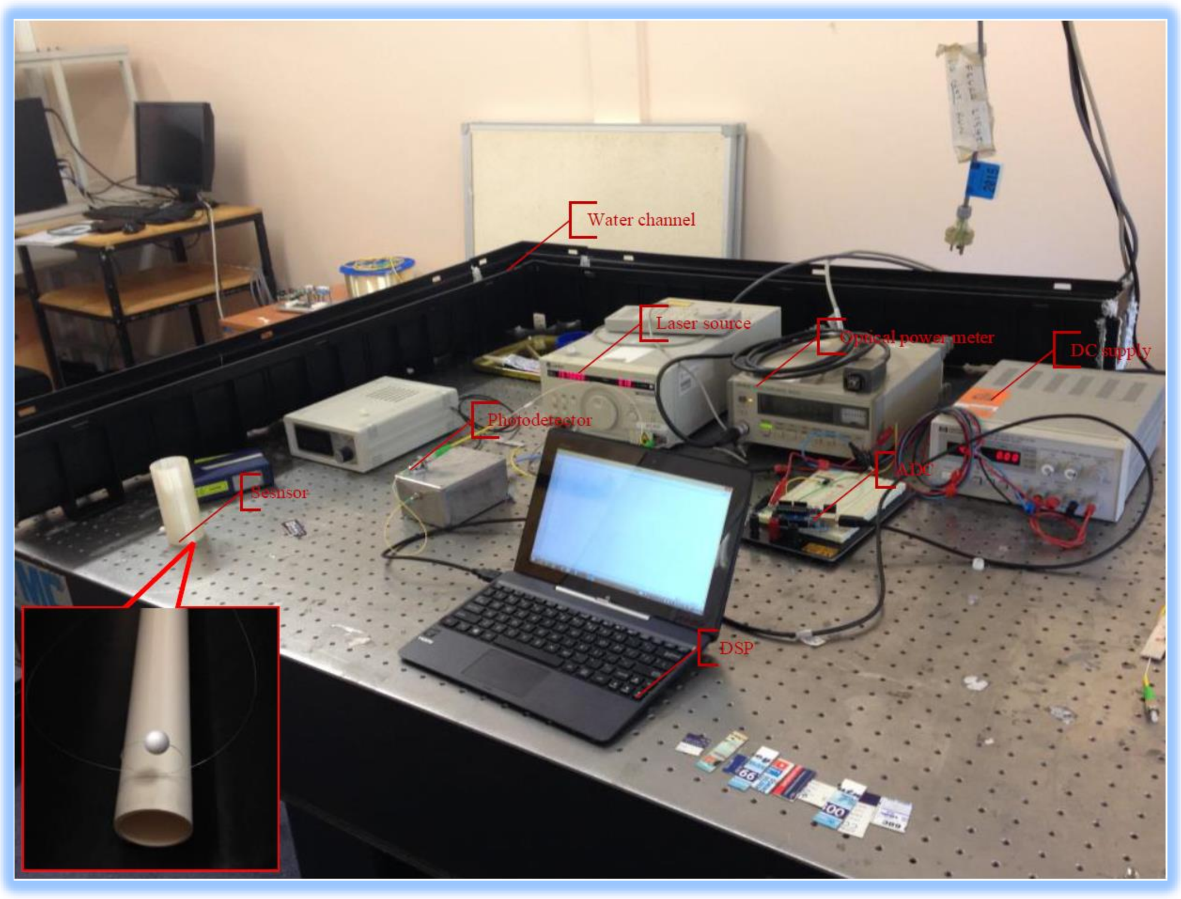

Fig 4. Setup for the vortex flow meter system

Results

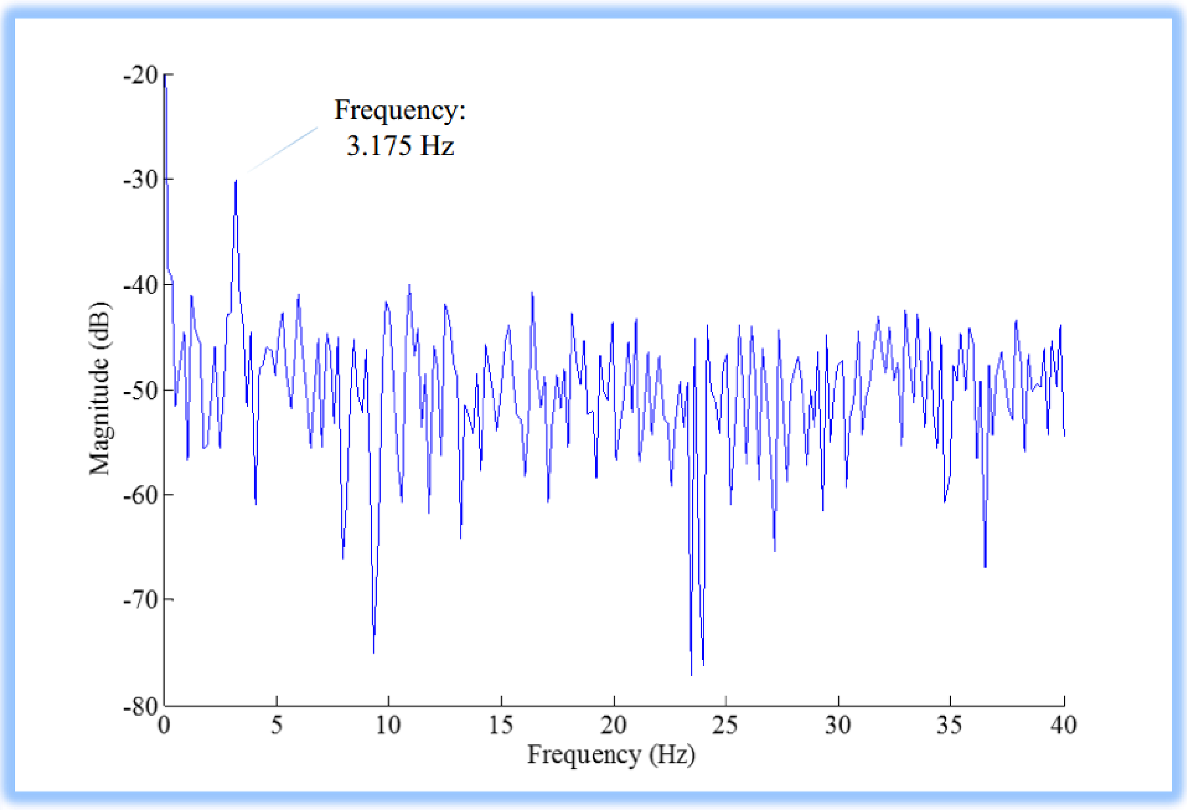

Fig 5. Frequency response for flow velocity 0.42 m/s

- Applying signal processing method to obtain vortex shedding frequency
- Using Karman vortex street to calculate the flow velocity
- Very sensitive, only several centimeter per second tolerance in experiment
- High response, quick data acquisition system

Conclusion

- Presented a new interrogation scheme for fibre grating sensor based on EDFA
- Proposed a novel fibre-optic vortex flow meter
- Successfully demonstrated proposed structure, overall system sensitivity is high

Future Work

- Further improve EDFA passive interrogation sensitivity
- Obtain measurement from different experimental environment
- Utilise EDFA passive interrogation for grating sensor concept in other fields:
  - Structure health monitoring
  - Acoustic sensing
  - Vibration sensing

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