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Development of an optical fiber-based groundwater flow sensor

Sandra Drusová
sandra.drusova@wetsus.nl

Motivation

Groundwater is the largest and most reliable reserve of drinking water in the world. Understanding groundwater flow patterns is essential for sustainable management of available resources and preventing groundwater-related problems, e.g. well clogging, salt water intrusion and pollution. Due to complexity of subsurface, these problems can not be sufficiently predicted using existing monitoring tools. A promising solution are optical fibers with **F**iber **B**ragg **G**ratings (FBGs).
Optical fibers are harmless to the environment and suffer low losses over great distances which opens the possibility for large area distributed network sensing. Fibers with FBGs will be placed in the ground for real-time and long-term monitoring of local groundwater flow.

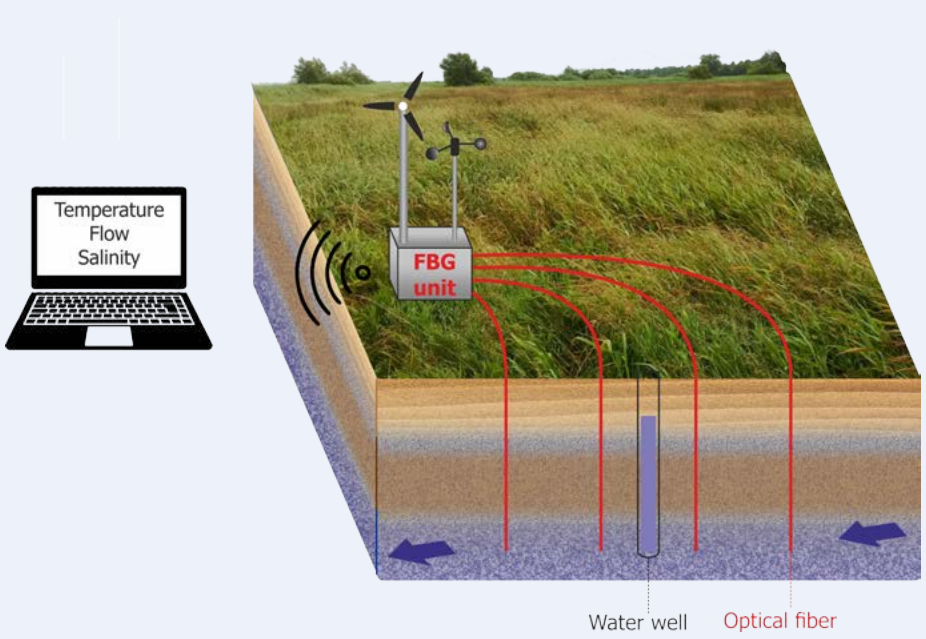

Fig. 1: FBG sensors gathering information about subsurface flow, temperature and salinity in order to identify source and quality of drinking water

Research goals

- Design a flow sensor capable of measuring slow flows (meters/day)
- Place FBG fibers without considerable disturbance of subsurface environment
- Design an autonomous sensing unit operational under field conditions
- Develop a combined sensing platform capable of detecting groundwater flow, temperature and salinity
- Assess long-term survivability of optical fiber sensors in the subterannean environment

References
[1] Mihailov, S. (2012), Fiber Bragg Grating Sensors for Harsh Environments, Sensors 12, doi: 10.3390/s120201898
[2] Anderson, M. P. (2005), Heat as a Ground water Tracer, Ground water 43, doi:10.1111/j.1745-6584.2005.00052.x

Concept

An FBG is a periodic variation of refractive index within the fiber core which acts like a wavelength-specific mirror. The wavelength of reflected light - Bragg wavelength, is sensitive to temperature of the environment and strain applied to the fiber.

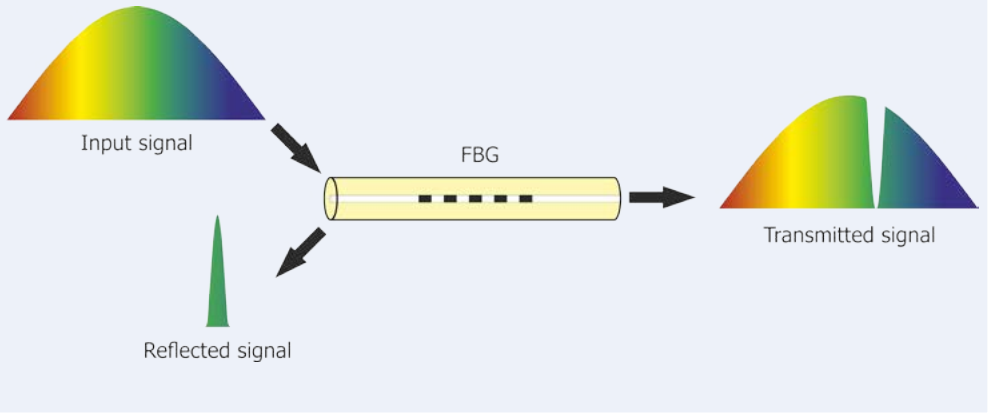

Fig. 2: Fiber Bragg grating reflecting narrow part of input spectrum

The proposed sensor will be capable of simultaneous flow and temperature measurements. The idea is to use heat as a tracer of flow since it does not affect the quality of drinking water. The sensor consists of a central heating element surrounded by multiple sensing fibers with FBGs (Fig. 3). A matrix of FBG temperature sensors creates a 3D map of heat distribution. When water flows through the sensor, heat convection will disturb the symmetry of heat field. Therefore, spatial temperature differences detected by the FBGs can be further translated into a 3D flow vector.

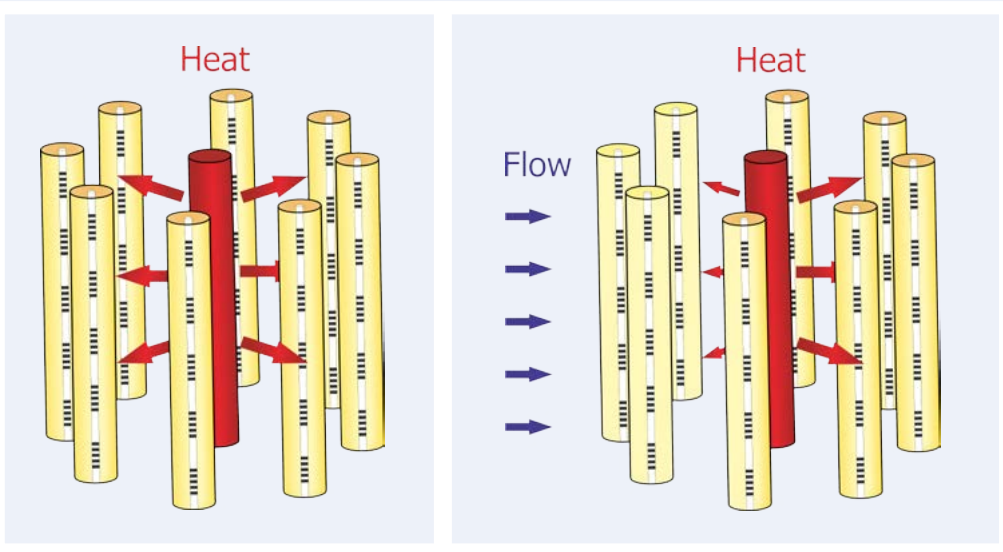

Fig. 3: Principle of FBG flow sensor. Without the presence of flow, all fibers should detect the same temperature if placed at the same distance from the heating fiber. Introducing flow from the left side will make the temperature on the left lower than on the right.

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MSc. S. Drusová, dr.ir. A. D. Wexler,
dr.ir. H. L. Offerhaus, prof.dr. J. Herek

Optical Sciences
UNIVERSITY OF TWENTE.