

All-Optical Passive Periodic Sawtooth Filter and its Application to Fast Interrogation of Fiber Bragg Grating Sensor Array

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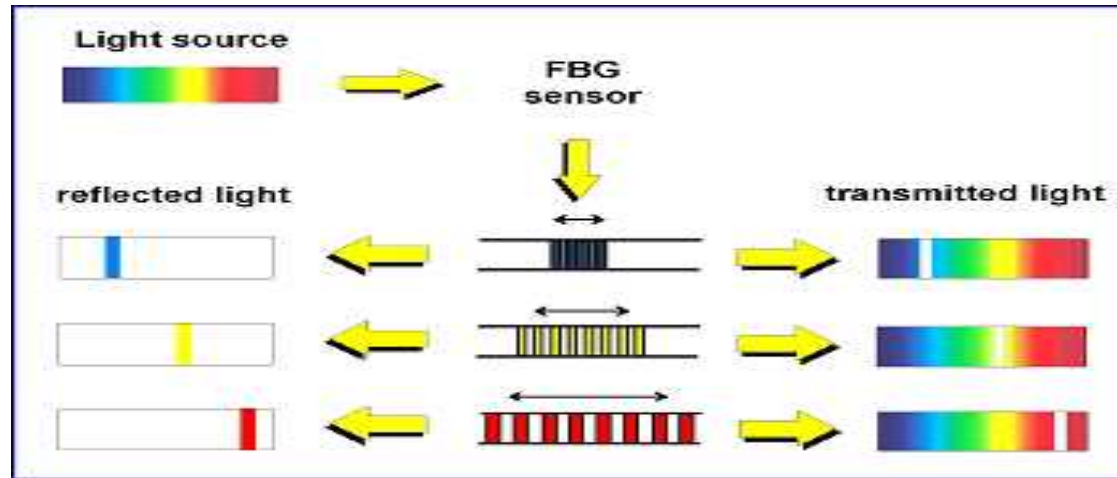
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Outline

- Introduction to FBG sensor interrogation techniques
(why sawtooth filter)
- Sawtooth filter using a virtually-imaged phased array (VIPA)
(how to achieve a passive sawtooth filter)
- Fast interrogation of FBG sensors using sawtooth filter
(application of the sawtooth filter)
- Summary

Introduction

➤ FBG sensor

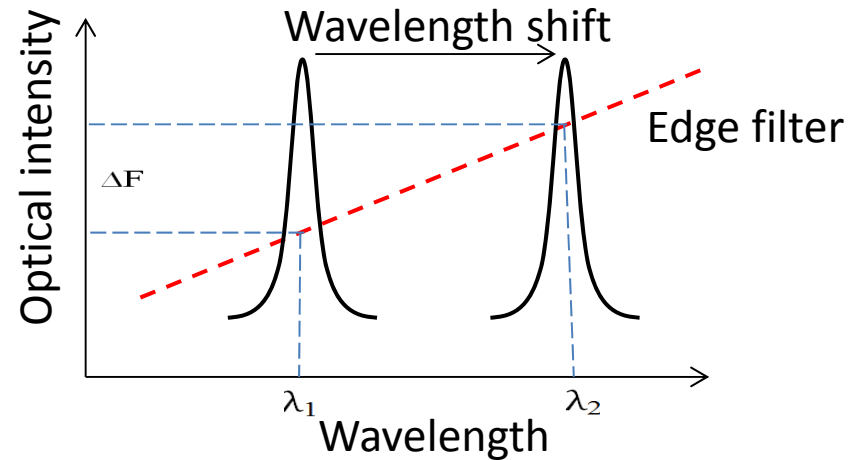


➤ Interrogation of FBG sensors

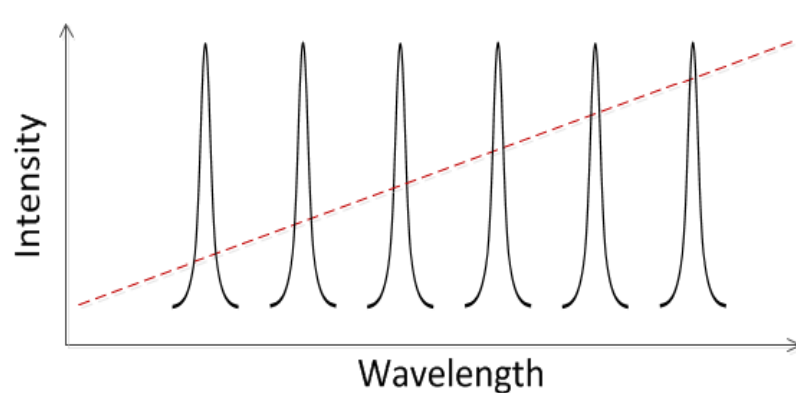
Interrogation Techniques	Resolution	Speed	Cost
Direct spectroscopic measurement	Limited by the diffraction grating	Limited by CCD read-out speed	High
Wavelength scanning	Limited by the laser wander	Limited by scanning devices	High
Linear edge filter	Depends on filter slope	High	Low

Introduction

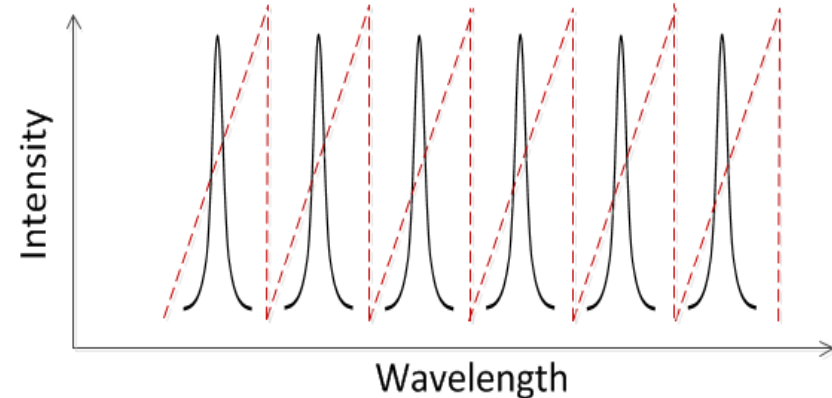
- Linear edge filter for FBG interrogation



- Trade-off between resolution and dynamic range (# of FBGs)



Single linear edge filter

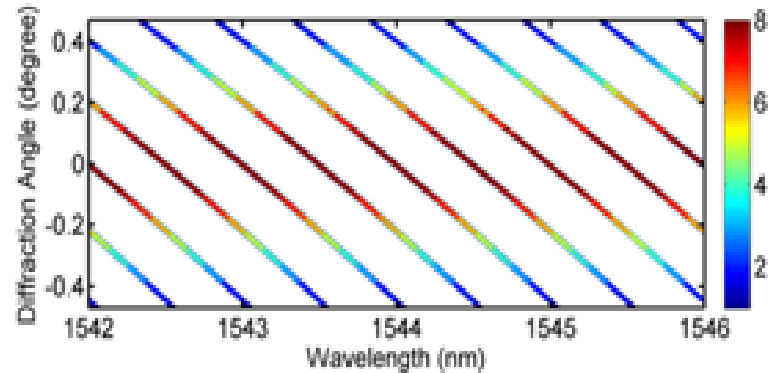
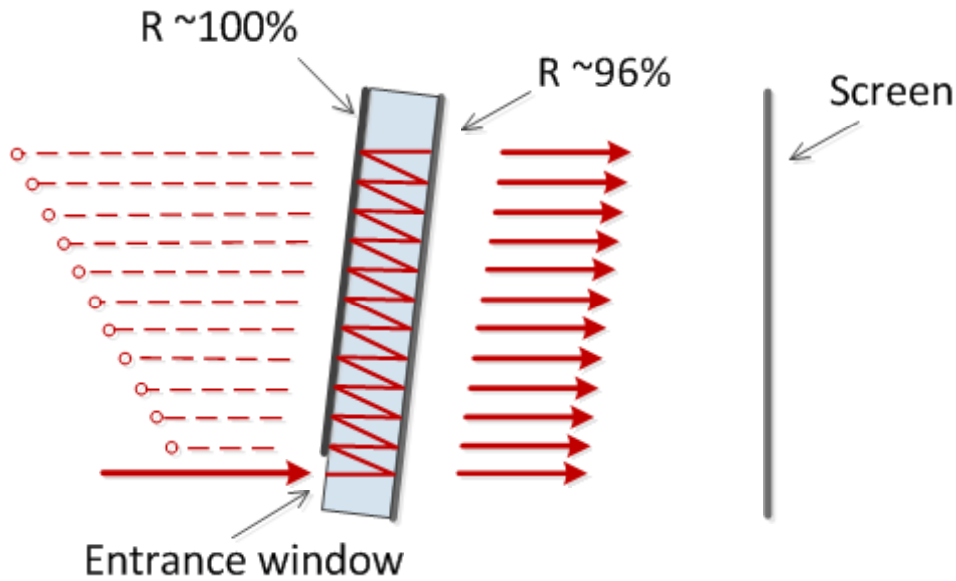


Periodic sawtooth filter

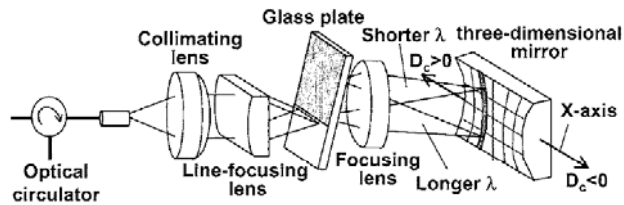
Low-cost passive sawtooth filter is desirable!

Virtually-Imaged Phased Array (VIPA)

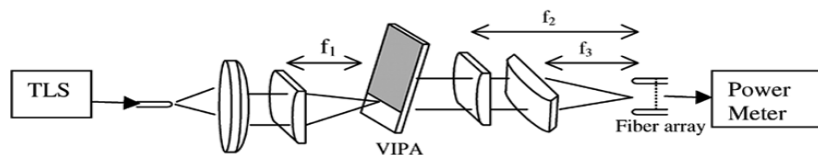
➤ Principle of VIPA*



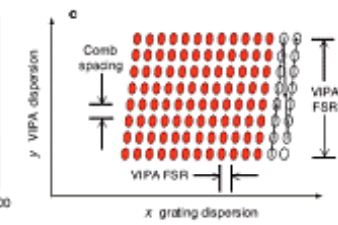
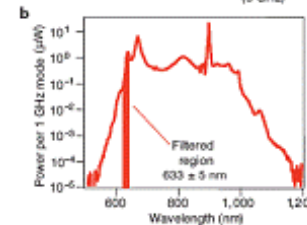
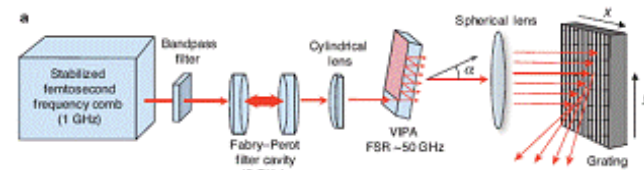
➤ Applications of VIPA



H. Ooi et al., *J. Lightwave Technol.* 20, 2196 (2002).



S. J. Xiao, A. M. Weiner, *IEEE Photon. Technol. Lett.* 17, 372 (2005).

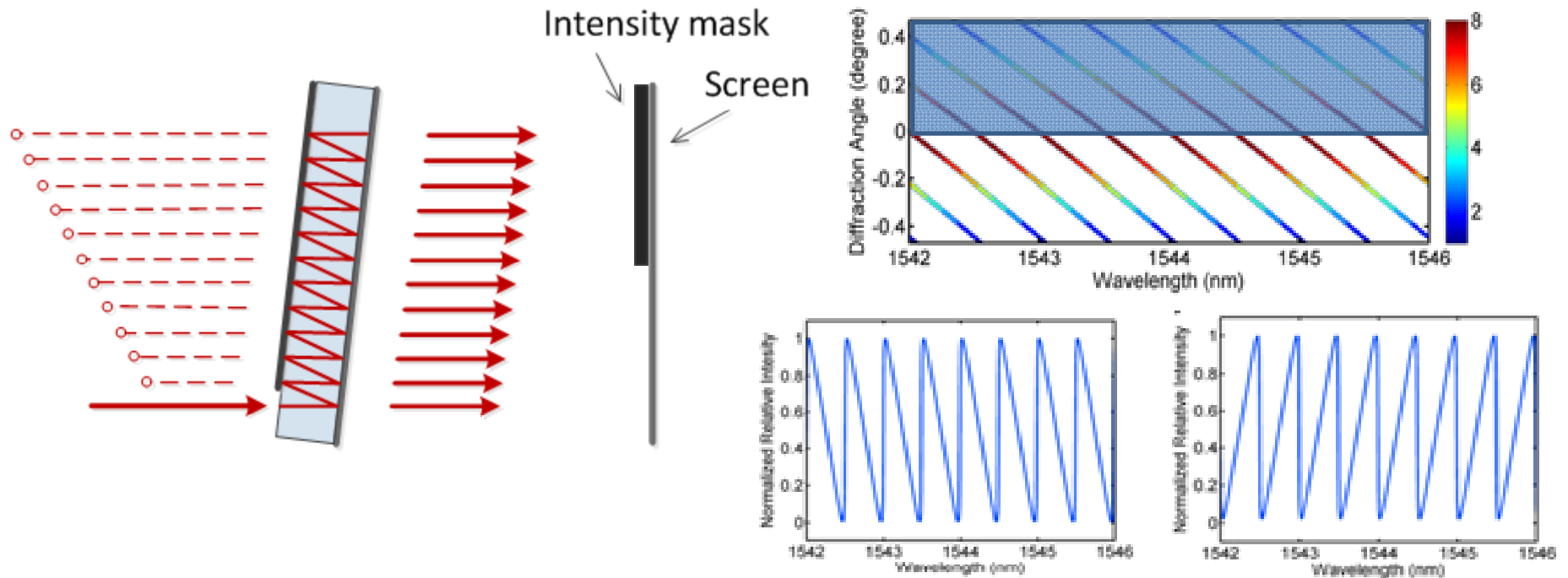


S.A. Diddams et al., *NATURE*, 445, 627 (2007)

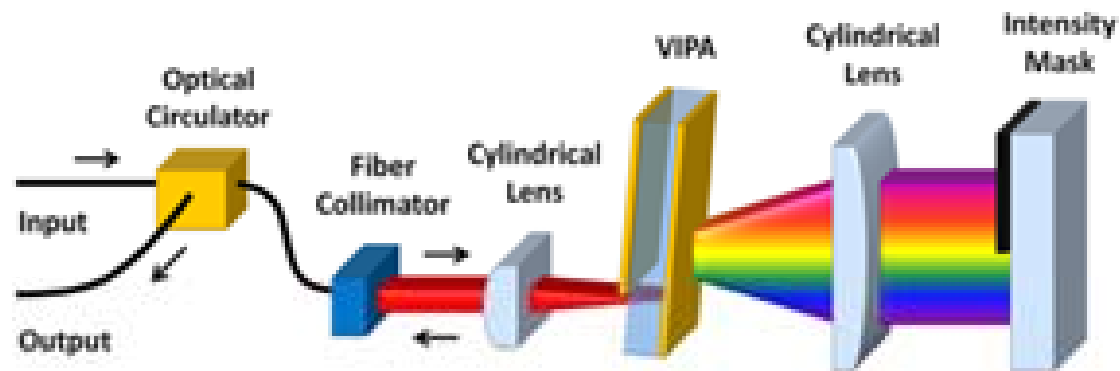
* M. Shirasaki, *Opt. Lett.* 21, 366 (1996).

VIPA-based Sawtooth Filter

- Principle of VIPA-based sawtooth filter

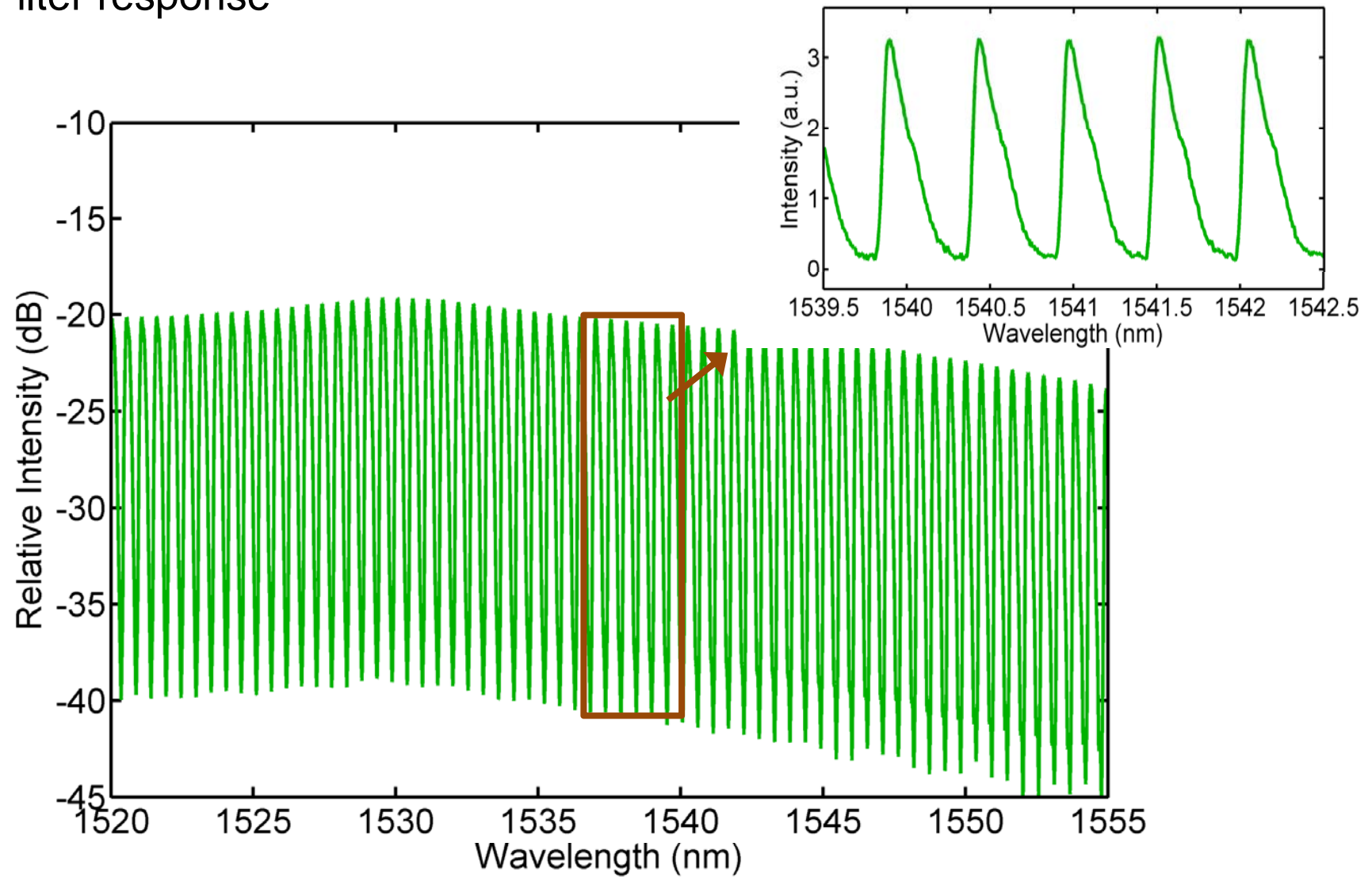


- Experimental setup



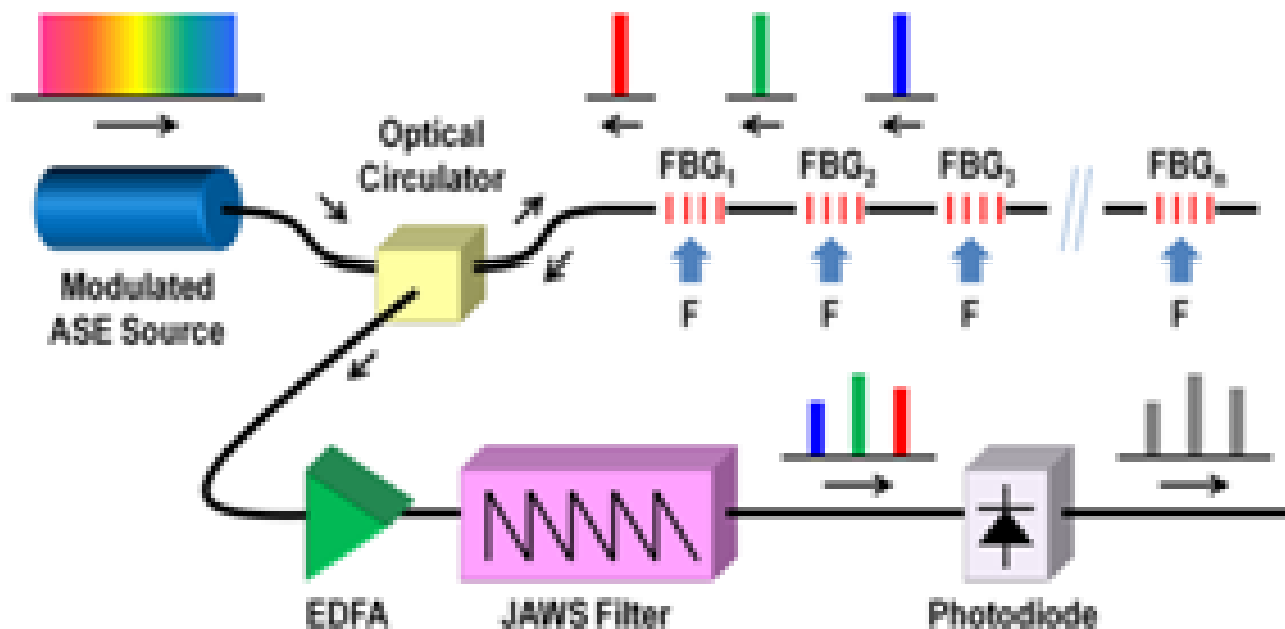
VIPA-based Sawtooth Filter

➤ Filter response



Fast Interrogation of FBG Sensors

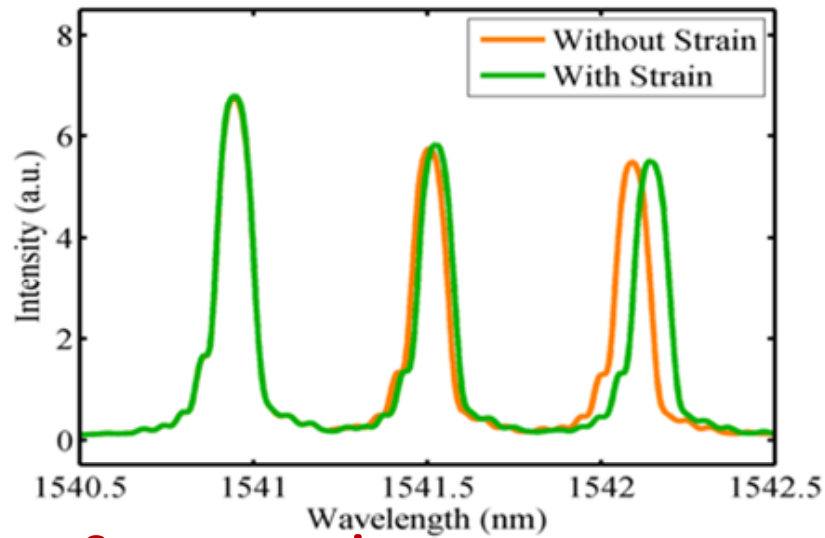
➤ Experimental apparatus



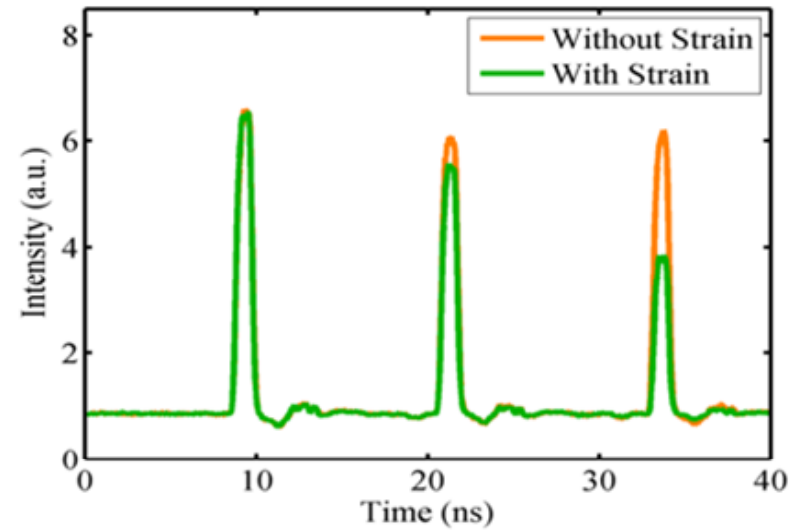
- Broadband pulse train (2 ns pulse width, 25 MHz repetition rate)
- Three FBGs (1541.1 nm, 1541.6 nm, and 1542.2 nm)
- Sawtooth filter converts wavelength shift into intensity change of the pulse train.
- Fast interrogation (25MHz) of multiple FBG sensors achieved.

Fast Interrogation of FBG Sensors

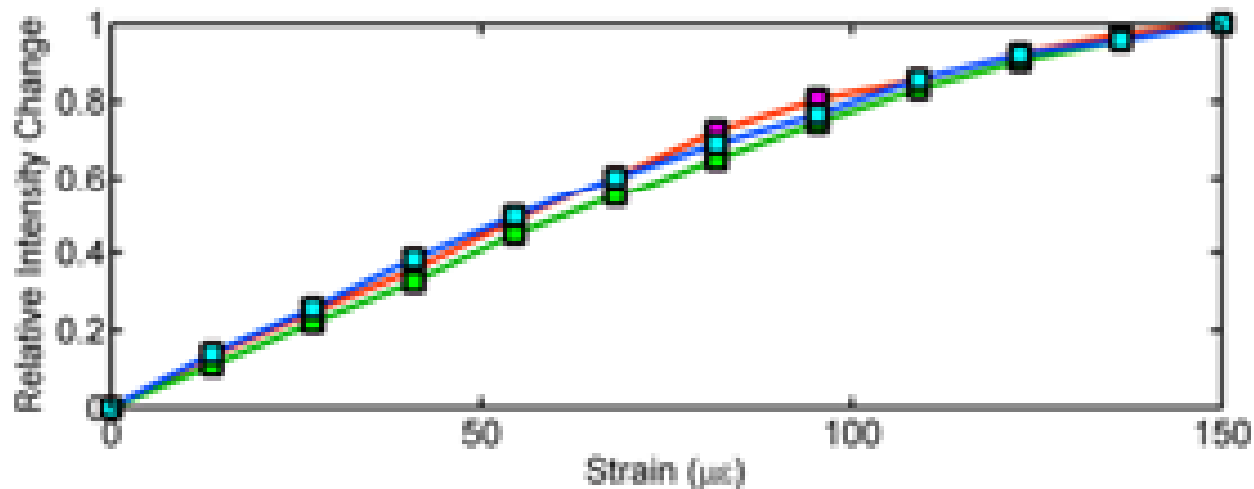
➤ Experimental results



Spectroscopic measurement

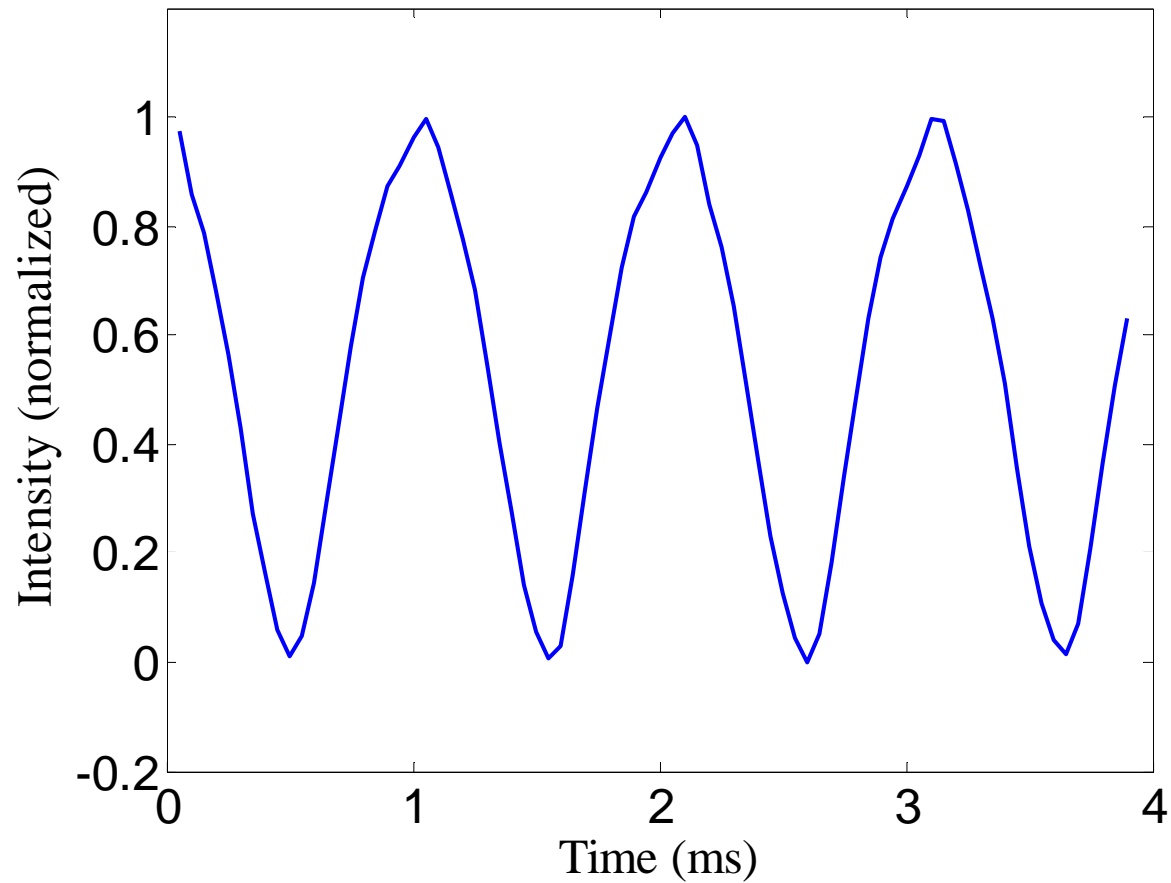


Intensity measurement



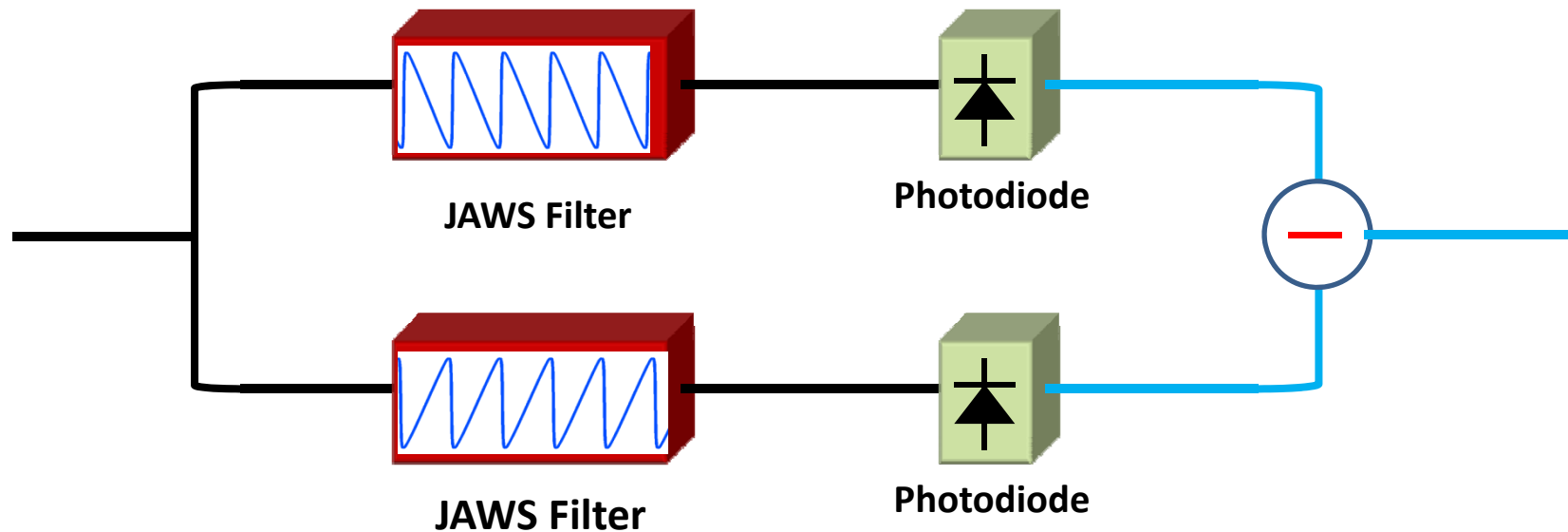
Fast Interrogation of FBG Sensors

- Dynamic measurement



Fast Interrogation of FBG Sensors

➤ Balanced sensor



- Two sawtooth filters with the opposite slope signs can be used to obtain differential conversion of wavelength into intensity and hence as a balanced sensor.

Summary

- Low-cost all-optical passive sawtooth filter is demonstrated using a VIPA and an intensity mask.
- The developed sawtooth filter features broadband operation, switchable slopes, and controllable FSR.
- Fast interrogation of FBG sensors using sawtooth filter was demonstrated.
- The sawtooth filter can be miniaturized for practical applications in FBG interrogation systems.