Fiber Bragg Gratings for DWDM Optical Networks

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Overview

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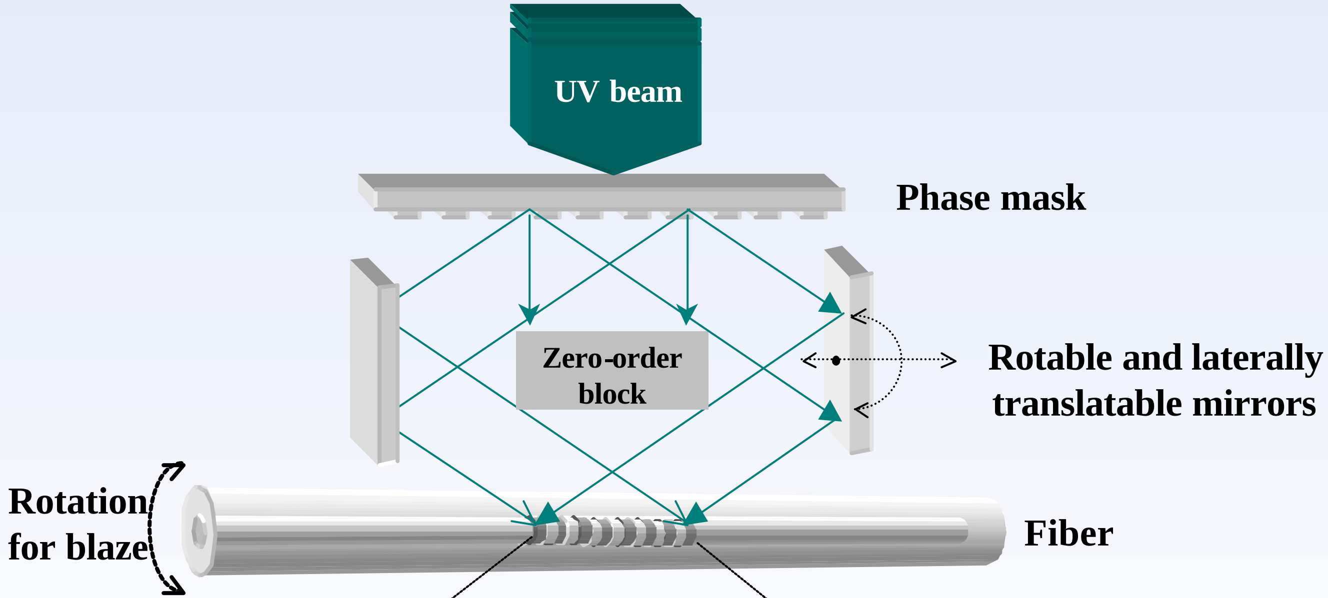
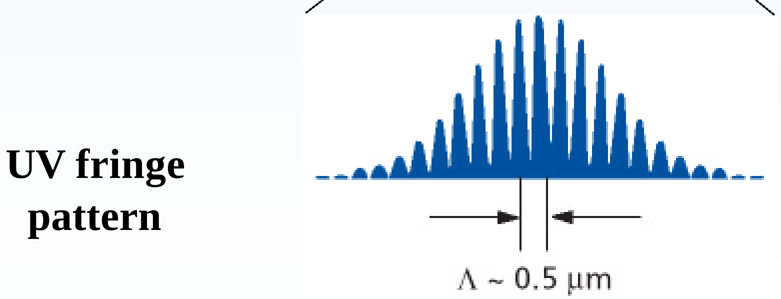
- **Physical properties.**
- **Applications in optical networks.**
- **Impairments of optical filtering in DWDM optical networks.**
- **Nonlinear optics in FBG.**
- **Conclusions.**

Introduction

- Fiber Bragg gratings represent a key element in fiber optical communications systems.
- Due to their fabrication process, they have very low insertion loss, immunity to electromagnetic interference, electrical isolation and light weight.
- The wide variety of applications has made it a highly developed technology, becoming one of the most stable and versatile technologies in the optical field.

Fabrication





$$l_{Bragg} = n_{eff} \frac{l_{UV}}{\sin a}$$

Physical Properties

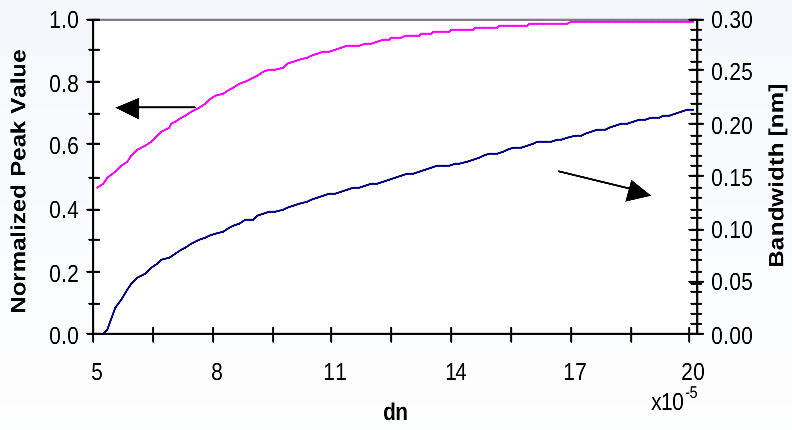
$$n(z) = n_{eff} + \overline{dn}_{eff}(z)\left[1 + s\cos\left(\frac{2p}{\Lambda}z + j(z)\right)\right]$$

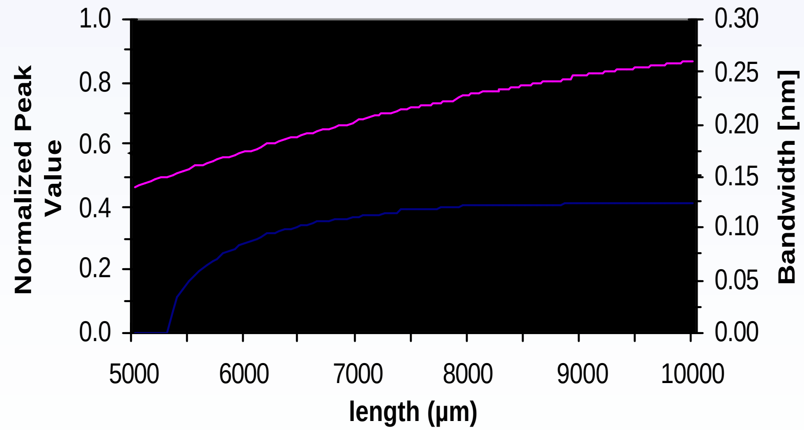
Apodization profile
(can be controlled for filtering optimization)

Fringe visibility
(influences the extinction ratio)

Period
(influences the Bragg wavelength)

Chirp
(can be controlled for dispersion compensation)

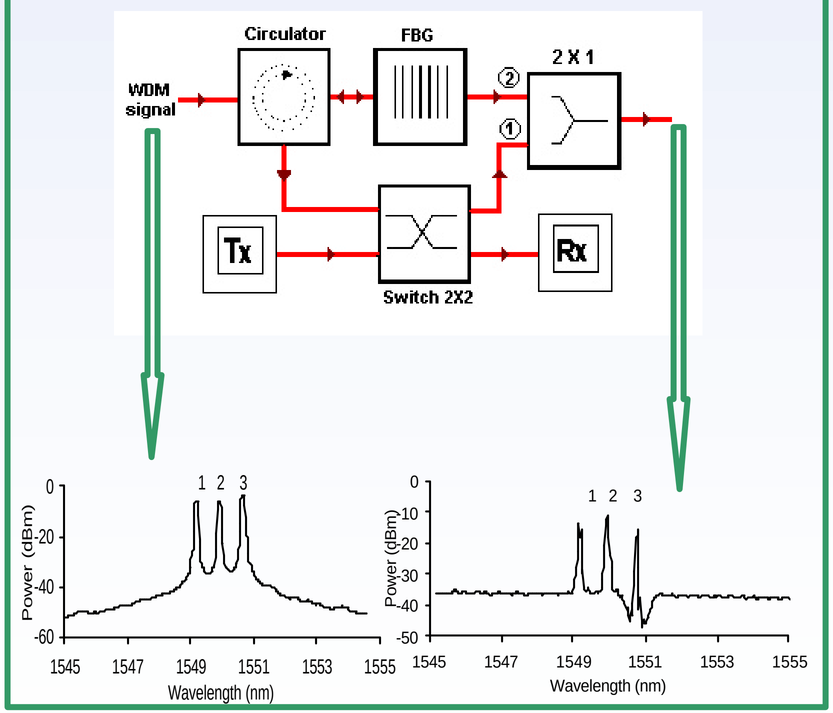




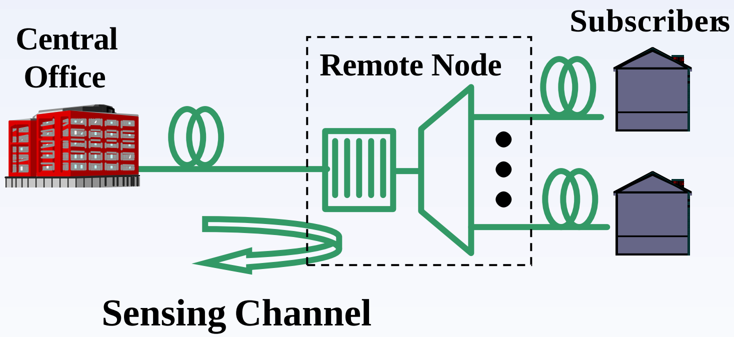
Applications	Description	Parameters
Fiber laser	Narrowband reflector	Δλ=0.1-1 nm R= 1- 100 %
Laser wavelength stabilization (980 nm, 1480 nm)	Narrowband reflector	Δλ=0.2-3 nm R= 1- 10 %
Pump reflector in fiber amplifiers (1480 nm)	Highly reflective mirror	Δλ=2-25 nm R= 100 %
Pump reflector in phase conjugator (1550 nm) and isolation filter in wavelength converter	Highly reflective mirror	Δλ=1 nm R= 100 %
WDM Demultiplexer (1550 nm)	Multiple high-isolation reflectors	Δλ=0.1-1 nm Isolation>30 dB
WDM add/drop filter (1550 nm)	High-isolation reflector	Δλ=0.1-1 nm Isolation>50 dB
Optical amplifier gain equalizer (1530 – 1560 nm)	Blazed Bragg gratings or long period grating	Δλ=30 nm Loss= 0 - 10 dB
Dispersion compensation for long-haul transmission (150 nm)	Chirped grating	Δλ=0.1-15 nm 1600 ps/nm
Network physical monitoring	Temperature, strain and humidity sensors	Δλ=0.1-1 nm R=100%
Optical code-division multiple-access (OCDMA)	Encoding / Decoding	Chirped moiré grating

Applications Examples for Optical Networks

Optical Add-Drop Multiplexer



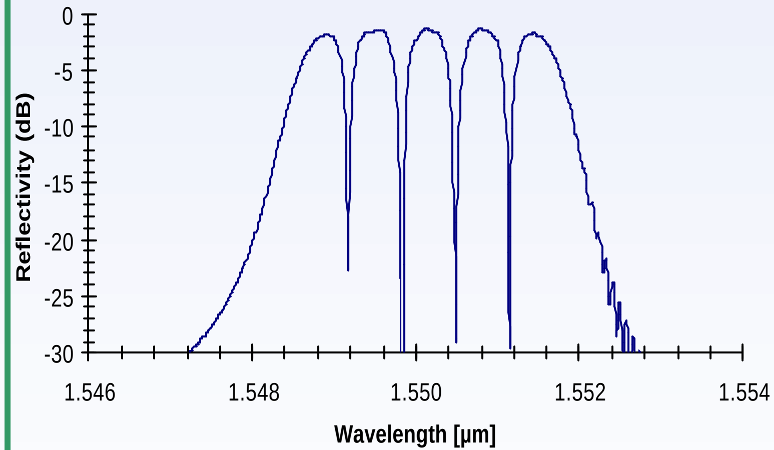
Network monitor



A FBG can be used for temperature, stress and humidity (polyimide-coated FBGs) sensors

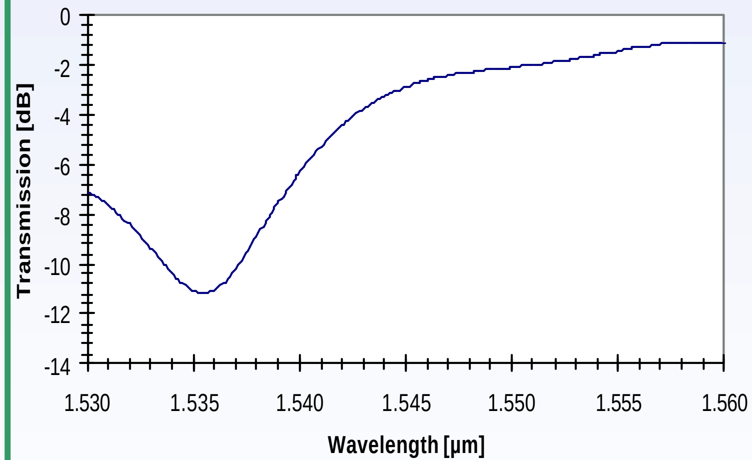
Applications Examples for Optical Networks

Multiple rejection/pass-band filter



A single chirped moiré FBG can be used as multiple pass band/rejection filter (Ex: OCDMA)

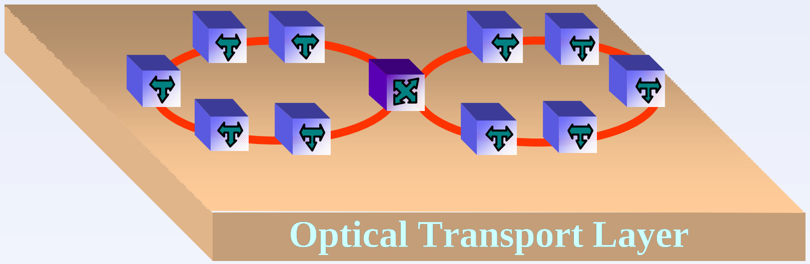
EDFA gain equalizer



2 long-period FBG can be used as an EDFA gain equalizer

Impairments of Optical Filtering in DWDM Optical Networks

Cascaded filtering:



Optical add-drop multiplexer

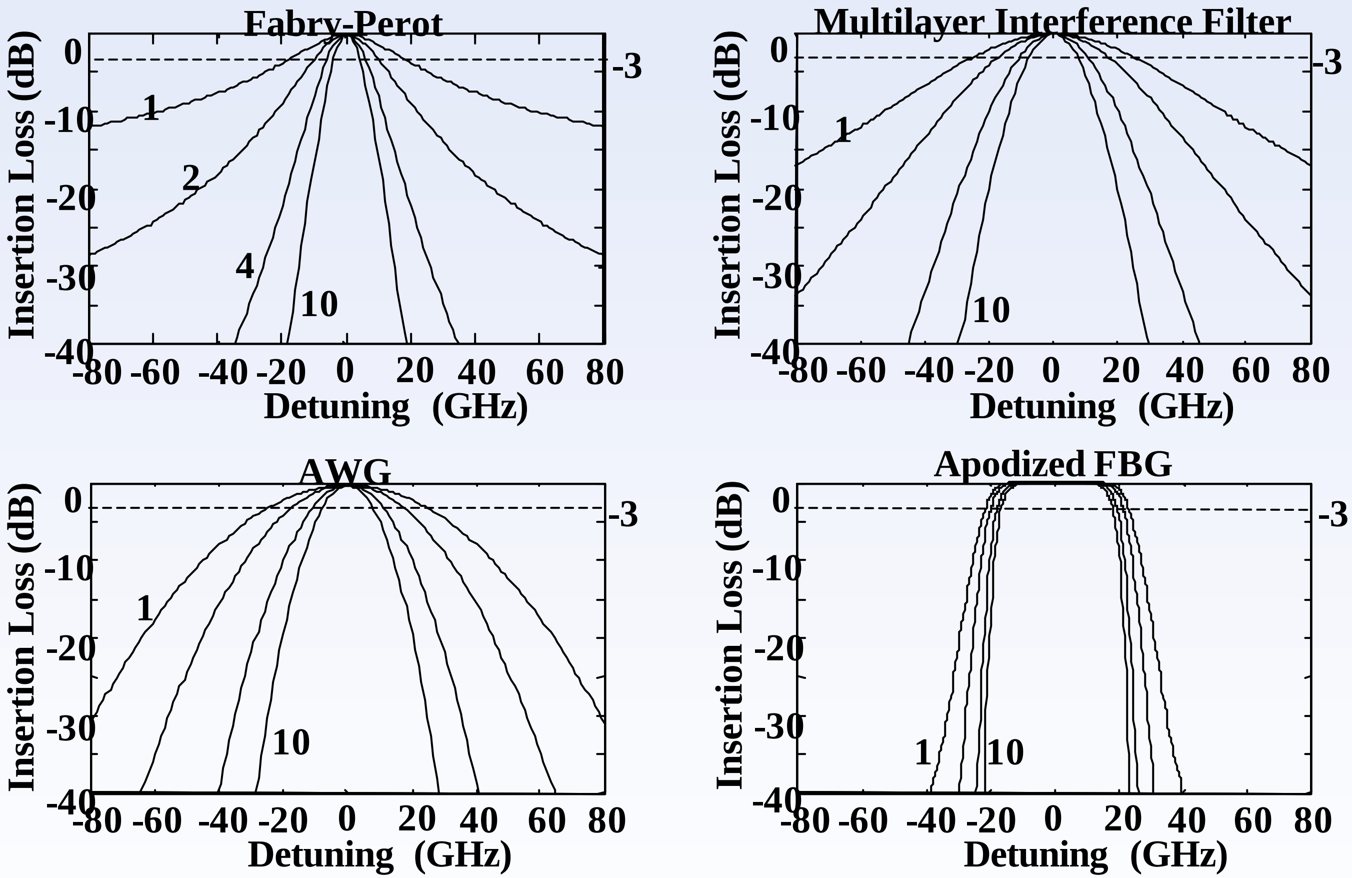
Optical cross-connect

Bandwidth Narrowing: Leads to performance degradation, especially if the signal has a sharp pulse shape

Phase distortion

Dispersion: limits the bit rate and leads to pulse distortion, which can result in transmission errors.

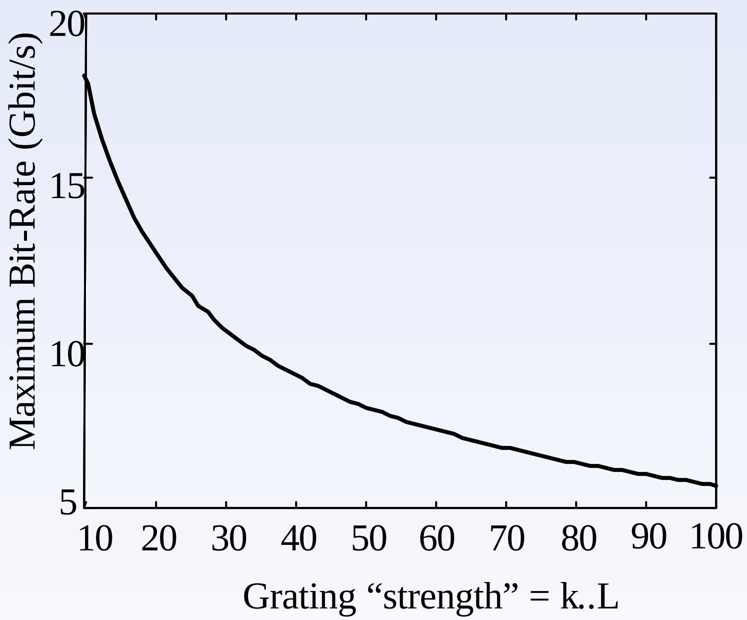
Bandwidth Narrowing



The apodized FBG has a flattened filter response, which reduces the effect of bandwidth narrowing in opposition to other types of optical filters.

Dispersion

- Due to the dispersion in the FBG, there must be a compromise between a good rejection value (higher grating strength) and less dispersion (lower grating strength).
- A linear-phase (dispersion less) FBG square-filter is still attainable, however it requires complex apodization profiles to achieve such performance.
- Another method is to use phase equalization techniques.



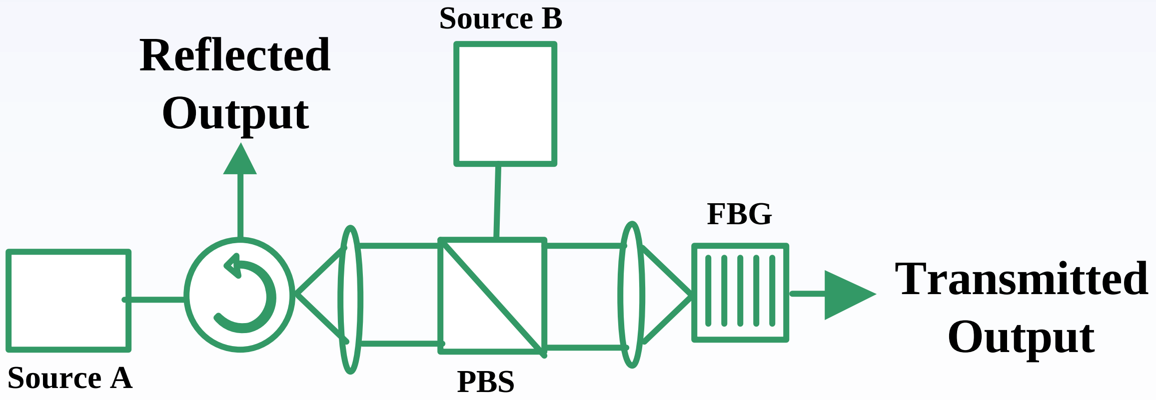
The simulation was made with a super-gaussian pulse with 100 Ghz spacing between channels

Nonlinear optics in FBG

- Experiments based on Kerr phenomenon, interplay between two or more beams, interplay between dispersion and nonlinearity, pulse shaping and optical switching are possible thanks to the exceptional flexibility in the choice of the grating parameters.
- Recent results, both theoretical and experimental demonstrated very interesting phenomena which suggest new applications and devices in the optical communications field.

Nonlinear applications

- The main idea is to use a probe with wavelength near the photonic band gap.
- A strong pump laser uses XPM to change the refractive index seen by the probe (XPM) thus changing the detuning of the probe from the center of the photonic band gap.



Optimization of nonlinear effects

- Use of phase shift FBG (notch bandwidth reduces propagation speed).
- Use of the latest generation of novel glasses such as the chalocogenides which have a Kerr nonlinearity 100 times that of silica).
- Use of air-silica microstructure fibers (“holey fibers”).

Conclusions

- A general overview of the characteristics of FBGs and their application to optical networks have been presented.
- Also, some of the new developments and applications of FBGs in optical networks have been presented.

Acknowledgments

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Thank You