

# 열팽창 계수를 이용한 마이크로밴딩 장주기 광섬유격자 기반 온도센서의 구현

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## Fabrication of Temperature Sensors Based on Microbanding-induced Long-period Fiber gratings using Coefficient of Thermal Expansion

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**요약** : 마이크로밴딩을 이용한 장주기 광섬유 격자를 금속선의 주기적인 배열로 구현하였으며 포토폴리머에 의한 자기 압력이 유지될 수 있게 하였다. 포토폴리머의 열팽창 계수가 소자제작에 사용된 다른 재질에 비해 상대적으로 큰 열팽창계수를 가지므로 온도 변화에 민감하게 반응하였다. 이러한 특징을 온도 변화를 감지하는 센서로 활용할 수 있음을 보여 주었다. 단일모드 광섬유의 플라스틱 코팅층이 있는 경우와 없는 경우에 대하여 각각 실험을 하였으며 그 결과를 비교 분석하였다.

**핵심용어** : 열팽창계수, 장주기광섬유격자, 광섬유온도센서, 위상정합, 단일모드광섬유

### Introduction

**Long period fiber grating (LPFG)**  
Gain equalizer in fiber amplifiers, Band rejection filters, Sensors (strain, pressure, temperature, etc.)

**Fabrication methods of LPFG**

- Photo-induced
- Mechanically formed

**Microbanding-induced LPFG (MLPFG) using Grooved plates**

- Different effective periods for tuning

**Motivations**

1. New technique of the fabrication method of MLPFG without external pressure to form the mechanical gratings.
2. Apply to loss-tunable filters and in-line fiber optic temperature sensors

### Principles of Long-period fiber gratings

**Phase matching condition**

$$\lambda_m = (n_{cl}^{eff} - n_{amb}^{eff})\Lambda$$

**Mode equation for the LP<sub>0m</sub> cladding mode**

$$2\pi \left[ \frac{a}{\Lambda} \sqrt{(n_{cl}^{eff})^2 - (n_{amb}^{eff})^2} - \left( m - \frac{1}{2} \right) \right] 2\pi = 2\pi \sqrt{(n_{cl}^{eff})^2 - (n_{amb}^{eff})^2}$$

$a$ : radius of the cladding,  $n_{cl}^{eff}$ : effective index of the cladding mode,  $n_{amb}^{eff}$ : refractive index of the ambient

### In-line Fiber Optic Devices

**Principles**

- Light attenuation Method
- Optical Time Domain Reflection Method

**Advantages**

- Small and embeddable
- No need for in-situ electrical cable
- Immune to electrical and electromagnetic fields
- Long distance transmission and acquisition of optical signal (several kilometers)

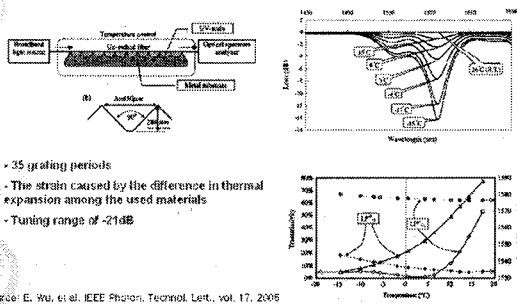
**Reported FOS types**

- Bragg gratings (Mason et al 1996, Volva et al 1999)
- Fabry-perot ones (Claus et al 1992)
- Brillouin scattering (Zeng et al 2002)
- Optical time domain reflectometry (Gu et al 2000)
- Long period fiber gratings (Saxon, et al. 2000)

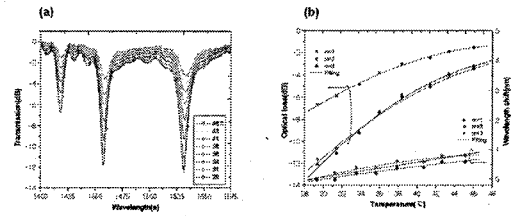
### Graphical Analysis of Mode Equation

The graph plots Phase (rad) on the y-axis (ranging from 0.0 to 2.0) against Wavelength (nm) on the x-axis (ranging from 1.40 to 1.70). It shows several curves representing different modes (m=1, 2, 3) and their phase matching conditions. A legend indicates parameters:  $n_{cl}^{eff} = 1.46$ ,  $n_{amb}^{eff} = 1.46$ ,  $a = 4.0 \mu m$ , and  $\Lambda = 100 \mu m$ .

## Thermally Controlled Loss-Tunable LPFG on Corrugated Metal Substrate

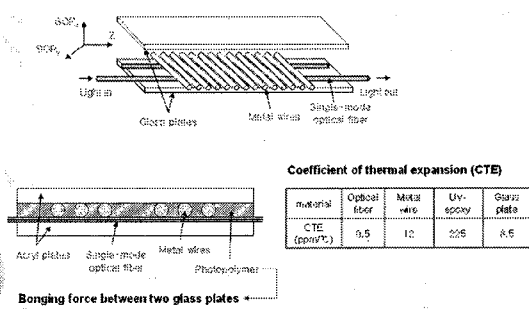


## Measured Transmission Spectrum (1)

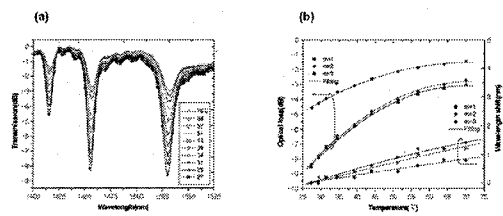


(a) Transmission spectra of MLPG1 versus temperature. The SMF with jacket was installed.  
 (b) A plot for optical loss and loss-peak shift versus temperature.

## Schematics of Proposed Loss-Tunable MLPGs

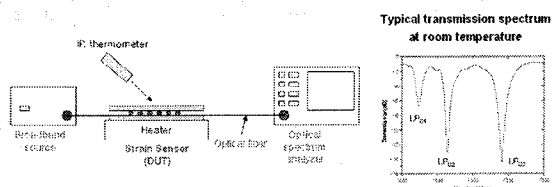


## Measured Transmission Spectrum (2)



(a) Transmission spectra of MLPG2 versus temperature. The jacket-removed SMF was installed.  
 (b) A plot for optical loss and loss-peak shift versus temperature

## Experimental Setup



## Conclusion

- we have presented a new type of loss-tunable MLPGs formed by bonding a SMF and arrayed metal wires between two flat glass plates.
- The mechanical force to induce the periodic index variation on the fiber is realized by the adhesion force of NOA65. So an initial built-in compressive strain in the fiber of MLPG was sustained by itself without external pressure.
- Loss tuning was achieved by the CTE of NOA65. By change the ambient temperature, the peak loss was easily controlled without appreciable shift of the center wavelength.
- The jacket of the fiber has influence to the temperature sensitivity and the measurable temperature range.
- The model of proposed MLPGs may be useful to realize compact, robust, and efficient loss-tunable filters and temperature sensors