# Characteristic of the fiber Bragg grating using the Meta-material

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The concept and distinct properties of artificial meta-materials (MTMs) with both negative permittivity $\varepsilon$ and negative permeability $\mu$, which is called as left-handed materials (LHMs), were first proposed by Veselage in 1968 [1]. These MTMs have recently drawn considerable attentions due to the experimental realizations of such materials, such as a prism-shaped sample, flat lens, filter and antennas, photonic crystals at the infrared region, surface plasmon waveguides at visible frequencies, and cloaking.

MTMs are potentially very versatile, but they are still subject to fundamental topics. So, in this paper, with an interesting academic curiosity, we theoretically propose fiber Bragg grating (FBG) whose refractive index of the core could become negative in optical frequency ranges. Basically, when a germanium-doped silica core fiber is exposed to ultraviolet radiation, it results in a permanent change in the refractive index of the germanium-doped fiber core, due to the photosensitivity nature of the germanium-doped silica, and, using such an exposure, it is possible to obtain refractive index changes by factors as large as $10^{-3}$ in germanium-doped silica fiber.

This periodic change of the refractive index of the fiber core is called fiber Bragg grating, and when light from a broadband source interacts with the grating, a single wavelength known as the Bragg wavelength is reflected as follows $\lambda_B=2n_{eff}\Lambda$. Here, the grating period ($\Lambda$) and effective refractive index ($n_{eff}$) of the single-mode fiber core are dependent on the temperature applied to the fiber core, so a Bragg wavelength can be shifted by the changes of the grating period and refractive index of the fiber core.

Fiber Bragg grating (FBG) has many advantages: high sensitivity, real-time processing, long-term stability, EMI immunity, multiplexing capability, and easy fabrication by controlling the period, length, amplitude, apodization, and chirp of a fiber grating. So, FBG is being received much attention and is regarded as one of key approaches for future optical devices, such as WDM optical communication devices and optical fiber sensors for measuring temperature and strain [2]. However, due to the relatively small change of the refractive index of the fiber core, the reflected power of Bragg wavelength is about 2~4 dB. So, when using MTM as the grating material of the FBG, the greater change of the refractive index of the fiber core difference could improve the power reflection of the Bragg wavelength.

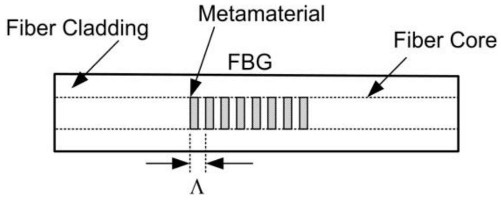


Fig. 1 Fiber Bragg grating using the meta-material

Figure 1 shows the presented FBG using the MTM as the fiber core. The electric fields in the grating are simplified to the superposition of forward-propagating and backward-propagating fundamental modes in the optical fiber core.

$$E(x,y,z) = A^{+}(z)e_{t}(x,y)e^{j(\omega t-\beta z)} + A^{-}(z)e_{t}(x,y)e^{j(\omega t+\beta z)} \quad (1)$$

The mode coupling of the electric fields along the fiber core occurs at the grating of the optical fiber core, which acts like as a perturbation in the refractive index. So the coupled mode can be written by the equation

$$\frac{dA^{+}}{dz} = \kappa^{*} A^{-} e^{j2\delta z}, \frac{dA^{-}}{dz} = \kappa A^{+} e^{-j2\delta z}. \quad (2)$$

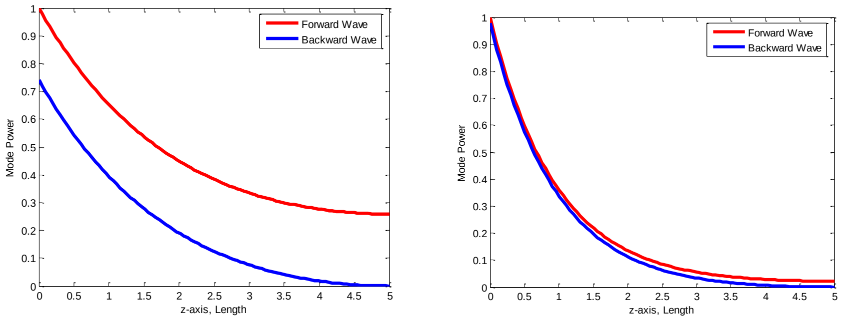
For uniform Bragg grating, the spatial period ($\Lambda$) along the z direction is described in terms of a Fourier series:

$$\Delta n^{2}(x,y,z) = \Delta n^{2}(x,y)\sum_{l=-\infty}^{l=\infty} a_{q} e^{j(l2\pi/\Lambda)z} \quad (3)$$

The length of a uniform grating is defined as $0<z<L_g$, while the boundary condition of the grating are $A^{+}(0)=1$ at $z=-L/2$ and $A^{-}(0)=0$ at $z=L$. Hence under the phase matching condition, the solution of the coupled-mode equation can be expressed by

$$A^{-}(z) = A^{+}(0)\frac{\sinh\left[\kappa(z-L_g)\right]}{\cosh\left(\kappa L_g\right)}, A^{+}(z) = A^{+}(0)\frac{\cosh\left[\kappa(z-L_g)\right]}{\cosh\left(\kappa L_g\right)}. \quad (4)$$

The forward- and backward-wave mode power intensities inside the grating region are plotted in Fig. 1, where the Bragg wavelength, $\delta n_{co}$, *a* and $w_g$ are 1550 nm, 0.001, 4 μm, and 5 μm, respectively.



(a) General FBG (b) Meta-material FBG

Fig. 2 forward- and backward-wave power intensities inside the grating region

In Figure 2, when using MTM as the grating material of the FBG, the power reflection of the Bragg wavelength was greater than that of general FBG, which shows the potential versatility of MTMs suitable to FBG components.

## Acknowledgement

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## References

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