Kent Academic Repository

Full text document (pdf)

Citation for published version

Qin, Huabao and Yan, Zhijun and Sun, Qizhen and Wang, Guoqing and Wang, Chao and Liu, Deming and Zhang, Lin (2017) Theoretical analysis of diffraction grating based on 45°-tilted fiber gratings. In: 2017 Opto-Electronics and Communications Conference (OECC), 31 Jul - 04 Aug 2017, Singapore.

DOI

https://doi.org/10.1109/OECC.2017.8114931

Link to record in KAR

http://kar.kent.ac.uk/61535/

Document Version

Author's Accepted Manuscript

Copyright & reuse
Content in the Kent Academic Repository is made available for research purposes. Unless otherwise stated all content is protected by copyright and in the absence of an open licence (eg Creative Commons), permissions for further reuse of content should be sought from the publisher, author or other copyright holder.

Versions of research
The version in the Kent Academic Repository may differ from the final published version.
Users are advised to check **http://kar.kent.ac.uk** for the status of the paper. **Users should always cite the published version of record.**

Enquiries
For any further enquiries regarding the licence status of this document, please contact:
researchsupport@kent.ac.uk

If you believe this document infringes copyright then please contact the KAR admin team with the take-down information provided at **http://kar.kent.ac.uk/contact.html**

KAR Kent Academic Repository

University of Kent

Theoretical analysis of diffraction grating based on 45°-tilted fiber gratings

Huabao Qin[1], Xi Guo[1], Zhijun Yan[*,1,3], Qizhen Sun[1], Guoqing Wang[2], Chao Wang[2], Deming Liu[1] and Lin Zhang[3]
[1]The School of Optical and Electronic Information, National Engineering Laboratory for Next Generation Internet Access System, Huazhong University of Science and Technology, Wuhan 430074, Hubei, P. R. China
[2]School of Engineering and Digital Arts, University of Kent, Canterbury, CT2 7NT, UK
[3]Aston Institute of Photonic Technologies, Aston University, Birmingham, UK, B4 7ET
* Corresponding author: yanzhijun@hust.edu.cn

Tilted fiber gratings (TFGs) are a special kind of grating with a pile of blazed structures, which could couple the light transmitted inside the fiber core into the cladding mode or radiation mode. Since G. Meltz firstly reported a TFG based fiber tap in 1990[1], the TFGs have been developed over two decades. During this period, massive applications based on TFGs have been demonstrated, such as in fiber polarimeters, fiber taper, polarization equalizer, polarizer, spectrometer, fiber sensors and mode locking fiber laser system[2,3]. According to different coupling behavior, the TFGs could be sorted into three types: 1, backward cladding mode coupling; 2, forward cladding mode coupling; 3, radiation mode coupling. 45°-TFGs were firstly proposed by Westbrook and demonstrated as an in-line polarimeter [4]. Because 45° is also the Brewster's angle of fiber grating, Zhou and Zhang et. Al have proposed to use 45° TFGs as an in-fiber polarizer in 2005[5]. So far, the main applications of 45° TFGs have been focused on the all fiber ultrafast laser systems [6-8]. Recently, researcher from Bern University of Applied Sciences in Switzerland and Kent University in UK have introduced the 45° TFGs as an in-fiber diffractive grating into spectroscopy and imaging system [9,10]. However, there was no report on detailed analysis about the diffractive characteristics of radiation mode of 45°-TFGs. In the paper, we would theoretically and experimentally analyze the diffraction characteristics of radiation mode of 45º TFGs, including the far field profile of radiation mode, the angular dispersion and the diffractive angle of 45º TFGs.

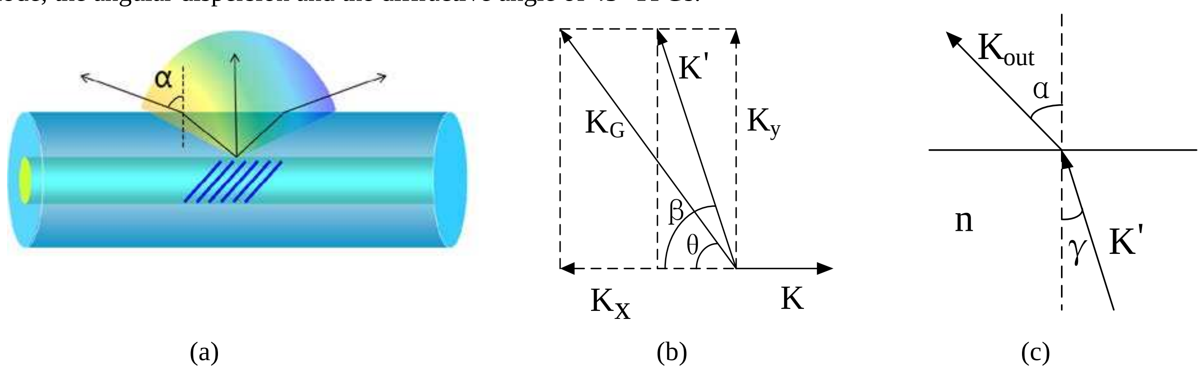


Figure 1 (a) the schematic drawing of radiation mode of 45º TFGs; (b) the vector relationship of grating vector, core mode and radiation mode; (c) the schematic of the light refraction at the interface

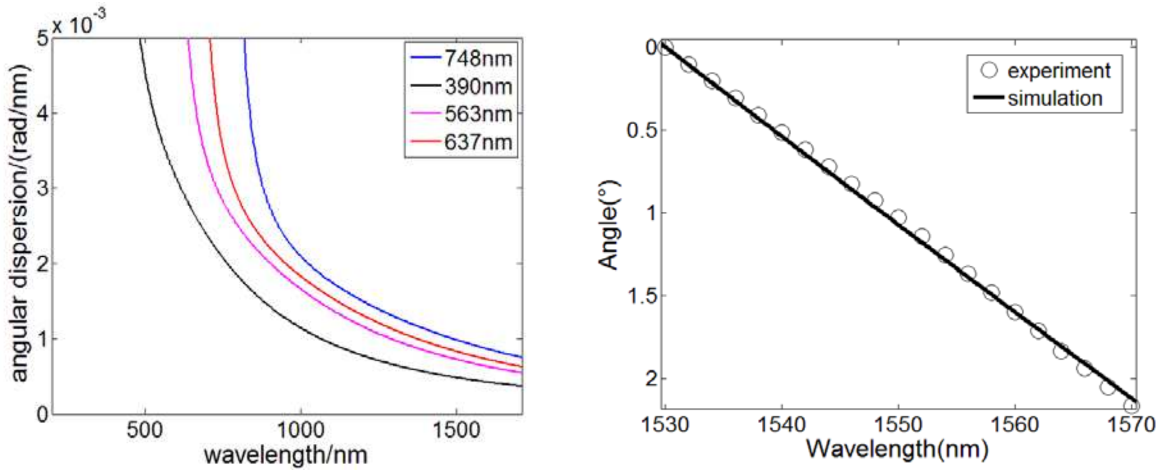
Figure 1 (a) showed the schematic drawing of radiation mode of 45º TFGs, in which the structure of TFG has a titled angle θ and a period Λ, and the different wavelength light was taped out of the fiber at the different radiation angle. The vector relationship between radiation mode, core mode and TFGs could be described in Figure 1(b), where, K is the wave vector of the incident light, which is $2n\pi/\lambda$ (n is the refractive index of the fiber and λ is the wavelength of the light); K_G is the wave vector of TFG, which is $2\pi/\Lambda$, and it is resolved into two orthogonal direction K_x and K_y; K_R is the wave vector of the radiation mode. According to the vector algorithm, the scattering angle of radiation mode inside fiber could be obtained from Equation 1.

$$\cot\beta = \frac{(K_x - K)}{K_y} = \cot\theta - \frac{n\Lambda}{\lambda\sin\theta} \quad (1)$$

Where, β the scattering angle with respect to the fiber axis; θ is the tilt angle of fiber grating.
In Equation 2, β is the scattering angle of radiation mode from the fiber core into cladding. When the light launched into the air, the refraction at the interface between fiber cladding and air should be considered (see in Figure 1(c)). The scattering angle of radiation mode outside the fiber would be rewritten as :

$$\sin\alpha = \frac{n\cdot(\cot\theta - \dfrac{n\cdot\Lambda}{\lambda\cdot\sin\theta})}{\sqrt{1+(\cot\theta - \dfrac{n\cdot\Lambda}{\lambda\cdot\sin\theta})^2}} \qquad (2)$$

Figure 2 (a) showed the simulated angular dispersion of 45º TFGs versus the wavelength with four different periods 390nm, 563nm, 637nm and 748nm, in which the angular dispersion is not a constant, under the same period, the angular dispersion is nonlinearly increasing as decreasing the wavelength, and the larger period is the higher angular dispersion. For a 45º TFGs with 748nm period, the simulated angular dispersion is around 9.189X10^{-4}rad/nm at 1550nm, which is around 0.053°/nm. Our experimental result has shown the angular dispersion is around $0.054°/nm$,which is perfectly agreed with the theoretical result.



(a) (b)

Fig.2. (a) Simulation results of angular dispersion with different period; (b)The Experimental and simulation results of diffractive angle of light at the wavelength range from 1530nm-1570nm.

Reference:

[1]. G. Meltz, W. W. Morey, and W. H. Glenn, “In-fiber Bragg grating tap,” in Proc. OFC’90, TuG1 1990

[2]. Albert, J., L.Y. Shao, and C. Caucheteur, "Tilted fiber Bragg gratings sensors," Laser & Photon. Rev., 7, 83-108, (2012).

[3]. C. Mou, H. Wang, BG Bale, K. Zhou, L. Zhang, I. Bennion, "All-fiber passively mode-locked femtosecond laser using a 45º-tilted fiber grating polarization element," Opt. Express, 18, 18906-11 (2010).

[4]. P.S. Westbrook, T.A. Strasser, T. Erdogan., "In-line polarimeter using blazed fibre gratings," IEEE Photon. Technol. Lett., 12, 1352-1354 (2000).

[5]. K. Zhou, X. Chen, L. Zhang, and I. Bennion, "High extinction ratio in-fiber polarizers based on 45° tilted fiber Bragg gratings," Opt. Lett., 30, 1285-1287 (2005).

[6]. Z. Yan, C. Mou, K. Zhou, X. Chen and L. Zhang, "UV-inscription, polarization-dependent loss characteristics and applications of 45° tilted fiber gratings," J. Lightwave Technol., 29, 2715-2724, (2011).

[7]. J. Li, Z. Yan, Z. Sun, H. Luo, Y. He, Z. Li, Y. Liu, and L. Zhang, "Thulium-doped all-fiber mode-locked laser based on NPR and 45°-tilted fiber grating," Opt. Express 22, 31020-31028 (2014)

[8]. X. Liu, H. Wang, Z. Yan, Y. Wang, W. Zhao, L. Zhang, Z. Yang, X. Hu, and G. Chen, "All-fiber normal-dispersion single-polarization passively mode-locked laser based on a 45°-tilted fiber grating," Opt. Express 20, 19000-19005 (2012).

[9]. G. Wang, C. Wang, Z. Yan, and L. Zhang, "Highly efficient spectrally encoded imaging using a 45° tilted fiber grating," Opt. Lett. 41, 2398-2401 (2016).

[10]. S. Remund, A. Bossen, X. Chen, L. Wang, A. Adebayo, L. Zhang, B. Považay, C. Meier, "Cost-effective optical coherence tomography spectrometer based on a tilted fiber Bragg grating". Proc. SPIE 8938, 2039409, (2014).