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一种基于取样光栅的 Sagnac 环滤波器的设计研究

王 露，武向农*，陶剑骅，汪光坤
200234

摘要： Sagnac
Jones
L ΔL P 6

Sagnac

关键词： Sagnac Jones
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Design of Sagnac loop filters based on sampled gratings

WANG Lu WU Xiangnong TAO Jianhua WANG Guangkun
College of Information Mechanical and Electrical Engineering Shanghai Normal University Shanghai 200234 China

Abstract To explore new structures of comb filters a new Sagnac loop filter based on the sampled fiber Bragg grating was proposed. Using the theory of Jones matrix the theoretical model of filter was established. Theoretical analysis and numerical simulation of transmission spectra of the proposed filter were carried on. By choosing the different value of the sampled fiber Bragg grating length L optical fiber ring arm length difference ΔL and the sampling period P six kinds of narrow-band comb transmission spectrums with discrete spectral lines high reflectivity and equal interval can be obtained. The spectrums have good wavelength selectivity and good channel isolation. The simulation results show that this filter can be used in the multi-channel narrow band filter of the wavelength division multiplexing system dual-wavelengthfiber laser and the distributed sensing system etc. It provides a certain reference for the filter combining fiber Bragg grating with the structure of the Sagnac loop in research and application.

Key words fiber optics Sagnac loop sampling grating Jones matrix filter

引 言

dense wavelength division multiplexing DWDM 4nm [8] 2
[1-2]
Sagnac [3-7]

Sagnac

1
Sagnac
0. 4nm
0. 2nm 10 20
Sagnac
0. 8nm 0. 1nm
[9]
Sagnac
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* E-mail xnwu@ shnu. edu. cn
2015-04-13 2015-07-22

P

6

1 理论分析

[10]

[11]

1 L $P = a + b$

a

b $T = a/b$

$n = L/P$

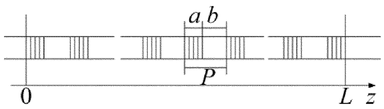

Fig. 1 Structure model of the sampled fiber grating

j

$$\begin{bmatrix} R_j \\ S_j \end{bmatrix} = \boldsymbol{F}_j \begin{bmatrix} R_{j-1}{}' \\ S_{j-1}{}' \end{bmatrix} \quad (1)$$

$$\boldsymbol{F}_j = \begin{bmatrix} \cosh(\gamma a) - \mathrm{i}\frac{\hat{\sigma}}{\gamma}\sinh(\gamma a) & -\mathrm{i}\frac{k}{\gamma}\sinh(\gamma a) \\ \mathrm{i}\frac{k}{\gamma}\sinh(\gamma a) & \cosh(\gamma a) + \mathrm{i}\frac{\hat{\sigma}}{\gamma}\sinh(\gamma a) \end{bmatrix} \quad (2)$$

$\gamma = \sqrt{k^2 - \hat{\sigma}^2}$ k

$\hat{\sigma} = \delta + \sigma$ $\delta = 2\pi n_{\mathrm{eff}}(\lambda^{-1} - \lambda_{\mathrm{B}}{}^{-1})$

σ

n_{eff} λ λ_{B} Bragg

$\begin{bmatrix} R_j \\ S_j \end{bmatrix}$ j

j

$$\begin{bmatrix} R_j \\ S_j \end{bmatrix} = \boldsymbol{F}_j \cdot \boldsymbol{M}_j \begin{bmatrix} R_{j-1} \\ S_{j-1} \end{bmatrix} \quad (3)$$

$$\boldsymbol{M}_j = \begin{bmatrix} \mathrm{e}^{-\mathrm{i}\beta b} & 0 \\ 0 & \mathrm{e}^{\mathrm{i}\beta b} \end{bmatrix} \quad (4)$$

$\beta = 2\pi n_{\mathrm{eff}}/\lambda$

L

[11]

$$\begin{bmatrix} R_n \\ S_n \end{bmatrix} = \boldsymbol{F} \cdot \boldsymbol{M} \begin{bmatrix} R_{n-1} \\ S_{n-1} \end{bmatrix} = (\boldsymbol{F} \cdot \boldsymbol{M})^2 \begin{bmatrix} R_{n-2} \\ S_{n-2} \end{bmatrix} = \dots =$$

$$(\boldsymbol{F} \cdot \boldsymbol{M})^n \begin{bmatrix} R_0 \\ S_0 \end{bmatrix} = \boldsymbol{T}_{\mathrm{g}} \begin{bmatrix} R_0 \\ S_0 \end{bmatrix} \quad (5)$$

$\boldsymbol{T}_{\mathrm{g}} = \begin{bmatrix} T_{11}(n) & T_{12}(n) \\ T_{21}(n) & T_{22}(n) \end{bmatrix}$ $T_{11}(n) = T_{22}{}^*(n)$

$T_{12}(n) = T_{21}{}^*(n)$ $\begin{bmatrix} R_0 \\ S_0 \end{bmatrix}$ $\boldsymbol{F}$

$\boldsymbol{M}$

$\boldsymbol{F}$ $\boldsymbol{M}$

5

$$\begin{bmatrix} S_n \\ R_0 \end{bmatrix} = \boldsymbol{G}_{\mathrm{g}} \begin{bmatrix} R_n \\ S_0 \end{bmatrix} \quad (6)$$

$$\boldsymbol{G}_{\mathrm{g}} = \frac{1}{T_{11}(n)} \begin{bmatrix} T_{21}(n) & T_{11}(n)T_{22}(n) - T_{12}(n)T_{21}(n) \\ 1 & -T_{12}(n) \end{bmatrix}$$

Sagnac 2

1 2 L_1

L_2

$\Delta L = L_1 - L_2$

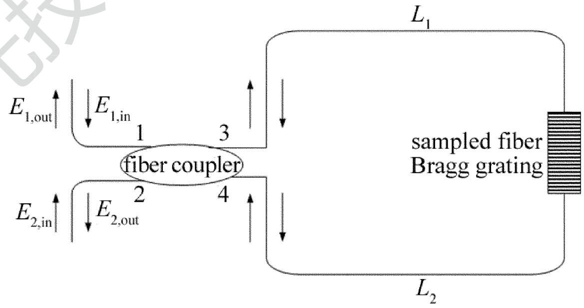

Fig. 2 Schematic of Sagnac loop microwave photonic filter with the sampled fiber Bragg grating

3dB K

$$\boldsymbol{G}_{\mathrm{c}} = \begin{bmatrix} \sqrt{1-K} & \mathrm{i}\sqrt{K} \\ \mathrm{i}\sqrt{K} & \sqrt{1-K} \end{bmatrix} \quad (7)$$

L_1 L_2

$$\boldsymbol{G}_{\mathrm{f}} = \begin{bmatrix} \exp(\mathrm{i}\beta L_1) & 0 \\ 0 & \exp(\mathrm{i}\beta L_2) \end{bmatrix} \quad (8)$$

1 $E_{1\,\mathrm{in}}$

$E_{1\,\mathrm{out}}$ 2 $E_{2\,\mathrm{in}}$ 0

$E_{2\,\mathrm{out}}$

$$\begin{bmatrix} E_{1\,\mathrm{out}} \\ E_{2\,\mathrm{out}} \end{bmatrix} = \boldsymbol{G} \begin{bmatrix} E_{1\,\mathrm{in}} \\ E_{2\,\mathrm{in}} \end{bmatrix} = \boldsymbol{G}_{\mathrm{c}}\boldsymbol{G}_{\mathrm{f}}\boldsymbol{G}_{\mathrm{g}}\boldsymbol{G}_{\mathrm{f}}\boldsymbol{G}_{\mathrm{c}} \begin{bmatrix} E_{1\,\mathrm{in}} \\ 0 \end{bmatrix} \quad (9)$$

9 2 Sa-gnac

$$T = \left|\frac{E_{2\ \mathrm{out}}}{E_{1\ \mathrm{in}}}\right|^2 = |G_{21}|^2 = G_{21} \times G_{21}{}^* \qquad 10$$

$G_{21}{}^*$ G_{21}

$K = 0.5$ 10

$$T = \frac{1}{|T_{11}\ n\ |^2}\left\{\frac{2|T_{12}\ n\ |^2 - |T_{11}\ n\ |^2}{2} + \frac{1}{4} + \frac{|T_{11}\ n\ |^2 - |T_{12}\ n\ |^2}{4}{}^2 - \frac{1}{2}\ \mathrm{Re}^2\ T_{12}\ n\ - \mathrm{Im}^2\ T_{12}\ n\ \cos\ 2\beta\Delta L + 2\mathrm{Re}\ T_{12}\ n\ \mathrm{Im}\ T_{12}\ n\ \sin\ 2\beta\Delta L + |T_{11}\ n\ |^2 - |T_{12}\ n\ |^2 - 1 \times \mathrm{Re}\ T_{12}\ n\ \sin\ \beta\Delta L - \mathrm{Im}\ T_{12}\ n\ \cos\ \beta\Delta L\right\} \qquad 11$$

2 2

$\overline{\Delta n}$ P T L K

ΔL Sagnac

L_1 L_2

2 数值仿真

11 MATLAB

3dB $K =$ 0.5 Bragg $\lambda_B = 1550$nm $\overline{\Delta n} =$ 0.0005 $T = a/b = 0.1$ 6

L P ΔL

MATLAB 2

3 ~ 8

3 ~ 8

P ΔL

3

16 0.06nm 0.8nm

1 16 100GHz

0.8nm DWDM [12]

4

8 0.06nm 1.6nm

1 8

200GHz 1.6nm DWDM

3 4

ΔL

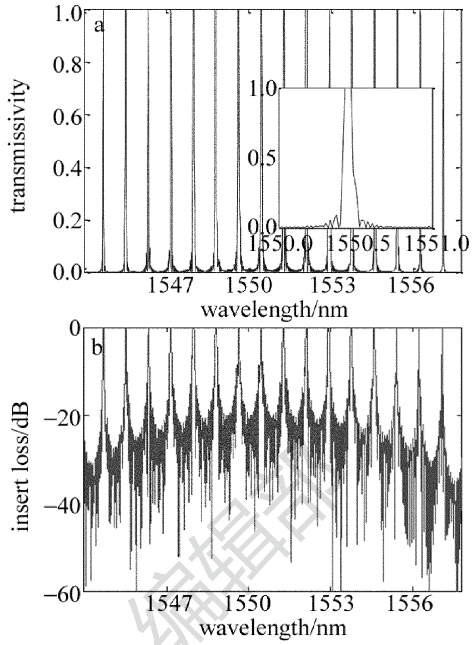

Fig. 3 Transmission spectrum of filter when $L = 120$mm $P = 1.0$mm $\Delta L = 0.9$mm

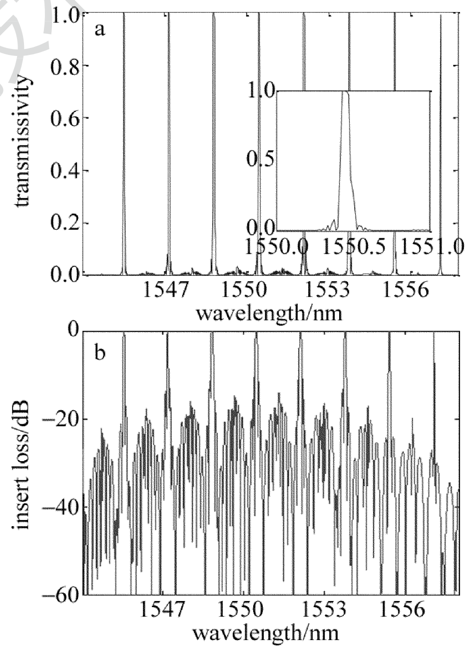

Fig. 4 Transmission spectrum of filter when $L = 120$mm $P = 1.0$mm $\Delta L = 2.4$mm

ΔL

5

4 0.06nm

3.2nm

6

0.06nm 8.1nm

13

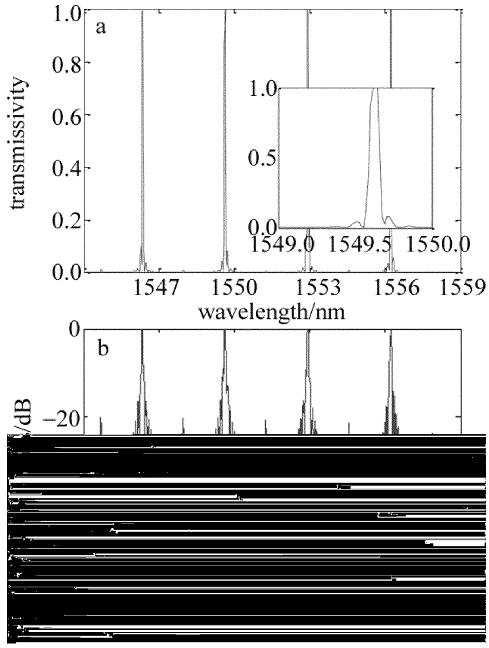

Fig. 5 Transmission spectrum of filter when $L = 60\mathrm{mm}$ $P = 0.5\mathrm{mm}$ $\Delta L = 0.2\mathrm{mm}$

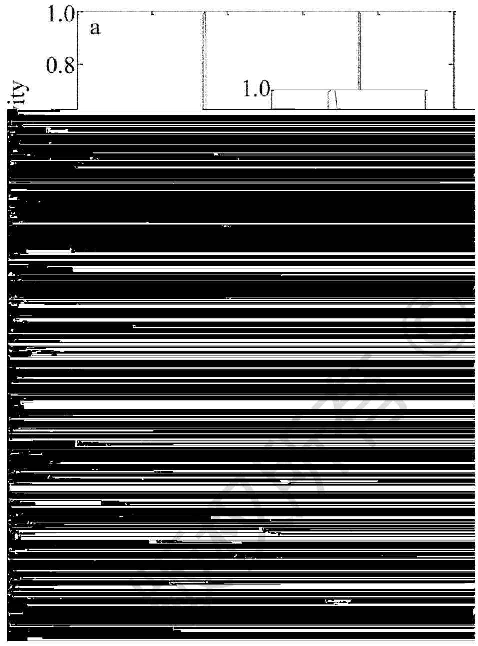

Fig. 6 Transmission spectrum of filter when $L = 30\mathrm{mm}$ $P = 0.4\mathrm{mm}$ $\Delta L = 0.2\mathrm{mm}$

5 6

P

P

7 8

0.07nm 1

1

14

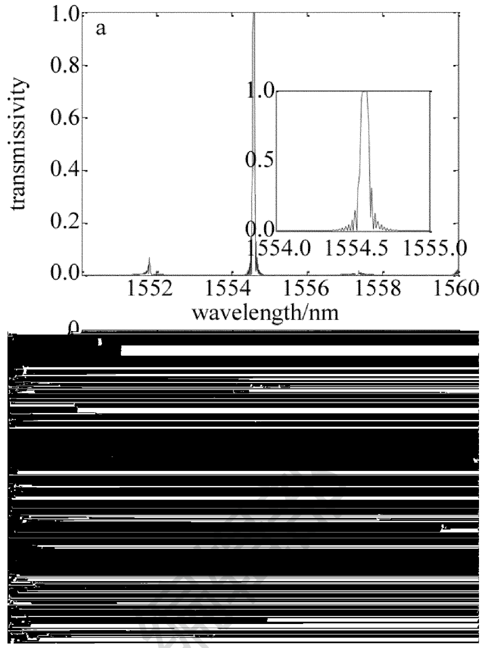

Fig. 7 Transmission spectrum of filter when $L = 30\mathrm{mm}$ $P = 0.3\mathrm{mm}$ $\Delta L = 1.3\mathrm{mm}$

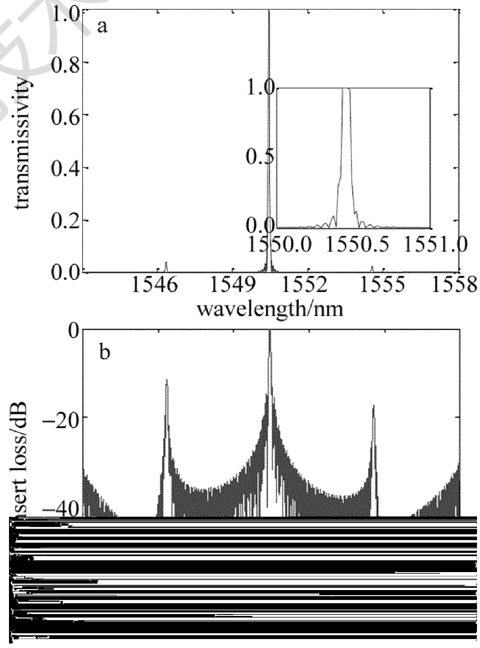

Fig. 8 Transmission spectrum of filter when $L = 25\mathrm{mm}$ $P = 0.2\mathrm{mm}$ $\Delta L = 0.1\mathrm{mm}$

3 结 论

Sagnac

L ΔL P

6

$L = 120\mathrm{mm}$

$P = 1.0\mathrm{mm}$ ΔL $0.9\mathrm{mm}$

2.4mm 16 100GHz
200GHz DWDM
$L = 30$mm $P = 0.4$mm
$\Delta L = 0.2$mm 8.1nm

$T = 0.1$
11 $T = 0.1$
6
Sagnac

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