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All-Fiber Drop-Pass Filters with Fiber Bragg Gratings

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Novel, all-fiber drop-pass filters with the implementation of fiber gratings are reported. Good controllability of the drop and pass power is demonstrated. Some preliminary results on the performance of the drop-pass filters are presented.

I. INTRODUCTION

Optical fiber Bragg gratings have attracted much attention in the past few years because of their numerous applications such as fiber lasers, simple reflection filters, fiber dispersion compensators, gain flattening devices, fiber sensors, and add-drop multiplexer (ADM) filters. The last devices are required in the dense wavelength-division multiplexing (DWDM) networks to multiplex or demultiplex different wavelength channels. A number of all-fiber add-drop multiplexer (ADM) filters with fiber Bragg gratings have been demonstrated [1-5]. In this paper, we report, for the first time, a new fiber grating device, called here all-fiber drop-pass filter (DPF). The all-fiber drop-pass filter seems to be very useful in DWDM networks especially when that dropping only a part of a signal at a certain wavelength and passing the rest of the signal to the next node is preferred. The proposed device has excellent controllability of the drop and pass power and wavelength tunability.

Some examples of unidirectional WDM networks with the DPFs are shown in Fig. 1. When a stream of several wavelengths $(\lambda_1, \lambda_2, \lambda_3, \lambda_4)$ enters the first node, a part of the light at λ_1 drops from the first drop-pass filter (DPF1), and the other part of the light at λ_1 and some or all of the light at λ_2, λ_3 and λ_4 pass to the next node. Similarly, in the next three nodes, parts of light at λ_2, λ_1 and λ_3 drop from the drop-pass filters DPF2, DPF3 and DPF4, respectively. An optical fiber amplifier (FA) is added in Fig. 1(a) to boost all wavelengths to the same high level, meanwhile an ADM filter (ADM1) at node 5 extracts λ_1 and inserts the same wavelength in Fig. 1(b). Note that all of the wavelengths still reach the first five nodes without using either optical fiber amplifiers or ADM filters. This is the reason why the DPF has potential impact on the realization of cost-effective WDM networks such as CATV distribution networks and broadcast networks.

Two different types of all-fiber DPFs with fiber Bragg gratings are proposed. The characteristics of the all-fiber DPFs are also discussed.

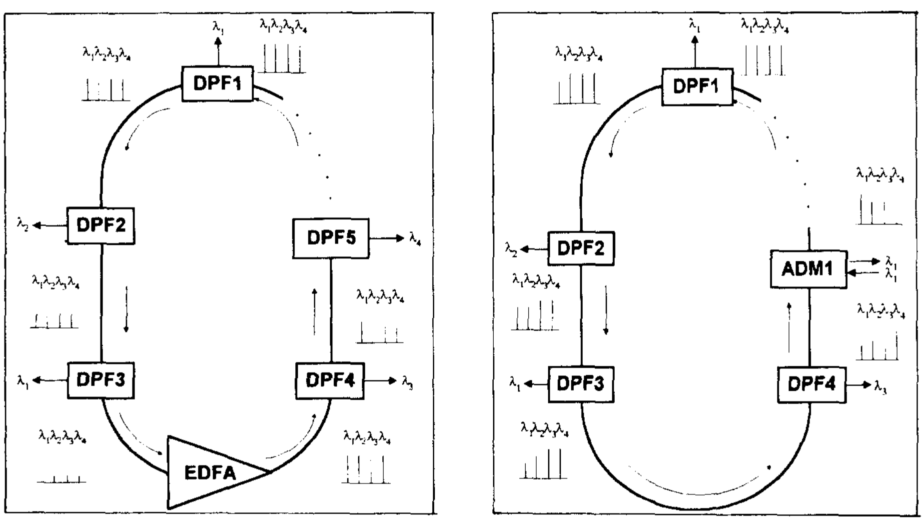
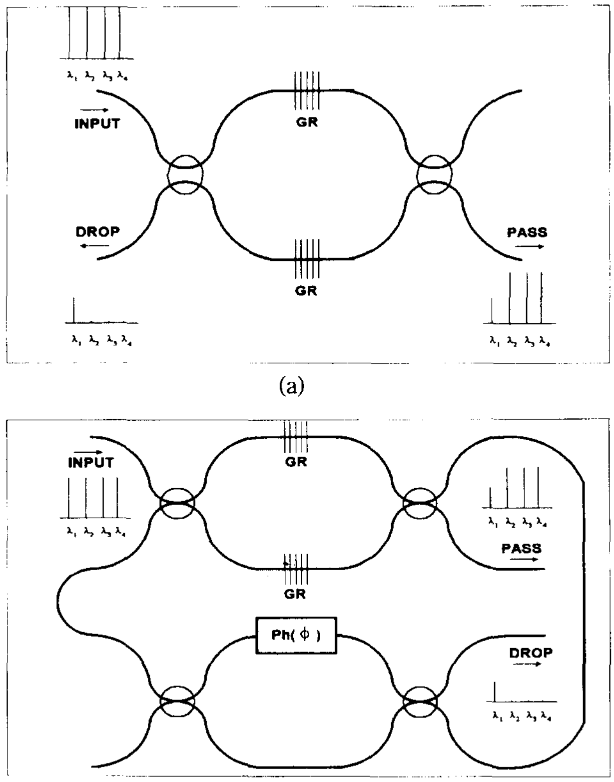


FIG. 1. Drop and pass operation for (a) type I and (b) type II filters in simple WDM Networks.

II. DEVICE OPERATION

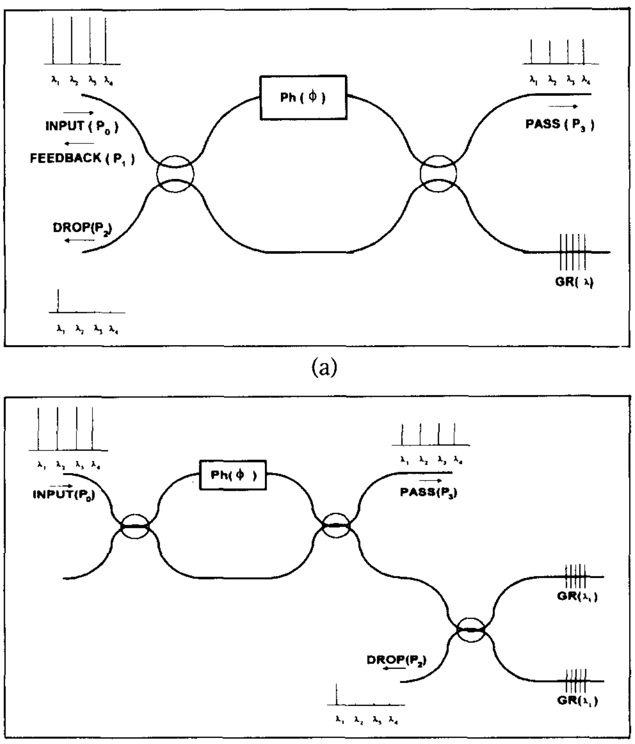
Two types of all-fiber DPFs are shown in Figs. 2 and 3. Fig. 2 shows two different configurations of 1st type of the DPF. They consist of an all-fiber Mach-Zehnder interferometer, a phase controller Ph and one or two fiber gratings GR. The 1st type of the DPF drops only a preset amount of the light at a wavelength λ_1 and passes all of the wavelengths at the same level as λ_1. The relative drop power, defined as the ratio of the drop power P_2 to the input power P_0, is controlled by the phase controller, which changes the phase difference ϕ between the interferometer arms. The predicted relative powers at the drop port, at the pass port, and at the input port as a function of ϕ for both the all-fiber DPF with a fiber grating (Fig. 2(a)) [6] and the all-fiber DPF with two fiber gratings (Fig. 2(b)) are also plotted in Fig. 4. Note that the relative drop power (P_2/P_0) for the all-fiber DPF with two fiber gratings (Fig. 2(b)) is controllable fully from 0 to 1, while the controllability of the all-fiber DPF with a grating (Fig. 2(a)) is limited to $P_2/P_0 \leq 0.25$. The feedback power P_1 for the all-fiber DPF (Fig. 2(b)) is zero regardless of ϕ.However, the feedback power for the all-fiber DPF (Fig. 2(a)) varies with ϕ. So to reduce the optical feedback to less than 2 %,the DPF (Fig. 2(a)) should be operated at the phase difference within $\pm 0.2\pi$ from $(2m+1)\pi$. For this reason the all-fiber DPF with two fiber gratings (Fig. 2(b)) is preferable.



(a)

(b)

FIG. 3. All fiber drop-pass filters (type II) (a) with weak gratings and (b) with high reflective gratings and drop-to-pass ratio controller.



(a)

(b)

FIG. 2. All-fiber drop-pass filters(type I) (a) with a fiber grating and (b) with two fiber gratings.

The configurations of the 2nd type of all-fiber drop-pass filters are displayed in Fig. 3. The 2nd type of the DPF drops a part of the light at a certain wavelength (here, λ_1), and passes the other part of the light at λ_1 and all of the light at λ_2, λ_3 and λ_4. A typical all-fiber add-drop filter [2] with two fiber gratings (Fig. 3(a)) can also function as an all-fiber DPF (type II) only if the two gratings are replaced by two weak gratings. However, the device (Fig. 3(a)) doesn't have any controllability. An all-fiber DPF (type II) with excellent controllability is shown in Fig. 3(b). The device is composed of two Mach-Zehnder interferometers, two high reflective gratings and a phase controller Ph. The fiber gratings are inserted in each arm of the first Mach-Zehnder interferometer, and the phase controller is attached to one arm of the second Mach-Zehnder interferometers for the control of the drop power and pass power. In addition to its full controllability, this new device shows no optical feedback. The fiber couplers in the DPFs are assumed ideal 3dB-directional couplers.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The performance of the all-fiber DPFs (type I) was

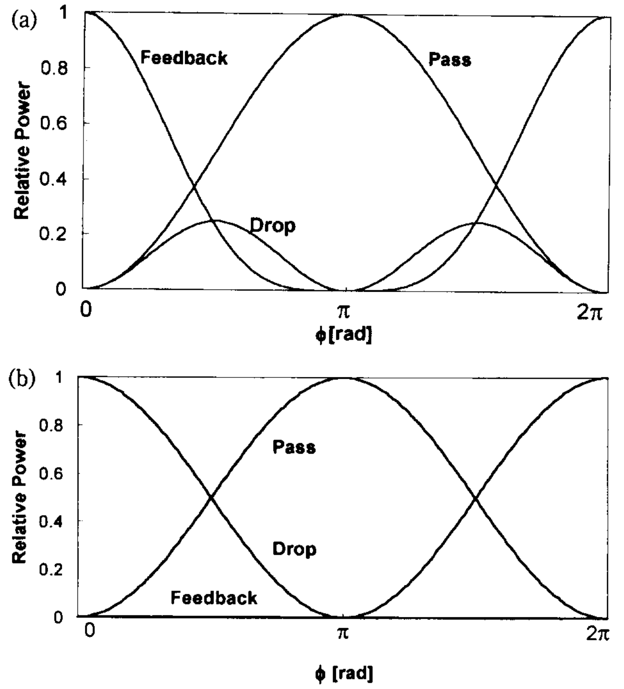


FIG. 4. Drop, pass and feedback powers as a function of phase differene ϕ for drop-pass filters (a) with a fiber grating (Fig 2.a) and , (b) with two identical fiber Bragg grating (Fig2.b).

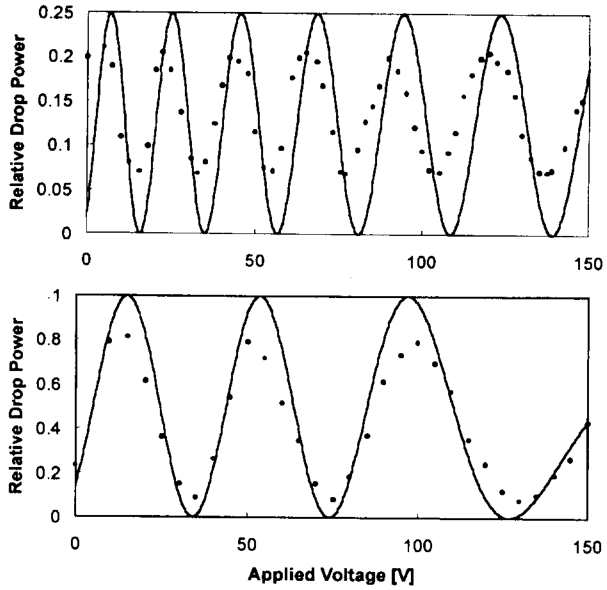


FIG. 5. Output power at the drop port versus the voltage applied to the drop-pass filters (a) with a fiber grating (Fig 2.a), and (b) with two identical fiber grantings (Fig 2.b).

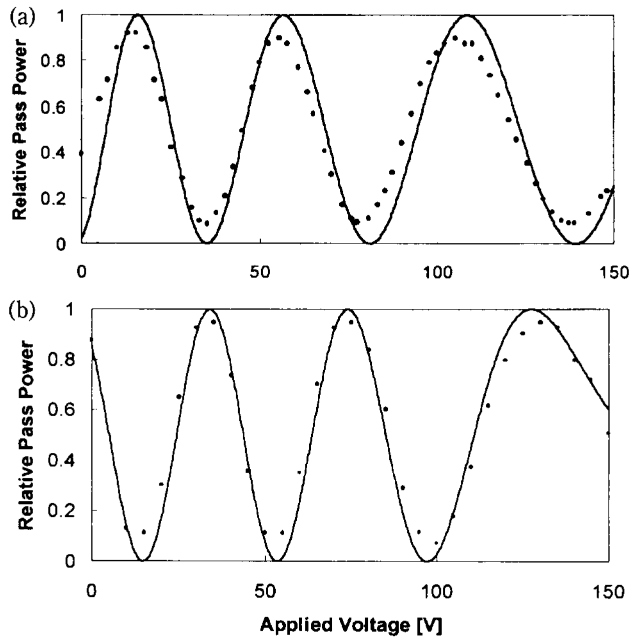


FIG. 6. Output power at the drop port versus the voltage applied to the drop-pass filters (a) with a fiber grating (Fig 2.a), and (b) with two identical fiber grantings (Fig 2.b).

measured. A Light emitting diode (LASER DIODE INC. , IRS 1502E, λ_P = 1550nm, $\Delta\lambda$ = 50nm) was used as a light source. The light emitting from the fiber pigtail was 5.79nW. A fiber grating with a peak reflectivity of 97.6% at 1550nm and a FWHM bandwidth of 0.285nm was used for the DPF (Fig. 2(a)). Two gratings in Fig. 2(b) have 96.15% peak reflectivity at 1550nm with the bandwidth of 0.265nm, and 96.64% peak reflectivity at 1550nm with 0.23nm bandwidth, respectively. The insertion loss of the couplers was about 0.1 ~2dB and the splitting ratio was better than 47/53% at 1550nm. The phase difference ϕ was controlled by changing the voltage V applied to the PZT (NLA 2 x 3 x 18 , TOKIN), which was attached to one arm of the Mach-Zehnder interferometer constructed with all single-mode fibers. We found that the phase difference was related to the applied voltage by, Φ (V) $=a + bV + cV^2 + dV^3$, where a, b, c and d are -2.827, 0.1885, -5.435$\times10^{-4}$ and 1.05$\times10^{-6}$ for the DPF (Fig. 2(a)), and -2.356, 0.157, 2.351$\times10^{-3}$, -2.763 $\times10^{-6}$ for DPF (Fig. 2(b)), respectively.

The relative drop power (P_2/P_0) and the relative pass power (P_3/P_0) at different voltages for the two DPFs (type I) were measured and plotted in Figs. 5 and 6. The dots and the solid lines represent the experimental data and the predicted values , respectively. The drop power and pass power measured while increasing voltage follow well the predicted values. Maximum drop power occurs in the DPF (Fig. 2(a)) at 7.2V, 24.8V, 44.8V, 65V, 92.6V and 120.3V corresponding to (m+1/2)π of the phase difference, and in the DPF (Fig. 2(b)) at 15V, 50V and 100V corresponding to (2m+1)π . Maximum pass powers in the DPF (Fig. 2(a)) and in the DPF (Fig. 2(b)) occur near (2m+1)π and 2mπ, respectively, as shown in Fig. 6. The relative drop power for the DPF (Fig. 2(a)) was controlled to between 0.06 and 0.21, while

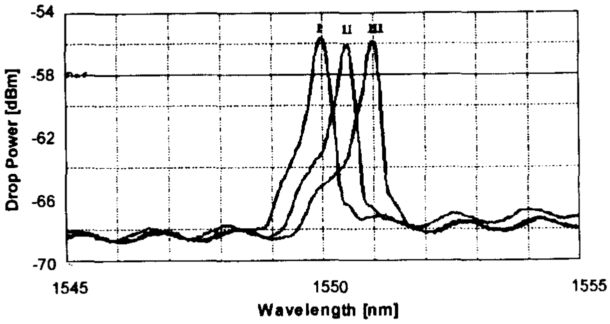


FIG. 7. The drop power spectra of the drop-pass filter (Fig 2.a) for three different strains.

the power was from 0.037 to 0.386 for the DPF (Fig. 2(b)). The discrepancy between expectation and measurement is mainly due to the losses at the couplers and fiber gratings. However, the experimental results on the pass power for the two DPFs agree pretty well with the theoretical values. Negligible feedback power P_1 was also detected for the DPF (Fig. 2(b)) during the measurement.

Shown in Fig. 7 is the drop power spectra of the DPF (Fig. 2(a)) for three different strains induced in the grating. The grating in this case was attached to the PZT. Three drop wavelengths λ_I(1550 nm), λ_{II}(1550.5 nm) and λ_{III} (1551 nm) were selected by tuning the PZT voltage. The strain values for λ_{II} and λ_{III} were $\sim$0.5 $\times 10^{-3}$,and $\sim 1 \times 10^{-3}$, respectively.

With high reflective gratings and loss-free 3dB couplers the filter's performance will be much improved. Especially, it is mandatory that the two gratings are identical for the DPFs discussed above to show good performance. The controller used (here, PZT) to control the drop and pass power and tune the gratings can be replaced by a more stable one, based on the thermooptic effect or other mechanisms. Reliability and application of the DPFs are under investigation.

IV. CONCLUSION

We have reported a number of novel, all-fiber drop-pass filters with one or two fiber gratings. Excellent controllability of the drop and pass power has been demonstrated for some drop-pass filters. Preliminary results on the performance of the DPFs were presented. The all-fiber DPFs with full controllability are potentially useful in a wide range of WDM systems including CATV distribution networks, broadcast networks, and ring networks.

REFERENCES

[1] F.Bilodeau, K.Hill, B.Malo, D.Johnson and J.Albert, IEEE Photon. Technol. Lett. **6**, 80 (1994).

[2] F.Bilodeau, D.Johnson, S.Theriault, B.Malo, J.Albert and K.Hill, IEEE Photon. Technol. Lett. **7**, 388 (1995).

[3] I.Baumann, J.Seifert, Wnowak and M.Sauer, IEEE Photon. Technol. Lett. **8**, 1331 (1996).

[4] L.Dong, P.Hua, T.Birks, L.Reekie andP. Russell, IEEE Photon. Technol. Lett. **8**, 1656 (1996).

[5] S.Kim, S.Lee, J.Chung, S.Kim, J.Jeong, S.Choi, OFC'97 Technical Digest, **3**, 282 (1997).

[6] S.Y.Cho, J.H.Lim, Y.T.Lee, K.S.Lee, Y.H.Won, "*Characteristics of All–Fiber Tunable Drop/Pass Filter*," OECC'97, 9EP-11, 300 (1997).