CHAPTER 7

DISCUSSION AND CONCLUSION

7.1. Discussion

Here, we discuss advantages and disadvantages of the proposed SOP control scheme. The experimental results obtained in Chapter 6 clearly demonstrate the feasibility of the polarization recombining in the present polarization control scheme which features endlessness in control. The main sources of error in these measurements were the intensity fluctuations in the laser light and imperfections in the polarization element used (i.e. optical cross talk resulted from imperfect polarization separation of the Wollaston prism). The drawback of this system is that the response is slow (few seconds) because it consists of mechanical devices.

A faster response may be achieved by an electrically controllable system. An example of the principle idea of such system is shown in Fig. 57. The optical elements version of the phase shifter can be replaced by an equivalent fiber cranks version, and mechanical movement of the HWP is replaced by an electrically controllable Faraday rotators configuration by applying simultaneously the same controlling current ($I_1 = I_2$) to both Faraday rotators. As a result, this has the same effect as rotating the

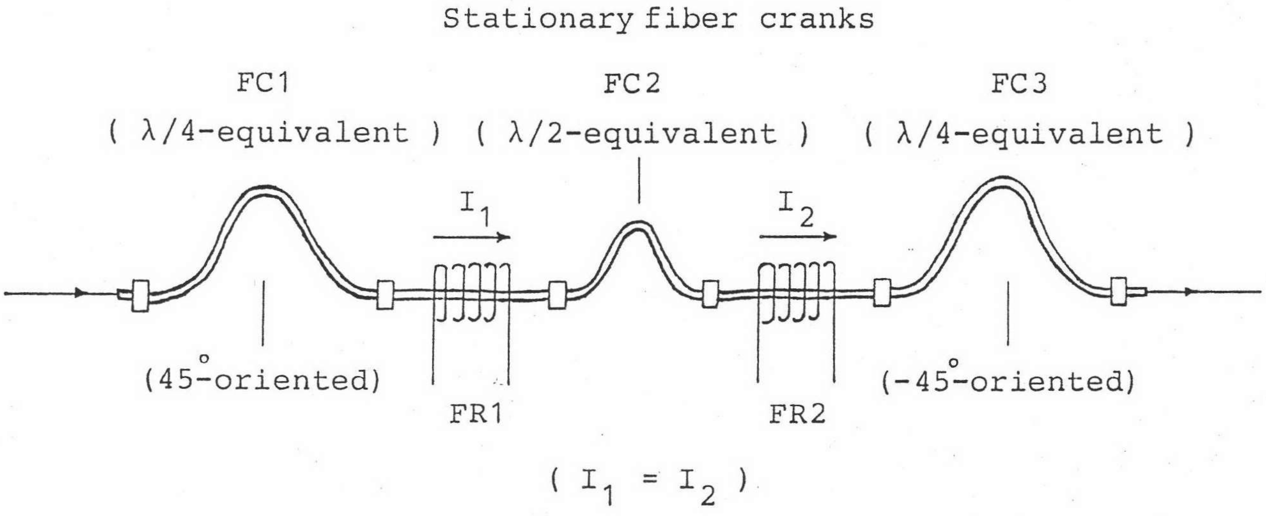

Fig. 57. Principle idea of an electronically controllable phase shifter. FR : Faraday rotator; FC : fiber crank.

HWP and thus results in polarization phase shift. The rotatable polarization rotator (FC2 in Fig. 50) can also be replaced by a Faraday rotator. However, the endlessness is loss in this arrangement. To achieve the endlessness, two sets of Faraday rotators are needed, and hence, resetting becomes necessary when the control range of each set becomes saturated. A low-insertion-loss all-fiber-type version of this system can be constructed using a fiber polarization splitter, a polarization preserving coupler, and the fiber crank configuration mentioned previously.

As discussed in Section 3.4, a SOP control scheme should, in general, be able to convert any polarization-state to any other. The schemes described in this dissertation convert an arbitrary SOP to a linear polarization-state with a specified inclination angle. If any other than linear polarization-state is desired, an additional controlling element (i.e. a phase shifter such as quarter-wave device) which controls the ellipticity of the polarized light will be required. Such a device should be placed at the output port of the proposed polarization control system and controlled through a feed back tracking circuit commonly employed in conventional SOP control scheme.

Obviously, the system becomes complicated and impractical. However, linear polarization-state of the signal light at the receiving end is often required in coherent optical fiber communication systems and fiber-optic interferometric sensors. Particularly, in the former systems when a 90° optical hybrid [101] is employed, a stable linearly polarized signal light is essential. In the two-port phase diversity [27], for example, the 90° phase shift between the in-phase and quadrature beat signals requires the combination between the linearly polarized light and the circularly polarized light of the received signal and the LO, respectively, or vice versa. In general, the SOP of the signal light is usually linear with 45° inclination angle and that of the LO is circular. Continuously controlling the SOP of the signal light requires a polarimeter to detect the instantaneous SOP. The "peak-search" optimization technique [82,83] can not be employed here, because such method matches the SOP of the two lights, in order to maximize the beat signal power, i.e. the SOP of the signal light is always controlled towards that of the LO, or vice versa. The use of the polarimeter is undesirable, as it is bulky and introduces system complexity. Furthermore, precise control of the linear polarization is not easily maintained. Hodgkinson et al. [27] showed that the 90° optical hybrid was very sensitive to polarization misalignement. Thus, the SOP control system error could cause a large penalty.

An unique solution to this problem has been proposed by Okoshi and Cheng [79] as discussed in Section 3.3 (see Fig. 14). Their system is attractive since it offers passive detection removing the need for both active phase locking and polarization-state control. However, in such system, the improvement in receiver sensitivity has not been dealt with. The sensitivity of a conventional single (unbalanced) receiver is usually degraded by the receiver thermal noise and LO excess intensity noise. A sufficient light LO power is required so that the LO shot-noise dominates the thermal noise. However, in practice, it is often a case that the LO power is limited or large amount of power is lost to another branch of a fiber coupler or a beam combiner. These problems apply to the phase and polarization diversities (hereafter Ph-Pol-Div, for short) receiver. The use of balanced (or dual) receiver can solve these. It offers LO excess intensity noise suppression, relaxes strict LO power requirement [106] and there is no signal loss since both outputs are utilized.

Although the Ph-Pol-Div system can accommodate balanced receiver, this is achieved with the expense of eight photodetectors. Increasing in numbers of detectors also increases receiver noise level especially when there is no signal in three of the four output ports to polarization and phase fluctuations. An alternative approach is to use the active SOP control system described in Sections 6.3 and 6.4. In these sections, we have shown, for the first time, that a balanced phase diversity receiver can be constructed by using only four photodetectors. In addition, sensitivity of this receiver is theoretically the same as that of the polarization aligned phase diversity receiver assuming shot-noise-limited operation.

In summary, despite the system poor temporal response as compared with all-electronics ones, the present scheme offers several advantages. These are: simplicity in control procedure; minimum signal power loss (in principle, monitoring intensity is zero); ability of remote control i.e. in the Type-II polarization combining scheme, the control system is separated from the receiver; immunity to phase noise i.e. in homodyne detection, IF monitoring signal used in conventional polarization control scheme fades not only due to the polarization fluctuation but also due to the laser phase noise, in comparison to the present scheme, the monitoring signal is resulted from the interference of the two beams originated from the same source, thus, the phase noise is canceled out in detection process; and finally ability in generating a stable linearly polarized light with a fixed inclination angle regardless of changes in the signal SOP without the aid of a polarimeter.

7.2. Conclusion

In this dissertation, the polarization-state fluctuation of signal light transmitted through a single-mode fiber in coherent (heterodyne or homodyne) optical fiber communications have been discussed, and recent progress in countermeasures against this problem has been reviewed. The emphasis is focused on a new SOP control scheme proposed by the author and his supervisor. It is found that the proposal scheme functions satisfactorily and offers some advantages over the previously reported SOP control schemes, although, as well as the others, it may not satisfy all the technical requirements simultaneously. One problem needed to be overcome is the temporal response. This can be accomplished by implementing an all-electronic controlling device such as Faraday rotator, but at the expense of complicated reset procedures.