Chapter 1

Fiber Birefringence

In circular fiber, because of the circular symmetry, two perpendicularly polarized waves that eh same propagation constant. Therefore, the polarization state of the wave stays teh throughout the propagation.

Real fibers may exhibit considerable variation in the shape of their core along the fiber length. They may also experience nonuniform stress, such that the cylindrical symmetry is broken. As a result the polarization state at the end of propagation is different than the initial state. This is the primary reason why optical communication components typically need to be polarization insensitive.

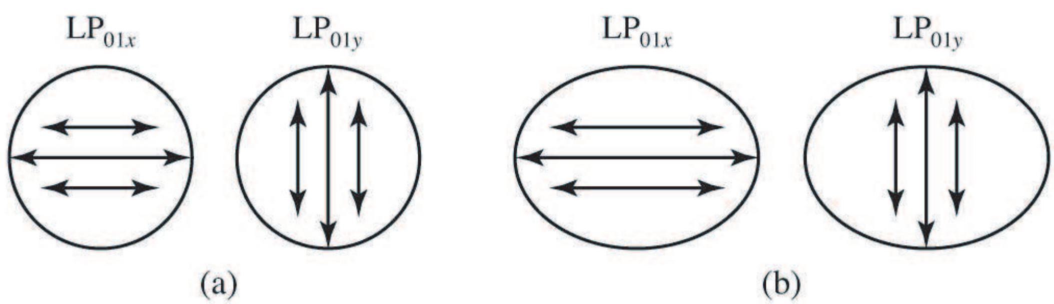

Figure 1.1: Polarization states of LP modes in optical fiber with an elliptical core. (a) In a circular fiber, the two modes are degenerate ($\beta_{LP_{01x}} = \beta_{LP_{01y}}$) and (b) in an elliptical core fiber (($\beta_{LP_{01x}} \neq \beta_{LP_{01y}}$)

The simplest case is a single segment of optical fiber with uniform birefringence. For an unpolarized beam 50% of the light is propagating along each of the LP modes. Let n_s and n_f be the effective indices of the slow and fast modes (see Fig. 1.2). The group time delay between these two components is given by

$$\tau = \left(\frac{d}{c} \Delta n + \frac{\omega d}{c} \frac{\partial \Delta n}{\partial \omega} \right), \tag{1.1}$$

where d is the length of the fiber segment and $\Delta n = n_s - n_f$.

One parameter used to characterize the circular symmetry of a fiber is called modal birefringence, which is defined as

$$B_m = |\overline{n}_x - \overline{n}_y| \tag{1.2}$$

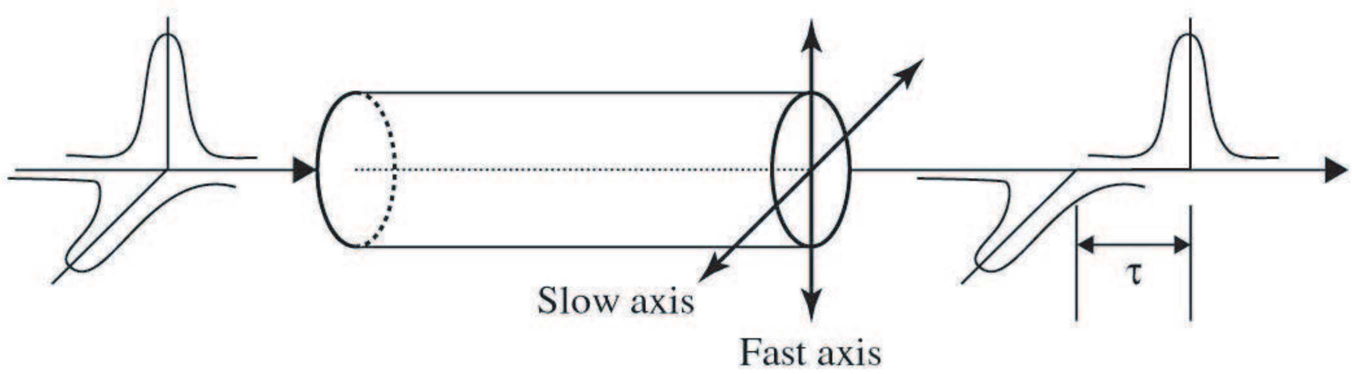

Figure 1.2: Pulse propagation through a uniform birefringent fiber. A time delay occurs between the slaow and fast components of the pulse.

This birefringence does not take into account any nonuniform stress. For a typical fiber $B_m \sim 10^{-7}$.

Birefringence leads to a variation in the polarization state of the electric field. Figure 1.3 shows the variation in the polarization state. The beat length is defined as

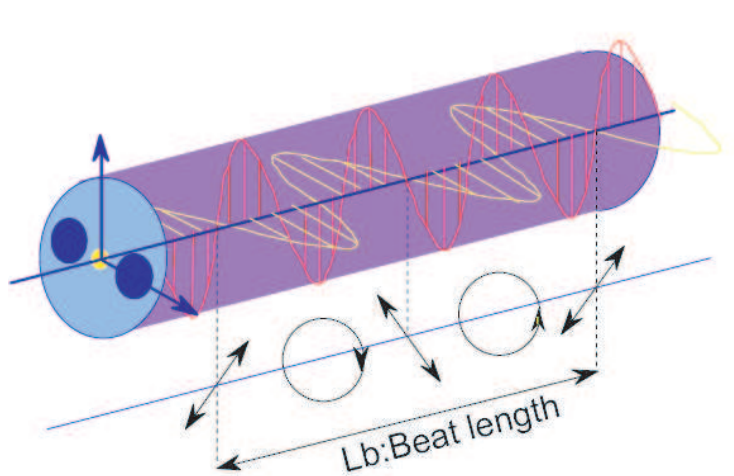

Figure 1.3: The beat length of a optical fiber.

$$L_B = \frac{\lambda}{B_m} \tag{1.3}$$

One way to eliminate this flucuation in the polarization state is to intensionally increase the birefringence. When the birefringence is large enough (on the order of 10^{-4}), coupling from one polarization to another is difficult. Similarly, by increasing the birefringence small changes in the birefringence does not significantly affect the final polarization state. Figure 1.4 shows the three most common methods used to create Polarization Maintaining (PM) optical fibers namely bow tie, PANDA, and elliptical core.

Examples of commercially available PM fibers:

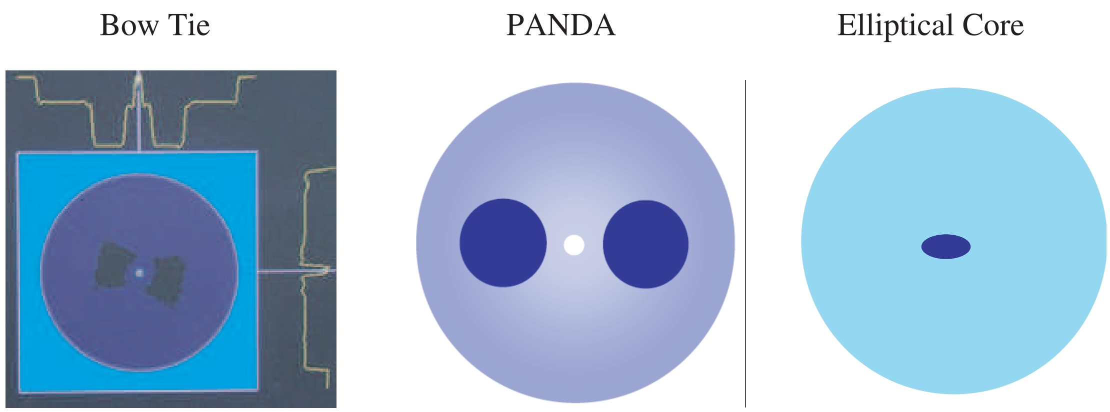

Figure 1.4: The 3 common methods used to create Polarization Maintaining optical fibers.

Supplier	**Fiber Type**	**Mode Field Diameter** (μm)	**Beat Length / Birefingence**	**Loss**
Stocker Yale	Bow Tie	10.5	4mm	–
Metrotek	Bow Tie	10.5	2mm	2 dB/km
Fibercore	Bow Tie	10.5	2mm	2 dB/km
KVH	Elliptical core	$2\mu m \times 4\mu m$ core	$B_m = 1.5 \times 10^{-4}$	9 dB/km
Fujikura	Panda	10.5	3-5mm	0.5dB/km