6.1 INTRODUCTION

In recent years the state of the art of optical fiber technology has progressed to where the achievable attenuation levels for the fibers are very near the limitations due to Rayleigh scattering. As a result, optical fibers, and particularly single-mode fibers, can be routinely fabricated with attenuation levels of about 0.5 dB/km at 1300 nm and 0.25 dB/km at 1550 nm. Employing these fibers in lightwave systems requires precise jointing devices such as connectors and splices. Considering the small size of the fiber cores, less than 10 μm in diameter for single-mode fibers and less than 100 μm for multimode fibers, it is not surprising that these components can easily introduce high optical losses. Furthermore, since single-mode fibers have practically unlimited bandwidth, they have recently become the favorite choice for most of the lightwave systems presently being designed for telecommunication networks and in the future may be used in local area networks as well. To provide low-loss connectors and splices for these single-mode fibers, alignment accuracies in the submicrometer range are required, and these submicrometer alignments must be both reliable and cost-effective. Achieving these goals is presently the challenge facing the jointing technologist.

This chapter will review the fundamental technology presently used for both demountable connectors and splices. In particular, since single-mode
fibers will more than likely dominate lightwave systems and require the greatest precision, most of our attention will be directed to the particular problems encountered in the jointing of these fibers.

We begin by defining the implied differences between a fiber connector and a fiber splice. The term \textit{connector} is commonly used when referring to the jointing of two fibers in a manner that permits and anticipates their unjointing by its design intent. Connectors are usually used for terminating components, for system configuration, testing, and maintenance. Generally, the connectors are either factory-installed or field-installed depending on the particular application. In this sense, the term \textit{field} usually refers to an environment outside the connector factory. However, in the case of single-mode fibers, the required submicrometer alignment tolerance generally dictates that the connector installation be done in the connector factory. Presently, this limitation hampers single-mode fiber installation, although it is expected that recent results in this area by research laboratories will soon become common installation practices.

In contrast with the term connector, the term \textit{splice} is commonly used when referring to the jointing of two fibers in a manner that does not lend itself to unjointing. Splices are usually used when the total span length can be realized only by the concatenation of shorter fiber sections. The splicing may be done either in the factory or during cable installation as required by practical fabrication and installation processes. Splices are also used for repairing broken or damaged fiber or cable lengths. In applications using single-mode fibers, splicing is also being used to attach preconnectorized short lengths of fibers (pigtails) to the ends of installed cables, fiber-terminated lasers, and other components terminated with single-mode fibers. As will be pointed out later, the practice of splicing preconnectorized single-mode fiber pigtails onto cable ends and component pigtails will probably be replaced by field-installing single-mode fiber connectors directly onto the fibers as is presently the practice in multimode fiber applications.

\section*{6.2 Factors Causing Optical Losses}

Factors causing optical losses (low coupling efficiency) in both connectors and splices can be conveniently divided into two groups (Table 6.1). Factors extrinsic to the optical fiber, both single-mode and multimode, such as lateral offset between fiber cores, longitudinal offset (end gap), angular misalignment (tilt), end-face quality, and reflections, are directly caused by the techniques used to join the fibers. The other group, intrinsic factors, are directly related to the particular properties of the two optical fibers that are joined. In particular, these intrinsic factors include mismatches in fiber core diameters, mismatches in index profiles, and the ellipticity of the cores.