complex III-V structures (including layers with different band gaps) makes possible the creation of III-V *multijunction* cells with efficiencies in excess of 30%, exceeding that of any single-junction device.

9.2 APPLICATIONS

9.2.1 Space Solar Cells

The higher efficiencies and radiation resistance of III-V cells have made them attractive as replacements for silicon cells on many satellites and space vehicles. Over the years, GaAs cells have replaced silicon cells on new satellite launches. The GaInP/GaAs/Ge cells are integrated into modules very much like single-junction GaAs solar cells and have the added advantage of operating at high voltage and low current, as well as having excellent radiation resistance. They also have a smaller temperature coefficient than silicon cells, which implies better performance under the operating conditions encountered in space applications. Space applications of GaInP/GaAs/Ge and other III-V solar cells are discussed in detail in Chapter 10.

9.2.2 Terrestrial Energy Production

The PV industry currently services a wide range of terrestrial applications, from power for small consumer products to larger grid-connected systems. III-V solar cells are currently too expensive for most one-sun applications. While satellites represent an example of an application for which the extra cost is acceptable, for bulk electricity generation, a concentration of 400 suns or greater may be needed to achieve an acceptable cost. Concentrator cells and systems are discussed in detail in Chapter 11.

The use of GaInP/GaAs/Ge cells in high-concentration (e.g. 1000X) systems has the potential of generating electricity at 7 cents/kWh [13]. The current space-cell production capacity of ~0.5 MW/year translates into a 1000X concentrator cell production capacity of ~0.5 GW/year. These solar cells have achieved a record efficiency of 34%, measured at 210X under the AM1.5 global spectrum [14]. An outdoor module efficiency for a linear (low X) concentrator has been reported in the range of 25.5 to 29% [15]. The high efficiency, the projected low cost, and the ease with which production of concentrator cells could be initiated with existing production equipment make terrestrial applications attractive for these cells. Nevertheless, considerable industry investment will be required to develop a product that is reliable. The specific issues associated with the development of concentrator solar cells are discussed below.

9.3 PHYSICS OF III-V MULTIJUNCTION AND SINGLE-JUNCTION SOLAR CELLS

9.3.1 Wavelength Dependence of Photon Conversion Efficiency

As a prelude to the detailed examination of the design and performance of multijunction cells, it is useful to review briefly the fundamental factors that limit the efficiency of