is restricted to either low concentration applications or as a secondary optical element. Nonimaging concentrators will be discussed more fully in Section 11.4.

11.2.2 Concentration Ratio

There are several definitions of concentration ratio in use. The most common is "geometric concentration ratio." This is defined as the area of the primary lens or mirror divided by the active cell area. The active cell area is the region of the cell that is designed to be illuminated. Unlike in most nonconcentrating systems, the entire cell need not be illuminated by the primary lens. The nonilluminated edge of the cell is often provided with buss bars for electrical connection, and this need not result in an efficiency loss as would be the case in a flat-plate module. Another measure of concentration is intensity concentration, or "suns." Since standard peak solar irradiance is often set at 0.1 W/cm^2, the "suns" concentration is defined as the ratio of the average intensity of the focused light on the cell active area divided by 0.1 W/cm^2. For example, if 10 W were focused onto a cell of 2-cm^2 active area, the intensity concentration would be 50 suns. If all the insolation from the direction of the sun (the so-called direct beam insolation), or more accurately from the region of the sky that is focused on the cell, had an intensity of 0.1 W/cm^2 and if the lens had 100% transmission, the geometric and intensity concentration would be the same. In actuality, whereas the global insolation is often close to 0.1 W/cm^2, the direct beam insolation is typically less. The difference is the diffuse insolation, the radiation that is scattered by the atmosphere or clouds, and comes from directions other than the sun. Typically, the direct beam radiation is around 0.085 W/cm^2 on a clear day, so many concentrator systems are rated at this level. If the lens has a transmission of 85%, then the intensity concentration will be $0.85 \times 0.85 = 0.72$ of the geometric concentration. In the above example the cell will be illuminated at 36 suns.

The reader will note that the reduction cell area through concentration, and hence cost for a given power, is not by a factor of one over the geometric concentration, but rather even less than the intensity concentration. First, the active area of the cell is often less than the actual cell area. A typical 1 cm × 1 cm cell will have an active area of around $0.8\text{ cm} \times 0.8\text{ cm} = 0.64\text{ cm}^2$. When it is also recognized that most concentrator cells are cut from a round wafer, much of the edge of the wafer cannot be used.[2] A 10-cm wafer will produce 52 cells of 1 cm × 1 cm (assuming 100% yield). Suppose this cell is operated at 100X geometric concentration. This means the primary lens is $8\text{ cm} \times 8\text{ cm} = 64\text{ cm}^2$. The total power on the cells from this wafer is then, assuming an 85% lens transmission, $0.85 \times 0.085 \times 64 \times 52 = 240$ W. If the wafer had been made into a flat-plate cell, it would have an area of 78 cm^2 and would receive a power of 7.8 W. Thus, the effect of the concentration is to increase the potential output by a ratio of 240 to 7.8, or 31. Our 100X concentrator is really only giving us a 31 times reduction in wafer usage.[3] This could still be very useful; however, sometimes, simplistic economic analyses of concentrators overlook this difference.

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[2] Also in single crystal one-sun cells, silicon ingots are round (cylindrical) and they are rendered almost square (prismatic) by cutting off lateral silicon chips.

[3] This assumes equal cell efficiency in both cases. In actuality, it will be seen below that most concentrator cells have a higher efficiency than flat-plate cells. Weighed against this advantage is the fact that, except in the sunniest of regions, concentrating systems have lower annual capacity factor (ratio of annual output to rated power times the length of a year).