Lighting represents one of the largest uses of electrical energy in residential and commercial buildings; lighting loads are highest during on-peak hours when electrical energy is most costly. Also, the thermal energy deposited into conditioned space by electrical lighting adds to the air conditioning load on the building which, in turn, adds to the electrical energy required to run the air conditioning system.

A novel lighting system consists of a sunlight collector and a light distribution system, as shown in Figure 1. The sunlight collector tracks the sun and collects and concentrates solar radiation. The light distribution system receives the concentrated solar radiation and distributes it into a building where it is finally dispensed in fixtures referred to as luminaires. Sunlight contains both visible and invisible energy (ultraviolet and infrared); only the visible portion of the sunlight is useful for lighting and therefore the collector gathers the visible portion of the incident solar radiation while eliminating the ultraviolet and infrared portions of the spectrum. (We will learn more about these characteristics of radiation in Chapter 7).

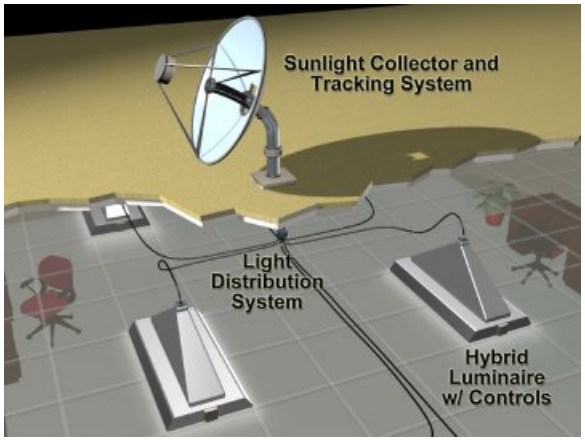

Figure 1: Hybrid lighting system (Cheadle, 2006).

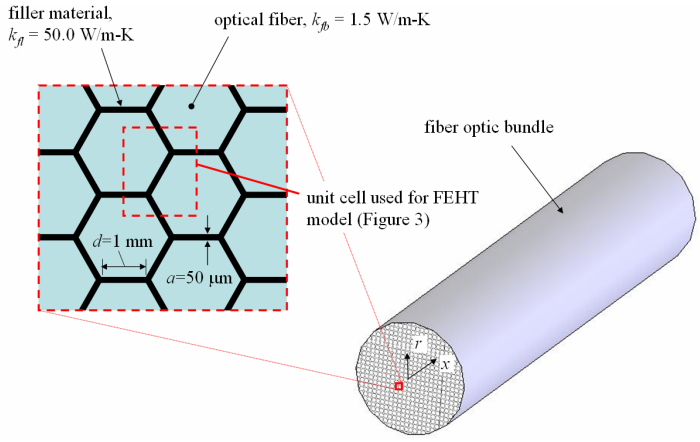

Figure 2: Array of optical fibers

The fiber optic bundle used to transmit the visible light is composed of many, small diameter optical fibers that are packed in approximately a hexagonal close-packed array. A conductive filler material is wrapped around each fiber and the entire structure is simultaneously heated and compressed so that the fiber becomes hexagonal shaped with a thin layer of conductive filler separating each fiber (Figure 2). The dimension of each face of the hexagonal shaped fibers is d = 1.0 mm and the thickness of the filler that separates the fibers is a = 50 μm thick. The fiber conductivity is k_{fb} = 1.5 W/m-K while the filler conductivity is k_{fl} = 50.0 W/m-K.

a.) Determine the effective radial and axial conductivity associated with the bundle.
b.) Is it appropriate to treat the bundle as an extended surface? Justify your answer.
c.) Develop an analytical model for the temperature distribution in the bundle.