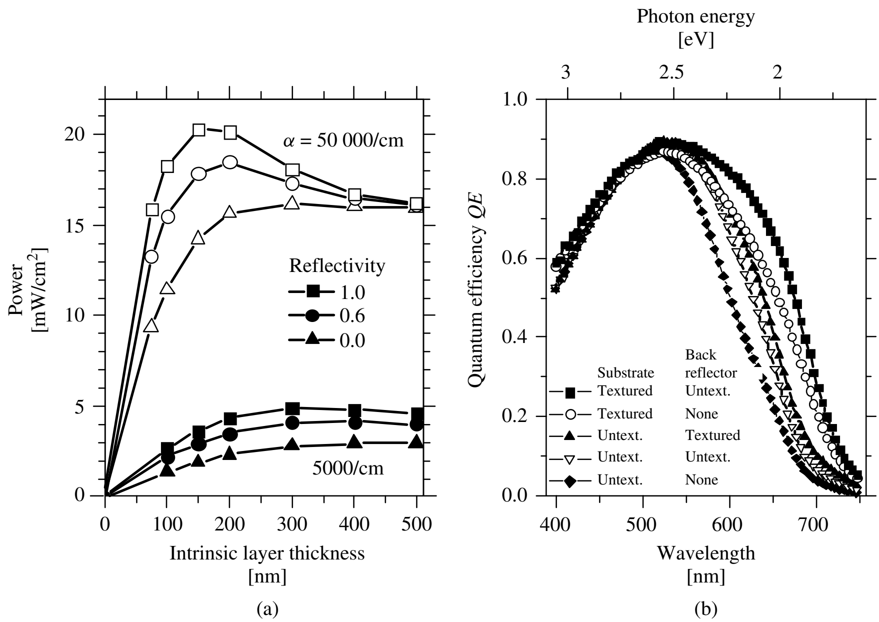

Figure 12.19 (a) Computer calculation of the power output from a *pin* solar cell as a function of intrinsic layer thickness. The two sets of curves indicate results for monochromatic illumination (photon flux $2 \times 10^{17}/cm^2s$) with absorption coefficients of 5000/cm (black symbols) and 50 000/cm (gray symbols). Results are shown for varying back reflectance; interference effects are neglected. (b) Quantum efficiency (*QE*) spectra for *nip* solar cells deposited under identical conditions, but with two differing substrate textures and differing back reflectors [138]. The sequence of layers in the structure was (TCO/*p*/*i*/*n*/TCO/glass/Ag). The Ag is the back-reflector material (when present); the TCO on top of the glass was either smooth or textured (14% haze).[10] Measured at −1 V bias

implies that a cell might fully absorb light even when its thickness is much less than the absorption length $1/\alpha$ for the light's wavelength.

Light trapping is realized in amorphous silicon (and other) solar cells by using substrates that are "textured" or rough on the same scales as the principal wavelengths in solar illumination. The idea is that the random reflection/diffraction of light by the irregular, textured topography leads to internal reflection. Yablonovitch [139] showed that the maximum gain for such "statistical light trapping" in a textured film on an ideal reflector is $4n^2$, where n is the index of refraction of the film; Yablonovitch's argument is fundamental and not based on any particular form for texturing. For silicon films, with $n \sim 3.5$, the maximum predicted gain is nearly a factor of 50 (for light that is *very* weakly absorbed).

Experimentally, optical gains up to a factor of ten have been reported from the use of textured substrates and weakly absorbed light [138, 140]. In Figure 12.19 we have presented measurements by Hegedus and Deng [138] of the "quantum efficiency" (*QE*)

[10] *Haze* is defined as the percentage of the light incident upon a film that is scattered incoherently. For transparent films, most of the remaining light is transmitted undeviated. Haze depends strongly upon the photon energy. The same value of haze can be obtained from films with quite different morphologies.