about the tumour activity and, indirectly, the associated proteins. The results of the imaging will be correlated with the biological analysis of the tumour. Two versions of the ENDOTOFPET-US have been built, one for the prostate and one for the pancreas. These will be tested at hospitals in Munich and Marseille, respectively.

Photonic crystals [40]

It is not only in physics and astronomy that inorganic scintillators find use in detection systems, but also in applications related to homeland security, medical, imaging, non-destructive industrial testing and more. In all of these detectors, light produced in the scintillator has to be transported towards a photodetector, but the standard optical coupling suffers from inefficient light extraction from the crystal due to the total internal reflections caused by the high refractive index of the scintillator. By using photonic crystals — i.e., by nano-structuring the different surfaces of the scintillator to produce constructive interferences of the evanescent wave near the surface — the transport of the light output can be tailored to optimize the timing performance and light yield of the detector. Some members of the Crystal Clear Collaboration have demonstrated that a factor of two in the light-extraction efficiency can be obtained with crystals commonly used in medical imaging. A European-funded project, TURBOPET, has been launched in collaboration with industry to demonstrate the clinical benefit of such a treatment, using the crystal on the MAMMI breast-imaging PET scanner that has been developed by a Spanish company.

10.5 Solar Collectors: When Nothing is Better

Cristoforo Benvenuti

In a standard solar thermal collector, the air molecules bouncing back and forth between the light absorber (hot) and the front glass window (cold) result in large thermal losses which limit the collector efficiency. To have a vacuum (i.e. nothing) inside the collector would remove this inconvenience.

Despite this well-known fact, evacuated flat-plate solar thermal collectors have never been produced because of the (almost) insurmountable difficulty of making a vacuum-tight joint between the glass window and the metal frame of the collector. A CERN patent [41] shows that this problem may be solved by plasma spray coating the perimeter of the glass with a metallic layer to which a metal joint may be fixed by soft soldering. This CERN patent was licensed in 2005 to a company, SRB Energy, created to produce and commercialize an evacuated thermal solar collector (Fig. 10.6).

The glass-to-metal joint is the main, but not the only, difficulty to be overcome to produce the collector. In addition:

- After the initial evacuation, the vacuum must be maintained despite the continuous outgassing of the collector components;
- The infrared emission from the hot light absorbers must be minimized;
- The pressure of 10 t/m^2 applied to the collector by the external atmosphere, tending to implode the collector glass, must be neutralized.

The vacuum inside the collector is maintained by a non-evaporable getter (NEG) pump [Box 7.3] [43] of which the surface is continuously cleaned by solar heating. The NEG thin-film technology developed for the LHC accelerator [Highlight 8.5] [44] has been used to coat a thin aluminium foil with a getter layer by means of a "roll-to-roll" coating machine developed *ad hoc* by SRB. This machine can coat automatically a few hundred metres of foil per week. To decrease the losses due to emission of radiation, the collectors are coated with a film that absorbs 90% of the solar light but presents a low emissivity in the infrared range (less than 0.07). The external pressure is withstood by spacers placed between the two glass plates.

Two cylindrical mirrors are coupled to the collector, as shown in Fig. 10.7. These mirrors convey the light they receive to beneath the panel, so as to double the incident power on the panel without doubling the cost. It is important to note that although the diffused light cannot be focused, these mirrors transmit it to the collector equally well as the direct light. This feature is particularly important in central Europe, where diffused light may exceed 50% of the total.

The collector with the mirrors may reach a temperature of 400°C in the best sunlight conditions. The available thermal efficiency is shown in Fig. 10.8. The pressure inside the collector varies between 10^{-4} Pa at 400°C and below 10^{-7} Pa

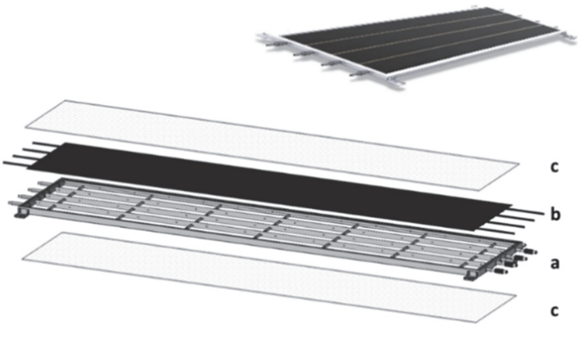

Fig. 10.6. Schematic of the SRB solar panel: (a) frame with spacers, (b) absorbers with cooling pipes, (c) glass windows [42]. (Courtesy SRB Energy.)

Fig. 10.7. The SRB collector with cylindrical mirrors. The collector is 3 m long and 70 cm wide. The mirrors enable the collection area and the power production to be doubled. (Courtesy SRB Energy.)

during the cold winter nights. These pressures, much lower than needed to profit fully from vacuum insulation (10^{-2} Pa), are a by-product of the large amount of NEG required to maintain the vacuum over 30 years.

The collector design was finalized in 2007 and a pilot production plant came into operation at the end of 2008. The SRB collector is multipurpose: it can be used for heating, water desalination, cooling and for the production of electricity. Among the many installations made so far, a good example is that of Geneva airport (about 1200 m^2), where it is used for both heating and air conditioning.

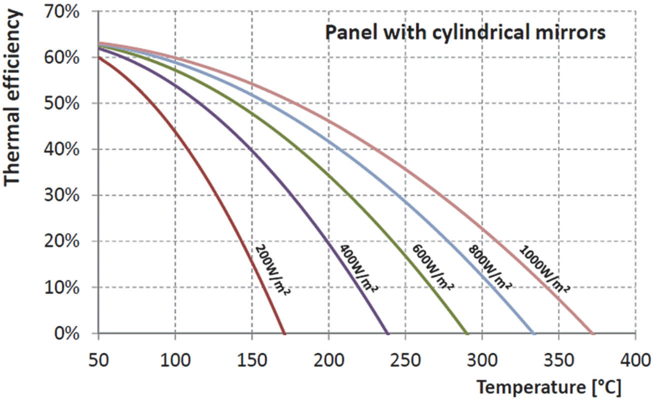

Fig. 10.8. Dependence of the SRB collector efficiency on the incident solar power and on the temperature of operation. The decrease of efficiency at higher temperatures is due to the increase of the thermal losses by IR radiation emission. (Courtesy SRB Energy.)