of 19% were achieved [73]. Concentrator silicon cells are also being researched. An innovative one-axis reflective tracking concentrator design was demonstrated that achieves 300X concentration through a refractive CPC-type secondary concentrator [41].

11.5.6 Ioffe Physical-Technical Institute

The Ioffe Physical-Technical Institute has a long history with compound semiconductor solar cell development, particularly for concentrator cells. Recently, they have been developing GaSb and AlGaAs cells for multijunction applications. As part of a European consortium, they have developed a unique, all-glass concentrator module that uses GaAs cells and a thin silicone Fresnel lens, molded to the inside of the top glass sheet. This approach appears very promising [69].

11.5.7 National Renewable Energy Laboratory

National Renewable Energy Laboratory (NREL) conducts leading-edge research on high-efficiency, multijunction solar cells. They have achieved a record 30% efficient GaInP/GaAs two-junction monolithic concentrator cell operating at 150X [74], and even higher efficiency in collaboration with Spectrolab, as seen below. Interestingly, the pioneering research on compound semiconductor solar cells conducted at NREL has found widespread application in high-efficiency space solar cells. It is curious to contemplate that when the concentrating PV industry is ready to accept high-efficiency multijunction cells, the lowest cost route to securing their supply could be through the space solar cell industry, which would have had considerable manufacturing experience with multijunction cells by then.

11.5.8 Polytechnical University of Madrid

The Polytechnical University of Madrid has had a long-term program on concentrators, of which the Euclides project mentioned above is only a part. This includes pioneering work in the optics of concentrators, as well as GaAs concentrator cells. Their work, particularly that on static concentrators, is well described in the textbook, *Solar Cells and Optics for Photovoltaic Concentration* [2]. Recently, a new type of concentrator has been invented and researched, called the RXI concentrator discussed in Section 11.4 [64]. It is designed to use small GaAs cells that are only 1 mm on a side and manufactured and packaged similarly to LEDs. Modules built using this approach will resemble flat-plate modules, yet potentially exhibit very high performance and low cost. Additionally, the large acceptance angle reduces the cost of tracking structure. Such modules could be applicable for certain markets currently served by flat-plate modules. A consortium has been formed to further develop the RXI concentrator including the University of Madrid, the Ioffe Physico-Technical Institute (Russia), Energies Nouvelles et Environment (Belgium), Vishay Semiconductors (Germany), and Progressive Technologies (Russia). The system is called Hercules [75]. The team calculates that it could deploy systems that produce electric power at 0.104 euros/kWh using present performance and ultimately 0.033 euros/kWh at a production volume of 1000 MW. This is the lowest cost of energy projection reported