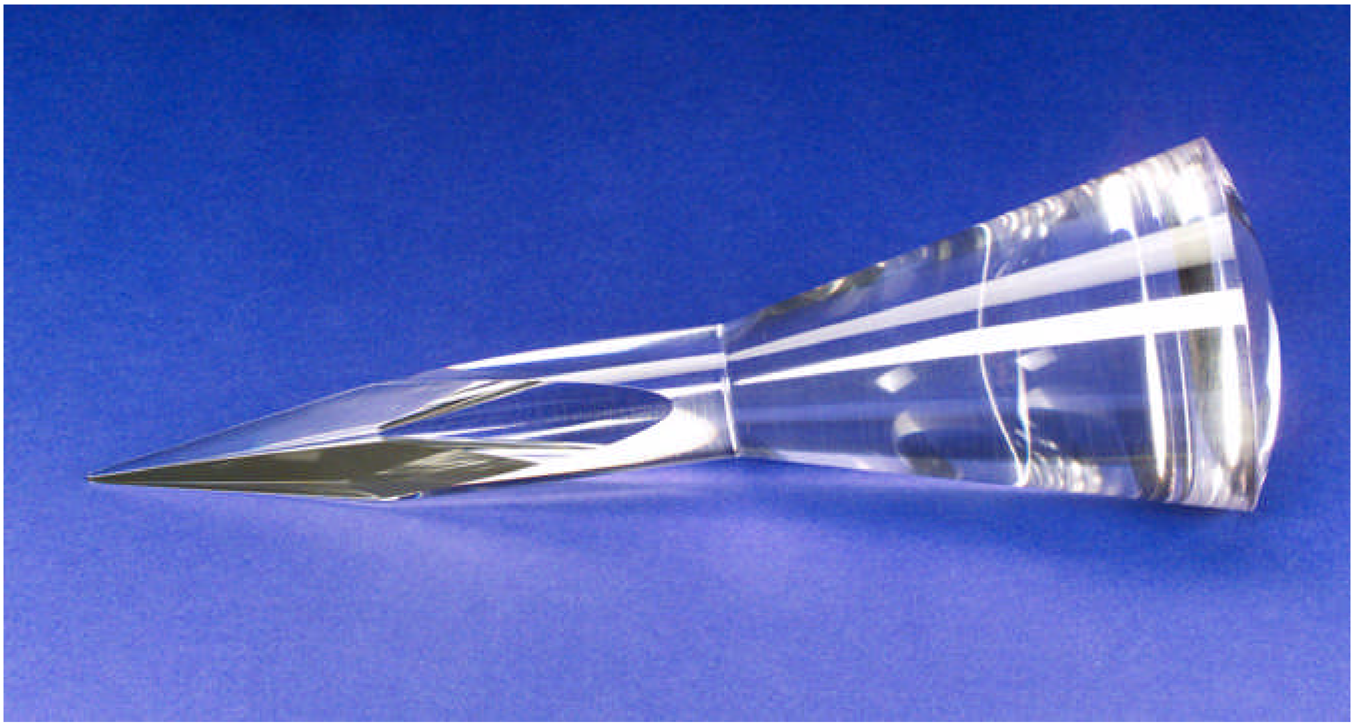
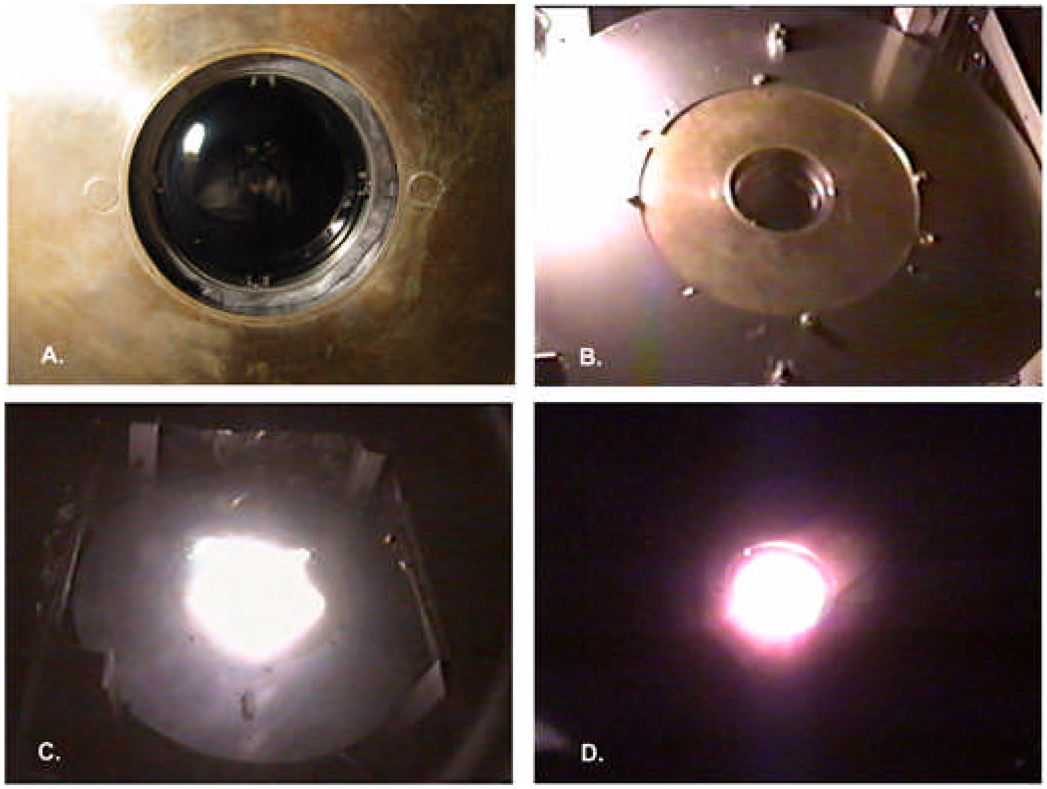
Refractive Secondary Solar Concentrator Demonstrated High-Temperature Operation



Prototype refractive secondary concentrator made of single-crystal sapphire.

Space applications that utilize solar thermal energy--such as electric power conversion systems, thermal propulsion systems, and furnaces--require highly efficient solar concentration systems. The NASA Glenn Research Center is developing the refractive secondary concentrator, which uses refraction and total internal reflection to efficiently concentrate and direct solar energy. When used in combination with advanced lightweight primary concentrators, such as inflatable thin films, the refractive secondary concentrator enables very high system concentration ratios and very high temperatures. Last year, Glenn successfully demonstrated a secondary concentrator throughput efficiency of 87 percent, with a projected efficiency of 93 percent using an antireflective coating. Building on this achievement, Glenn recently successfully demonstrated high-temperature operation of the secondary concentrator when it was used to heat a rhenium receiver to 2330 °F.



(a) Closeup of refractive secondary concentrator inlet surface. (b) Concentrator installed in receiver behind the splash shield. (c) Concentrated solar energy illuminates the secondary concentrator and splash shield. (d) With no solar illumination, the inner receiver, which reached a maximum of 2330 °F, radiates through the secondary concentrator.

The high-temperature demonstration of the concentrator was conducted in Glenn's 68-ft-long Tank 6 thermal vacuum facility equipped with a solar simulator. The facility has a rigid panel primary concentrator that was used to concentrate the light from the solar simulator onto the refractive secondary concentrator. NASA Marshall Space Flight Center provided a rhenium cavity, part of a solar thermal propulsion engine, to serve as the high-temperature receiver.

The prototype refractive secondary concentrator, measuring 3.5 in. in diameter and 11.2 in. long, is made of single-crystal sapphire. A water-cooled splash shield absorbs spillage light outside of the 3.5-in. concentrator aperture. Multilayer foil insulation composed of tungsten, molybdenum, and niobium is used to minimize heat loss from the high-temperature receiver. A liquid-cooled canister calorimeter is used to measure the heat loss through the multilayer foil insulation.

The objective of the test was to measure the resulting temperature in the receiver as the solar simulator input power was increased, demonstrating the effectiveness of the refractive secondary concentrator for high-temperature applications. Two steady-state points were attained during the test. With 460 W input to the refractive secondary concentrator (approximately 9 percent of this input power is lost because of reflection off the inlet surface), the receiver temperature reached 1620 °F. With 1.25 kW input to the refractive secondary concentrator, the receiver reached 2160 °F. While going to a third steady-state point, with 1.96 kW input to the refractive secondary, the receiver reached a maximum of 2330 °F before the receiver temperatures unexpectedly started to drop. Because of this anomaly, the test was concluded.

Posttest examination of the hardware revealed that, although the refractive secondary concentrator was intact, numerous fractures had developed in the unit. An investigation is underway to determine the cause of the fractures. Preliminary evidence suggests that the fractures may likely have been caused by either movement in the support hardware and splash shield (resulting in localized heating or cooling of the secondary concentrator) or by outgassing of the surrounding materials at high temperatures that coated onto the secondary concentrator (resulting in uneven heating of the secondary concentrator surface). Both of these issues indicate that the fractures were not due to some inherent limitation in the refractive secondary concentrator technology, and both can be easily remedied through modifications to the support hardware and the selection of appropriate materials.

Find out more at Glenn's Thermo-Mechanical Systems Branch.
http://www.grc.nasa.gov/WWW/tmsb/

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