Resistively Heated SiC Nozzle for Generating Molecular Beams

This nozzle is more durable and efficient relative to its predecessors.

Goddard Space Flight Center, Greenbelt, Maryland

An improved nozzle has been developed to replace nozzles used previously in an apparatus that generates a substantially unidirectional beam of molecules passing through a vacuum at speeds of several kilometers per second. The need to replace the previous nozzles arose from a complex set of causes that can be summarized as follows:

(1) The previous nozzles had short operational lifetimes because it was necessary to fabricate them from components made of several different materials that, when used together, do not last long at the high operating temperatures needed to generate the requisite high molecular speeds and

(2) To protect the vacuum chamber from excessive heating, it was necessary to surround the operating nozzle with a cooling shroud that robbed the nozzle of reflected heater power and thereby contributed to energy inefficiency.

The basic principle of operation of the apparatus is the same for both the previous and the present nozzle designs. The main working part of the nozzle is essentially a cylinder that is closed except that there is an inlet for a pressurized gas and, at one end, the cylinder is closed by a disk that contains a narrow central hole that serves as an outlet. The cylinder is heated to increase the thermal speeds of the gas molecules into the desired high-speed range. Heated, pressurized gas escapes through the outlet into a portion of the vacuum chamber that is separated, by a wall, from the rest of the vacuum chamber. In this portion of the vacuum chamber, the gas undergoes a free jet expansion. Most of the expanded gas is evacuated and thus does not become part of the molecular beam. A small fraction of the expanded beam passes through a narrow central orifice in the wall and thereby becomes a needle-thin molecular beam in the portion of the vacuum on the downstream side of the wall.

In a nozzle of the previous design, the cylinder was made of molybdenum, and the disk with the outlet hole, also made of molybdenum, was welded onto the cylinder at one end. In the improved nozzle, the cylinder and the disk at one end containing the narrow outlet hole are made of a single piece of silicon carbide. In a nozzle of the previous design, the molybdenum cylinder was surrounded by an alumina electrical-insulation cylinder that was, in turn, surrounded by a silicon carbide cylinder that served as an electrical resistance heater. In the improved nozzle, the silicon carbide cylinder serves as its own electrical resistance heater.

In the improved nozzle, the silicon carbide cylinder is brazed to a molybdenum fitting that is brazed to a stainless-steel fitting that is electron-beam welded onto a length of stainless-steel tubing. Electrodes made of tungsten wire are attached to the ends of the silicon carbide cylinder by means of two-piece molybdenum hinge clamps, wherein the electrodes serve as the hinge pins. Sufficient clearance is provided between each molybdenum clamp and the SiC cylinder nozzle to accommodate a piece of graphite tape that both cushions and ensures a high degree of electrical contact. To reflect some heater power to the SiC cylinder and thereby both increase energy efficiency and reduce heating of the vacuum chamber, the nozzle as described thus far is surrounded by a radiation shield in the form of 12 concentric cylindrical layers of 50-μm-thick tungsten foil that are dimpled to maintain gaps between successive layers. The radiation shield is cooled by a circulation subsystem.

The nozzle has been tested using a gas mixture comprising 1 percent argon and 99 percent hydrogen at feed pressures up to 450 psi (≈3.1 MPa) and temperatures up to 2,000 °C. In one test at 1,600 °C, the speed of the argon fraction of the beam was observed to be 3.3 km/s. On the basis of performance data from the tests, it has been estimated that the nozzle would have unlimited operational lifetime at room temperature, could operate for many hundreds of hours at 1,000 °C, and could operate for at least 100 hours at 1,500 °C. At operating temperatures above 1,500 °C, the nozzle is vulnerable to clogging, though in the absence of oxygen, it may still be capable of operating for many hours.

This work was done by Steven Cagiano of Goddard Space Flight Center; Robert Abell of Swales Aerospace; Edward Patrick and Mirl Bendt of Honeywell Technical Services, Inc.; and Cynthia Gundersen of AMU Engineering, Inc. Further information is contained in a TSP (see page 1).
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Compact Packaging of Photonic Millimeter-Wave Receiver

Bulky positioning mechanisms are not needed.

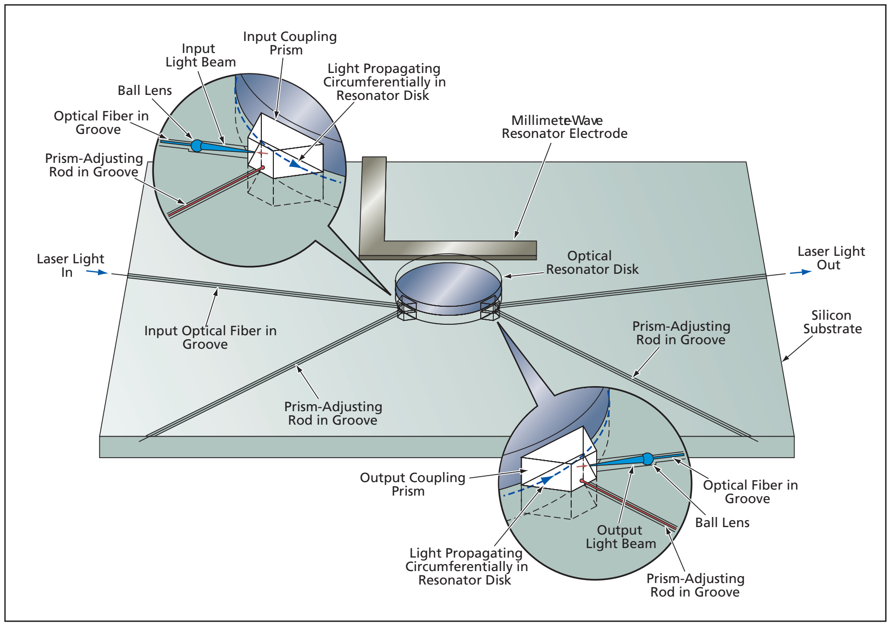
John H. Glenn Research Center, Cleveland, Ohio

A carrier structure made from a single silicon substrate is the basis of a compact, lightweight, relatively inexpensive package that holds the main optical/electronic coupling components of a photonic millimeter-wave receiver based on a lithium niobate resonator disk. The design of the package is simple and provides for precise relative placement of optical components, eliminating the need for complex, bulky positioning mechanisms like those commonly used to align optical components to optimize focus and coupling. Although a prototype of the package was fabricated as a discrete unit, the design is amenable to integration of the package into a larger photonic and/or electronic receiver system.

The components (see figure) include a lithium niobate optical resonator disk of 5-mm diameter and ≈200-μm thickness, positioned adjacent to a millimeter-wave resonator electrode. Other components include input and output coupling prisms and input and output optical fibers tipped with ball lenses for focusing and collimation, respectively.

Laser light is introduced via the input optical fiber and focused into the input coupling prism. The input coupling prism is positioned near (but not in contact with) the resonator disk so that by means of evanescent-wave coupling, the input laser light in the prism gives rise to laser light propagating circumferentially in guided modes in the resonator disk. Similarly, a portion of the circumferentially propagating optical power is extracted from the disk by evanescent-wave coupling from the disk to the output coupling prism, from whence the light passes through the collimating ball lens into the output optical fiber.

The lens-tipped optical fibers must be positioned at a specified focal distance from the prisms. The optical fibers and the prisms must be correctly positioned relative to the resonator disk and must be oriented to obtain the angle of incidence (55° in the prototype) required for evanescent-wave coupling of light into and out of the desired guided modes in the resonator disk. To satisfy all these requirements, precise alignment features are formed in the silicon substrate by use of a conventional wet-etching process. These features include a 5-mm-diameter, 50-μm-deep cavity that holds the disk; two trapezoidal-cross-section recesses for the prisms; and two grooves that hold the optical fibers at the correct positions and angles relative to the prisms and disk. The fiber grooves contain abrupt tapers, near the prisms, that serve as hard stops for positioning the lenses at the focal distance from the prisms.



Optical Components of a millimeter-wave photonic receiver are kept in alignment by mounting them in precise recesses in a silicon substrate.

There are also two grooves for prism-adjusting rods. The design provides a little slack in the prism recesses for adjusting the positions of the prisms by means of these rods to optimize the optical coupling.

This work was done by Hung Nguyen, John Pouch, and Felix Miranda of Glenn Research Center, and Anthony F. Levi of the University of Southern California. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17694-1.

Diffractive Combiner of Single-Mode Pump Laser-Diode Beams

Multiple beams can be combined without inducing multifrequency lasing.

NASA's Jet Propulsion Laboratory, Pasadena, California

An optical beam combiner now under development would make it possible to use the outputs of multiple single-mode laser diodes to pump a neodymium: yttrium aluminum garnet (Nd:YAG) nonplanar ring oscillator (NPRO) laser while ensuring that the laser operates at only a single desired frequency. Heretofore, an Nd:YAG NPRO like the present one has been pumped by a single multimode laser-diode beam delivered via an optical fiber. It would be desirable to use multiple pump laser diodes to increase reliability beyond that obtainable from a single pump laser diode. However, as explained below, simplistically coupling multiple multimode laser-diode beams through a fiber-optic combiner would entail a significant reduction in coupling efficiency, and lasing would occur at one or more other frequencies in addition to the single desired frequency.

Figure 1 schematically illustrates the principle of operation of a laser-diode-pumped Nd:YAG NPRO. The laser beam path is confined in a Nd:YAG crystal by means of total internal reflections on the three back facets and a partial-reflection coating on the front facet. The wavelength of the pump beam — 808 nm — is the wavelength most strongly absorbed by the Nd:YAG crystal. The crystal can lase at a wavelength of either 1,064 nm or 1,319 nm — which one depending on the optical coating on the front facet. A thermal lens effect induced by the pump beam enables stable lasing in the lowest-order transverse electromagnetic mode (the TEM_{00} mode). The frequency of this laser is very stable because of the mechanical stability of the laser crystal and the unidirectional nature of the lasing. The unidirectionality is a result of the combined effects of (1) a Faraday rotation induced by an externally applied magnetic field and (2) polarization associated with non-normal incidence and reflection on the front facet.

In order to restrict lasing to a single frequency, it is necessary to confine the pump beam within the region occupied by the TEM_{00} mode of the NPRO laser beam near the front facet inside the crystal. In practice, this means that the pump beam must be focused to within a given solid angle (Ω) and area (A). [If a