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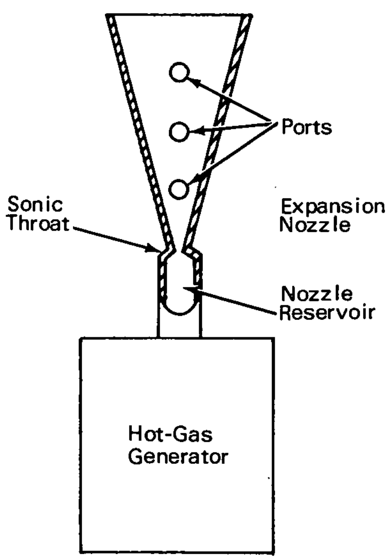
Diatomic Infrared Gasdynamic Laser Permits Selection of Wavelengths

The gasdynamic laser is potentially capable of providing large amounts of power. No electrical discharge or chemical reaction is needed to induce laser action, as the necessary conditions for operation are established solely by thermal expansion of lasing media to supersonic flow speeds.



Previous forms of gasdynamic lasers have relied on population inversions created among the lower vibrational levels of a polyatomic gas, such as carbon dioxide. Because such lasers utilize lower vibrational levels, they operate principally in a narrow wavelength band centered at about 10.6 μm; moreover, they also require a large optical resonator dimension in the flow direction to extract all of the latent power available.

The novel gasdynamic laser described below utilizes an infrared-active diatomic gas which emits laser energy from numerous upper vibrational levels. Laser wavelengths depend on particular vibration-rotation transitions and have been obtained throughout the band between 4.78 and 5.4 μm, for example, when using carbon monoxide. Moreover, the removal of laser power from one vibrational transition enhances the ability of the adjacent levels to lase. When operated with multiple transverse modes, the laser media are able to give energy as laser power in a distance characterized by the time required for several radiative transitions. This time is much shorter than the collisional pumping times limiting the power of previous polyatomic gasdynamic lasers of the same optical cavity dimensions. Therefore, a smaller optical resonator size in the flow direction is required to extract an equal fraction of latent power. By installing several optical resonators at different locations in a single apparatus, it is possible also to provide laser operation on numerous separate vibrational transitions with significantly different wavelengths.

A mixture of three gases is used in the laser: The first is a diatomic, infrared-active gas such as carbon monoxide. The second is a gas that has vibrational energy states which are spaced only slightly greater from those of the active gas; nitrogen has been found suitable for this purpose. The proportion of the active gas to nitrogen may vary over a wide range, e.g., from 1 to 80 percent by volume. The third gas must be an inert monatomic gas such as argon and can be used up to about 90 percent by volume to enhance the lasing by reducing the kinetic temperature of the expansion at a given location. The upper vibrational states of the active diatomic gas become excessively populated in the expansion because of the anharmonicity of the vibrational energy levels and the way in which it affects the energy transfer. As an example of the inversions that occur at numerous levels, laser power has been

(continued overleaf)

obtained from carbon monoxide transitions at all upper level vibrational quantum numbers between 2 and 11.

The selection of wavelengths may be controlled by introducing wavelength-dependent losses in the optical resonator, and also by locating the optical axes at different positions along the expansion axes. The latter method utilizes a novel feature of diatomic gasdynamic lasers, that is, the wavelength of maximum gain varies with the expansion cross-section area.

In the gasdynamic laser shown in the diagram, the gas mixture is heated and compressed and then allowed to expand through a supersonic nozzle with an optical path length through the active medium that is long enough to allow radiative gain to overcome the optical losses. The ratio of the expansion cross-section area to its minimum cross-section area must be greater than 100. The gas is heated to a temperature of at least 1600° K and may be at 2000° K or even higher. Laser power increases with reservoir pressure up to pressures exceeding 200 atmospheres.

Various means may be used for generating the high temperatures and pressures, such as a helium-driven shock tube, a combustion chamber, a carbon resistance heater, nuclear heater, etc. In one form of the apparatus, four different ports were employed. Since the area ratio must be at least 100, the area of the throat to the first port must be at least 100 times that of the sonic throat and the area ratios at the second and third ports are much greater than this. The nozzle is axisymmetric; in one practical system, the nozzle was at a half angle of 10° while the sonic throat had an area of 1.27 cm^2. The four mirror ports were located at area ratios of 120, 577, 1455, and 2730.

An optically resonant cavity can be provided in any one of the ports by installing two mirrors. For example, mirrors with a 4.4-cm-diameter aperture and an inside spherical surface of 10 meters in radius have been used. One of the mirrors was germanium-coated for 3% transmission over the spectral region between 5 and 6 μm. The other mirror was coated for maximum reflectivity over the same spectral region.

Reference:

McKenzie, Robert L.: Laser Power at 5 μm from the Supersonic Expansion of Carbon Monoxide. Applied Physics Letters, vol. 17, no. 10, page 462, 1970.

Notes:

1. Diatomic gases, such as carbon monoxide, have been used in lasers in the past, but an electric discharge or a chemical reaction has been required to create the necessary conditions for lasing. Such lasers are not gasdynamic lasers and their principles of operation are significantly different.
2. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference:
   NASA TM-X-62006 (N71-11668), 5-μm Laser Radiation from a Carbon Monoxide Gasdynamic Expansion.
3. No additional documentation is available. Specific questions, however, may be directed to:

   Technology Utilization Officer
   Ames Research Center
   Moffett Field, California 94035
   Reference: B72-10206

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to:

Patent Counsel
Mail Code 200-11A
Ames Research Center
Moffett Field, California 94035

Source: R. L. McKenzie
Ames Research Center
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