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NASA TECH BRIEF

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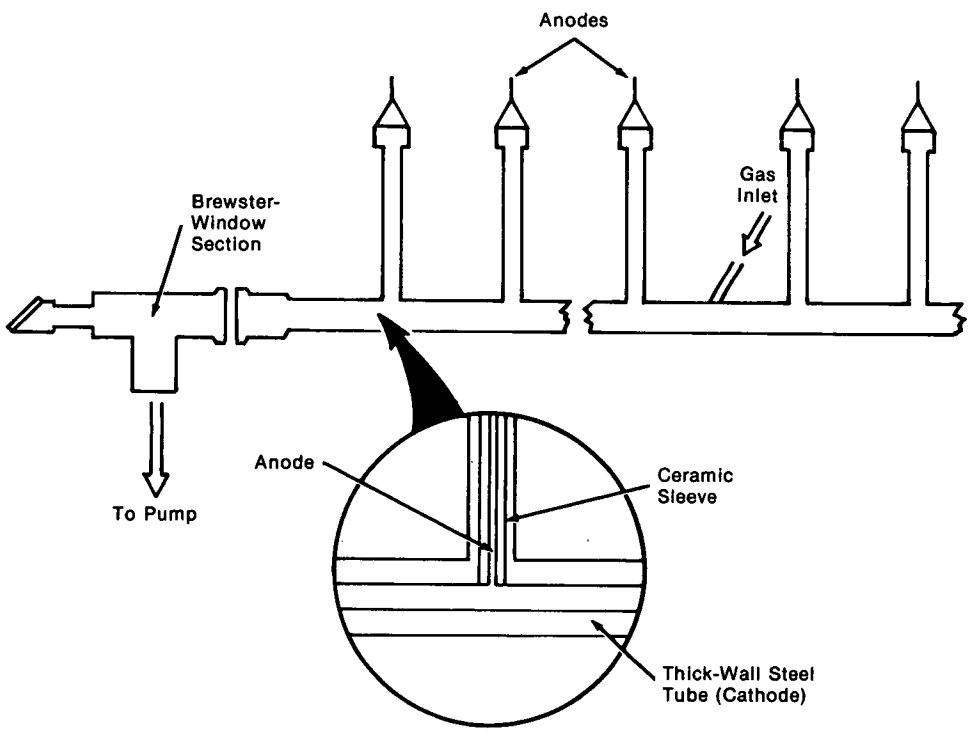
Chemical-Ionization Visible and Ultraviolet Gas Lasers: A Concept

Lasing action can be achieved by a chemical reaction instead of the more usual mechanism of electron impact and transfer of excitation between colliding atoms and molecules. A method has been proposed in which charge-transfer reactions or Penning ionization reactions are used to produce population inversions between electronic states of molecular ions which should result in stimulated emission in the ultraviolet and visible regions. Such lasers could be used in the study of short-lived reaction intermediates, crystal structure and scattering, and photolysis.

In these reactions, a diatomic or simple polyatomic neutral gas is mixed with an excess of an inert gas such as helium in a hollow cathode or pulsed transversed discharge tube terminated in a standard optical laser cavity. The reactions produce very specific excited states in the polyatomic or diatomic gas:

$$X^+ + M \rightarrow X + (M^+)^* \rightarrow M^+ + h\nu \quad (1)$$

$$X^* + M \rightarrow X + (M^+)^* \rightarrow + e^- \; M^+ + h\nu \quad (2)$$



Schematic Diagram of Multiple-Anode Hollow-Cathode Laser Tube

(continued overleaf)

where X is an inert gas; M is O_2, N_2, CO, HCl, or a similar species; and the asterisk denotes a molecule or ion in an excited electronic state.

Equation 1 is a charge-transfer reaction, and equation 2 is a Penning ionization reaction. Either one could be used to produce a population inversion of excited states. As lasing action occurs, the ground state (M^+) will begin to build up, but there are two mechanisms available to deplete the ground state that might allow continuous-wave rather than pulsed operation. First, electron/molecular ion recombination rates are extremely fast and the long-lived ground state molecular ion may be rapidly destroyed by dissociative recombination.

A second method is to deplete the ground state by reaction with another molecule that does not compete with the initial reaction. For example, if a Penning ionization reaction is used in which N_2^+ is formed by He*, H_2 can be added. The cross section for destruction of He* by H_2 is very small, and the rate constant in the reaction is large.

$$N_2^+ + H_2 \rightarrow N_2H^+ + H$$

Thus the N_2^+ ground state is rapidly depleted, and the population inversion maintained.

The figure shows one configuration for carrying out these reactions in a laser cavity. These chemical reactions have several specific advantages as a method to produce lasing action. The reactions are selective, and there are no interfering processes which will significantly populate lower excited states. Population inversion of the excited states should be easier to achieve than in a neutral molecular laser, where all the molecules are in the ground state initially. Finally, the particular excited electronic molecular state populated can be varied by changing either the ion used for charge transfer or the metastable used for Penning ionization; and by ionizing different molecules, various wavelengths can be achieved.

Note:

Requests for further information may be directed to:

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NASA has decided not to apply for a patent.

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