NASA TECH BRIEF

Rectangular-Bore, High-Gain Laser Plasma Tube

The small signal unsaturated gain (gain factor) of the $3s_2$–$2p_4$ neon transition (6328 angstroms) in a conventional circular-bore laser discharge tube is limited by the degree of population inversion that can be obtained between the upper laser state ($3s_2$) and the terminal laser state ($2p_4$). An experimental tube of rectangular bore, which has been constructed, provides a method for improving the population inversion, resulting in a significant increase in the unsaturated gain factor.

It had been reported previously that for circular-bore tubes the gain factor for the $3s_2$-$2p_4$ neon transition increases in direct proportion to a reduction in the bore diameter. The large reduction in the volume of the active gas which results from a straight reduction in bore diameter makes this solution unattractive for laser amplifier applications. Also, for laser oscillator applications, a reduced bore diameter results in a proportionate increase in the diffraction losses, if the length of the discharge tube is not altered. Thus this solution for circular-bore plasma tubes is of limited practical value.

The electron distribution and subsequently the density of $3s_2$ neon states is influenced by the plasma tube geometry. As a result, a rectangular-bore plasma tube with a large height-to-width ratio exhibits a radial and an axial electric field distribution which is quite different from that of an equivalent cross-sectional area circular-bore tube. By appropriately shaping the radial field, more efficient pumping of the upper laser state ($3s_2$) can be obtained. Also, the narrow dimension of a rectangular-bore tube should result in an increased diffusion flow of neon 1s metastable states to the tube walls because of an increase in the concentration gradient. For this transition, a buildup of metastable 1s neon states produces a bottleneck in the decay chain for the lower laser state $2p_4$. The partial removal of this bottleneck through radial diffusion flow processes results in a larger population inversion and, thus, an increased gain factor.

As a part of a study of the discharge current (pumping power) induced saturation of the 6328 angstrom transition, a 100-cm-long rectangular-bore glass tube with a 2.5 by 10.0 mm cross-sectional area was constructed. The tube was terminated with the usual quartz Brewster angle windows. An experimental investigation of the gain factor associated with this tube confirmed the predicted increase in the gain factor. Under optimum operating conditions (5–1 He–Ne, 1.07 torr at an excitation current of about 50 mA), a measured gain factor of 1.20 dB/m (about 32%/m) was recorded. This gain factor measurement represents the highest value obtained to date for this useful transition.

The favorable gain factor attained with this amplifier tube was quite evident when it was converted into a laser oscillator. The incremental gain was sufficient to allow oscillation to occur within a relatively high-loss optical cavity formed by a 2- and 3-meter radius-of-curvature mirror. It lased quite easily and remained on even though coherent radiation was noticeably being scattered from the side walls of the discharge tube at the junction of the rectangular-bore tubing with the short, terminal, circular-bore tubing.

The rather complex mode pattern of this laser is approximately rectangular (with rounded corners). Under the optimum gas conditions, this laser exhibited an output power of about 70 milliwatts. This figure is by no means the best output power that could

(continued overleaf)

be obtained. Because of the limited number of optical elements available at the time of this study, no serious attempt could be made to obtain the maximum output power. The rectangular mode pattern of this laser could be quite useful as a coherent, high-power illuminator for optical experiments involving monochromators and/or other optical instruments that utilize an entrance slit. The high gain factor shown by this plasma tube, coupled with a cross-sectional geometry that is quite favorable to signal-beam folding, removes one of the most serious previous objections to the construction of practical traveling-wave laser amplifiers for this transition.

Note:

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