Characterization of Highly Stable, Mid-IR, GaSb-Based Laser Diodes

Introduction

Mid-IR, 3000- to 3500-nm laser sources are important for various applications including gas sensing, spectral analysis, infrared illumination, countermeasures, medical diagnostics, and others. One particular application is layering cryogenic targets for inertial confinement fusion (ICF) implosions at the Omega Laser Facility.[1] Careful layering of cryogenic targets is important to maximize the fuel density in ICF implosions. These targets consist of ~900-μm-diam microcapsules that contain frozen D_2 (deuterium–deuterium) gas. The frozen deuterium is “layered” so that it is uniformly distributed around the inner surface of the capsule.[2,3] The layering process relies on the target being in a spherical isotherm that is uniformly illuminated by mid-IR light. The wavelength is tuned to the absorption peak in the fuel material (3160 nm with ~20-nm FWHM for D_2 targets[4]). Since thicker regions of ice will have a longer path length, they absorb more radiation, so they will be relatively hot spots. Fuel material sublimes from the hotter regions and condenses and refreezes on the thinner, colder regions, leading to a uniform distribution of fuel material. For this process to produce layers with the required uniformity, the temperature must be held very close to the material’s melting point. As a result, the mid-IR source’s output power and spectrum must be temporally stable to avoid over- or underheating.

Currently a mid-IR optical parametric oscillator (OPO) is used to layer the targets.[5] It was shown in Ref. 6 that mid-IR, GaSb-based quantum-well laser diodes can be used for target layering. Here we report on selection and characterization of a mid-IR laser diode that performs optimally for the cryogenic target layering.

Laser-Diode Selection

Three laser diodes emitting at ~3160 nm have been grown and assembled as described in Ref. 6. During the selection process, the output power versus driver current and spectral shape at 3160 nm were measured (see Fig. 122.20).

Diode #1 delivered the highest output power of >50 mW at 2400 mA of driver current. Its spectrum was centered at 3160 nm and had a compact envelope with <20-nm FWHM. Diode #2 had the same slope efficiency as diode #1 with lower

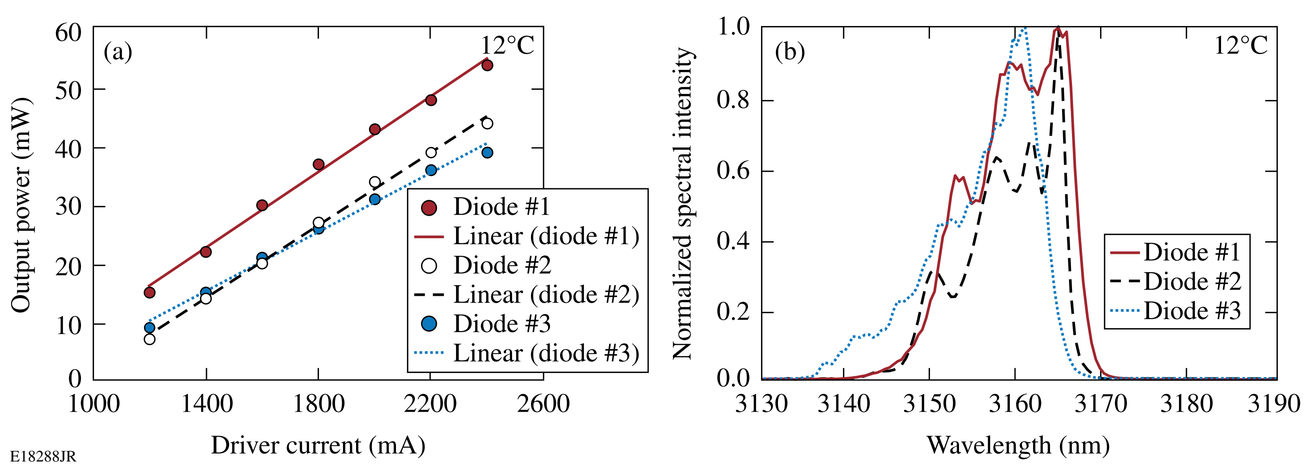

Figure 122.20
(a) Output power versus driver current and (b) spectra at 3160 nm for three tested laser diodes.

output power. Its spectrum had more-pronounced intensity variations than diode #1. Diode #3 had lower slope efficiency and output power than both diodes #1 and #2. Its spectrum was asymmetric and had a wide short-wavelength wing. Diode #1 has been selected for further characterization.

Laser-Diode Characterization

The output power of diode #1 was measured at various driver currents and heatsink temperatures (see Fig. 122.21). The highest power—54 mW—was produced at 12°C and 2400 mA of the driver current. A further temperature decrease might cause condensation and higher current might damage the diode. The output-power variations over 24 h of operation were ~1.3% rms and might be reduced by improving temperature stabilization of the diode.

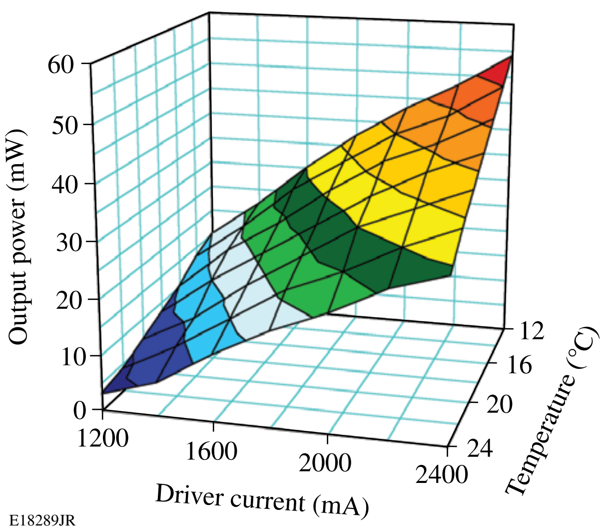

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Figure 122.21
Output power versus driver current at various temperatures for diode #1.

The spectral position and shape were measured at various temperatures and currents (Fig. 122.22). The output spectrum moved toward a longer wavelength at a rate of ~2 nm per °C of temperature increase and at a rate of ~2.5 nm per 100 mA of current increase.

Providing constant absorbed power and preventing target melting require irradiation with a highly stable spectrum that matches the D_2 absorption band. The 3160-nm–centered, 20-nm FWHM D_2 absorption band[4] is well represented by a fourth-order super-Gaussian shown in Fig. 122.23 (red). The diode #1 spectra at various diode temperatures and driver currents were multiplied by the D_2 absorption curve to find a relative power absorbed by D_2. After integration over the wavelength, the absorbed power, plotted in Fig. 122.24, showed optimal temperature and current settings for the maximum absorbed power –12°C and 1800 mA, which correspond to ~37 mW of absorbed power. Figure 122.23 shows spectral

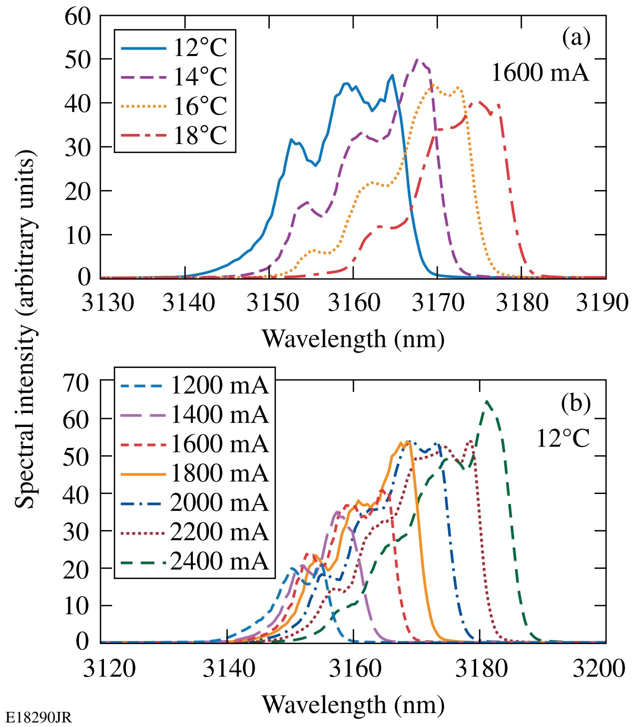

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Figure 122.22
Output spectral shape and positions for various (a) temperatures and (b) currents for diode #1.

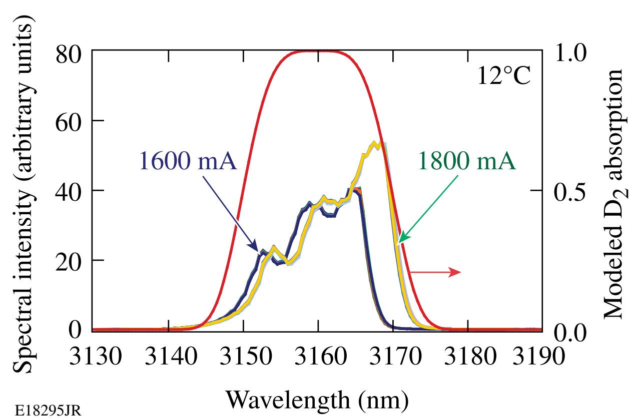

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Figure 122.23
Diode #1 spectral stability at 1600- and 1800-mA driver currents. The D_2 absorption band is shown in red.

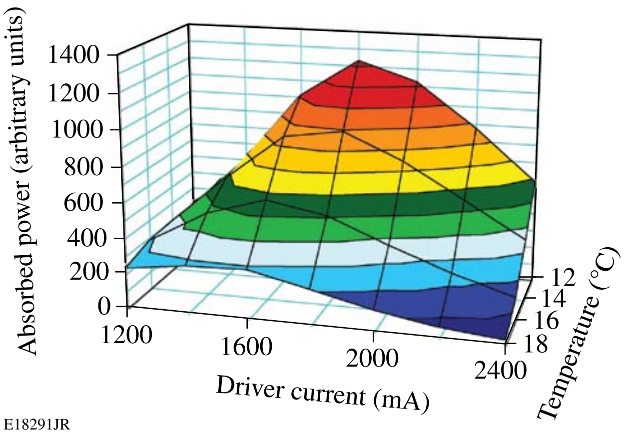

Figure 122.24
Diode #1 output power absorbed by the D_2 target at various diode temperatures and driver currents.

diode #1 stability at 12°C and 1600- and 1800-mA current settings. Plotted for each current setting are nine spectra that were taken at 15-min intervals over 2 h. Diode #1 represents high spectral stability and a compact spectral envelope over optimal temperature and current settings.

Conclusion

We demonstrated and characterized a highly spectrally stable, mid-IR, GaSb-based laser diode with a 3160-nm–centered, <20-nm FWHM spectrum and >35-mW output power at room temperature for cryogenic target layering at the Omega Laser Facility. A highly stable operation with output-power variations of ~1.3% rms has been demonstrated over 24 h. Future research will consist of optimizing the growing process to achieve consistent laser-diode performance with >100 mW of output power to meet the mid-IR layering-source requirement.

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REFERENCES

1. T. R. Boehly, D. L. Brown, R. S. Craxton, R. L. Keck, J. P. Knauer, J. H. Kelly, T. J. Kessler, S. A. Kumpan, S. J. Loucks, S. A. Letzring, F. J. Marshall, R. L. McCrory, S. F. B. Morse, W. Seka, J. M. Soures, and C. P. Verdon, Opt. Commun. **133**, 495 (1997).

2. T. C. Sangster, R. Betti, R. S. Craxton, J. A. Delettrez, D. H. Edgell, L. M. Elasky, V. Yu. Glebov, V. N. Goncharov, D. R. Harding, D. Jacobs-Perkins, R. Janezic, R. L. Keck, J. P. Knauer, S. J. Loucks, L. D. Lund, F. J. Marshall, R. L. McCrory, P. W. McKenty, D. D. Meyerhofer, P. B. Radha, S. P. Regan, W. Seka, W. T. Shmayda, S. Skupsky, V. A. Smalyuk, J. M. Soures, C. Stoeckl, B. Yaakobi, J. A. Frenje, C. K. Li, R. D. Petrasso, F. H. Séguin, J. D. Moody, J. A. Atherton, B. D. MacGowan, J. D. Kilkenny, T. P. Bernat, and D. S. Montgomery, Phys. Plasmas **14**, 058101 (2007).

3. D. R. Harding, D. D. Meyerhofer, T. C. Sangster, S. J. Loucks, R. L. McCrory, R. Betti, J. A. Delettrez, D. H. Edgell, L. M. Elasky, R. Epstein, V. Yu. Glebov, V. N. Goncharov, S. X. Hu, I. V. Igumenshchev, D. Jacobs-Perkins, R. J. Janezic, J. P. Knauer, L. D. Lund, J. R. Marciante, F. J. Marshall, D. N. Maywar, P. W. McKenty, P. B. Radha, S. P. Regan, R. G. Roides, W. Seka, W. T. Shmayda, S. Skupsky, V. A. Smalyuk, C. Stoeckl, B. Yaakobi, J. D. Zuegel, D. Shvarts, J. A. Frenje, C. K. Li, R. D. Petrasso, and F. H. Séguin, J. Phys., Conf. Ser. **112**, 022001 (2008).

4. A. Crane and H. P. Gush, Can. J. Phys. **44**, 373 (1966).

5. L. M. Elasky, D. J. Lonobile, W. A. Bittle, D. R. Harding, A. V. Okishev, and J. D. Zuegel, presented at the 15th Target Fabrication Specialists' Meeting, Gleneden Beach, OR, 1–5 June 2003.

6. A. V. Okishev, D. Westerfeld, L. Shterengas, and G. Belenky, Opt. Express **17**, 15760 (2009).