Single Longitudinal Mode Operation of Semiconductor Laser Arrays with Etalon Control

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A simple method is devised to obtain a single longitudinal output beam from high-power multilongitudinal mode diode laser arrays. Mode control is achieved by simply placing a thin etalon in front of the laser. The three-cavity laser formed by addition of the etalon favors a single longitudinal mode. This technique is applicable to both continuous wave and pulsed laser modes of operation. Experimental results demonstrating the technique along with future work and possible applications are discussed.

I. Introduction

The GaAlAs semiconductor diode array laser and the diode laser pumped Nd:YAG laser are two of the leading candidate sources of radiation for free-space optical communication (Refs. 1 and 2). High electrical-to-optical efficiency along with small size and low mass are some of the features distinguishing these lasers for use in satellites. In general, available diode array lasers have a multilongitudinal mode output. For the heterodyne (coherent) detection technique and various power summing schemes, a single longitudinal mode laser is essential. Also, for such applications as optical pumping of solid-state lasers that have narrow absorption bands, a single mode diode array laser, tuned to a particular absorption band, could be beneficial for more efficient optical excitation.

Most attempts for obtaining single mode array lasers have been directed towards modification of the internal structure of the laser or the use of optical feedback from an external cavity (Ref. 3). When successful, these attempts are limited by low output power from the laser array.

Here a simple method is described to force the multimode output of a laser array into a single longitudinal mode structure. This is accomplished by placing a thin (150- to 250-μm thick) etalon plate at the output port of the diode laser. This etalon (which acts as a resonant reflector) along with the reflective surfaces of the diode laser itself form a three-cavity laser. Resonant operation, where all retroreflections are in phase, results in selection and enhancement of a particular longitudinal mode and simultaneous suppression of the adjacent modes. This method was recently applied to single-element diode lasers with significant (>34 dB) suppression of the adjacent modes (Ref. 4). However, applicability to multimode diode array lasers has not been reported until now. The experimental results presented here pertain to the latter and demonstrate the effectiveness of the method on laser arrays.

II. Experiments

A schematic of the experimental set up is shown in Figs. 1 and 2. The 120-mW output of a 10-element diode gain guided array laser was collimated by a 6.5-mm focal length and 0.615 numerical aperture lens. Three etalon thicknesses were examined: 1-mm, 200-μm, and 150-μm thick solid uncoated etalons. The 150-μm thick plate was just a microscope slide cover glass plate. At such a small thickness, the two faces of the plate are flat and parallel enough to act as an etalon. The 1-mm thick etalon proved ineffective, whereas the Fresnel reflection from either of the two thin ($\leq$200-μm) uncoated glass plates provided sufficient control of the laser mode structure. The etalon was placed on an adjustable mount for fine control. At distances greater than 2 mm from the array (no collimating lens was used), the alignment of the etalon relative to laser facets becomes critical. Just prior to entering the single mode operation, spectral instabilities can be observed due to improper feedback. The addition of a thin uncoated etalon is very power efficient. The overall laser power is reduced by less than 3%.

A typical laser emission spectrum before etalon feedback and after proper etalon alignment is shown in Fig. 3. The measured side mode suppression on this unoptimized setup is about 26 dB. The laser remained single mode for over an hour of examination time. The diode laser was temperature regulated using a thermoelectric cooler. However, single mode operation was maintained with up to 4°C of temperature tuning after which realignment of the etalon was necessary to regain single mode operation. Single mode operation was also maintained when the diode array was pulsed. For pulse rates up to 0.1 MHz, no degradation was observed in the single mode output. Single mode operation is expected to be retained at even higher pulse rates.

The single mode operation method was also examined with an antireflection coated diode laser. Such a diode gain element requires a partially reflecting (typically 50%) output coupler for radiation feedback in order to lase. In this case, the etalon was placed outside the cavity (Fig. 2) where it effectively forces the multilongitudinal mode laser into a single mode. Work is underway to examine this method for the case in which the etalon is placed inside the laser cavity.

Improved efficiency of the diode laser pumped Nd:YAG laser is of major interest. Since the Nd:YAG crystal has a number of narrow absorption bands around the emission wavelength of the laser, a pump laser tuned to one of these bands should result in higher laser power. In preliminary studies where the Nd:YAG crystal was optically pumped with a single mode laser, only 5% improvement in the output power was observed. However, no attempts have been made yet to tune the laser wavelength. Wavelength selection is achievable by diode laser temperature tuning (typically about 3 angstroms per °C), by adjusting the spacing between the laser front facet and the etalon or a combination of both.

For a compact structure and nominal alignment requirement, the etalon may be attached very close to the front facet of the laser, perhaps in place of the window of the protection housing used with many of the commercially available diode lasers. Since the resonant peaks of multiresonant reflectors are sharper and more separated than is the case of a single-element etalon, the effect of using a multiple number of etalons all aligned with the original laser cavity needs to be examined.

III. Conclusion

In conclusion, a simple method is described to obtain single longitudinal mode laser output from multitemporal mode laser arrays with nearly 100% optical efficiency. Work is underway to study the effect of the etalon on the near-field and far-field patterns (the transverse mode structure) of laser arrays, as well as their application to diode array pumping of solid-state lasers.

References

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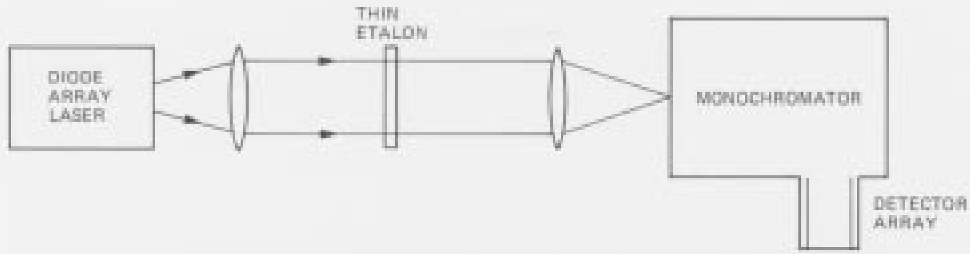

Fig. 1. A Schematic of the experimental setup where a regular ten-element diode array laser is used

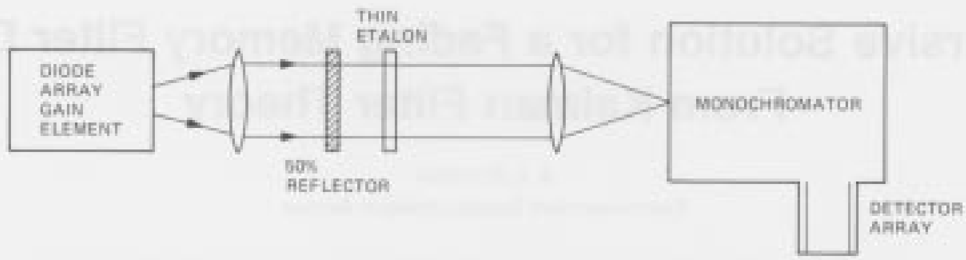

Fig. 2. A schematic of the experimental setup consisting of a front facet antireflection coated diode array laser (diode array gain element)

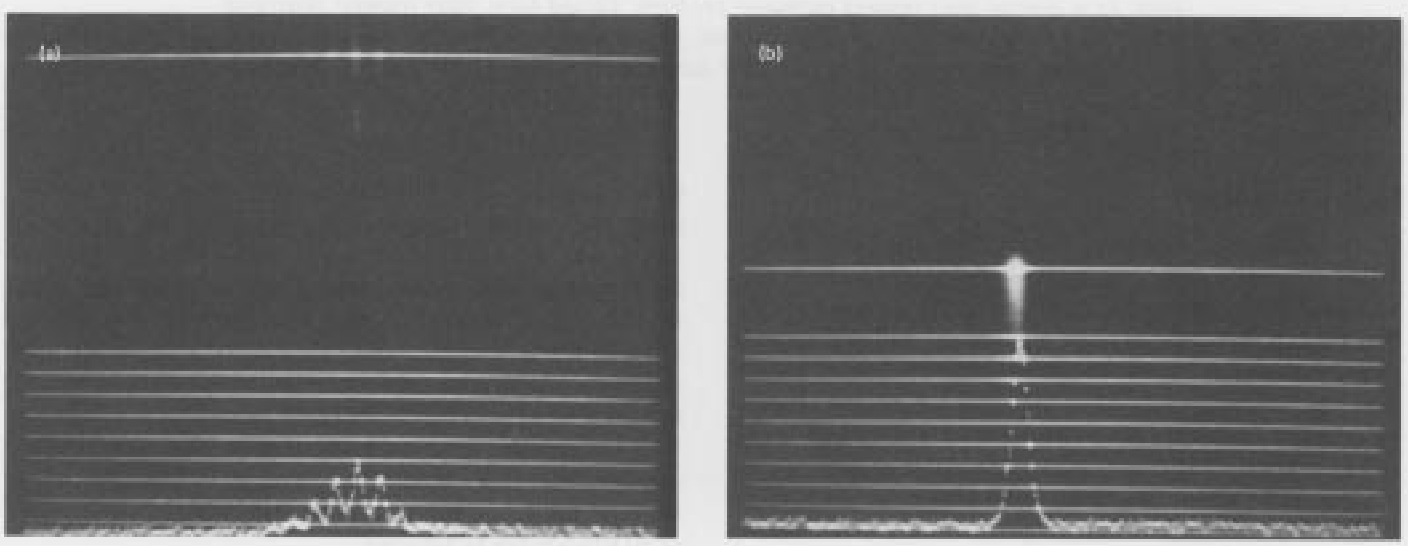

Fig. 3. The spectrum of a ten-element diode array laser as analyzed by a monochromator: (a) before etalon feedback; (b) after etalon alignment with the array