26C5

TUNABLE MULTIPLE WAVELENGTH EXTERNAL CAVITY DIODE LASERS FOR REMOTE SENSING APPLICATIONS

GEORGE C. PAPEN, GEORGE M. MURPHY
Department of Electrical and Computer Engineering, University of Illinois
1406 W. Green St., Urbana, Illinois 61801 USA
Ph. (217) 244-4115 Fax. (217) 333-4303 e-mail: g-papen@uiuc.edu

GRADY J. KOCH
NASA Langley Research Center, Hampton VA 23681 USA

RUTH Y. DEJULE, ROBERT W. KALISKI
Micro Photonics, 150 W. Warrenville Rd., Naperville, Illinois 60566 USA

INTRODUCTION

Semiconductor diode lasers are used in a variety of remote sensing systems. Major applications include injection seeding other solid state lasers for DIAL systems [1] and compact short range systems based on CW pseudo-random modulation [2,3]. Here, we report on novel external cavity lasers that generate multiple geometrically controlled wavelengths. These devices can be used as tunable injection seeders or with post-amplification as direct lidar transmitters.

TUNABLE INJECTION SEEDERS

The geometry of the multiple wavelength injection seeder is shown in Figure 1. Two discrete lasers or individual elements of a diode array are spaced a distance d apart. The facets are coated AR/HR for external cavity operation. The individual channels are collimated by GRIN lenses and are incident at an angle θ with respect to the grating normal. Each channel diffracts off the grating and off a different part of a curved feedback mirror. The curvature of the mirror destroys the shift invariance of the system and thus each channel lases at a different wavelength. The wavelength is determined by applying ray tracing and the grating equation and is given by

$$\lambda_n = \Lambda[\sin(\theta)+\sin(\phi_n)] \qquad (1a)$$

with

$$\phi_n = \tan^{-1}\left(\frac{x+[d\,(n-1)]/\cos\theta}{y}\right) \qquad (1b)$$

where n =(1,2), Λ is the grating period, and x and y are measured from the center of the radius of curvature of the mirror. Wavelength tuning is accomplished by moving the feedback mirror with respect to the array and the grating.

Verification of the design was conducted using an individually addressable diode array fabricated by Micro Photonics. Without external feedback, each element was single mode. The back surface was HR coated (~98%) while the front facet had an optimized AR coating (<0.2% over 50 *nm*) centered at 810 *nm*. Two diodes in the array 3.5 *mm* apart were individually collimated using 0.18 pitch 1.8 *mm* diameter single layer AR coated GRIN lenses.

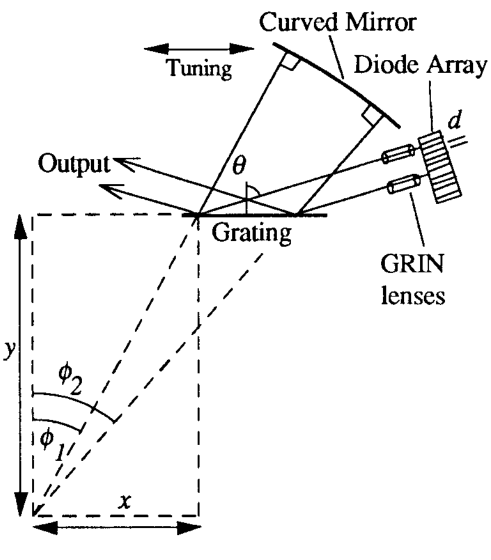

Figure 1. Geometry of the diode array coupled to the external cavity.

Figure 2 shows the peak lasing wavelength as a function of the lateral distance the mirror was moved relative to the array and the grating. Both the wavelength offset and the slope of the tuning curve agree well with the calculated slope.

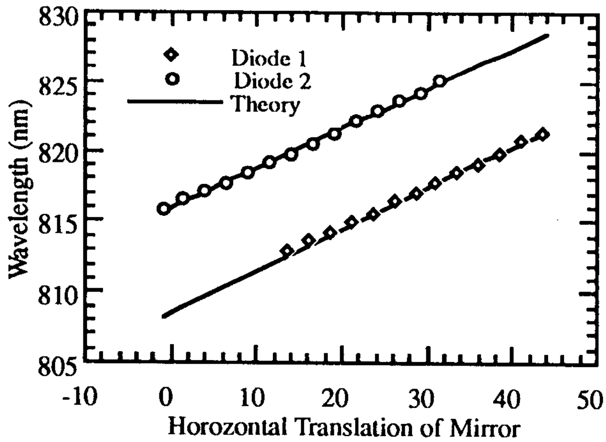

Figure 2. Tuning curves for the two laser elements along with the calculated tuning slope.

The principle advantage of the design is that the wavelengths and wavelength spacing are independently selectable through geometry and exhibit "single-knob" tuning for all wavelengths while maintaining a fixed wavelength separation. The geometrical tuning eliminates hysteresis problems encountered with room temperature current/temperature tuning.

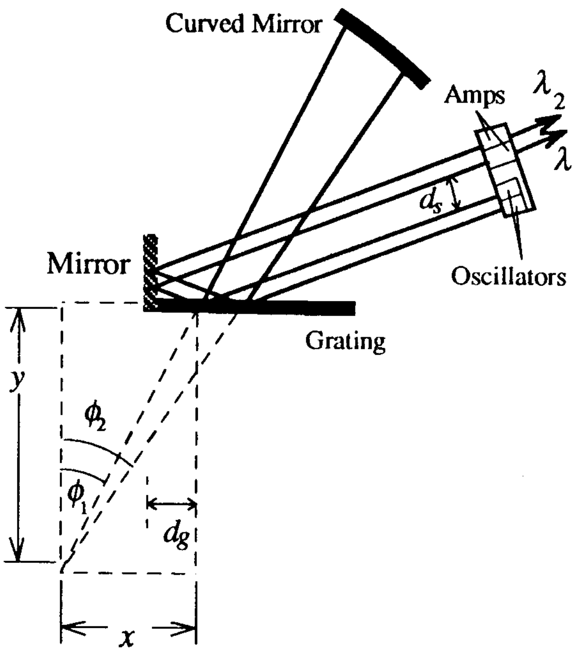

Figure 3. Geometry of a Master Oscillator Power Amplifier configuration for semiconductor laser based DIAL system.

For DIAL seeding applications, a single channel is tuned using a combination of rotation and a piezo mirror to the absorption line of interest. The other channel then tracks the tuning providing the "off" wavelength at a fixed wavelength offset.

HIGH POWER DEVICES

For direct remote sensing, the output can be retroreflected using a mirror perpendicular to the grating and amplified by semiconductor amplifier co-located with the oscillator (see Figure 3). This allows for all the devices or a monolithic device to be placed on the same substrate to reduce thermal effects.

The relationship between the oscillator and the amplifier spacing is given by

$$d_s = d_g \frac{\sin(\pi - 2\theta)}{\sin(\theta)} \qquad (2)$$

where d_g is the distance from the mirror to where the first channel intersects the grating and d_s is the distance between the amplifiers and oscillators. For typical devices, the output of the oscillators is ~1-5 mW and the power gain of the amplifiers is ~20 dB implying output powers on the order of 100-500 mW. Devices operating at ~940 nm are currently being investigated for use as both injection seeders for Ti:Sapp DIAL systems and as direct DIAL transmitters using PN modulation[2]. The compactness of the design should allow these transmitters to be deployed on small airborne platforms such as NASA's Perseus.

CONCLUSION

Tunable external cavity diode lasers are attractive candidates for several types of lidar systems and have the potential to be used directly as efficient compact transmitters.

REFERENCES

1. N. P. Barnes, J. C. Barnes, *IEEE J. Quantum Electron.* **29**, 2670-2683 (1993).
2. N. N. Takeuchi, N. Sugimoto, H. Baba, K. Sakurai, *Appl. Opt.* **22**, 1382 (1983).
3. J. B. Abshire, J. A. R. Rall, "AlGaAs aerosol lidar - theory and measurements", Optical Remote Sensing of the Atmosphere Salt Lake City, Utah, 1993, OSA tech. series vol. 5 Postdeadline Papers, pp. PD 2-5.