

# Single longitudinal mode blue-violet laser diode for data storage

Christophe Moser, Lawrence Ho, Frank Havermeyer

*Ondax, Inc. 850 E. Duarte Road, Monrovia, CA 91016, U.S.A*

*Phone: 626 357 9600 Fax: 626 357 9321*

*moser@ondax.com, lho@ondax.com, havermeyer@ondax.com*

## Introduction:

Commercially available blue-violet diodes near 405 nm for Blue-ray and HD-DVD disks lase with multiple longitudinal modes and have thus a sub-millimeter coherence length. Optical data storage technologies requiring coherent interference, such as holographic e.g., will benefit from having a compact blue-violet laser diode source with a long coherence length and some level of wavelength tuning.

Prior approaches, such as external cavities with diffraction gratings [1], have been used to generate single longitudinal mode tunable lasers near 405 nm. Such cavities require a very low reflectivity front facet coating, precise alignment, occupy a volume on the order of several cm<sup>3</sup> and are prohibitively expensive for any mass markets. In contrast, we propose and experimentally demonstrate an ultra-short external cavity laser based on reflective volume holographic gratings. The main advantages of this laser is its sub mm<sup>3</sup> volume, thermal wavelength tuning and compatibility with the existing high volume automated manufacturing lines of Blue-violet lasers because the external cavity can be passively aligned.

## External cavity

It is well known that volume holographic gratings (VHG) have a narrow angular and spectral response [2]. Because of this unique property, a reflection-mode VHG will Bragg-match and strongly diffract only a narrow range of wavelengths anti-parallel to the incident beam. This property makes it possible to implement a compact external cavity laser diode without additional optical components, as shown in 1 [3]. The VHG is placed in the diverging beam of the laser diode. The distance between the VHG and the laser diode facet should be as small as possible. A narrow angular cone whose direction is normal to the grating vector provides the feedback to the laser cavity. Because the divergence of the laser beam is much larger than the cone surrounding the direction normal to the VHG, a misalignment of the VHG (i.e a change in the grating vector direction) by several degrees is automatically compensated by a different cone direction.

For a typical VHG with a thickness of 0.5 mm and Bragg wavelength of 405 nm, the FWHM angle selectivity is a cone subtending 3.3 degrees in air for close to anti-parallel diffraction. The laser diode (LD) emits light with a large divergence angle, dictated by the aperture of the LD's active area. The typical beam divergence of a blue-violet laser diode is 10 degrees in the slow axis and 20 degrees in the fast axis. The ratio of the area subtended by the diffracted cone and the laser beam is approximately 5%. This means that a fraction of 5% of the light contributes to the feedback to the laser. The other 95% of the light in the diverging beam can "escape" the grating without diffracting. The VHG acts as an angularly-spectrally sensitive output coupler.

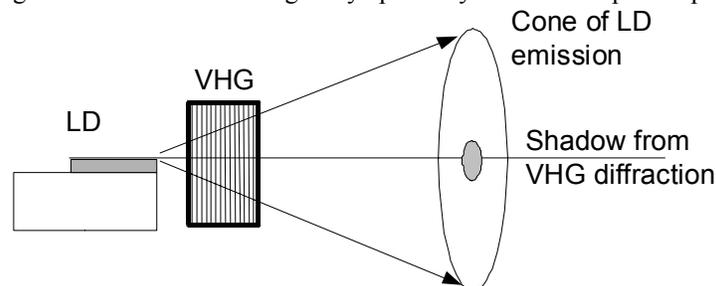


Figure 1: Ultra-short external cavity with a reflective volume holographic grating placed in the diverging beam of the laser diode.

## Experimental results:

We manufactured volume holographic gratings in glass with center wavelengths of 403 nm and 407 nm to match the center wavelengths of commercially available blue-violet laser diodes. The spectral bandwidth of the

VHGs was approximately 0.15 nm FWHM. The VHGs were mounted close to the output facet of the laser diode (see fig.1).

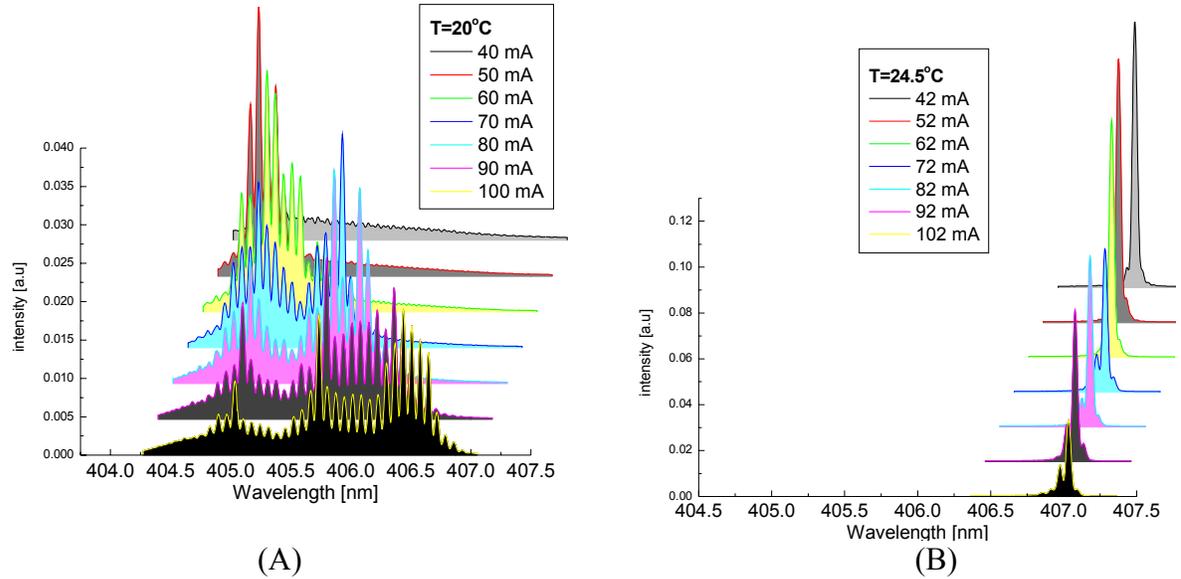


Figure 2: (A) Mode spectrum from the original blue-violet diode at different current level  
(B) Mode spectrum from the same blue-violet diode laser with feedback from a volume holographic grating mounted according to figure 1.

Figure 2 left shows the spectrum of the original blue-violet laser diode as a function of operating current. The threshold for the diode is 38 mA. A spectral resolution of 0.01 nm was achieved with a home-built spectrometer based on a rotating thick volume holographic grating. The diode is multimode longitudinal at all currents with a mode spacing of approximately 0.035 nm.

In contrast, after mounting the VHG, the spectrum of the diode is reduced to single mode for operating current below 65 mA (20 mW optical power) and four to five modes above 65 mA. The maximum number of modes oscillating in the cavity is limited by the bandwidth of the VHG (0.15 nm). We plan to use thicker VHGs to reduce the bandwidth and thus increase the maximum optical power for single longitudinal mode operation.

Single mode operation in the wavelength locked range was confirmed by the reading of a wavelength meter (Coherent Wavemaster, 1 pm resolution).

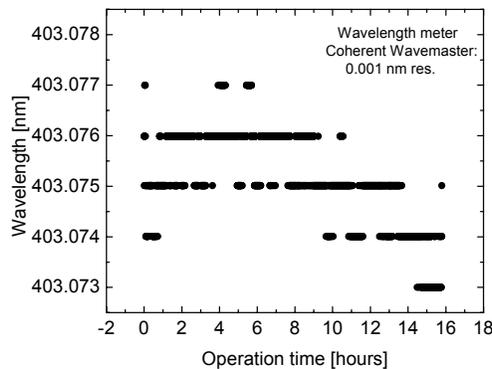


Figure 3: Wavelength stability of a single mode blue-violet laser wavelength stabilized with a volume holographic grating centered at 403 nm.

A second diode with 10 mW power was assembled with a 403 nm VHG. The laser diode was held at a constant temperature in a Thorlabs temperature and current controller. The laser diode had a single longitudinal

mode within the locked temperature range. The wavelength stability was measured with a wavelength meter. The result is shown in figure 3. A 4 pm wavelength shift was observed during 16 hours of operation at constant current.

A michelson interferometer was used to measure the coherence length of the laser diode. The visibility of the interference fringes confirmed that the coherence length of the laser diode was larger than 1 meter.

The wavelength of the locked laser diode can be tuned by thermally tuning the semi-conductor laser and the VHGs independently. A schematic of a proposed implementation is shown in figure 4. Following the basic implementation of the fixed wavelength laser, the VHG is mounted against a low thermal conductor, itself mounted on the laser diode heatsink. Current flowing through the deposited metal on the side of the VHG provides heating and thus wavelength tuning. The small size of the VHG ( $0.2 \text{ mm}^3$ ) is expected to provide relatively fast tuning and consume low electrical power.

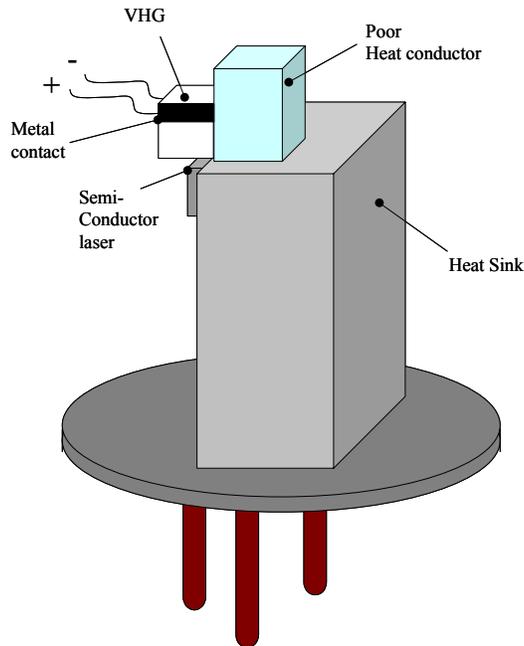


Figure 4: Schematic of a TO-can laser with wavelength tuning by heating the small VHG element.

We have shown that single longitudinal mode performance with a coherence length of over 1 meter can be obtained from a commercially available blue-violet laser with a passively aligned reflective volume holographic grating placed in the diverging beam of the laser diode. The ultra-short external cavity fits inside a TO-can 5.6 mm package. A method for tuning the wavelength of the laser is presented

#### References:

- [1] L. Hildebrandt et al, "Anti-reflection coated blue GaN laser diodes in an external cavity and Doppler free indium absorption spectroscopy," *Applied Optics.*, 42 (12) : 2110-2118, 2003
- [2] H. Kogelnik, "Coupled wave theory for thick hologram gratings," *Bell Syst. Tech. J.*, 48:2909-2947, 1969.
- [3] G. Steckman et. al "Volume Holographic grating wavelength stabilized laser diodes", *IEEE J. Quantum Electronics*, 13 (3): 672: 678, 2007