Optical alignment for wavelength locking by use of a LuxxMaster™ element

1. General comments

1.1 The LuxxMaster™ should be handled like other optical components, e.g. lenses.

1.2 Regular cleaning procedures can be applied including the use of ultra-sonic tubs. The use of regular cleaning solutions (e.g. acetone, alcohols, soap etc.) is permitted without restrictions.

1.3 The hardness of the bare LuxxMaster™ glass is similar to BK7. However, most LuxxMaster™ elements are anti-reflection coated and these coatings can be damaged more easily than the bare glass. Use of the soft-tip tweezers or vacuum-picks is strongly advised to avoid chipping and/or scratching of the LuxxMaster™ elements.

1.4 No special storage conditions are necessary.

1.5 When performing the wavelength locking tests, the cylindrical lens can be either adjusted independently of the LuxxMaster™ (Method 1) or attached directly to the LuxxMaster™ surface (Method 2).

2. Installation

2.1 Clean the LuxxMaster™ element and the lens.

2.2 If the experiments will be performed with the lens adjusted independently of the LuxxMaster™ element (Method 1), proceed to step 2.3.

2.2.1 Attach the lens to the LuxxMaster™, if desired. To do so locate the coated sides of the LuxxMaster™.

2.2.2 Place the lens directly on the surface of one of the coated LuxxMaster™ sides and align the axis of the lens parallel to the long side of the LuxxMaster™.

2.2.3 Fix the lens at its ends using adhesive.

2.3 Mount the lens and the LuxxMaster™ in their holder(s).

2.4 Prepare the laser diode bar.

2.5 Position an integrating sphere so that it captures all the light from the laser diode bar.

2.6 Connect the fiber port of the integrating sphere to a spectrometer or an optical spectrum analyzer.

3. *Alignment*

In general, wavelength locking is achieved when the fast axis of a laser diode is near collimation and the LuxxMaster™ element is positioned behind the lens to reflect some of the laser diode light back into the laser cavity (see Figures 1 and 2). Note that "perfect" collimation of the fast axis is not necessary. The required degrees of freedom for the alignment Methods 1 and 2 are shown in Figure 3 a) and b), respectively.

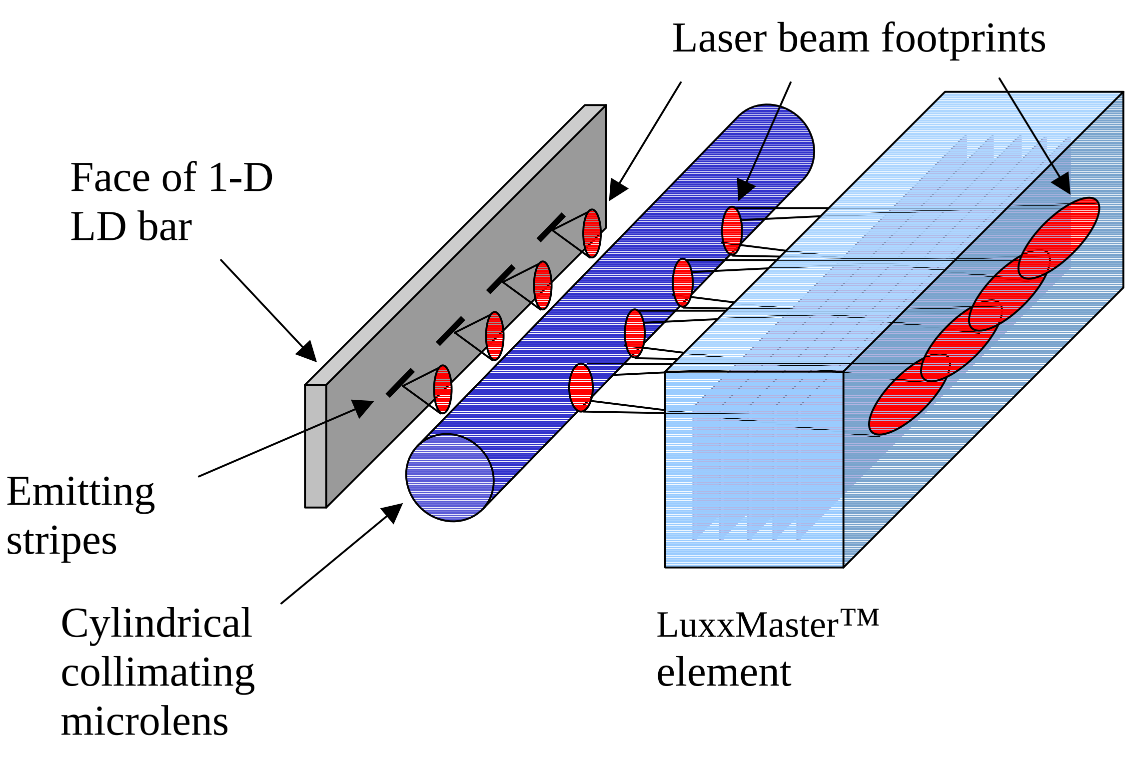


Fig. 1. LD bar wavelength locking using a single LuxxMaster™ element: general arrangement.

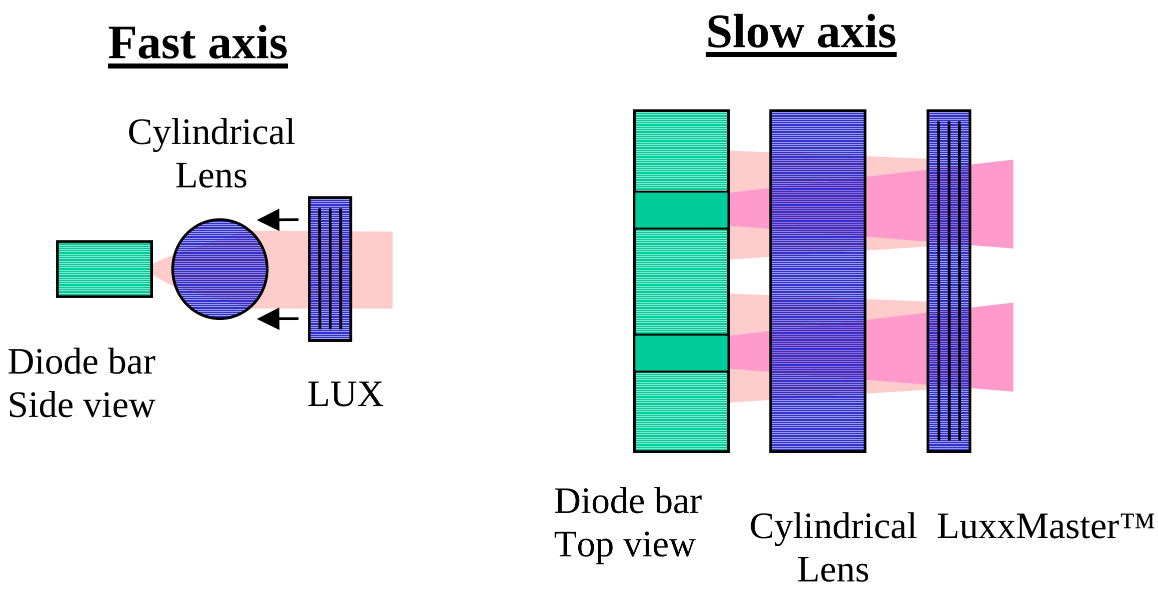


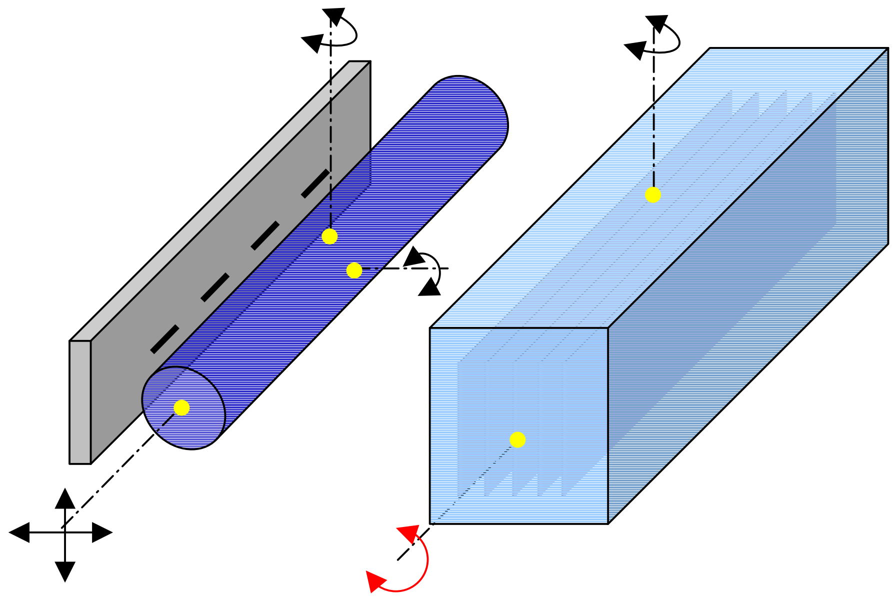
Fig. 2. Collimation schematic on the fast and the slow axis.

3.1 Bring the lens into close proximity to the laser diode bar and achieve collimation for all the emitters in the bar. The light output of the laser diode bar should appear as a sharp straight line at this point, without significant curvature or blurred edges.

3.2 Observe the output spectrum of the laser diode bar and begin adjustments of the LuxxMaster™ element. The most sensitive adjustments are the LuxxMaster™ rotation around the long axis of the LuxxMaster™ element in Method 1 or its vertical translation in Method 2.

3.3 When the LuxxMaster™ position is near its optimum, an additional narrow peak will appear on the emission spectrum of the laser diode bar at the LuxxMaster™ peak wavelength. Once this peak is observed, utilize all the alignment degrees of freedom to maximize the optical power in that peak.

a) Method 1: lens and the LuxxMaster™ adjusted independently



b) Method 2: lens attached to the LuxxMaster™

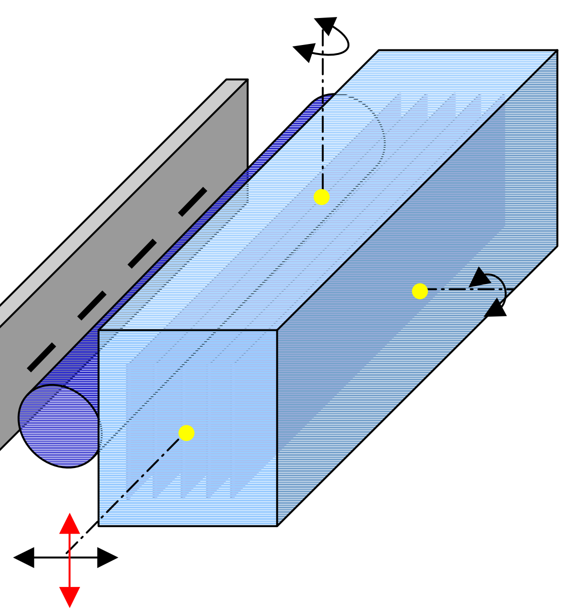


Fig. 3. Alignment adjustments to achieve locking.

LuxxMaster™ 素子についての技術資料

UPGRADING PERFORMANCE OF HIGH POWER LASER DIODES AND ARRAYS WITH LuxxMaster™ WAVELENGTH STABILIZATION

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Introduction

For many applications, a serious drawback to employing high power laser diodes (HPLD) is the width of the spectrum (for most manufacturers product offerings in the near IR and visible something between ±3 and ± 10 nm) and the temperature dependence of the emitted wavelength. One US company, PD-LD Inc. has recently demonstrated a technology for greatly improving spectral characteristics of high power laser diodes by using LuxxMaster™, a proprietary technology based on holographic volume Bragg gratings (VBG™) to lock and narrow their emission wavelength. The technique is applicable to high power laser diodes (HPLD) of any wavelength or power and has been demonstrated for 1W single emitters as well as for 40 W linear arrays.

Table 1 illustrates these improvements by comparison with typical commercial high power laser diodes:

Table 1. Comparison of the emission spectra of commercial high-power laser diodes with and without LuxxMaster™.

Laser type	Line width	nc control	dn/dT
Commercial diodes	3 – 6 nm	+/- 3 nm	0.3 nm/C
Commercial diode +LuxxMaster™	<0.5 nm	< +/- 0.5 nm	0.01 nm/C

As Table 1 shows, LuxxMaster™ element has the ability to transform a multimode high power laser diode or diode bar into extremely narrow-band emitters with precisely defined nc and a very low sensitivity to temperature changes.

Some applications of HPLDs, arrays and stacks will greatly benefit from a stabilized emission spectrum, most notably spectroscopy, the diode pumping of solid state lasers (DPSS) and some medical applications (notably PDT), where a precisely controlled wavelength and spectral width would result in more efficient and consistent operation. In practical applications, the emission wavelength of HPLDs is controlled by controlling the temperature of diodes with various cooling methods, e.g. by thermoelectric coolers (TECs) or water circulation. With LuxxMaster™ technology, the cooling requirements are greatly relaxed or even eliminated in many cases, leading to a significant simplification and cost reduction of systems incorporating HPLDs. Furthermore, the emission wavelength increases with aging of high power devices (the so called “red shift”), often limiting the useful lifetime of HPLDs to about 10,000 hours of operation. By applying the LuxxMaster™ wavelength stabilization, the red shift can be eliminated.

Principle of LuxxMaster™ stabilization

The PD-LD LuxxMaster™ technology is based on a proprietary inorganic photorefractive glasses that changes index of refraction in areas exposed to UV light. The glasses and the produced filters are physically and chemically very stable. For example, LuxxMaster™ filters have been tested to 200^{o}C and showed no degradation of performance.

The physical properties of the glass, such as chemical stability, hardness, optical damage threshold etc., are very similar to other common optical glasses, e.g. BK7. LuxxMaster™

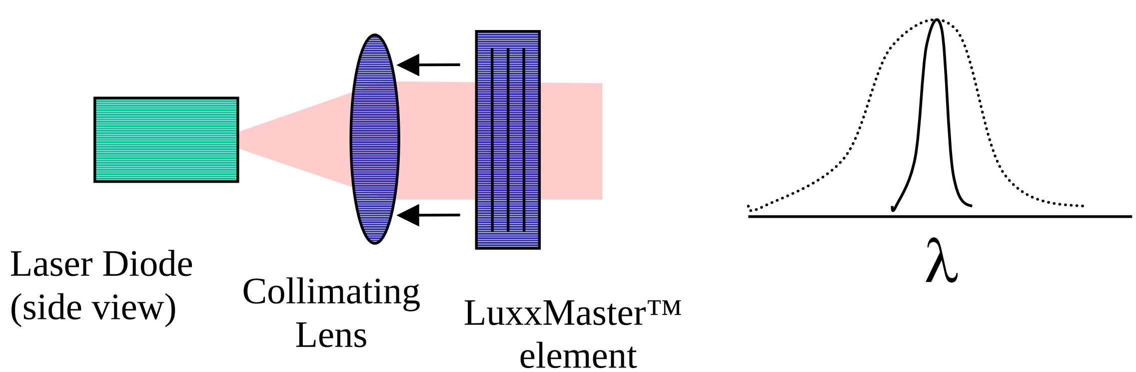

Figure 1. LuxxMaster™ element, placed in front of a laser diode chip after collimating lens, reflects narrow portion of the emitted light back into the laser cavity forcing it to lase at the reflected wavelength determined by the LuxxMaster™ element.

Figure 1 depicts schematically how this technique can be used to control the emission spectrum of HPLDs. LuxxMaster™ filters can have extremely narrow bandwidth, ranging from 0.05 nm to 0.5 nm. Only this narrow portion of the emitted laser light spectrum is reflected back into the laser diode, while other wavelengths pass through. The LuxxMaster™, thus, “self-seeds” the laser with narrow-band light and the laser diode is forced to lase at the injected wavelength determined by the LuxxMaster™ element. The central wavelength of the LuxxMaster™ can be controlled with much better accuracy [+/- 0.5 nm] than that of HPLDs, hence the tight control of central wavelength in LuxxMaster™ stabilized laser diodes.

Performance of LuxxMaster™ stabilized high power laser diodes and arrays

LuxxMaster™ elements can be made in a variety of sizes, most typically 1.5 x 2 mm for single emitters and 1.5 x 12 mm for linear arrays which are easily mounted in front of a lensed diode or a lensed array, as shown in Figures 2 and 3. Practically any of the commonly used HPLD packages including 9mm, TO-3, P5 etc. can be fitted with a wavelength stabilizing

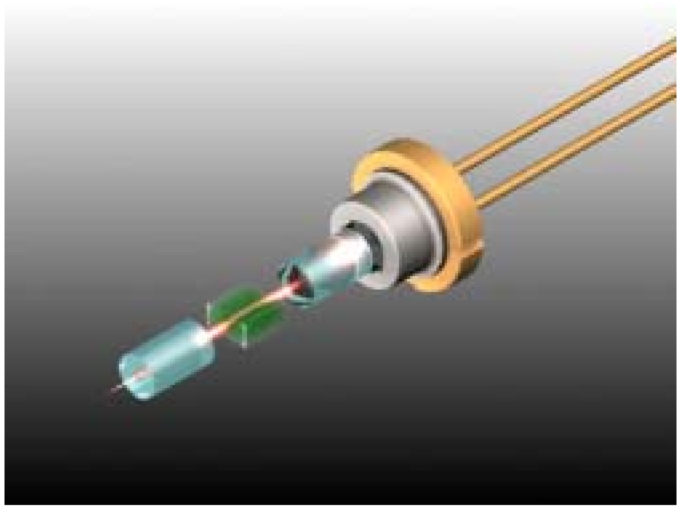

Figure 2. A wavelength-stabilized TO-packaged high-power laser diode with a cylindrical lens and a LuxxMaster™ element installed in front of it.

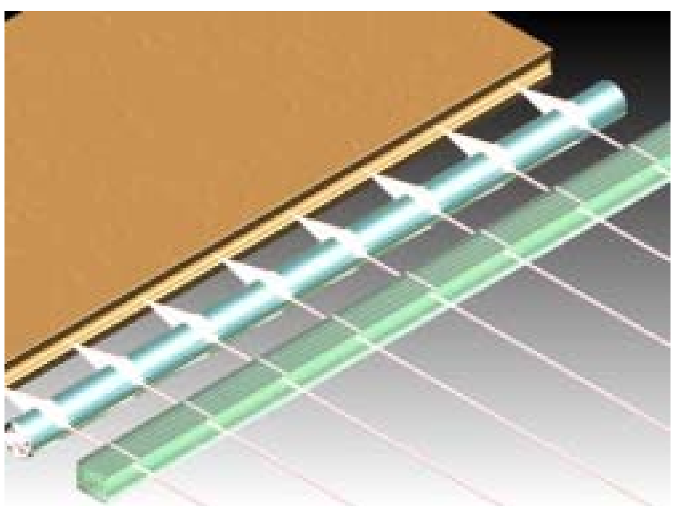

Figure 3. A wavelength-stabilized conduction-cooled laser diode bar with a cylindrical lens and a LuxxMaster™ element based VBG™ technology installed in front of it.

Figure 4 compares the emission spectrum of a standard commercial 1 W 808 nm laser diode with the emission spectrum of the same diode fitted with a wavelength stabilizing LuxxMaster™ element.[1]

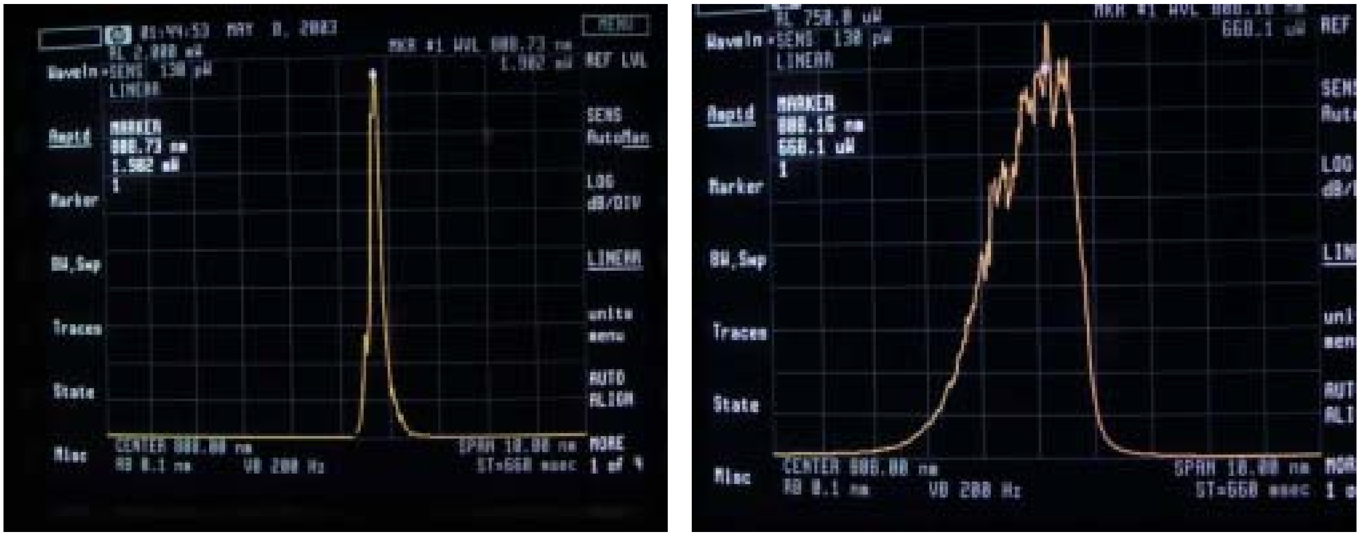

Figure 4. Comparison of the output of a free-running (left) and LuxxMaster™ locked (right) broad area emitter. The power is shown on a logarithmic scale.

Figure 5 compares the emission spectrum of a 40 W diode array with and without the wavelength stabilizing LuxxMaster™ element at different heat sink temperatures.

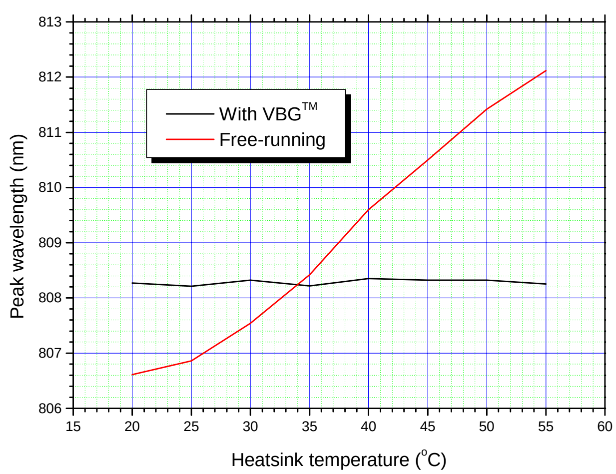

Figure 5. Temperature-induced wavelength drift comparison.

[1] Laser diode for this experiment was provided by Innovative Photonic Solutions, Inc.

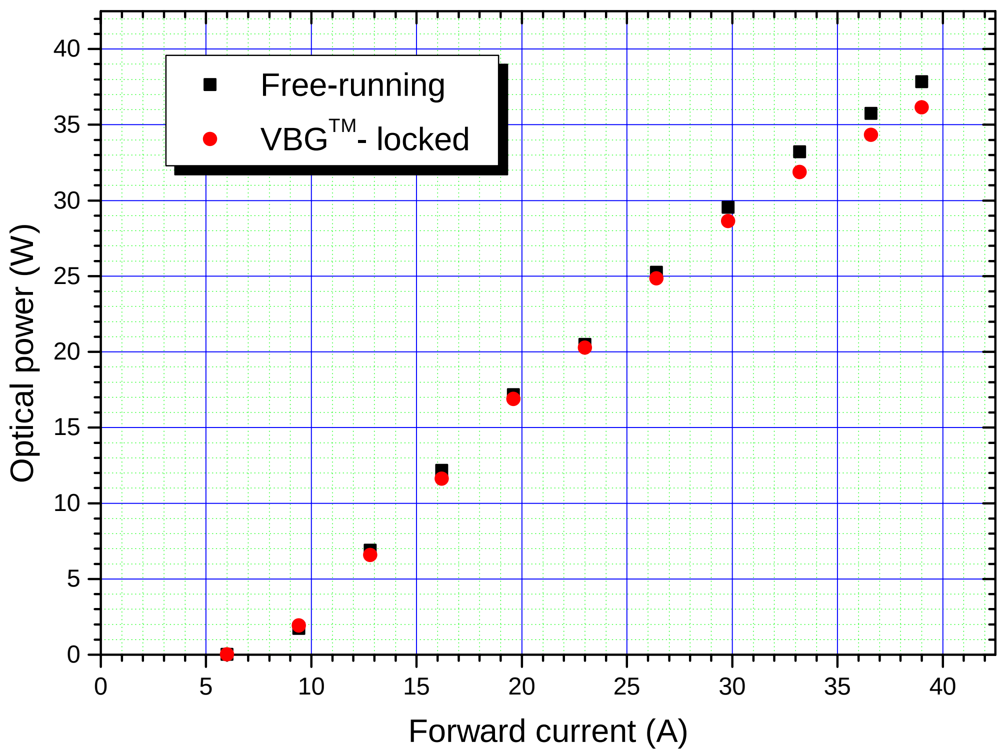

Figure . Comparison of the total output power of a free running and LuxxMaster™ locked 40W commercially available, off-the-shelf laser diode bar.

Summary

LuxxMaster™ technology offers a simple, practical and robust method for greatly improving the emission spectra of high power laser diodes. Primary effects are that the spectral line width is significantly narrowed and the central wavelength is precisely defined, with an added benefit of a greatly reduced thermal drift . These improvements will have important ramifications in many applications of high power lasers:

- The economics of DPSS lasers can be significantly improved because of the increased pumping efficiency and relaxed cooling requirements.
- The pumping efficiency remains consistent over the wide range of temperatures and drive currents.

- Improved emission characteristics of LuxxMaster™ locked diodes will lead to new applications of high power lasers (e.g. DPSS lasers based on new host materials).
- Medical and sensing applications requiring wavelength stability and/or high power in a narrow spectrum will benefit from LuxxMaster™ stabilization.
- Consistent performance over the lifetime of LuxxMaster™ locked laser diodes can be achieved by controlling the “red shift”.
- Manufacturing yields of high power laser diodes can be significantly increased due to wavelength pulling by the LuxxMaster™
- LuxxMaster™ locking is cost effective and simple to implement.

LuxxMaster™ elements are commercially available as are complete units of locked lasers and laser bars , which incorporate this technology. Also available are services to modify an existing array or stack to similarly utilize VBGs.