Multi-Color QCW Array For Uncooled Pumping of Nd:YAG Laser

P. Thiagarajan[+], J. Nettleton*, C. Cao[+], M. Sheldon[+], J. Helmrich[+], M. McElhinney[+]

[+]Lasertel Inc.,
7775 N.Casa Grande Hwy,
Tucson, AZ 85743

* ARMY NVESD,
Ft. Belvoir, VA 22060

Laser diodes are increasingly becoming the preferred pump source replacing the more traditional flash lamps for pumping Nd:YAG based solid state lasers. Laser diode pumps have several advantages over flash lamps some of which are increased overall efficiency, they can be matched to the gain medium, and require a less elaborate cooling systems. However, the operating wavelength of the laser diodes changes with the operating temperature. In environments where the operating temperature of the laser diodes changes, in order to maintain efficient pumping of the gain medium, the temperature of the laser diodes needs to be actively controlled to maintain the performance of the solid state laser. In many applications, it is very desirable to eliminate active cooling because of size, weight, cost, and available power budgets. These requirements are especially critical for portable laser designator systems.

One of the approaches that is used to stabilize the operating wavelength of the laser diode with varying operating temperatures is to use feedback, either internal or external to the laser diode [1,2]. Unfortunately, such techniques have to date yielded only an operating temperature window of approximately 20ºC. An alternative to this approach is the use of a laser diode array with an intentionally widened emission spectrum coupled with an end-pumped Nd:YAG laser crystal. This approach ensures that the Nd:YAG crystal is constantly being pumped by part of the emission spectrum across a wide temperature range with almost total absorption of the pump laser emission due to the long absorption path inherent in this pump geometry. The emission spectrum can be easily tailored to the desired operating temperature window and the desired absorption peak of the Nd:YAG laser crystal. In this paper we present results from successful operation of an end pumped solid state laser using an uncooled multi-color pump source over a temperature range of 100ºC.

The construction of an uncooled pump source also requires special consideration due to the environmental conditions that the pump and the laser systems are required to operate. Operating temperatures can reach extremes of -30°C and +70°C in addition to a wide range of mechanical shock and mechanical vibration profiles. Traditional assemblies using soft solders and thermally unmatched materials have been known to have issues with these environmental operating conditions [3].

The pump source used here for the pumping the Nd:YAG laser crystal was a 1.2kW QCW laser diode array. The array consisted of twelve 5mm wide bars stacked at pitch of 0.4mm thus forming an emission area of 4.4mmx5mm. The bars were grown using solid source molecular beam epitaxy that has been proven to have excellent wafer uniformity, wavelength control, and run to run repeatability. Three to five different operating wavelengths were used in the array to cover a spectral range of 790nm to 815nm were chosen for the bars in the QCW array. The array was constructed using Lasertel Inc. proprietary hard solder technology and expansion matched materials. This construction technology has been proven to withstand temperature ranges from -60°C to +100°C, temperature shocks of up to 200°C/min, and mechanical shocks in the excess of 50g. The light output verses current characteristics of the laser diode array is shown in figure 1 and the spectral characteristics is shown in figure 2. The environmental performance of this array technology is shown in figure 3.

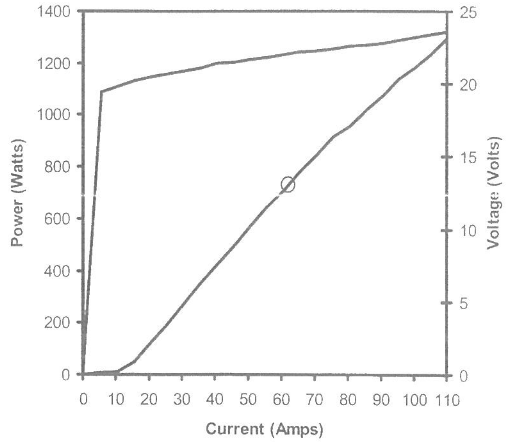

Figure 1. Light output verses current and voltage verses current for 12 bar 1.2kW QCW array

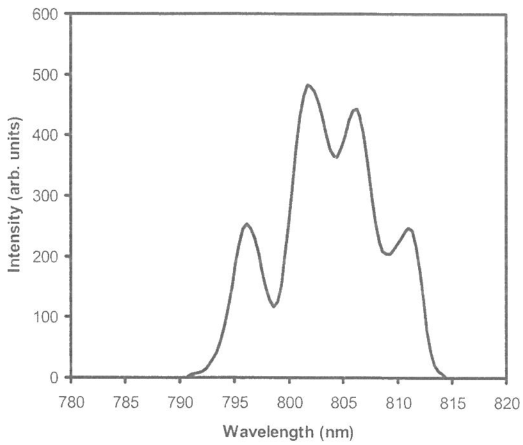

Figure 2. Spectral output of QCW pump array at 1.2kW and 25°C

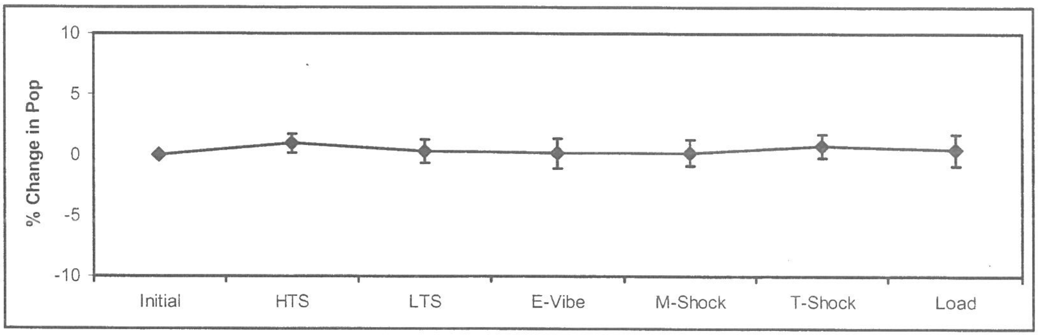

Figure 3. Sequential environmental test performance of Lasertel QCW arrays. HTS - storage +100°C, LTS - storage -60°C, E-Vibe – 3 axis vibration 20grms, M-shock – mechanical shock 50g, T-shock – temperature shock 200°C/min, Load – acceleration 20g. Error bars are standard deviation of output power changes for all the devices tested.

The laser diode arrays allow for the laser cavity to be end-pumped. The solid state laser design required very close coupling of the laser diode pump array and the end of the Nd:YAG gain medium. The end-pumped laser design overcomes conventional laser diode pump schemes in that it enables the operation of the laser diode array over military temperature ranges without the requirement of temperature control which would add size, weight and cost. The solid state laser layout is shown in Figure 4. The laser diode array was operated over a 100°C temperature span with no thermal control. The output of the solid state laser is shown in Figure 5. The drive current to the laser diode array was adjusted over this temperature range to keep a constant pump energy of about 360 mJ.

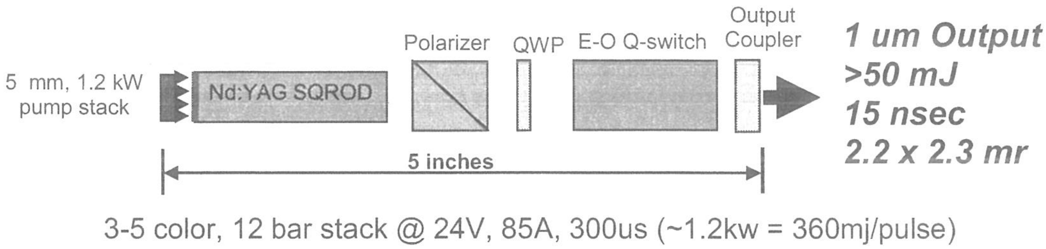

Figure 4. Solid state laser layout using 4.4mm x 5 mm active area for end pumping

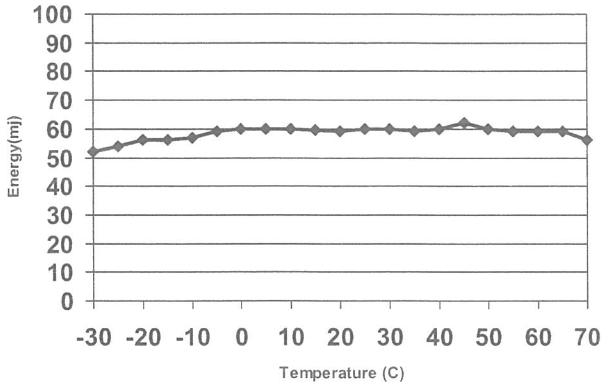

Figure 5. SSL output vs temperature of the laser diode array

The lightweight laser designator components developed were incorporated into a less than 5 pound package, including battery! The Ultra Light Designator (ULD) is shown in Figure 6. The ULD has been used in many field tests to validate the system, the latest being successful live, laser guided bomb drops at Nellis AFB.

Prototype Ultra-light Laser Designator

- 4.6 lbs (with batteries)
- 10 to 20 Hz (NATO codes)
- >50 mJ/pulse
- 15 nsec pulsewidth
- 2 hour continuous lasing per set of batteries
- interfaces to US Army's current fielded laser designator (LLDR) system

Figure 6. Photo and performance summary of ultra-light laser designator

In summary, we have successfully demonstrated SSL laser operation with uncooled multicolor laser pump sources over a temperature range of 100°C. The output energy of the SSL was >50mJ with a pump energy of 360mJ for temperatures between -30°C and 70°C. The SSL system was incorporated into an ultra-light weight designator that was field tested. Higher output energies for the ultra-light laser designators are expected with further increase in the brightness of the pump sources.

References

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