Watt Level Compact Green Laser Module for Laser Display

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Abstract
A watt level compact green laser based on an integrated Nd:YVO_4 and MgO:PPLN module (i.e. mGreen module) is presented for the first time. A linearly polarized 532 nm laser light of 1.02 Watt is obtained, which corresponds to an optical-to-optical conversion efficiency of 25.5%. The mGreen module can dramatically decrease the complexity and cost of the conventional green diode pumped solid state laser.

Author Keywords
laser display, portable projector, green laser, frequency doubling, periodically poled lithium niobate, neodymium doped yttrium vanadate

1. Introduction
Since the invention of lasers, significant effort has been made to develop practical and powerful visible laser sources for numerous applications. Laser based display is one of the most attractive field that requires red, green and blue (RGB) laser sources. Laser display has been a dream of laser researchers for years because compared with other display technologies, laser display can provide much better vision experience and low power consumption due to the excellent color saturation and high brightness of lasers. However, the commercial viability of laser display is limited mainly due to the large size, complex structure and high cost of RGB lasers available on the market. Although semiconductor laser diodes that can directly emit red and blue light are readily available commodities, efficient green semiconductor laser diodes with sufficient power and reasonable cost are currently not available on the market. A practical solution to the green bottleneck of laser display is the diode pumped solid state (DPSS) green lasers based on the frequency doubling (i.e. SHG) technology [1][2].

The frequency doubled green DPSS laser usually consists of five components, i.e. an 808 nm pump laser diode, a focusing lens, a laser crystal, a nonlinear crystal, and a coupling mirror. The laser crystal is to generate 1064 nm infrared light while the nonlinear crystal is to generate 532 nm green light. Precisely alignment of these small optical components is necessary in green DPSS laser packaging. Thus the cost and size of current commercial green DPSS laser still cannot satisfy the requirement of consumer laser display products.

Plane-parallel cavity design and optical bonding technology has been employed to reduce the cost and difficulties of green DPSS laser packaging. Optical bonded Nd:YVO_4/MgO:PPLN microchips can provide several hundred milliwatt green output within an extreme compact package [3]. Microchips are only suitable for low power applications which is mainly due to the large heat dissipation of the optically bonded structure – normally not an issue in the discrete Nd:YVO_4 and MgO:PPLN structures. In the microchip, 40% to 50% of the pump energy is converted to heat by Nd:YVO_4 and then transferred to the bonded MgO:PPLN crystal. In high power applications, this heat will damage the optical bonding since the two materials have different thermal expansion coefficients. In addition, the heat will deteriorate the QPM condition and reduce the conversion efficiency of the MgO:PPLN. On the other hand, watt level green DPSS laser using discrete MgO:PPLN and Nd:YVO_4 and the plane parallel cavity structure has been reported [4]. In order to further reduce the cost and simplify the packaging process, recently a novel compact Nd:YVO_4/MgO:PPLN integrated module (namely mGreen module) has been developed (by CQ Laser Technologies). In this paper, the performance of mGreen module based laser is demonstrated by a simple two-component configuration. A linearly polarized 532 nm green light of over 1W is achieved, which corresponds to an optical-to-optical conversion efficiency of 25.5%. The mGreen module can dramatically decrease the complexity of current green DPSS laser fabrication to satisfy both the cost and performance requirements of mobile laser projectors.

2. Structure of mGreen Laser Module

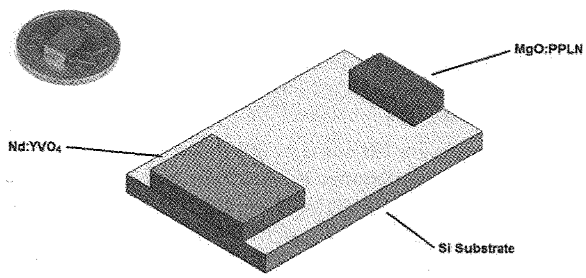

Figure 1. A schematic structure diagram and a photograph of a mGreen module

As shown in Figure 1, unlike the traditional DPSS green lasers, an mGreen module integrates a laser crystal and a nonlinear optical crystal together on a silicon substrate. The two crystals are precisely aligned to form an alignment-free plane-parallel cavity. The input facet of the laser crystal was coated for high transmission at 808 nm pump wavelength, and high reflection at both 1064 nm and 532 nm wavelength. The output surface of the nonlinear crystal had a high reflection coating for 1064 nm and high transmission coating for 532 nm light. The gain medium is an 1% neodymium doped yttrium vanadate (Nd:YVO_4) crystal which is suitable for low and medium power 1064 nm laser generation due to its high absorption over a wide pumping wavelength bandwidth, linear polarized emission and large stimulated-emission cross section at the lasing wavelength [5]. The nonlinear crystal used in mGreen module is a 5 mol% magnesium-oxide doped periodically poled lithium nioabte (MgO:PPLN) crystal. Currently, potassium titanyl phosphate (KTP) and lithium triborate (LBO) are nonlinear crystals widely used in the commercial green DPSS lasers. However, neither of them can meet the strict cost/performance requirements for laser display applications. KTP crystals can only be used in low power green DPSS lasers due to the gray track problem and uncertain lifetime in high power operation. Moreover, the polarization distinction ratios of the green lasers based on KTP crystals can be very low and polarization direction of the laser beam is

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unpredictable, which could cause large power loss in many polarization-sensitive components in laser display systems. On the other hand, LBO crystals have high optical damage threshold that can be used in high power applications. However, they are too expensive and too big to satisfy the critical low-cost compact requirement of the laser display. MgO:PPLN crystals have superior properties to KTP and LBO, including high optical damage threshold, large nonlinear coefficient and low cost [6]. However, few commercial green DPSS lasers are made from MgO:PPLN mainly due to the high cost and thin thickness (which leads to difficult alignment in laser packaging) of MgO:PPLN crystals. The development of mGreen module solves this problem completely. As shown in Figure 1, the mGreen module has an extremely compact size of only 7(L) × 4.5(W) × 2(H) mm^3 (i.e. 0.063 c.c.) and is a monolithic component without the need of further alignment between $Nd:YVO_4$ and MgO:PPLN crystals. Only two discrete components (i.e. one 808-nm pump laser diode and on mGreen module) are needed to form a compact green laser. Therefore, green lasers based on mGreen can significantly simplify laser packaging, increase production efficiency and reduce the cost.

3. Experiments and Results

Figure 2 shows an experimental setup for a green laser based on mGreen module, which basically consists of only two components, one 808-nm laser diode and one mGreen module. To achieve high second harmonic generation (SHG) efficiency, the polarization direction of the fundamental light should be in parallel with the z-axis of the MgO:PPLN crystal. In our experiments, a standard broad-stripe 4 W TM polarized C-Mount 808-nm LD was used as the pump source. The distance between the LD emitting facet and the mGreen input facet was set at 0.5 mm. The pump LD and mGreen module were set on a TEC which was connected to a temperature controller. The 808-nm LD used in the experiments was fast-axis collimated to ensure the good mode overlap between pump beam and laser beam.

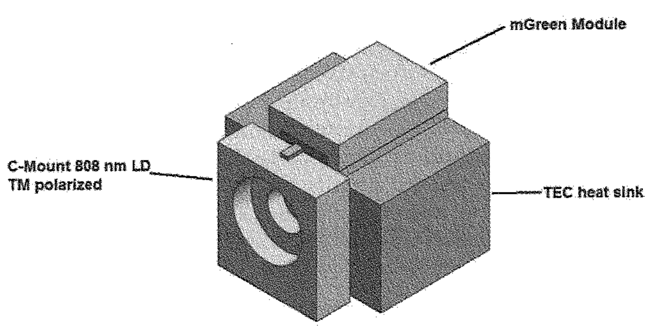

Figure 2. Experimental configuration of a green laser based on an mGreen module

The output performance is shown in Figure 3. The maximum output power of 1.02 Watt was achieved with 4 Watt pump power, which corresponds to an optical-to-optical conversion efficiency of 25.5%. The trend of the curve does not show any saturation, implying that the green output power can be further increased by using a higher pump source. Temperature dependence of the mGreen module was also studied. The highest output power is reached at 18°C. It is expected that this temperature can be increased by employing MgO:PPLN with higher QPM temperature.

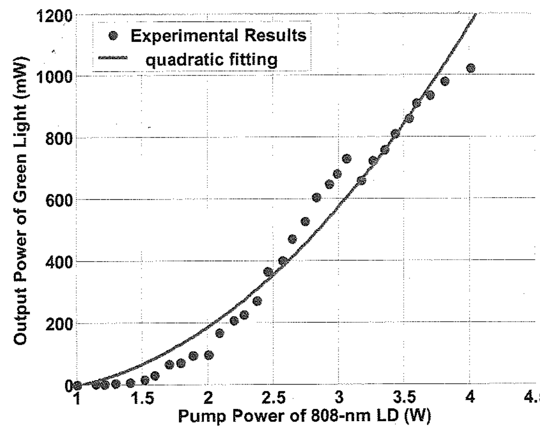

Figure 3. Output power of green laser versus pump power of 808-nm LD

4. Conclusion

In conclusion, it has been demonstrated that Watt level green laser can be obtained by employing a novel compact $Nd:YVO_4$/MgO:PPLN integrated module with a volume of only 0.063 c.c.. Linearly polarized green light with a maximum power of 1.02 Watt and an optical-to-optical efficiency of 25.5% has been achieved from the mGreen module through a very simple two-component configuration. Compared with the traditional LBO based DPSS lasers, compact green lasers based on mGreen modules can be easily mass produced with very low cost. Therefore, mGreen modules are very suitable for laser display devices or other cost sensitive green laser applications.

5. Acknowledgements

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6. References

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