A green laser for display projectors

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Combining a solid-state laser with intracavity frequency doubling, large conversion efficiency, and a high optical damage threshold results in a low-cost, miniature 532nm light source.

Recently, research into laser displays has attracted significant interest around the world due to its wide range of possible applications, such as picoprojectors embedded in cell phones, portable projectors, and laser televisions. A laser display requires separate low-cost, compact, efficient, and high-power red, green, and blue lasers. However, satisfactory green lasers are not readily available, although there are suitable red and blue semiconductor laser diodes.

Currently, two main approaches are used to develop green lasers: directly emitting green light from semiconductors (i.e., green laser diodes); and frequency doubling using a nonlinear crystal (i.e., diode-pumped solid-state lasers, also known as DPSS lasers). Despite recent significant progress in the development of green semiconductor laser diodes, their reported performance is still far below the requirements of laser displays. At present, the green DPSS laser is a more realistic solution for this application.

Commercially available DPSS green lasers are mainly based on potassium titanyl phosphate (KTP) and lithium borate (LBO) nonlinear crystals. For KTP-based DPSS green lasers, uncertain lifetime at high power makes KTP useful only for low-power applications. In addition, photochromic damage often occurs in KTP in high-power nonlinear frequency conversion interactions, causing a visible gray track in the crystal (the ‘gray track problem’) and degrading the performance of KTP or even making it unusable. A further drawback of KTP is that the polarization of the output green light changes with temperature, which causes problems in laser displays when liquid crystal on silicon is used as display panels.

In contrast, green lasers based on LBO can generate high power. However, a long LBO crystal, usually more than 10mm, is required, which makes the LBO-based green laser too big to be used in laser displays. Moreover, the working temperature tolerance of LBO is very narrow (8–10°C), which is undesirable for consumer products. To make things worse, the price of both KTP- and LBO-based DPSS green lasers is one to two orders of magnitude higher than the price target, which is unacceptable to the laser display industry. Therefore, there is strong demand for new green lasers.

We have developed the first green laser that combines high output power (>700mW), high efficiency (~30%), and small size (~4cm³). It has an extremely simple two-component structure, i.e., an 808nm pump laser diode and a newly developed ‘mGreen’ module (provided by CQ Laser Technologies). The mGreen module is composed of a 1% doped neodymium:yttrium orthovanadate (Nd:YVO4) crystal and a 5mol% magnesium oxide:periodically poled lithium niobate (MgO:PPLN) crystal that are aligned precisely with an air gap and mounted on a silicon substrate (see Figure 1) so that facets of the two are parallel.

A copper cover protects the packaging. The input facet of the Nd:YVO4 crystal is coated for high transmission at 808nm pump wavelength and high reflection at both 1064 and 532nm wavelengths. The output surface of the MgO:PPLN crystal has a high-reflection coating for 1064nm light and high transmission.

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In summary, we have designed and developed a new green laser for portable laser projectors, based on an extremely simple two-component structure that can be mass produced at very low cost. We are now working to further improve the performance of the laser, including conversion efficiency and brightness. We are also refining our design to reduce production costs.

Figure 2. Photographs of (a) the mGreen module and (b) the miniature green laser.

Figure 3. Power of green laser versus current of 808nm LD.

casting for 532nm light. This forms the laser cavity between the input facet of the Nd:YVO$_4$ and the output surface of the MgO:PPLN crystals. The mGreen is as small as 2mm (thickness) × 4.5mm (width) × 7mm (length): see Figure 2. A plano-parallel cavity reduces the total cavity length, and the whole laser has dimensions of only 11mm (height) × 22mm (width) × 18mm (length), which corresponds to a volume of 4.36cm$^3$. It is worth noting that using a properly packaged 808nm laser diode can further reduce the size.

The laser output power is also high (see Figure 3 for output power as a function of driving current). We could achieve a maximum power of 710mW, which corresponds to an optical-to-optical efficiency of 29.6%. The output beam is a clear round spot (see Figure 3, inset). With their excellent performance, easy assembly, and potentially very low cost, these green lasers can satisfy both the cost and performance requirements of portable laser projectors, unlike conventional green lasers based on KTP and LBO crystals.

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References


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