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HIGH-EFFICIENCY GREEN LASER SOURCE FOR COMPACT PROJECTORS

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ABSTRACT

Compact and efficient green lasers are of high interest to consumer electronics applications such as handheld and pocket projectors. Since direct green laser sources are not available, a number of second-harmonic-based approaches have been proposed recently. However, challenges in low-efficiency and high-cost structure have not been successfully overcome yet. We demonstrate a novel green laser source based on the monolithic cavity microchip laser platform. The use of our highly efficient, periodically poled MgO-doped Lithium Niobate as the frequency doubler allows obtaining significant increase in the overall efficiency of the green microchip laser. Specifically, we demonstrate 200 mW green output with >10% wall-plug efficiency in the 35°C temperature range.

Keywords: Projection Displays, Green Laser, Periodically Poled, PPLN, PPMgOLN

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Introduction

Compact and efficient green lasers are of high interest to consumer electronics applications such as mobile (compact, pocket, handheld, etc.) projectors. Mobile projectors are part of a huge emerging market, estimated to achieve multi-million unit ranges [1]. First-generation, LEDbased mobile projectors have just appeared in 2008. One could mention handheld projectors from Toshiba, 3M, and Optoma. However, brightness and efficiency of LEDs (especially green LEDs) are not adequate to satisfy all the requirements for efficient projection of the clear and large images. Lasers are superior but there is no adequate product directly producing green (semiconductor red and blue lasers are available now).

Since direct green laser sources are not available, a number of second-harmonic-based approaches have been proposed recently by Novalux, Corning, Osram, etc. (see for example Refs [2-4]). However, challenges in low-efficiency and high-cost structure have not been successfully overcome yet. We demonstrate a novel green laser source, based on the microchip (monolithic assembly of Nd:YVO_4 crystal and PPMgOLN crystal) laser platform. The use of our highly efficient, periodically poled MgO-doped Lithium Niobate as the frequency doubler allows obtaining significant increase in the overall efficiency of the green microchip laser. Specifically, we demonstrate 200 mW green output with >10% wall-plug (electrical-to-optical) efficiency in the 35ºC temperature range.

Periodically-Poled MgO-doped Lithium Niobate

The 532 nm laser source is monolithic assembly of Nd:YVO_4 crystal and Periodically-Poled, MgO-doped Lithium Niobate (often abbreviated as PPMgOLN or MgO-doped PPLN). PPMgOLN crystals are the most efficient nonlinear crystals available for Second Harmonic Generation (SHG) from infrared into the visible wavelengths. PPMgOLN is an engineered material utilizing highest nonlinearity of the Lithium Niobate and providing efficient conversion by quasi-phase-matching between infrared and visible wavelengths due to periodical domain inversion in the crystal. Periodical domain inversion is achieved by a process called poling – applying electric field spatially periodically modulated to achieve desired period of inversion. Periodically poled crystals can be engineered for second harmonic generation to any visible wavelength (including blue and red).

Widely available periodically-poled materials are based on congruent, easily grown, Lithium Niobate crystals (PPLN). This material allows easy domain inversion and periodical poling; however, it has very low resistance to the optical (photorefractive) damage by the intense visible light. To avoid this damage PPLN crystals must be heated to high temperatures (>100°C) which makes this material unsuitable for the mobile projection applications.

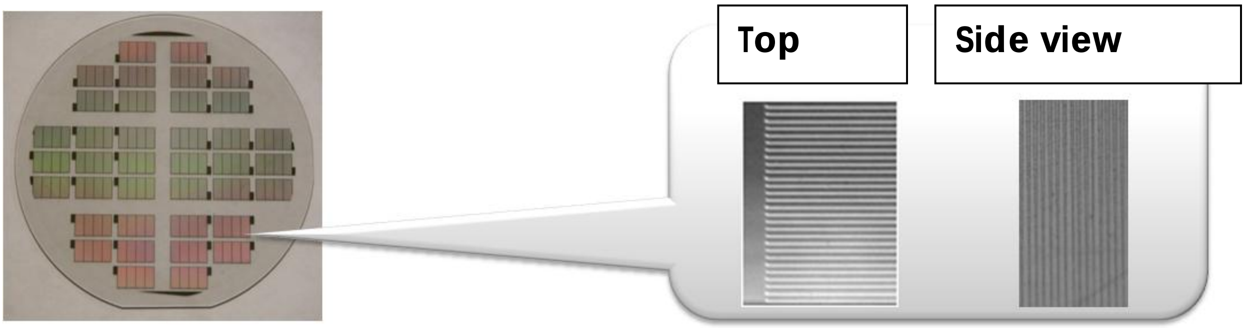

Figure 1. PPMgOLN wafer with periodical electrode structure. The insert shows periodically inverted domains observed under the microscope.

PPMgOLN is much more resistant to the optical damage but it is much more difficult to create periodical domain structure in this crystal. Proprietary technology of poling thick (1 mm) PPMgOLN crystals, suitable for microchip fabrication, has been developed by Spectralus in the last few years [5]. Figure 1 shows 1-mm thick MgO-doped Lithium Niobate wafer with periodical electrode structure applied to the wafer lithographically. Electrodes are removed after the poling process. Insert shows periodical structure in the processed material.

Spectralus Green Laser

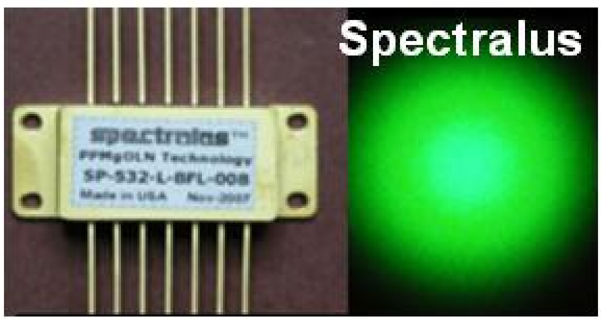

Figure 2. Spectralus Green Laser in the 14-pin Butterfly package.
The output beam shape is also shown.

Spectralus laser (patent pending) is based on a microchip technology (see, for example, [6]). The monolithic microchip assembly of $Nd:YVO_4$ crystal and PPMgOLN crystal is pumped by an 808-nm diode laser. We integrated this green laser assembly in a 14-pin butterfly package and performed power and efficiency testing for different ambient temperatures, thus addressing one of the major concerns of consumer electronics industry. Results of wall-plug efficiency (WPE) measurements are shown in Figure 3. WPE is higher than 10% over the operation range of more than 35 degrees Centigrade (from 3°C to 40°C). To our knowledge, this is the first reported result on such high efficiency of the green laser in the wide temperature range. The output power of this laser was about 200 mW over the whole temperature range.

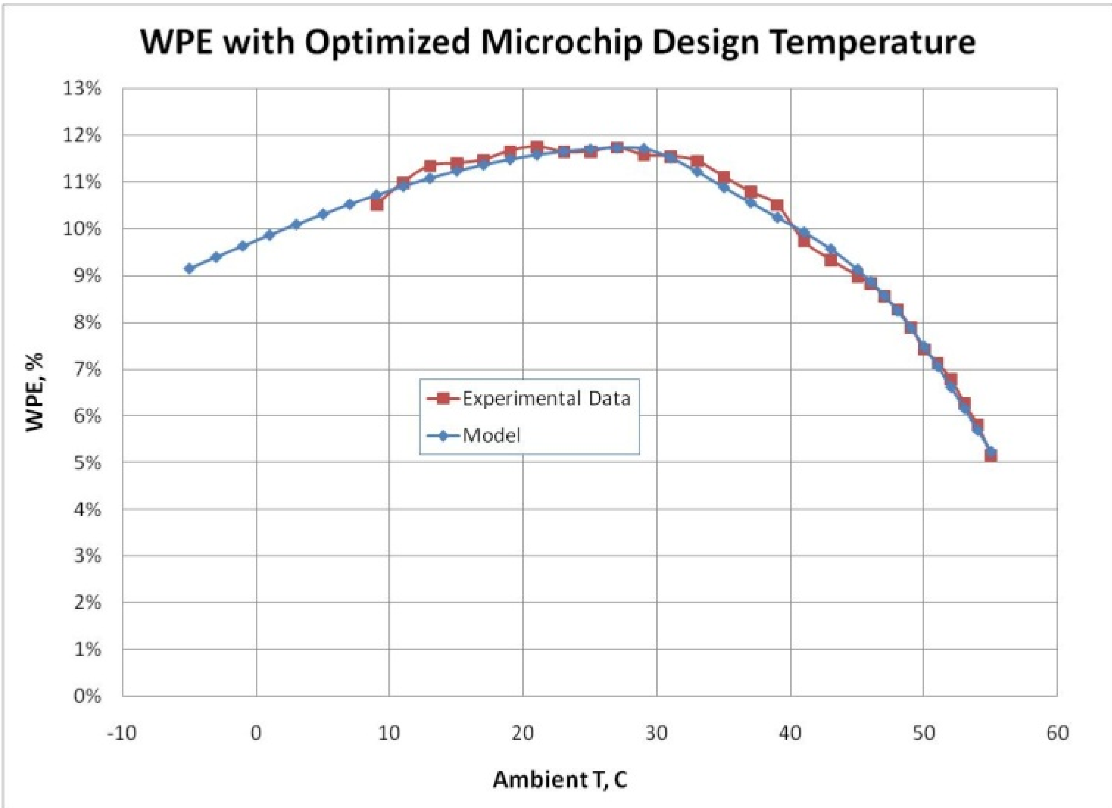

Figure 3. Wall-plug efficiency (WPE) for the Spectralus Green Laser vs. ambient temperature. Microchip design temperature is optimized for the operation range from 3°C to 40°C.

Conclusion

We have demonstrated highly efficient green laser source for the compact projector applications. It delivers up to 200 mW green power with efficiency exceeding 10% in a wide ambient temperature range from 3°C to 40°C.

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