>25 Gbit/s LiFi with Dual Wavelength Emission, Eye-safe, Laser Based White Light Collimated and Fiber Delivered Light Sources

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***Abstract*— We report on high-speed > 25 Gbit/s LiFi (Light Fidelity) communication systems deploying Semipolar GaN laser diode (LD) based single and dual wavelength emission, eye-safe, white light illumination light sources in collimated beam and fiber delivered configurations. Additionally, we report on recent demonstrations of high power Semipolar GaN violet LDs with similar properties to blue LDs described here which have potential for LiFi communications and anti-bacterial optical illumination.**

Keywords*— laser diode, semipolar GaN, LiFi communication, laser lighting, free space optical communication, optical disinfection, gallium nitride laser diode, GaN LD

I. Introduction

Recently, gallium nitride (GaN) based laser diodes (LDs) operating in the visible wavelength range combined with wavelength converting phosphors are emerging as next generation solid-state lighting white light sources offering the 10-100X the luminance, 10X the range, 1/10 the size, and drastically higher delivered lumens per watt over existing LED based solid state lighting technology. LiFi communication technology leveraging GaN-based solid state lighting technology is gaining momentum as a complimentary wireless communication technology to conventional WiFi. The benefits of LiFi communication include the ability for both lighting and communication functionality from a single source, enabling 6G systems by mitigating spectral saturation in the radio frequency (RF) portion of the spectrum, eliminating interference with RF sensitive devices, and providing data security with line of site transmission links [1]. The unique properties of LDs offer drastic advantages for laser-based white light sources over LED sources in LiFi communication systems. By comparing watt-class LED versus watt-class LD, the modulation bandwidth of LDs enables 10-100X higher data rates than LEDs for emitters generating equivalent light output. The narrow linewidth of LDs facilitates wavelength division multiplexing (WDM) for multiple simultaneous communication channels, and the ~100X brightness of LD based white light sources can allow wireless transmission distances over 10X greater than LED [2].

II. Collimated beam LIFI system

We have demonstrated a collimated beam LiFi system utilizing a Semipolar GaN blue LD to excite a phosphor in a white light surface mount device (SMD) source with 500 lumen of white light with a high brightness of 1000 cd/mm2 [3]. The source is collimated with a 35 mm reflector to 1.7 degree FWHM. This source exhibits 1 km range with more than 0.35 lux, and is eye-safe, with UL 8750 certification and class 2 rating. We utilize QAM (Quadrature amplitude modulation) and OFDM (Orthogonal frequency division multiplexing) technique with robust operation under direct sunlight with less than 5% reduction in data rates. By detecting the blue portion of the spectrum, we deliver 10 Gbit/s at 5 meters, and 1 Gbit/s at 50 meters distance.

We also recently demonstrated a more advanced LiFi system using a laser-based white light source that integrated two blue LDs with slightly shifted lasing wavelengths into single surface mount device (SMD) package as a transmitter with 1000 lumen output and 1000 cd/mm2. This source is coupled into a 1mm plastic optical transport fiber with 2 meter length, and the fiber output is collimated with a 25 mm optic to 3 degree FWHM. By detecting the blue portion of the spectrum, we deliver more than 20 Gbit/s to a dual wavelength detector 5 meters away [2].

This laser-based white light SMD source offers high design flexibility in the LiFi system while providing the capability for extremely high data rates of over 20 Gbit/s by utilizing both OFDM and WDM. Unlike LEDs with broad emission spectra, the narrow spectral width of LDs allows for efficient wavelength division multiplexing (WDM) and low optical interference as proved by the two blue LDs operating at peak wavelengths spaced by only a few nanometers. This result shows the capability of high density WDM with the laser-based SMD platform.

In this work, we also demonstrated a laser-based white light source that integrates an IR LD and a blue LD into a single SMD package to utilize the dual wavelengths and form communication links with the blue wavelength and the IR wavelength as shown in Fig. 1. Due to the very wide wavelength spacing, the optical interference of the two channels is expected to be negligible in this LiFi system. The SMD based transmitter technology integrating multiple LDs allows for straightforward scaling of the data rate through WDM without adding excessive complexity to the Tx design of communication system.

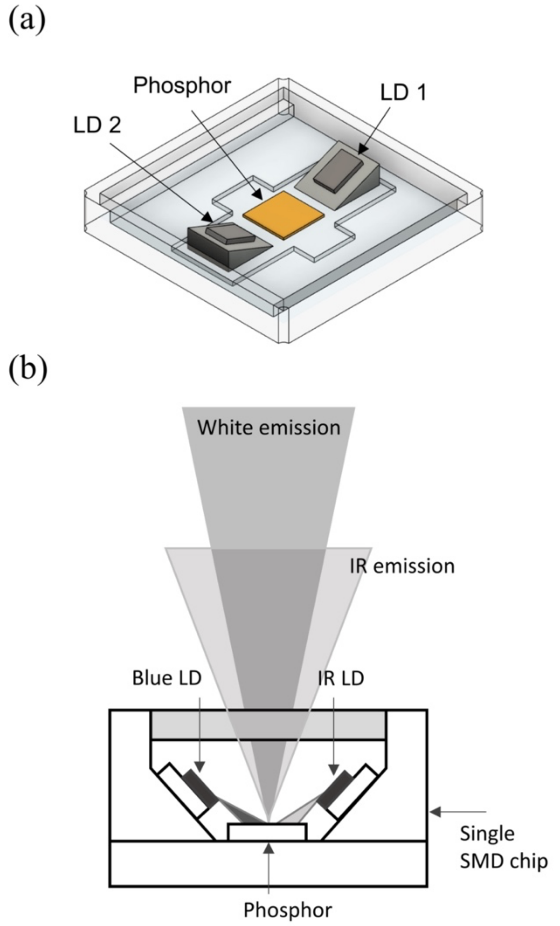

Figure 1. (a) Schematic of the SMD light source with two LDs operating with blue and IR wavelengths. (b) Cross-section schematic for dual wavelength emission from blue and IR LDs in the SMD.

Using this source and similar techniques, we configured a dual wavelength white / infrared (IR) fiber delivered LiFi system utilizing one Semipolar GaN blue LD and a GaAs IR LD. In this case, the Semipolar GaN blue LD excites a phosphor in SMD with 500 lumen and 1000 cd/mm2, and the IR LD scatters from a common spot on phosphor. This dual emission source is coupled into a plastic optical transport fiber, collimated and delivered to a dual wavelength detector. The data link was established over free space from the output of the launch optic of the transmitter module to the receiver positioned 3 meters away. 26 Gbit/s of data rate was achieved by combined white and IR free space channel through launch optic connected to Tx module. These dual emission white/IR sources have been utilized in sensing applications, paving the way for next generation, eye-safe, white light laser based sources with multi-functional illumination, sensing, and communication capability.

III. Emissive Fiber delivered LIFI system

The same SMD light source was coupled into a side-emissive fiber in Tx module as shown in Fig 2. Figure 3. shows 2 Gbit/s data transmission using fully packaged transmitter and receiver units. In this fiber system, the data link is established from the transmitter unit emitting white light along the length of a side emissive fiber to the receiver unit with a detector placed laterally beside the fiber 2 inches away.

Figure 2. Image and schematic of the fiber coupled SMD light source showing SMD on electronic board, collimating and focusing optics, and housing.

It is noted that data transmission using side-emissive fiber for LiFi systems could find use in many communication applications and open the door for future fiber-based ambient lighting LiFi systems.

Figure 3. Experimental system of dual laser LiFi system with emissive fiber shown.

IV. High power Semipolar GaN violet LDs

Lastly, we report on recent demonstrations of high power Semipolar GaN violet LDs with similar properties to blue LDs, specifically 5 watts of optical output power and 40% wall-plug efficiency. These violet sources may be utilized for LiFi communications and anti-bacterial optical illumination that is safe for human exposure and therefore compatible with specialty lighting systems. These future LiFi systems have promise in collimated beam applications and fiber applications in healthcare, avionics, and other environments wherein RF communication is challenging and where illumination and antibacterial illumination is critically important.

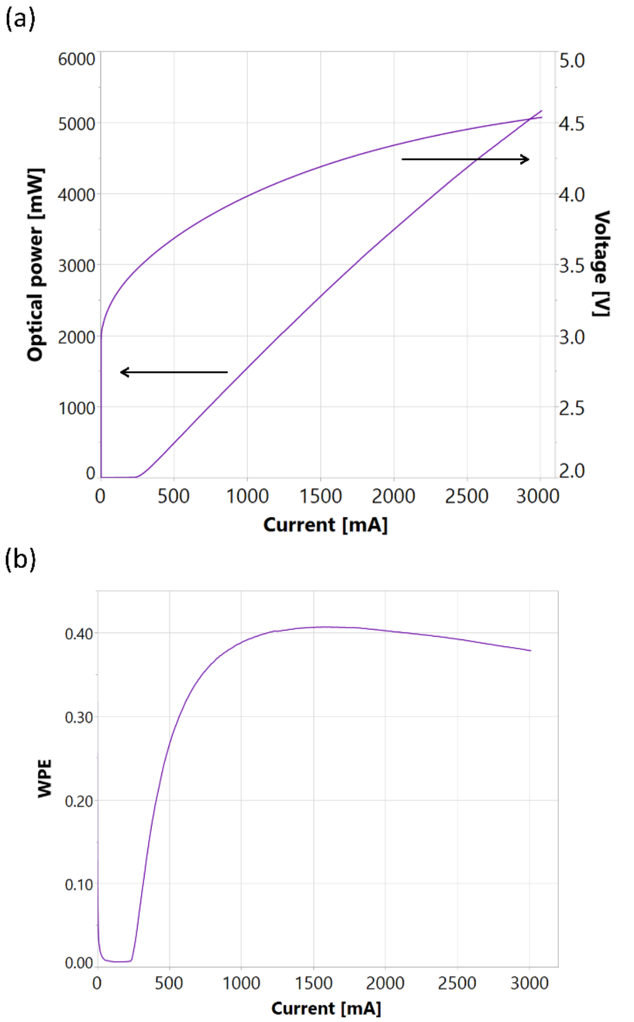

Figure 4. (a) Experimental data of 5 watt violet laser diodes at 405 and (b) corresponding wall plug efficiency (WPE) of 40%.

V. Conclusion

We report on high-speed > 25Gbit/s LiFi (Light Fidelity) communication systems deploying Semipolar GaN laser diode (LD) based single and dual wavelength emission, eye-safe, white light illumination light sources in collimated beam and fiber delivered configurations. Additionally, we report on on recent demonstrations of high power Semipolar GaN violet LDs with high power and high efficiency which have potential for LiFi communications and anti-bacterial optical illumination.

References

[1] H. Haas, "LiFi is a paradigm-shifting 5G technology," Rev. Phys. **3**, 26–31 (2018).

[2] C. Lee Mohamed Sufyan Islim, Stefan Videv, Adrian Sparks, Binith Shah, Paul Rudy, Melvin McLaurin, Harald Haas, James Raring, "Advanced LiFi technology: Laser light," Proc. SPIE 11302, 1130213 (2020).

[3] Kyocera SLD Laser, "https://www.kyocera-sldlaser.com/products/product-list"