Gallium Nitride Super-Luminescent Light Emitting Diodes for Optical Coherence Tomography Applications

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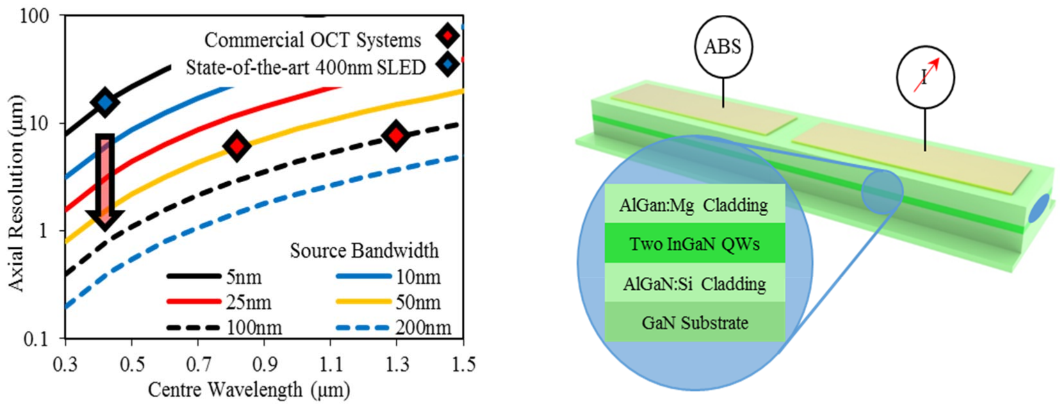
Abstract: *The role of biasing of absorber sections in multi-contact GaN ~400nm SLEDs is discussed. We go on to assess such devices for OCT applications. Analysis of the SLED emission spectrum allows an axial resolution of 6.0µm to be deduced in OCT applications.*
Keywords: *GaN, SLED, OCT*

I. INTRODUCTION

OCT utilises the coherent properties of light to permit non-invasive and *in situ* imaging of biological tissues, in particular the eye and skin. Since OCT was first reported, the imaging speed and axial resolution have both been increased, with the latter limited by the light source's central wavelength and bandwidth [1]. As demand has increased for greater axial resolution, super-continuum lasers [2] and non-linear fibre based light sources [3] have been developed; demonstrating *in vivo* OCT imaging at short wavelengths is possible on human skin, and even ultraviolet light can propagate to the dermal layer [4]; providing images which can inform clinicians. Additionally, it has already been identified that if a broader bandwidth can be reached for blue-green super-luminescent light emitting diodes (SLEDs), sub-cellular resolution could be achieved [5]. We also note that because of the shorter wavelength, lateral resolution should also be enhanced in such short wavelength OCT systems. Figure 1(a) plots the calculated axial resolution of an OCT imaging system as a function of central wavelength and 3dB bandwidth of the source. Typical commercial OCT systems at 1300nm (e.g. skin tissue) and 800nm (ophthalmic) are indicated along with predicted resolutions for state-of-the-art GaN SLEDs [6]. The first blue GaN SLED was reported in 2009 [7], suppressing lasing through the use of angled facets. Device development has since focused on pico-projection applications [8], with high powers, low speckle, and relatively narrow bandwidths desired. Although GaN multi-contact SLEDs have been reported, only a passive absorber has been included to either reduce the optical density at the front facet [9], or suppress lasing [10] with the latter suffering from "burn through" [11] when the propagating light optically pumps the absorber. In this paper we present the development of broad-spectral band-width GaN based SLEDs utilising absorber sections under different bias conditions, and assess their performance with regard to OCT applications.



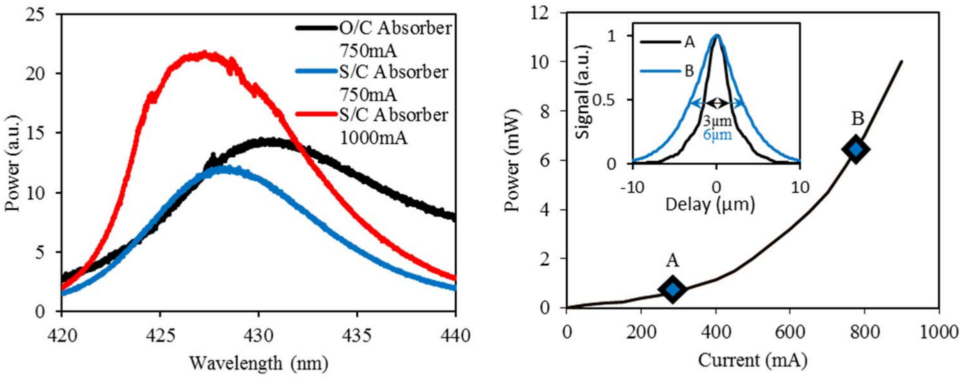
(a) (b)

Fig.1(a) Axial resolution for OCT systems as function of spectral-bandwidth and centre wavelength. Fig 1(b) Schematic of multi-section GaN device

II. DEVICE FABRICATION

The SLED was fabricated from a 2 InGaN quantum well (QW) laser epi-wafer, grown by metalorganic vapour phase epitaxy (MOVPE) on a 2 inch GaN substrate by Novagan [6,7]. As shown schematically in Figure 1(b), the SLED does not feature tilted facets, but instead these were fabricated perpendicular to the 10µm wide, straight waveguide (2250µm total length). The waveguide is constituted of 2 contacts that are electrically isolated with the rear 1125µm section absorbing backward propagating light with the aim of suppressing parasitic lasing.

III. RESULTS



(a) (b)

Fig.2(a) Emission spectra for a passive and grounded absorber at a range of currents. Fig 2(b) LI curve and PSF (inset) for current A and current B

Figure 2(a) shows the EL spectrum obtained from the device for a range of front and rear section bias conditions. The highest drive current that can be applied to the front section with an open circuit absorber is 750mA, which yields an emission spectrum with a 3dB linewidth of 16nm. Higher currents result in parasitic lasing within the device. With a grounded absorber section, a power of 10mW and spectral bandwidth of 10.4nm is obtained, but the front section may now be driven to 1000mA before the onset of parasitic lasing due to burn-through. We attribute the change in maximum drive current which can be achieved to more efficient carrier sweep-out in the case of a grounded absorber. Under open circuit conditions, photo-created carriers may act to negate the built-in E-field, resulting in more susceptibility to "burn through". For achieving higher output powers, a grounded absorber is therefore favourable. The increased spectral band-width for an open circuit absorber is also attributed to the operation of the optically pumped absorber. In this case, the open circuit absorber emits photons to longer wavelength, which are subsequently amplified in the forward biased section. A balance between high powers and high spectral band-widths through the choice of biasing of the absorber is therefore highlighted. Figure 2(b) shows the L-I characteristic of the device with the absorber section under short circuit conditions. Clear super-luminescent behaviour is observed. The inset shows the point-spread-function, determined from the emission spectrum which defines the OCT system axial resolution for 250mA (current A) and 750mA (current B). OCT resolutions of 3.1µm are predicted at low output powers, increasing to 6.0µm for more practical output powers of 7mW. At the conference, preliminary imaging results with such devices will be discussed.

IV. CONCLUSION

The realisation of 10mW, 10.4nm GaN based SLEDs has been reported. The importance of choosing a suitable biasing of the absorber section with regard to high power or band-width is noted. The resolution of OCT systems using these devices has been determined indicating ~6um resolutions to be possible, matching present commercial systems at longer wavelengths.

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