A Multi-pixel LED Print-Head for Novel Imaging Applications

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Abstract

The majority of Non-Impact Printing applications currently use lasers as their light source. In order to generate a pattern on the media of interest these laser sources must be coupled with an imaging engine.

Using an array of LEDs as the light source combines the imaging engine with the light source, making all the components solid state. This leads to a higher degree of integration and ease of manufacturability.

Some products are available demonstrating the viability of LEDs arrays as the imaging source and engine.

This paper presents advances in LED technology that will enable LED arrays to replace other light sources as well as the imaging electronics in a manner that provides the advantages of lower power, higher speed and higher resolution (addressability).

InfiniLED has demonstrated high density monolithic individually addressable µLED arrays that can be assembled to provide a single line of emitters for A4 or wider non-impact printing applications. We present the micro-led array technology and describe how it can increase performance and quality in non-impact printing while decreasing cost.

Introduction

In Non-Impact Printing applications based on light, the source of choice is primarily laser diodes.

The laser based systems use rotating polygon mirrors combined with a flat field lens to scan the width of photosensitive material. By contrast LED based Print-Heads do not require moving components such as rotating mirrors. A large number of diodes (1 per image pixel) are aligned across the above the photosensitive material (generally a photoconductive drum). The LEDs are then individually switched to produce the required image. [1]

LED light sources have a number of benefits over laser devices. LEDs have longer operating lifetimes due to running at lower current densities. They have increased temperature stability and less complex packaging. They are also lower cost. However, when used in applications where the area of interest is small (i.e. as a single pixel in a Print-Head) the additional optics required for control of the diffuse light from the LED may make them impractical.

InfiniLED have developed a Print-Head system based on patented µLED™ technology (see **Figure 1**). This light source combines the benefits of Laser and LEDs and allows for the generation of high resolution image patterns without the need for complex optics or a separate imaging engine. The flexibility of the underpinning technology means it is suitable for a range of applications including as a print-head for non-impact printing.

Results and Technology

The µLED™ technology is capable of producing high intensity, quasi-collimated emission directly from the semiconductor. Figure 1 shows the structure of the µLED. A parabolic reflector is etched into the semiconductor material around the site of light generation. This integrated reflector causes the light generated to be directed in a collimated beam towards the bottom of the chip. A large proportion of the light generated is therefore within the exit cone of the material system.

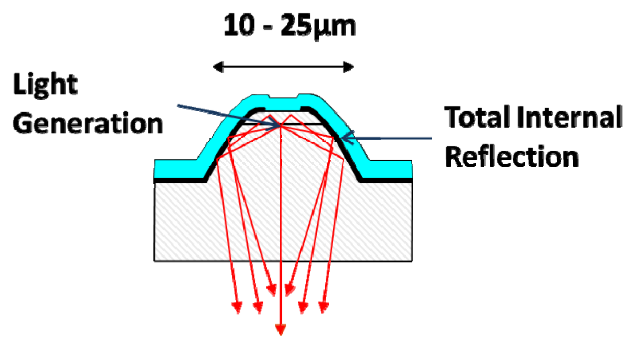

***Figure 1**: Structure of the µLED™ emitter.*

This patented structure results in a high extraction efficiency of the light generated through a single surface of the chip and this light is contained within a quasi-collimated beam. The use of the µLED structure results in an increase of 4 x in the light extracted in comparison to a reference planar device (see Figure 1). In addition, the light exits the chip with an emission half angle as low as 13˚. An emission half angle for a standard chip is 60˚. [1]

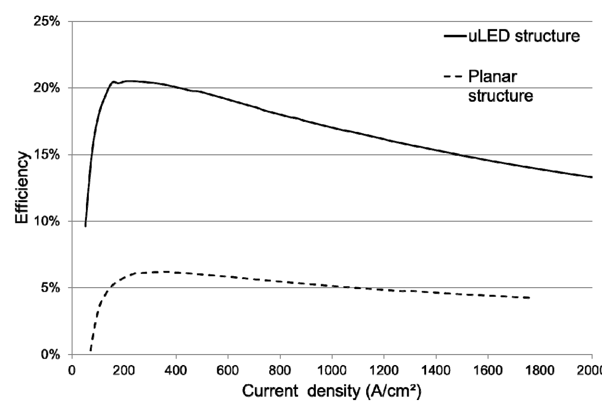

***Figure 2**: Extraction Efficiency of Light from µLED versus planar emitter.*

In addition, novel approaches have been developed regarding emitter placement and chip packaging. These approaches reduce the cross-talk between pixels while maintaining the emitter density, resulting in a high resolution print-head.

Each individual µLED emitter is 10 to 25 um in diameter. For applications requiring higher powers or with a larger area of interest, a number of µLED emitters can be closely packed and driven in unison (referred to as a cluster).

Figure **3** shows a cluster of 25 parabolic shaped emitters beside the head of a needle.

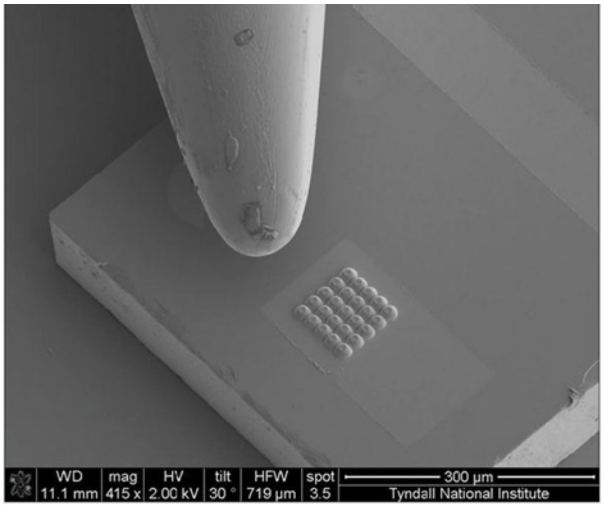

Figure 3*: SEM image of a cluster of 25 uLED emitters beside the head of a needle.*

Arrays of these emitters can be fabricated on monolithic chips and the µLED structure is fundamental to ensuring superior performance. The collimated beam and high extraction efficiency enables a high contrast ratio as there is minimal light trapped which can spread within the chip. The collimated beam also results in minimal cross talk between neighbouring pixels. Since all light generated within the µLED emitter is directed towards a single surface, this results in high light density at this surface.

The fabrication of the µLED emitters on large monolithic chips has a number of benefits. The relative position of the pixels is highly accurate as they are created during the semiconductor fabrication process. A common n-contact may be used for a large number of individual emitters which reduces the number of interconnects required. The µLED emitters are also optimised for flip-chip assembly which simplifies the packaging and provides excellent thermal sinking of the chips. The monolithic chips with large number of emitters also reduced the number of packaging steps required.

The µLED arrays are available in UV, blue and green wavelengths are present. Red and IR devices will be available before the end of 2012.

A plug-and-play linear 1D array of µLED emitter is currently under development. This consists of 4096 individually addressable emitters of 20 µm in diameter over 80 mm (3.14”). On board ASIC based controllers allow for the switching and power modulation of the individual emitters. The module is capable of providing 500 µW of power (emission wavelength = 410 nm) in 20 µm spots across the full 80 mm without the need for translation of the source.

Figure **4** shows a photosensitive material that has been imaged using the µLED light source.

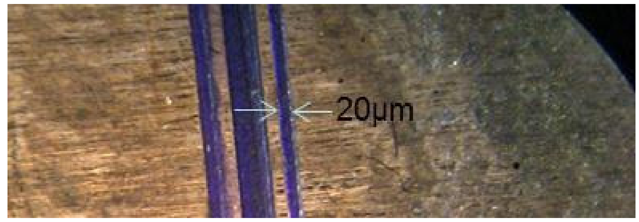

Figure 4*: 20 µm lines in photosensitive polymer creating using µLED emitters.*

In addition, 2D form factors for the arrays have been fabricated. These devices include integrated CMOS controllers that can be used to directly drive the emitters. Applications of these LED array heads included for DNA chip synthesis, displays, diagnostic devices and microscopy.

Discussions and Conclusions

The 1D Print-Head is currently being evaluated for the mask-less lithography applications. While this work is on-going, initial studies have shown that the light generated is capable of modifying the photosensitive material (see

Figure **4**). A further application for this technology is as a replacement for Laser or standard LED Print-Heads in the hardcopy peripheral market. A 210 mm bar of individually addressable emitters can be fabricated and integrated with the control components given above.

The InfiniLED system addresses has a number of issues that currently effect devices currently on the market.

By comparison to laser based printers, the µLED Print-Head would remove the need for rotating mirrors and other imaging engines. The removal of this moving component would result in more reliable equipment and faster page per minute (ppm).

LED based printers have been shown to be economically viable with a number of solutions currently on the market. However, these systems do not have the equivalent pixel resolution for similarly priced laser systems. This is due to a number of reasons. Firstly, complex optical systems (such as an array of aligned micro-mirrors) are required to control the light generated by the individual pixels and to minimise cross-talk. This adds to the costs of the systems. Secondly, precise alignment between emitters is required. This necessitates added costs during manufacture or extra quality control steps to compensate for misalignment. Thirdly, the packaging of a large number of individual chips results added complexity

The µLED based systems addresses these issues due to the core benefit of its technology. The collimated emission directly from the chip reduces the need for complex optical systems. It also allows for high pixel density as the light generated does not spread to neighbouring pixels. The fabrication of the emitters on monolithic chips ensures a high level of alignment as it is carried out during semiconductor processing. The monolithic chips also simplify the packaging process. A common cathode design can be used for the addressable µLEDs which greatly reduces the number of connections that are required. The use of a flip-chip process also removes the need for time-consuming wire-bonding packaging.

The µLED Print-Head is available at a range of wavelengths. The higher power emission from blue wavelengths allows for shorter pulsed to be used to discharge the photoconductive drum.

This results in faster switching speeds and greater power efficiency. The µLEDs have ultra-low capacitance due to their small active area (the emission region is approx. 10 µm in diameter) which allows nanosecond switching speeds. Photoconductive drums with high sensitivities at these wavelengths are available for visible wavelengths and are used for analog plain paper copying. [4]

The µLED technology is currently being evaluated in a number of applications including consumer electronics, diagnostic and detection systems and OEM equipment. The applicability of linear µLED arrays has been demonstrated for maskless lithography applications. Although there are challenges associated with the fabrication of a 210 mm 1D array of µLED emitters, InfiniLED believe that the multi-pixel LED Print-Head has strong potential in the hardcopy peripherals market (i.e. consumer LED printer applications). InfiniLED are eager to work with the partners to further understand the needs in this market and to evaluate the µLED Print-Head in working systems.

References

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[2] S. Tanriseven, P. Maaskant, B. Corbett, "Broadband Quantum micro-light-emitting diodes with parabolic sidewalls", Appl. Phys. Lett., 92, 123501(2008).

[3] K. Kataoka, Y. Shibayama, K. Doi, "Multiple Beam Scanning for Laser Printing Application to Optical Fibre Array Method", Opt. Rev. vol. 8, 218 – 222 (2001).

[4] http://www.fujielectric.com/products/photoconductor_drum/lineup

Author Biography

Dr. Bill Henry received a B.Sc. (Hons) in Chemistry from University College Dublin, Ireland in 2000. After a number of years in the pharmaceutical industry, he undertook a Ph.D. in Inorganic Photophysics.

In 2007 he joined Tyndall National Institute, Cork, Ireland looking at the commercial applications of photonic technologies. In 2010 he co-founded InfiniLED and joined as Chief Commercial Officer. He has 13 peer reviewed publications and 4 patent applications.