Invited I-5

Gallium nitride micro-LEDs: a novel, multi-mode, high-brightness and fast response display technology

Martin D. Dawson
Institute of Photonics, Department of Physics, University of Strathclyde, Glasgow G1 1RD, UK

Abstract
Gallium nitride micro-LED technology interfaces very effectively to silicon CMOS to facilitate highly sophisticated data modulation and structured lighting functions. This rapidly emerging capability is poised to play a key role in the prospective convergence of displays with communications, lighting, sensing and imaging systems, including multiple scenarios where the display can be interactive with its environment. We will provide an overview of these new capabilities which are challenging conventional conceptions of display technology and set these in the broader context of the evolution of micro-LEDs.

1. Introduction

Micro-LED technology, based principally on the capabilities of gallium nitride inorganic semiconductor epi-structures, is emerging very rapidly to commercial maturity to provide a new generation of robust and high-performance displays [1]. These devices, which comprise high-density formats of individual LED pixels with dimensions of a few microns to tens of microns, are of the self-illumination type with high-brightness, broad viewing angle, and very rapid (ns) response time. Demonstrator capabilities spanning wearables, to augmented (AR) and mixed reality (MR) systems, through to large screen TVs and displays, are currently being trialed by innovative new businesses and multi-national corporations.

In parallel with these developments, the lighting industry - in its move to solid state lighting - is beginning to embrace new operating models (such as Lighting-as-a-Service) which will embed additional functionality such as optical wireless communications via LiFi. The developments underway posit a move from first-generation, so-called 'smart lighting' towards what might be called digital lighting. Micro-LED technology is also setting performance benchmarks in LiFi, and the exciting prospect is emerging of combining micro-LED based capabilities for displays with lighting and communications, potentially also involving sensing, ranging and imaging functions.

2. Micro-LEDs in Displays, Lighting and Communications

Micro-LED technology fits naturally into high-pixel density 1-D and 2-D emitter array formats to provide electronic visual display capability. Furthermore, the detailed physics of micro-sized pixels offers enhanced modulation bandwidths into the GHz range per pixel [2], more than two orders of magnitude higher than that typical of conventional broad area LEDs. These factors can be combined in new forms of spatially multiplexed or spatially modulated LiFi communications, such as space-shift keying (SSK) or multiple input multiple output (MIMO), to enhance data communications channel capacity [2]. In this format, the display function embodies the spatial registration/distribution of information in a communications link, rather than necessarily embodying direct view physically meaningful images. However, the frame rate or image refresh rate is so fast for micro-LEDs that the displays could operate multi-modally, to implement display and spatially modulated communications functions in parallel.

Furthermore, high refresh rate binary mask patterns can be generated with CMOS-interfaced micro-LED displays, at frame rates which may exceed MHz. These systems can project such checkerboard-like high-frame rate patterns to provide unique digital signatures to each location in the imaged frame, which can be used to implement location, tracking and navigation functions [3]. Thus the projected output of such a display can be used e.g. to track moving objects in the space around it, potentially including viewers of the display.

An additional variant of these digital lighting systems uses LED projections from multiple spatial directions (usually four) in conjunction with a camera to implement photometric stereo imaging. Given the current size scaling of micro-LED displays and the prospective ability to incorporate light sensing functions through front plane integration, it is possible in future that the projected output from a micro-LED display can also image the environment around it.
We will review these exciting emerging capabilities and speculate on how they will develop.

3. Acknowledgements

We acknowledge support from EPSRC under grants EP/K00042X/1 and EP/M01326X/1.

4. References

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