26^{th} IEEE Photonics Conference

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Introduction

The 26^{th} IEEE Photonics Conference took place in Seattle (Bellevue area) between the 8^{th} to the 12^{th} of September, 2013. Amongst several conferences being held by corporate representatives/researchers of some major corporations/ institutions (i.e. Hewlett Packard, Corning, IBM, Jet Propulsion Laboratory, etc.), there were also several Plenary sessions and Tutorial sessions being held by leading researchers on their very own fields of expertise (Brian Cunningham, Roel Baets, Yasunobu Nakamura, John Rogers, etc…).

The attending public had access to a wide variety of topics ranging from biophotonics, displays/lightning, semiconductor lasers, photonic integration and packing, nanophotonics, optical communications, etc.

During this conference I also presented a talk entitled "*Nano-positioning transfer-printing of AlInGaN Light-emitting devices*" where I reported the transfer printing with 150nm (±14nm) minimum spacing of ultra-thin GaN-based micro-LEDs to mechanically-flexible PET/PDMS substrates. The 2µm-thick devices were positioned in array configurations by parallel transfer, and were characterized electrically and optically. The electroluminescent emission of a typical individual LED was centered at 486 nm. The devices could be driven up to a current density of 20 A/cm2 before reaching thermal roll-over and had a turn-on voltage ~3.5 V after transfer. The forward optical output power was up to 80µW per device, or 355mW/cm2 at the device surface. The nanoscale transfer printing accuracy was obtained by using an adapted commercial nano-patterning system, which was shown to be suited for a high-throughput, automated printing process with large-area scalability. The talk had a good attendance and a few questions regarding some capabilities of the used system and some structural and thermal properties of the transferred LEDs.

Considering my very own background as a physics engineer and a device engineer, the most relevant attended talks are hereby reported, where I was searching for new ideas and new concepts that could be implemented on my very own devices. Most of these addressed several device architectures, hybrid materials integration, photonic crystals and resonators.

Plenary Sessions

Hany Aziz from the University of Waterloo presented '*Recent progress on the vacuum deposition of OLEDs with feature sizes ≤20 um using a contact shadow mask patterned in-situ by laser ablation*' where a new technique was developed allowing the fabrication of extremely small pixel sizes (16x25 um^2) for high resolution OLED displays. Sheets of polymide films are deposited and later laser ablated creating patterned openings limited by the thin (~7.5) um plastic shadow mask used. The active organic material is then evaporated and the remnant polymide is removed without damaging to the organic layers. Repeating three coatings and exposures (for the Red, Green, Blue colours) yields a full-colour organic display. The most surprising aspect of this technique is the way the mask is kept in close proximity to the substrate, being stacked together due to electrostatic forces. I inquired if the removal of the polymide sheets coated on top of the already deposited emitting material wouldn't cause portions of the material to be removed. The author addressed the question and described the observed low adhesion that the organic materials displayed to the protecting layer. However, several images were displayed where the occurrence of pin-holes (also known as dark-spots) would cause the pixels to contain zones that emitted no light.

Arto Nurmikko from QD Vision presented '*Red, Green and Blue colloidal quantum dot-based optically pumped distributed feedback lasers*' where holographic interference lithography gratings were patterned and corresponding colloidal solutions were deposited thus creating optically pumped devices. The author reported that the red-coloured quantum dot lasers present the shortest lifetime though with an energy conversion efficiency of 28%, resulting in a similar performance to that achieved by common semiconductor laser pointers in terms of power, collimation and efficiency.

Palab Bhattacharya from the University of Michigan presented "*InGaN/GaN quantum dot lasers*" where epilayers where sequentially grown by metal organic chemical vapour deposition (MOCVD). These lasers are grown as a ridge waveguide architecture containing multiple InGaN/GaN quantum dot layers inserted on the waveguide region itself, with varying parameters (processing temperature, V-III ratio and In-III ratio) to yield devices emitting across the visible spectrum at red (630 nm), green (524 nm) and blue (420 nm). The inclusion of a quantum dot confined layer results in laser devices with reduced threshold and high temperature stability.

J. Eden from the University of Illinois presented "*Microplasma light tiles for videography, commercial and residential interior lightning*" which described a new architecture for a new generation of lamps. The devices contained processed dielectric layers with imbibed microplasma (Xe_2) containers which were able to emit significant luminance values beyond 26.000 cdm^{-2}. This new architecture of array-patterned micro light sources allows an extremely uniform emitting surface. These point sources excite a mixture of phosphors resulting in a very thin overall device thickness (<4mm) with a luminous efficacy approaching $30lmW^{-1}$. The author brought a demonstrator device that was used in the end of the slides presentation. The device displayed an extremely emission uniformity on its emitting surface ($40x40cm^2$) with room temperature operation.

From Corning Incorporated, Sean Garner presented "*Flexible glass substrates for display and lighting applications"*. The talk covered Corning the new Willow glass product that the company has recently developed and is making it available only to selected research groups to demonstrate the capabilities and multiple applications that these substrates support. The flexibility displayed showed that thin sheets of the flexible glass can be laminated and be used as substrate and as a hermetic encapsulation layer altogether. One of the most *advertised* features was the ease of process of this kind of substrates on a roll-to-roll process, making it ready for a full-process integration and mass-production ready. Several devices were demonstrated with the flexible OLED devices being the most interesting ones, showing good emission uniformity and long lifetimes. Laminated devices protected from moisture and humidity were demonstrated and assembly architectures were discussed that allowed the most efficient encapsulation barriers. The advertised water vapour transmission rates showed $<5x10^{-5}$ gm^{-2} per day, limited by the detection sensitivity of the used system itself.

The most impressive talk I attended was presented by Raymond Beausoleil from HP Laboratories titled "*A multi-directional backlight for a wide-angle, glasses-free 3D Display*". The presenter described several current 3D display architectures (lenticular displays, pixel block hierarchy) and how these create the sensation of depth to the viewer. Although as known, these require the use of polarizing glasses which makes these displays unsuitable for portable electronics applications. The presenter introduced a multi-directional diffractive backlight technology which allows the rendering of full parallax 3D images with a very wide view zone (180º in principle) at an observation distance up to a meter, well within the range of a portable device from the user's eyes. The key factor on this design is the illumination technique that produces wide-angle, ghost free and multi-view images from a thin planar hexagonal-shaped light guide. The cornerstone of this light guidance is a set of directional gratings deposited at the surface of each of the pixel hexagons where the 1st order diffraction is scattered out in a well-defined normal direction. This also allows the spatial multiplexing of three pixel sets which can be selectively addressed by changing the illumination angle. The substrates where these pixels are created are transparent and are able to project 3D RGB images or animated sequences, resulting in 200 views per colour. This architecture does not require the use of colour filters and at the moment, each pixel does not yet contain perfect uniformity on the intensity of the scattered light from the edge to the centre although the presenter referred solutions that might overcome this issue via the use of groove depth on the gratings or their area variation. Several demonstration videos were shown with the working displays where static images were shown with a visible depth variation and pixel overlapping neighbouring pixels nicely and without any ghosting effects. But, as the presenter said, viewing a video about it doesn't show the details and sharp images attained with this new display architecture. Simply fantastic!

Plenary symposia

Roel Baets from Gehnt University presented "*Lab-on-chip and point-of-care applications of silicon photonics*" where he started out by pointing something the audience should be aware of: "*Silicon photonics is not about silicon*". The talk focused on the advantages of using CMOS fabrication facilities to create ultra-compact and powerful photonics devices to reach volume markets and the so critical cost range within acceptance. The author focused on several lab-on-chip applications where the fabricated chip is considered a consumable. In several point-of-care medical applications, the presenter focused on the requirements where affordability and portability of an instrument is key. The enabling that generic silicon photonics brought in recent years became a significant platform to develop a wide range of devices for biosensing, gas sensors, laser spectroscopy on a chip, etc.

Professor Yasunobu Nakamura presented "Microwave quantum optics in superconducting circuits", where these circuits were characterized on their behaviour as high-quality microwave resonators with low-loss transmission lines. The author described the concept of quantum bits and circuit-level quantum electrodynamics where atoms and microwave photon interactions are quite strong. With a developed quantum-optics toolbox at the microwave level, Prof. Nakamura described a range of useful components that can be integrated as a single microwave photon sources and detectors.

The highlight of the plenary sessions had John Rogers presenting "*Digital cameras in bio-inspired designs: from humans to flies*" where different imaging systems were described from a flat sensors to curvilinear adaptable geometries. The optics of the human eye were compared to the ones existing on insects (in this case, flies) and the differences on how we/they recognize the surrounding environments. The author described the underlying materials science and mechanics where a full description of modelling and experimental results were shown. Rogers described the photodetector arrays placed on a deformable substrate interconnected by flexible metal contacts and covered with elastomeric microlenses. The lenses physics were described and their geometries engineered to accommodate strain and deformation from the flexible substrate. The inclusion of a black matrix in order to avoid light contamination in between the detecting pixels emulates a similar architecture from the insects where their photoreceptor cones are individually protected from other surrounding cones. The operating principles of the hemispherical camera were described where the image acquisition performed only by an 8x8 array of photodetectors was shown. Each image was initially modelled using ray-tracing analysis and compared afterwards where each acquired photodetector signal was rendered in a hemisphere showing a wide range cover from -5.5° to 5.5° in the θ and ϕ directions with 1.1° steps. Rogers also described the use of this cameras to detect motion and proximity. Hemispherical cameras are able to detect motion '*sooner*' than flat sensor cameras, since objects come in view at different polar angles relative to the centre of the camera. Typical cameras have a field of view of approximately 90° (for cameras with an already relative high-angle lenses) where the hemispherical ones are able to detect objects within a 180° field of view. The surprising capabilities of the camera were revealed when two different objects were placed at different distances on the field of view. Even though sometimes the objects differed in distance from 2cm, these varied in the detected size but were constantly in focus, revealing a better knowledge on the behaviour of the insect world and how these always avoid enemies (mostly human trying to annihilate them). An inspiring talk by one of the lead researchers in the flexible integrated optoelectronics field.

Tutorial symposia

Brian Cunningham presented a tutorial session called "Optical sensors in life science and medicine" where he reported on several design considerations, fabrication and applications of biosensors that his team is researching currently at the University of Illinois. Different portable biosensing applications were demonstrated making use of the integrated CCD cameras existent on consumer smartphones as high resolution spectrophotometers to perform label-free and label-base analysis. The author also showed the use of label-free biosensing systems based on external cavity lasers in pharmaceutical research which were capable to detect small molecule drugs binding to large proteins by detecting fluctuations on the emission wavelength, sometimes with shifts within the picometer scale. The author followed to describe a new microscope imaging technique called "Photonic Crystal Enhanced Microscopy (PCEM)" that is capable of imaging and quantifying the strength of cell attachment to a PC biosensor surface with sub-cell spatial resolution, that is being used to study fundamental processes including chemotaxis, proliferation and stem cell differentiation. Another technique described was surface-enhanced Raman scattering (SERS) where photonic crystals or nanostructured surfaces are used to generate spatially confined, high intensity electromagnetic hot spots thus enhancing the output of SERS for detecting surface-based fluorescence analysis for cancer biomarker proteins. These nanostructures can be inexpensively manufactured from plastic, glass or silicon to enable single-use applications, namely sensors into intravenous drug delivery tubing or rapid multiplexed disease biomarker testing using simply a droplet of serum. To conclude the talk, the author showed a recent application of a narrowband resonant optical filter in the infrared region of the electromagnetic spectrum as a new histological imaging modality called discrete frequency infrared absorption spectroscopy (DFIR), allowing rapid chemical imaging for a wide range of applications in pathology as well as forensic analysis.

Overview and final comments

Despite this conference not having a conference dinner, there were plenty of coffee/tea breaks to allow for socializing and networking. There were multiple opportunities to exchange knowledge and learn something from other researchers with common goals or previous experience. The next conference location was revealed to be in San Diego, California on October 2014.

Attending this conference was really an excellent experience, allowing to acquire further knowledge on several new device architectures and techniques. It was also a fantastic opportunity to know one of the mentors and most recognizable and respectable researchers in the field of flexible optoelectronics, John A. Rogers and his team. I would like to thank my funding agencies (EPSRC, University of Strathclyde, Institute of Photonics and the UKNC) for providing access to funding and living costs during my attendance.

Thank you.

Antonio Jose Trindade, 2013