28th IEEE Photonics Conference

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The 28th IEEE photonics conference took place in Reston, Virginia on the 4th-8th October 2015. There approximately 460 attendees at the conference with over 350 talks and tutorials, including several invited and contributed talks, and 4 plenary talks from prominent researchers in the field of photonics. The main topics covered over the course of this conference included integrated photonic circuits, display technology, high performance lasers, spatial multiplexing, and III-V materials.

During the conference I presented a talk entitled "*Integrated dual-colour InGaN light-emitting diode array through transfer printing*". My talk gave an overview of the work done in the Institute of Photonics using a transfer printing technique to pick up and "print" micro-LEDs onto non-native substrates. I then focussed on the fabrication of an integrated dual-colour device, where blue-emitting InGaN LEDs are printed in between the pre-fabricated green-emitting InGaN LED pixels in an array fabricated on a sapphire substrate. The bandwidth, IV and LI characteristics of the separate green GaN-on-sapphire and transfer printed blue LED pixels was reported. This dual-colour device can be used in visible light communication applications to increase the data rate compared to a single-colour device. The talk was fairly well attended and received several interesting questions on how the technique works, as well as the fabrication process.

Plenary Talks

There were 4 plenary talks, over two afternoon sessions. The first was from Professor Nader Engheta, University of Pennsylvania. He discussed metamaterials and how they can be used to manipulate photons and make them behave in unpredicted ways. He made an analogy of how electrons behave in semiconductors and different materials to describe how photons would behave in different materials with extreme conditions. The materials can be tailored, for example with near zero permeability and permittivity, to make tailor waves and fields and therefore shape photons in different ways.

The second plenary talk was from Professor David Miller, Stanford University, on how to fabricate any arbitrary linear optical component. He talked about how a linear optical component can be written down completely as a mode converter that converts the input mode from a set of orthogonal modes to a corresponding set of output modes and as a result any optical component can be described.

For me, one of the highlights of the conference was the third plenary talk given by Professor Hiroshi Amano, one of the 2014 Nobel Prize winners, for his pioneering work with GaN LEDs. His work used metalorganic vapour phase epitaxy (MOVPE), which at the time was a fairly unknown process, to grow thick, high quality gallium nitride on sapphire substrates. Such thick layers had previously been unachievable without far too high a concentration of dislocations and therefore low performance. Amano's discovery of how to combine the use of buffer layers and low temperature MOVPE growth to fabricate high quality GaN on sapphire led to the ability to fabricate efficient blue-emitting LEDs.

This revolutionised lighting technology, and white LEDs could then be produced. Our group at the institute of Photonics works extensively with GaN materials for LED fabrication, and Professor Amano's account of how the material evolved into the high quality films we use today was fascinating and very engaging.

The final plenary talk was given by Miles Padgett, from the University of Glasgow. His talk was entitled "light's twist" and explained how light carries an angular momentum. This can be used to manipulate and spin tiny micron-sized objects.

Selected Contributed and Invited Talks

With my research focussed on heterogenous integration and GaN LEDs, this was a fantastic opportunity to see some of the different work being done in these fields. It also gave me a chance to learn about some of the wider applications of semiconductor photonics, in bioscience for example. I will summarise here a few of the talks from the conference I found particularly interesting.

MC1.1 Monday 5th October 8:30am
"Quantum dot LEDs for next generation displays"
P.Holloway, Nanophotonica, University of Florida, USA

One of the first invited talks of the week was from Nanophotonica, a company attached to the University of Florida. They fabricate thin (200nm thick) quantum dot light emitting diodes (QLEDs) which have an active region of core-shell quantum dots, rather than the multiple quantum well active region in conventional LEDs. The colour of light emitted by these QLEDs is tuned by changing the composition of the quantum dots, and so can have very narrow spectral emission peaks compare to LEDs containing multiple quantum well structures.
These QLEDs have a high colour gamut (90%of REC2020) and have a PLQY of 18%green, 12%red and 11%blue.
One of the issues raised in the questions after the talk was that of lifetime of these QLEDs, and further work must be done to increase the lifetime by at least 4 times its current level for these QLEDs to meet industry demands for commercially available displays.

M.J 3.4 Monday 5th October 2:45pm
"Space division multiplexing of blue lasers for undersea communications"
E.Johnson, Clemson University, USA

This was one of the III-Nitride-based talks I found most interesting. It links with the visible light communication work done within our group at the Institute of Photonics. This group is using blue laser diodes for under water communications. Measurements are currently taken as data is sent through a 3m tank, but future work will extend this to data transmission in a 10m tank. Results so far show data transmission at 1Gb/s in water with $0.4m^{-1}$ attenuation, and 2.5Gb/s in completely clear water.

Tu.E 2.3 Tuesday 6th October 11:15am
"Physical model for indium-rich InGaN/GaN self-assembled quantum dot ridge-waveguide lasers emitting at red wavelengths (~630nm)"
G.Su, University of Illinois at Urbana-Champaign, USA

This was another talk focussing on III-V materials. They modelled LEDs with high indium composition quantum dots in the active region to emit red light. This was mostly theoretical work, but with some early LEDs fabricated.

They described a process where red-emitting LEDs could be fabricated with the InGaN/GaN materials system which is widely used to produce efficient blue- and green- emitting LEDs. Quantum-well-based devices are limited to the shorter wavelengths because increasing the indium concentration generated too much strain in the quantum wells. Quantum dot devices are a solution to this, involving compressive strain at the bottom of the quantum dot and tensile strain at the top of the device. This strain make-up of the lasers has been modelled extensively by this group.

WE1.2 Wednesday 7th October 9am
"Continuous-wave emission of III-V quantum dot lasers grown directly on Si substrates"
S.Shutts, Cardiff University, UK

This talk focussed on the techniques used by this group at Cardiff to grow GaAs on Si, with a reduced amount of dislocations. Because of the lattice mismatch between GaAs and Si, direct integration is usually difficult. By using dislocation filters to discourage threading disloactions from propagating through the GaAs, they have fabricated InAs/GaAs lasers directly on silicon. These lasers emit at 1.3µm, and have achieved power outputs exceeding 20mW.

WJ2.2 Wednesday 7th October 10:45am
"A universal surface-enhanced Raman spectroscopy substrate for "all" excitation wavelengths"
N.Zhang, State University of New York at Buffalo, USA

This group have developed a cost-effective broadband substrate for surface enhanced Raman spectroscopy (SERS) sensing. This is a technique where Raman scattering of incoming molecules is enhanced by roughening or patterning a metal substrate. The enhancement is such that single molecules can be detected.
In contrast with existing SERS sensing substrates, this can work for wavelengths from 450nm-1000nm. The substrate is fabricated by sputtering gold at a low deposition rate, and then annealing to give a nanoparticle "pattern" on the surface of a stack of SiO_2, Ag on a glass substrate.
The nano-particle size can be well controlled by annealing temperature, with absorption 80% between 414nm-956nm. This can be used to detect and measure molecules showing fingerprints within this broad design band.

WA3.4 Wednesday 7th October 2:30pm
"Heterogeneously integrated InGaAs and Si membrane four colour focal plane arrays"
L. Menon, University of Texas at Arlington, USA

This talk reported the design and fabrication of transfer printed four-colour multi-junction Si/InGaAs photo-detector arrays. These arrays make use of depth dependent absorption of different wavelengths for filter-free colour detection and multi-spectral imaging. Due to the absorption coefficient, the penetration depth into silicon differs for different colours of visible light, similarly different wavelengths of IR light can penetrate InGaAs to different depths. By fabricating an array of Si and InGaAs detectors allows for light across the visible and IR spectrum to be detected and measured.
This group was the only other group at the conference presenting work which, like my own PhD project, uses transfer printing to pick up and place fabricated semiconductor devices. This work differs from my own however because it is done by hand. Fast retraction of a PDMS slab pressed into contact with the device picks it up from its growth substrate, while slow peeling retraction leaves the device printed on the new substrate. This was interesting to see, as it differs from my own work. The devices I fabricate are held in place on their growth substrate by sacrificial anchors for easy

removal, while in this work a photoresist pedestal is used under each device in order to allow for release from the growth wafer. Using this technique, large arrays of 6x6 devices can be picked up, transported and printed.
I had a chance to ask my own question about the repeatability of the process as well as the placement accuracy compared to our own findings with the technique. Because the work is done manually, these can vary greatly between each printing run.

Conclusion

The wide range of topics at the conference, gave me an interesting insight into various areas of photonics I would otherwise not have looked into. The plenary talks were all very well presented, with engaging overview of a range of exciting and important topics in photonics as a whole. The 50th anniversary of the IPC celebratory dinner, and various tea breaks throughout the conference, were a great opportunity to socialise and network with other researchers. This allowed for knowledge exchange and interesting discussions with researcher from other groups with common research goals or previous experience in the areas we work on at the Institute of Photonics.

It was also a great experience for me to present a talk on my work to the international photonics community at a conference of this size.

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