BIANCHO Publishable summary

The BIANCHO project aims to develop photonic components designed to significantly reduce power consumption at the component and system level in advanced communication systems, thereby saving significant electricity, and enabling unlimited bandwidth through integration, more optical processing and very high spectral-density photonic transmission.

Current telecom components suffer severely from intrinsic losses. Around 80% of electrical power is wasted in a 1.55μm laser chip as heat. Most systems require thermo-electric coolers (TECs) and an air-conditioned environment, further increasing the energy budget by over an order of magnitude. The intrinsic losses in semiconductor lasers and optical amplifiers (SOAs) are due to Auger recombination. Incremental approaches to overcome these problems have reached their limits.

The overarching target of the BIANCHO project was to achieve the challenging objective of demonstrating dilute bismide lasers at telecom wavelengths with a reduced Auger contribution to the threshold current. This is expected due to the band structure of the laser active region being modified to achieve a situation where the fundamental energy gap is less than the spin-orbit-splitting energy at the valence band maximum, $E_g < \Delta_{SO}$, leading to the elimination of the dominant CHSH Auger recombination process in the alloy.

Around the time that the BIANCHO project started, there had been one demonstration of optically pumped lasing from a $GaAs_{1-x}Bi_x$ structure at low temperature. The BIANCHO partners have made major steps forward during period 3 in the development of GaAsBi/GaAs laser structures.

We achieved the ***first-ever*** electrically pumped semiconductor laser including a dilute bismide (GaAsBi) active region. This was also the first GaAsBi laser operating at room temperature and the first bismide quantum well laser. The laser was grown using MOVPE in a commercially available AIX 200-GFR reactor system. By carefully designing the growth conditions, we were able to form high-quality GaBiAs single-quantum-well lasers with a bismuth incorporation of 2.2%. These devices, measured in ‘as-cleaved’ form under pulsed operation to minimize heating effects, produce 950 nm emission at room temperature and have a threshold current density of 1560 A/cm^2, as illustrated in Figure 1. Optimisation of the waveguide design reduced this to 1100 A/cm^2.

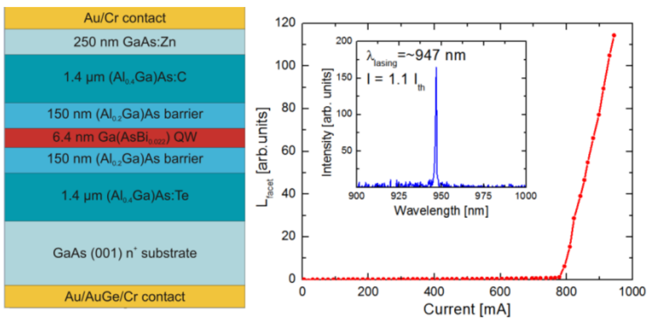

Figure 1: Schematic of first dilute bismide laser layer structure (*left*), and room-temperature L-I characteristics of a broad area device (*right*)

The challenge in growing dilute bismide alloys is to incorporate sufficient Bi in the active region to reach the condition where $E_g < \Delta_{SO}$, which we had shown during period 1 occurs once x > ~10%. Because of the lower growth temperature that can be used in MBE growth, it is generally easier to incorporate a larger Bi fraction using MBE rather than MOVPE. We therefore sought to grow laser structures where the GaBiAs active region was grown using MBE at FTMC, while the barrier and cladding layers were grown using MOVPE at Marburg.

This allowed us to drive the Bi composition to x = 6% in a $GaAs_{1-x}Bi_x$ active region, the highest Bi composition reported to date in any dilute bismide laser.

Having established laser action at x = 6%, a major effort was then devoted to the development of $GaAs_{1-x}Bi_x$/GaAs QWs with good optical quality at higher Bi compositions. Figure 2 shows the measured room temperature photoluminescence (PL) peak amplitude and wavelength for an extensive series of quantum well structures. Empty points represent single quantum well samples, full stars structures with 3 to 5 quantum wells. The PL wavelength range from 1.1 to 1.45 μm corresponds to the Bi content in a 6 nm quantum well ranging from 6% to 11.5%. The horizontal dashed red line shows the PL peak amplitude for the 6% QW structure that demonstrated lasing. It can be seen PL was obtained from samples with x ~9%, of comparable quality to that obtained from laser material with x ~6%. This strongly indicates that lasing should be possible at x ~9%, although we have not yet been able to lasing action at this composition. The data point at 1.45 μm shows room temperature PL from a $GaAs_{1-x}Bi_x$/GaAs QW structure with x ~11.5%, indicating the potential for laser action to be extended to this composition and beyond.

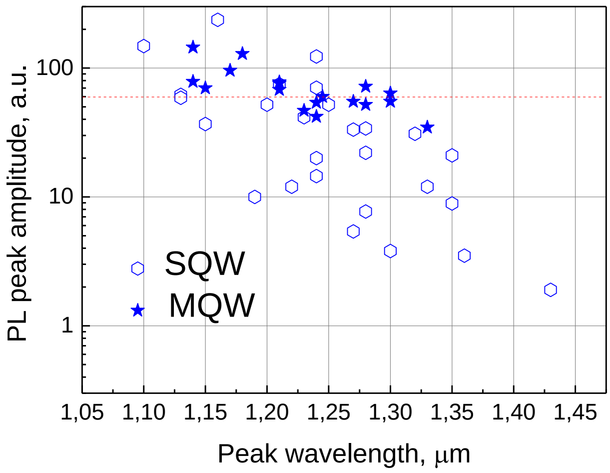

Figure 2: PL peak amplitudes and wavelengths measured on various single and multiple QW samples (see text for further details).

Overall, the project succeeded to study several samples where $E_g < \Delta_{SO}$. Temperature-dependent optical measurements on structures close to the $E_g = \Delta_{SO}$ resonance have provided the first evidence for Auger suppression once $E_g < \Delta_{SO}$. This was achieved in both GaAsBi/GaAs and InGaAsBi/InP test structures.

The BIANCHO project was carefully designed to include leading European groups with complementary expertise in epitaxy, device physics, band structure modelling and advanced design and fabrication, in a well focused consortium. Overall, our work and analysis have clarified many aspects of the growth and optimisation of dilute bismide alloys, including demonstration of the first electrically pumped dilute bismide lasers, and the first lasers with x > 6%. Without question, we have opened this field and have provided Europe with a lead in this field. The exploitation activities of the project participants lay strong foundations for enhancing European competitiveness in the global telecommunications market and ultimately leading to new high technology jobs for Europeans, based on the development and application of uncooled telecom components with significantly reduced power consumption both at the component and system level.

Project website: www.biancho.org