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First comparison of InGaAsP and InGaAlAs electro-absorption modulator in COBRA generic platform

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Introduction Electro-absorption modulators (EAMs) are an attractive solution in applications where high speed modulation is required with high extinction ratio, low drive voltage and integration with lasers. They are particularly promising for high-bandwidth optical communication systems. The possibility of using InGaAlAs compounds, instead of InGaAsP, has shown improved performance at high operating temperatures due to the favourably high band offset for electrons [1].

We have previously fabricated InGaAsP/InP (P quaternary or P-Q) multi-quantum well (MQW) EAMs with a bandwidth of 12.5 GHz [2]. This device is used in here as a reference for comparison with a recently fabricated InGaAlAs/InP (Al-Q) MQW wafer containing EAM structure. The devices on the second wafer are processed to match the COBRA generic integration platform requirements [3].

Device structure The operation principle of an EAM is based on changing the absorption coefficient with the applied electric field. In a MQW structure the effect responsible for this change is the quantum confined Stark effect (QCSE). In response to a DC voltage applied to the device, there is an induced electric field in the undoped MQWs. As the applied electric field increases, the bandgap of the modulator experiences red shift. This also decreases the detuning between the modulator's bandgap and lasing wavelength. For a given detuning we measure the extinction ratio, and its slope determines the optimum operating voltage. Our device is 200 µm long with a 2µm wide shallow ridge structure grown epitaxially on n-InP substrate. The optical confinement factor in MQW is $\Gamma = 0.04$. While a higher optical confinement would be used for lower voltage operation, we have used the same structure as previously fabricated P-Q to enable a direct comparison.

Experimental results The optical transmission of the modulator is measured as a function of the wavelength and of the applied reverse bias. For measurements we have used an amplified spontaneous emission (ASE) source, polarization controller and an optical spectrum analyser (OSA). The operating temperature is 25°C and the results presented here are performed for an input TE polarization. The measured transmission characteristics are shown in Figure 1 (left) as a function of wavelength at zero bias. The coupling with fibre introduces 3dB loss on each side, and we keep the reflectance low by antireflection coating. In our case the optical loss is higher, as the lensed fibres used are not optimal for these structures. Therefore we obtain a zero-bias −14dB insertion loss for all of the measured structures. This loss takes into account coupling loss, passive waveguide loss and the device internal loss. The latter two are negligible compared to the first one and the loss within the EAM is estimated to be 3-4dB.

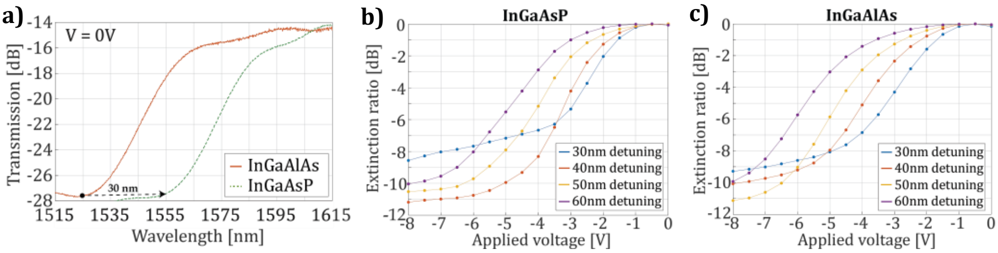

Fig. 1. (a) Transmission spectrum of P-Q and Al-Q at zero bias. Normalized extinction ratio of the InGaAsP (b) and InGaAlAs (c) structure for different detuning wavelengths.

The bandgap of the EAM in the case of P-Q is at 1555 nm, whereas in the case of Al-Q is at 1525 nm. According to this, we have recorded the extinction ratio at corresponding detuning wavelength for each wafer (Figure 1 – middle and right). Both Al and P-Q EAMs show similar extinction ratio for the same detuning. For highest extinction ratio the optimum operating point is at 40nm detuning, where we obtain 11dB extinction for a voltage change of 5V. The Al-containing structures show slightly better extinction ratio for higher detuning wavelengths. At high temperature operation of the EAM integrated with a laser, the detuning would be lower due to lasing wavelength drift and the required voltage for the same extinction ratio becomes lower.

Conclusion We have fabricated and measured the InGaAsP and InGaAlAs electro-absorption modulators in the COBRA generic integration platform. EAMs are integrated with passive waveguides enabling the first like-for-like comparison of P-Q and Al-Q EAM performance in an integration platform. Comparable performance is observed at room temperature for the same number of quantum wells and device length. The successful inclusion of Al-Q devices is expected to enable high performance at high temperature, ultimately enabling semi-cooled and cooler-free operation.

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