Modulating retro-reflectors operating in the range of 0.95-1.1 μm for asymmetric communications

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Abstract

Wireless optical communications can be implemented using a modulating retro-reflector on one end of the link, whereas the other is based on a conventional laser transmitter/receiver system. This approach is useful to relax the payload requirements for the onboard communication system, for example, in space-to-ground links or other asymmetric scenarios, thus providing relevant savings in terms of power consumption and mass, as well as reducing the pointing requirements. Modulating retro-reflectors basically consist of the combination of an optical retro-reflector and an electro-optic shutter. The switching speed required for most applications makes the use of nanostructures the most promising solution. In particular, multiple-quantum-well (MQW) structures have been successfully applied to develop electroabsorption modulators operating from ultraviolet to near infrared, similarly to the case of emitters and photodetectors where these structures are routinely used as a means to reduce threshold and control wavelength or spectral selectivity [1][2][3]. Unfortunately, MQW-technology is not well established for certain wavelength ranges, including the bands associated to 1030-nm and 1064-nm lasers, mainly due to the lack of suitable substrates for growth, even though some results were reported [4].

In this work, we address the design, simulation, fabrication and characterization of (In,Ga)As/(Al,Ga)As-MQW-based electroabsorption modulators operating in the range of 0.95-1.1 μm. The design covers aspects related to both the material growth, and the device and system engineering. As a result of this study, a segmented modulator based on a p-i-n device structure grown on a linearly graded buffer layer to accommodate the large lattice mismatch between the substrate and the quantum well materials was fabricated. Optical material characterization was performed by means of photoluminescence and reflectance, whereas device parameters were extracted from bias dependent electro-optic measurements and dark current. In order to explain the experimental results and assess the device performance, numerical calculations were also carried out to determine the wave functions and energy levels of the 1s exciton state for each band within the multiband envelope theory (**k·p** formalism), so that absorbance and reflectance could be theoretically obtained. Figure 1 shows the expected performance as a function of applied electric field for a selected structure close to the absorption edge. The results indicate that the degree of strain under which well layers are subjected plays a critical role on the device optimization (see, for example, the surface pattern of the as-grown wafer in Figure 2). Moreover, the device speed is limited by RC considerations. Finally, we discuss the practical implementation issues related to the optical assembly and packaging, and the system parameters, including speed, modulation efficiency, power consumption, temperature stability and insertion loss, as well as the potential applications of this non-commercial technology for security and defense, proposing future directions of development.

References

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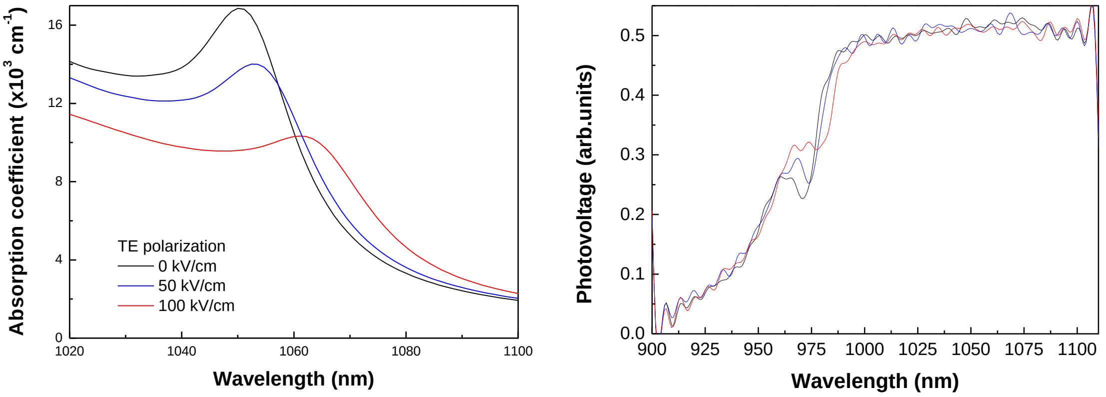
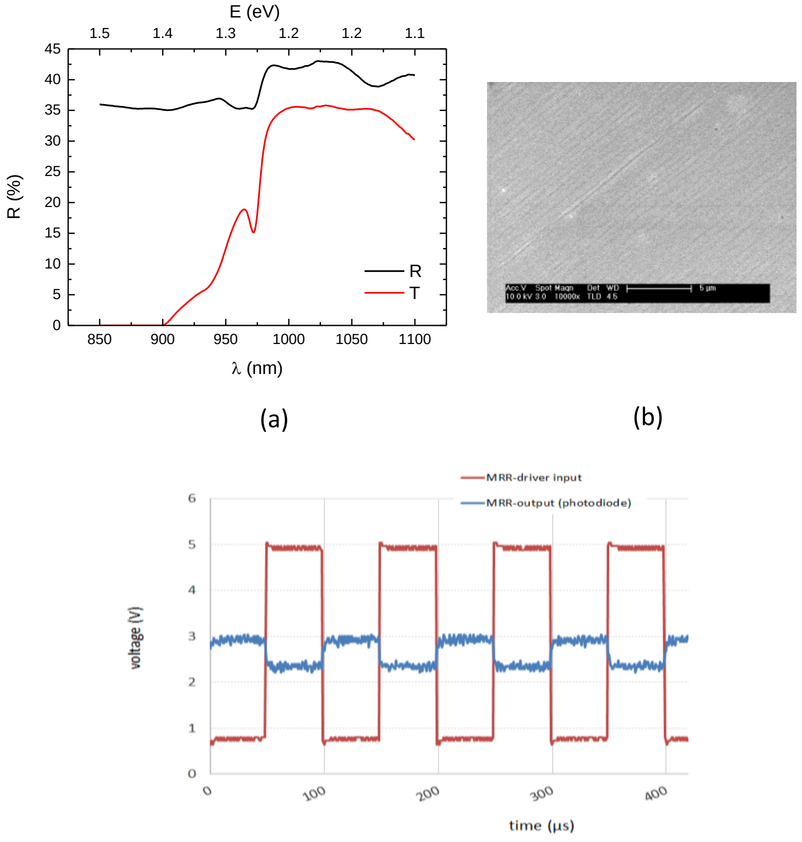
Figures



(a) (b)

Figure 1. (a)Absorption coefficient for the optimized structure inserting a strain relief layer to improve material quality in the well (linearly graded buffer) as a function of electric field. (b) Measured transmittance as a function of applied reverse bias (0 V black line, 5 V blue line and 10 V red line).



(a) (b)

(c)

Figure 2. (a) Reflectance and transmittance for one as-grown sample operating at 975 nm. (b) Scanning electron microscope micrograph of the surface of a (In,Ga)As/(Al,Ga)As-MQW-based structure, where crosshatch defects can be observed. (c) Modulator response: driver input (red) and optical modulation measured by a photodiode (blue).