Monolithically integrated DBR waveguide laser and intensity modulator in erbium doped LiNbO₃

J. Söchting, H. Schütz, R. Widmer, R. Corsini, D. Hiller, C. Carmannini, G. Consonni, S. Bosso and L. Gobbi

Indexing terms: Integrated optics, Distributed Bragg reflector lasers, Waveguide lasers, Lithium niobate

For the first time, a DBR laser has been integrated with a Mach-Zehnder intensity modulator in Er diffusion doped, Z cut LiNbO₃, with Ti indiffused waveguides and dry etched Bragg gratings. The monolithically integrated device has a threshold of 54.8mW incident pump power ($\lambda_p = 1480$nm) and emits in a single longitudinal mode, up to 0.63mW CW output power at $\lambda_m = 1561$nm. The Mach-Zehnder type intensity modulator has an optical bandwidth $> 3$GHz.

Introduction: Free running lasers, tunable lasers, modelocked lasers and distributed Bragg reflector (DBR) waveguide lasers have all been demonstrated in erbium diffusion doped LiNbO₃ [1-4]. We report the first singlemode Er:LiNbO₃, DBR waveguide laser monolithically integrated with a Mach-Zehnder type intensity modulator. This transmitter prototype is an attractive device for high speed analogue transmission and sensor applications. Details of the distributed Bragg reflector (DBR) waveguide laser combined with the Mach-Zehnder type intensity modulator configuration and the basic steps for the formation of the integrated chip are described, followed by a discussion of the optical properties of the laser and frequency modulation characteristics of the modulator.

Fabrication of the integrated laser/modulator device and characteristics of the components: The fabrication of the compact, single chip, source/modulator device involves the following steps:

i) Planar doping of a Z cut LiNbO₃ wafer close to the surface by indiffusion of erbium at 1100°C for 10 h in an oxygen atmosphere.

ii) Transversal monomode stripe waveguide and Mach-Zehnder interferometer formation by a subsequent thermal diffusion of titanium stripes at 1030°C for 9h.

iii) Dry etching of a 352.5nm period Bragg grating to define one part of the compound DBR waveguide laser cavity: This surface corrugated reflector mirror is the key component allowing for monolithic integration with further components on the same chip. The first order DBR grating was holographically exposed in resist using a setup with beam collimating optics. This allows the recording of the two beam interference pattern of plane waves rather than spherical waves, and drastically reduces grating period chirp.

The resist pattern was then transferred 300 nm deep into the surface of LiNbO₃ by dry etching techniques described in detail in [4, 5]. The mirror shows a transmission drop exceeding 3.5dB at the Bragg resonance, which indicates a high reflectivity of more than 50%.

iv) Deposition of an SiO₂ buffer layer of the travelling wave Au-electrode outside the laser cavity on top of the Mach Zehnder structure.

v) End face deposition of a dielectric mirror stack of quarter wave layers of SiO₂/TiO₂ to complete the DBR laser cavity: The dichroic mirror shows a transmittance of 60% at the pump wavelength ($\lambda_p = 1480$nm) and simultaneously a high reflectance (98%) at the laser emission wavelength ($\lambda_m = 1561$nm).

Characterisation of the laser: The device, pumped with a commercial fibre pigtailed semiconductor laser diode, had a threshold of 54.8mW incident pump power and a slope efficiency of 0.69%. The device had a threshold of 54.8mW incident pump power and a slope efficiency of 0.69%.

Characterisation of the modulator: The frequency response of the integrated laser/modulator device with a serial resistance of the electrode of 10Ω and the calculated RF impedance of 27Ω was measured with an HP 8703A lightwave component analyser. Fig. 3 shows the response under electro-optical modulation in lumped electrode configuration. The integrated laser/modulator device shows a bandwidth of 3.057GHz at -6dB. Although designed for travelling wave operation (see Fig. 1) impedance matched surface mounted chip resistors could not be attached owing to the voltage

Fig. 1 Layout of integrated laser modulator sample

Fig. 2 Power characteristics, emission spectrum and longitudinal mode spectrum of integrated laser/modulator sample

Fig. 3 Electro-optic bandwidth measurement of combined laser/modulator

-5.87 dBc at $\Delta f = 3.057$GHz

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Oxide-confined vertical-cavity laser with additional etched void confinement

H. Deng and D.G. Deppe

Indexing terms: Vertical cavity surface emitting lasers, Semiconductor junction lasers

A vertical-cavity surface-emitting laser that incorporates oxide confinement with additional etched void photon confinement is described. A room-temperature continuous-wave threshold of 75μA for a 3.5μm-diameter lateral device size is achieved.

The threshold current of vertical-cavity surface emitting lasers (VCSELs) has been decreased dramatically with the introduction of native oxide confinement [1–6], and such devices can play a future role in low power optoelectronic interconnects. The native Al2O3 serves as a buried insulator in addition to yielding a large lateral refractive index step within the laser cavity from -1.6 (Al2O3) to -2.95 (AlAs). Although the lateral index step occurs in only one or two thin layers within the cavity, when placed close to the active region it results in good lateral index confinement [2–4]. Before the oxide-confined VCSEL we demonstrated another fabrication process for achieving a buried lateral index step based on an etched void [7]. In that work we found that, despite the nearly planar geometry of the laser cavity, a thin etched void placed within the distributed Bragg reflector (DBR) stack results in significant reduction in the lateral mode size, similar to what occurs with the native oxide confinement. In this Letter we show how the etched void can be conveniently combined with the buried native oxide layer. Side by side comparisons show that increased optical mode confinement occurs along with a threshold reduction when the etched void is included. A minimum room-temperature CW threshold current of 75μA is measured for a 3.5μm-diameter device.

Acknowledgments: This work has been supported by the EU and the Swiss BBW, under the EU RACE programme project R2013 EDIOLL and under the BBW contract No. 92.005a.

References

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Electronics Letters Online No: 19960602
J. Söchtig, H. Schütz and R. Widmer (Paul Scherrer Institut, Badenstrasse 569, CH-8048 Zurich, Switzerland)
L. Gobbi (Alcatel Cavi, SpA, DBR/EST/COS, Vallo Storico 222, I-20126 Milan, Italy)