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Towards high-speed tuning Cavity Resonator-Integrated Guided-mode Resonance Filters

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Summary

We report the experimental demonstration of tunable Cavity Resonator-Integrated Guided-mode Resonance Filters made on lithium niobate on insulator. Temperature-induced tuning over a wavelength span greater than the full-width half-maximum of a filter with a Q factor of ~1600 is achieved.

Introduction

Cavity Resonator-Integrated Guided-mode Resonance Filters (CRIGFs) [1] form a family of grating-based filters whose characteristics in terms of spectral selectivity and peak reflectivity and angular tolerance make then attractive for use as wavelength-selective mirrors for extended-cavity diode lasers (ECDLs) [2,3]. Since their behavior is ruled by the excitation of a localized mode, their implementation in conventional SiN technological platforms typically leads to fixed wavelength operation. To overcome this limitation, CRIGFs with spatially-graded structures have been successfully demonstrated [4] and used to introduce broadband tuning of ECDLs [5].

In this article, we report progress towards tunable CRIGFs with no moving parts exploiting the lithium niobate on insulator platform.

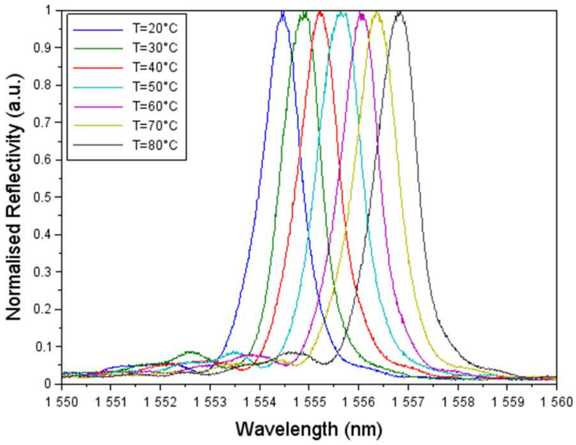
Device design and fabrication

To demonstrate resonance electronic tuning in CRIGFs, we selected the lithium niobate on insulator technology as this material platform is compatible with the fabrication of low-loss integrated optics [6] and provides various means to electronically modify the material refractive index, namely using either thermal, electro-optic, piezo-electric or acousto-optic effects.

The CRIGFs were designed for operation at a wavelength of 1550nm using a combination of rigorous coupled-wave analysis [7] and coupled-mode theory [8]. The devices under study are made on an X-cut $LiNbO_3$ substrate and rely on a 323nm SiO_2/72 nm Si_3N_4/297nm $LiNbO_3$/2µm SiO_2 planar waveguide. 50-µm-wide structures consisting of an 11-period 865-nm-pitch central grating coupler embedded between two 400-period 432.5-nm-pitch Distributed Bragg Reflectors were fabricated using a combination of nano-imprint lithography and dry-etching. The rear surface of the sample is covered by a 266-nm-thick SiO_2 single-layer anti-reflective coating to avoid back-reflection from this interface.

Device characterization

The device spectral characteristics are measured using a fibre-coupled tunable laser around 1550 nm whose output is relayed using free-space optics to form a 5.3-µm-waist beam and on the sample. The transmission and reflectivity responses are respectively calibrated against sample-free transmission and the reflection from a silver mirror. For a substrate temperature of 20°C, a resonant feature is observed at ~1554.4 nm with a 0.96-nm linewidth and an on-resonance transmission factor and peak reflectivity of 32±2%. As shown in Fig. 1 left, when varying the sample substrate temperature, a resonance shift of 0.0382±0.0008nm/K was observed. This value is in good agreement with the rate of 0.0364nm/K derived numerically (RCWA) using the experimentally-inferred material coefficients of references [9,10]. Furthermore, as shown in Fig. 1. right, should 70-µm-separated electrodes be added to the current set of devices, an electro-optic tuning rate of 0.002nm/V is predicted.



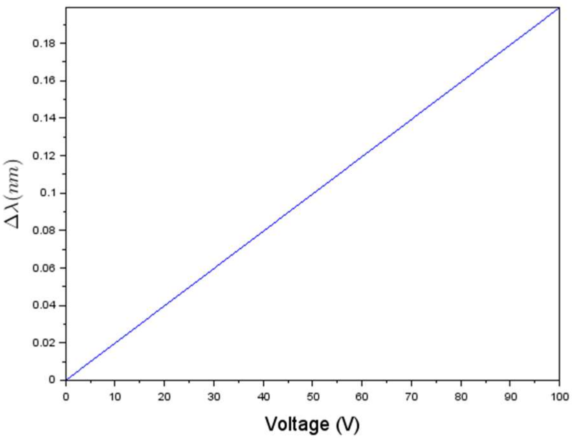


Fig. 1: left: Temperature-dependent evolution of the CRIGF normalized reflectivity spectrum.
right: Predicted tuning for electro-optically actuated CRIGFs based on the current design.

Conclusions

We presented the design, fabrication and characterization of CRIGFs made using lithium niobate on insulator technology. Filters exhibiting Q-factors of ~1600 at a wavelength of ~1550nm and a resonance shift of ~2.6 nm upon a rise in temperature of 60°C are reported. Investigations of electro-optically-tuned devices is under way and the associated results will be shown at the meeting.

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