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Neodymium-diffused tunable Y-branch waveguide laser in $LiNbO_3$ operating at room temperature

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Rare-earth-doped waveguide optical lasers and amplifiers have received considerable attention in recent years, both in fibre form and as channel waveguides on planar substrates. Channel waveguide geometries lend themselves ideally for applications in active integrated circuits, with the potential for photolithographic definition of complex-cavity devices and monolithically integrated modulators for tuning, line-narrowing, Q-switching and mode-locking.

$LiNbO_3$ is a particularly attractive substrate for integrated optics, owing to its excellent electro-optic, acousto-optic and non-linear properties. Efficient channel waveguide lasers have been realised, by various research groups, in bulk doped Nd:MgO:$LiNbO_3$ using both titanium indiffusion and proton-exchange techniques, and using thermal indiffusion of neodymium and erbium into the crystalline substrate. Localised doping techniques employing the indiffusion of rare-earth ions allow the confinement of the gain to specific regions, enhancing the potential for monolithic integration of passive and active devices. Furthermore, this method offers the possibility of selectively doping one $LiNbO_3$ substrate with different rare-earth ions. On-chip modulation of waveguide lasers in $LiNbO_3$ has resulted in Q-switched and mode-locked devices. However, waveguide devices in Nd:$LiNbO_3$ fabricated by Ti-indiffusion have been hampered by the strong photrefractive effect present at the pump wavelength, even when doped with MgO. CW operation in these devices has only been made possible by continuously annealing the photorefractive damage at high temperatures, hence limiting their application.

We have demonstrated, for the first time, a tunable coupled-cavity waveguide laser in neodymium-diffused Ti:$LiNbO_3$. The waveguide laser comprised a Y-junction cavity, and CW lasing operation was observed at room temperature, in contrast to all previous reports of Nd:$LiNbO_3$ devices in which the waveguides have been fabricated by titanium indiffusion. Using 95% reflectivity mirrors at the waveguide ends, a lasing threshold of 4mW of launched pump power was obtained, with a slope efficiency of 2.6%. Wavelength tuning over the fluorescence band between 1091.4nm and 1093.7nm was demonstrated using an intracavity integrated phase modulator to electro-optically adjust the optical path length of one arm of the branching section. The Y-branch configuration is also expected to allow line-narrowing and Q-switching of the waveguide laser. In addition, the low pump threshold achieved suggests that diode-pumping is possible. We speculate that such multi-functional devices in $LiNbO_3$ may find applications in many areas of optics.