Highly coherent electronically tunable waveguide extended cavity diode laser

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Highly coherent lasers emitting either a stable frequency or capable of fast tunability are required for several applications, for instance coherent transmission systems, LIDAR detection, and RF signal processing. Extended cavity diode lasers can provide both good spectral purity and tunability. Fast scans over tens of GHz have been achieved by electrical means, e.g., intra-cavity electro-optical (EO) crystals[1]. However, high voltages are needed to provide such sweeps. Moreover, the different elements constituting the cavity make it very sensitive to external perturbations. These laser key-characteristics can be improved using waveguide structures. Such an integrated cavity has been proposed in a KTP substrate[2], but no real improvement in the EO tuning was performed. We here demonstrate a waveguide extended cavity diode laser (WECDL) in a $LiNbO_3$ substrate working at 1.5 µm, with a high stability and a large EO tuning slope.

The laser architecture is sketched in Fig. 1(a). The active medium is a HR/AR-coated diode laser. Light is coupled into the waveguide using an aspheric lens. Different waveguide structures delineated along the Z-axis are fabricated by Ti-indiffusion into the surface of a X-cut $LiNbO_3$ crystal. The resulting waveguides are either 14-µm (two mode guiding) or 7-µm (single-mode guiding) wide. The substrate is 4.8-cm long, 1-mm thick, with end faces polished under an angle of 5.8°. The input face is AR-coated. A 13-mm long Bragg grating is engraved and thermally fixed in a Fe-doped section of the waveguide exploiting the photorefractive effect[3].

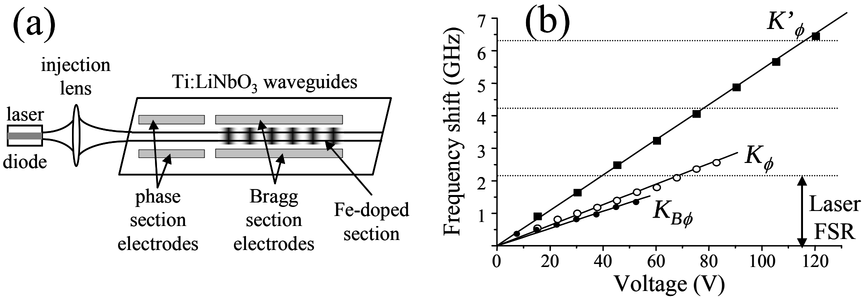

Fig. 1: *(a) Laser architecture; (b) EO tuning of the Bragg phase response (filled circles), the phase section (empty circles) and both sections (squares).*

Up to 60 % of the diode light can be coupled in both single- and multi-mode waveguides. A Bragg reflectivity of 20 % and a diode current of 75 mA yield a 7-mW optical output power of the WECDL at λ = 1553.75 nm. The laser operation is single frequency with a side mode suppression ratio larger than 40 dB. The diode spontaneous emission is suppressed by 50 dB. The coherence time of the laser reaches 18 µs (18-kHz linewidth) at 7 mW output power. The laser stability on short timescales obeys a quasi-1/f noise spectrum on a 100 kHz bandwidth only. As for long term stability, the laser wavelength drifts within +/- 1 pm during several hours without any external stabilization.

Finally, we test the frequency agility of the WECDL. Two sets of electrodes are implemented on the substrate in order to shift the cavity optical length and the Bragg wavelength (see Fig. 1(a)). The phase section exhibits an EO tuning slope K_ϕ = 32 MHz/V, with continuous tuning over one cavity free spectral range (see empty circles in Fig. 2(b)). The Bragg wavelength moves with a scale factor K_B = 69 MHz/V. As the grating is engraved in the propagation direction, the Bragg section also exhibits a phase response $K_{B\phi}$ = 22 MHz/V (see filled circles in Fig. 2(b)). When one applies the same voltage on both Bragg and phase electrodes, the laser EO slope is K'_ϕ = 55 MHz/V (see squares in Fig. 2(b)). One can achieve 6.6 GHz-wide frequency scans without mode-hop, and very fast chirp capability up to 5.5 GHz in 5 µs has been demonstrated. We believe this laser corresponds to an ideal source for many applications.

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[1]L. Levin, *"Mode-hop-free electro-optically tuned diode laser"*, Opt. Lett. **27** (2002) 237, and references therein.
[2]K. Repasky et al., *"Tunable external-cavity diode laser based on integrated waveguide structures"*, Opt. Eng. **42**, (2003) 2229.
[3]C. Becker et al., *"Integrated optical Ti:Er:LiNbO$_3$ distributed reflector laser with a fixed photorefractive grating"*, Opt. Lett. **23**, (1998) 1194.