A STUDY OF EXTERNAL-CAVITY DIODE LASERS WITH INTRACAVITY LIQUID CRYSTAL ELEMENTS AND APPLICATIONS

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ABSTRACT

This dissertation mainly focused on the study of external-cavity diode lasers (ECDL) with intracavity liquid crystal elements and applications.

An ECDL with an intracavity planar-aligned nematic liquid crystal (NLC) cell for wavelength tuning was developed. Varying the voltage driving the NLC cell, its extraordinary index of refraction would change due to field-induced reorientation of the LC director. This is equivalent to tuning the laser cavity length. As a result, the laser wavelength can be continuously tuned. The NLC cell behaves no apparent hysterisis, good tuning repeatability, and the response time is several tens milliseconds. With a NLC cell 35.5 μm in thickness, the output frequency of a 15-cm-cavity laser can be continuously tuned over 4 GHz. The root-mean-square (rms) driving voltage required was 1.5 volts. By varying the driving voltage of the NLC cell and laser diode bias current simultaneously, single-mode oscillation and mode-hop-free tuning over 19.2 GHz at 775 nm were achieved. The tuning range is in good agreement with the theoretical predictions.

Digitally wavelength tuning of a channel-selectable laser (LCPM based ECDL) can be achieved by tuning the driving voltage of the LCPM and the intracavity NLC cell. Continuous tuning of 140 MHz of one selected channel was achieved by tuning the LCPM from 2.8 V to 6.36 V. Tuning of a 35.5-μm-thick NLC cell, continuously tuning over 1.75 GHz from 0.9 V

to 2.26 V was achieved. The mode-hop-free tuning range is limited by the requirement of dedicated adjustment of the LD current.

The developed ECDL was applied for spectroscopy, wavelength stabilizations, fine-tuning of a channel-selectable laser, and liquid crystal cell gap measurements. The hyperfine structures of the Rb 85B and 87B D_2-line ($5S_{1/2}$ - $5P_{3/2}$, 780.245 nm) was observed. The output wavelength of the ECDL was locked to an étalon by feedback control of the NLC cell. Relative wavelength stabilities of 2.46×10^{-8} (sampling time 20 s) were achieved. Frequency locking of the developed ECDL to femtosecond combs was implemented. The frequency fluctuation achieved was 1.5 MHz for a period of about10 minutes. We expect that it can be further improved and the scheme can be applied for locking a dual-wavelengths laser system for stable cw terahertz generation.

The developed ECDL was applied for measuring the gap of the LC cell placed in the laser cavity through tuning of the wavelength of the laser. Measurement errors of ±0.5 % and ±0.6 % for 9.6-μm and 4.25-μm planar-aligned cells with phase retardations of 1.63 μm and 0.20 μm respectively were demonstrated. The accuracy of cell gap measurement is limited mainly by the resolution of the wavelength meter and the frequency drift of the ECDL. This method is particularly suitable for measurement of LC cells of small phase retardation.