Contribution ID: **10** Type: **Invited Poster**

High bandwidth linewidth reduction of a cateye laser using a lithium niobate wafer as output coupler and intracavity modulator

Laser linewidth narrowing is critical to advances in frequency standards and metrology, including optical clocks, trapped ion qubit manipulation, gravity wave detection, and quantum sensing. Common feedback actuator mechanisms include piezoelectric transducers and laser diode injection current, but non-linear crystal electro-optic modulators (EOMs) are preferred for their higher bandwidth and reduced secondary effects such as amplitude modulation. Nevertheless, they have seen little application to tunable external cavity diode lasers (ECDLs), due to high cost and high voltage driver complexity, and the difficulty of incorporating a bulk crystal into an ECDL which usually has a short cavity to minimize mode-hopping.

We show that an intracavity modulator can easily be incorporated into a cateye laser; that is, an ECDL with an intracavity filter for wavelength tuning, and optical feedback from a cat's-eye reflector [1]. We use a small chip from a lithium niobate (LN) wafer as the partially reflective output coupler at the focus of the cat's-eye. Gold electrodes allow modulation of the refractive index and thus optical cavity length and lasing frequency. The electrodes can be closely spaced because of the tight cateye focus, and thus the frequency modulation sensitivity is relatively high, in our example 1 MHz/V. The ECDL free-running linewidth is typically of order 50 kHz, so that feedback voltages of below 1 V are sufficient to compensate for the fluctuations of the free-running laser, removing the need for a high-voltage driver. We measured the –3 dB modulation bandwidth to be 25 MHz without any attempt at impedance matching, a closed-loop bandwidth of 5 MHz, and final laser linewidth below 1 Hz [2].

References
[1] DJ Thompson and RE Scholten, "Narrow linewidth tunable external cavity diode laser using wide bandwidth filter,"Rev. Sci. Instrum., vol. 83, no. 2, p. 23107, 2012.
[2] S Palmer, SA Boes, G Ren, TG Nguyen, SJ Tempone-Wiltshire, N Longhurst, PM Farrell, A Steiner, ChD Marciniak, T Monz, A Mitchell and RE Scholten, High bandwidth frequency modulation of an external cavity diode laser using an intracavity lithium niobate electro-optic modulator as output coupler, APL Photonics, vol. 7,086106, 2022.

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Track Classification: Precision and Low Noise Signal Generation and Techniques