

Wavelength-Locked Loops for Optical Communication

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The optical community has shown considerable interest in wavelength tunable lasers for optical communications. Applications include wavelength division multiplexing (WDM) and optical amplifiers with dynamic gain equalization. Tunable lasers provide lower cost, increase unrepeated distance and reduce crosstalk. They can also compensate for wavelength drift due to semiconductor laser aging and environmental effects.

Current approaches suffer from the need for additional etalons, sensitivity to noise at their zero crossings and non-signed error signals requiring calibrated differential receivers.^{1,2,3} We have developed a new feedback technique called a wavelength-locked loop (WLL).^{4,5} It offers advantages over existing thermal- or etalon-based tuning, producing a bipolar, signed error signal proportional to the desired wavelength offset and a unique frequency-doubled signature when the laser is locked to the desired wavelength.

The WLL can potentially eliminate thermoelectric cooling in tunable lasers; it

is also self-calibrating, as it locks the laser wavelength to an external wavelength-selective device such as an optical filter. This filter is ideally a peaked function such as a Gaussian frequency profile. However, variations on the WLL use derivative signal processing to accommodate nonlinear filters.

The basic WLL uses dual amplitude modulation with a desired data stream and a low frequency dither, inducing a corresponding dither in the laser center wavelength. The laser optical output passes through a bandpass filter (or other wavelength-selective element), which converts the laser wavelength modulation into an intensity modulation. About 1 percent of the filtered light is sampled and converted into an electrical feedback signal by a PIN photodiode, which is used to calculate a vector cross-product with the original dither modulation.

When the laser center wavelength is locked to the filter peak, the vector product is frequency doubled. As the laser wavelength drifts either above or

below the filter peak, the filtered signal is at the same dither frequency but is either in phase or out of phase with the original dither modulation.

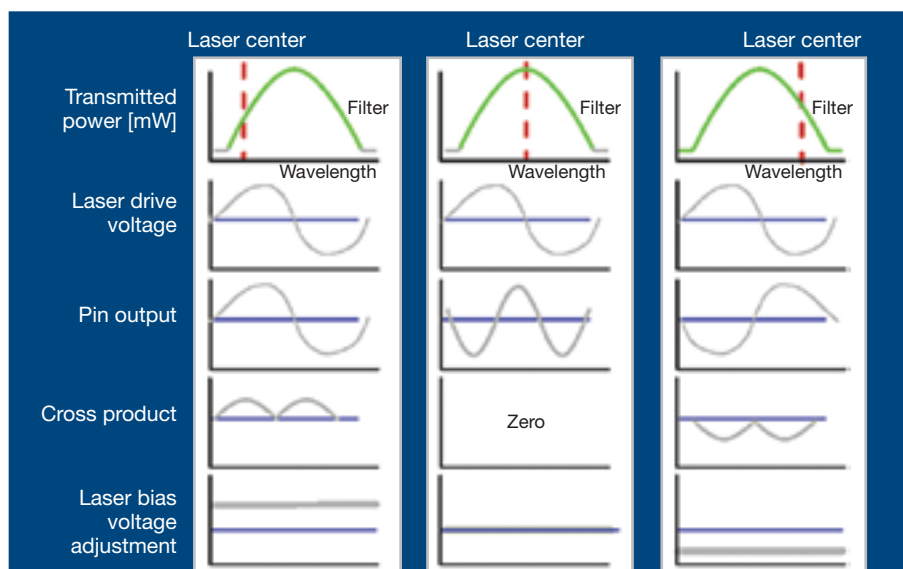
The vector cross-product is then low pass filtered and averaged, producing a bipolar error signal proportional to the offset between the laser center wavelength and the bandpass filter. The error signal is positive or negative depending on whether the laser's center wavelength is less than or greater than the filter peak. The error signal is thus used to correct the laser wavelength; an optional external tuning circuit can be added to introduce a controlled offset between the laser and filter—for example, to design a variable optical attenuator or dynamic gain equalizer.

The WLL technique has been experimentally demonstrated using a very low frequency dither (2 Hz), a commercially available, non-Gaussian ITU grid 4-channel DWDM filter (Nortel Optera 5200 4H2395), and a standard DFB laser (Lasertron 9127023 2LM715-11925) with 10 mW output power.⁴ A stable tuning range of 3.2 nm was realized around a nominal wavelength of 1,553.5 nm without the use of a separate thermoelectric cooler. ▲

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References

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Feedback signals generated in a wavelength-locked loop. The three columns illustrate cases where the laser center wavelength is below the filter peak, at the filter peak and above the filter peak.