A ”dual”, feed-forward + feed-back frequency control for efficient and convenient diode laser line narrowing
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DFB diode lasers have linewidths in the MHz range. Narrowing the linewidth can be obtained by locking the diode to a frequency discriminator (Michelson interferometer, ...). But the lock bandwidth has to reach 10 MHz or higher.

The current-to-frequency transfer function of DFB lasers is complex: thermal effects at low frequency, carrier physics at high frequency, and a [1MHz-20MHz] transition zone in which the phase and amplitude show variations that prevent from locking in the MHz range.

Adding a phase modulator in feed-forward (FF) configuration allows convenient control of the laser frequency, in excess of 15MHz, and convenient-efficient line narrowing with commercial, off-the-shelf components of the telecom industry.

**Pros and cons**

<table>
<thead>
<tr>
<th>Feed-back</th>
<th>Feed-forward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer function design</td>
<td>Not difficult, integrator around 0kHz^{*}</td>
</tr>
<tr>
<td>Transfer function implementation</td>
<td>Some</td>
</tr>
<tr>
<td>Low noise reduction factor</td>
<td>Large low frequency signal (kHz)</td>
</tr>
<tr>
<td>Overshoot at unity gain</td>
<td>If ph. with gain or phase margin</td>
</tr>
<tr>
<td>&quot;loop&quot; delay</td>
<td>Usually compensated by same delay on the loss path</td>
</tr>
<tr>
<td>Non-linearity of the error function</td>
<td>Generally not a problem</td>
</tr>
<tr>
<td>Lock loop stability</td>
<td>Possibly critical</td>
</tr>
<tr>
<td>Efficiency measurement</td>
<td>Requires extra error measurement</td>
</tr>
</tbody>
</table>

{^*} Unit gain frequency

**Implementation**

1. **1.54 μm diode laser + driver**
2. **Electrooptic phase modulator**
3. **Thermal control**
4. **Current feedback correction signal**
5. **Phase feedback correction signal**
6. **Optical frequency discriminator**
7. **Feed-forward correction**
8. **Spectral narrowing @ 125mA**

**Characterization**

1. **Spectral narrowing vs laser diode current**
2. **Occupied bandwidth** of the free-running laser

**Conclusions**

Feed-forward is the ideal frequency control when using large bandwidth electrooptic phase modulator. Control bandwidth >1MHz if delays are compensated by a fiber roll (impossible with a nested loop).

Achieves narrowing of DFB diodes, with 4kHz FWHM.

More than 99% opt. power in the ±150kHz central peak.

Implementation using off-the-shelf telecom components @ 1.5μm and commercial servos.

Settings (gain, ...) are stable. If current change needed, gain has to be re-adjusted => a "monitor" interferometer helps in finding new optimum settings.

@ λ ≤ 1.0μm Faraday mirrors may be available => replace FM with PM fiber and gold-coated mirrors.