A "dual", feed-forward + feed-back frequency control for efficient and convenient diode laser line narrowing

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Abstract

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 15 MHz, and convenient+efficient line narrowing with commercial, off the shelf components of the telecom industry.
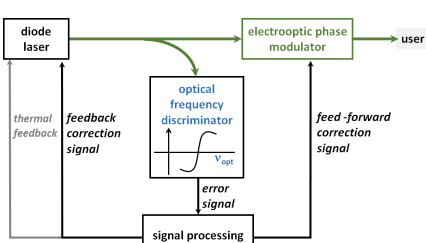
Current to optical frequency transfer function
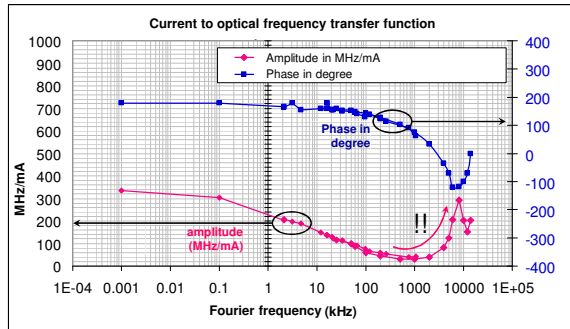
double ("nested") feed-back loop?
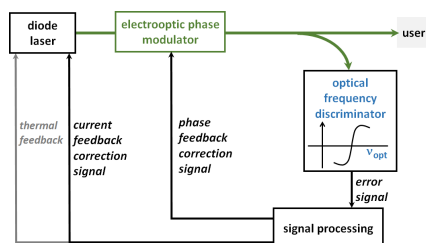
**Difficult to implement
(loop delay, complicated transfer function)**

## Instead, prefer "dual", feed-back + feed forward control...

...using an integrated electrooptic phase modulator

pros and cons

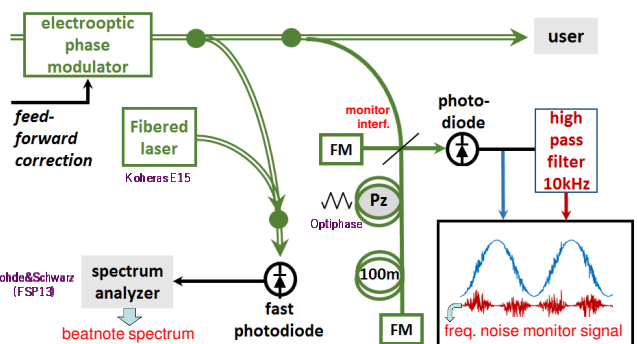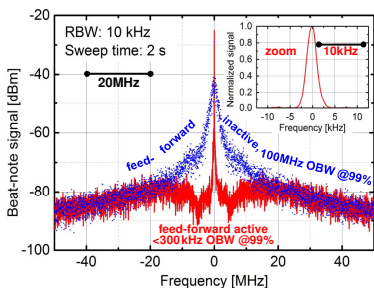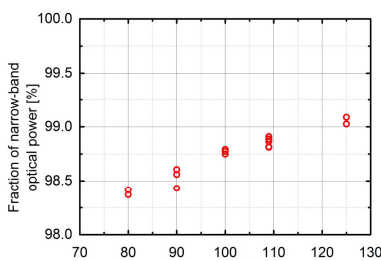|	feed-back	feed-forward
transfer funct. design	Not diffic.: integrator around UGF*	easy: error + corr=0 => G=-1 !
transfer funct. implementation	same	G=-1 over the whole bandwidth !
large noise reduction factor ?	large loop gain (1/f^n)	G very close to -1 !
overshoot at unity gain	if pb. with gain or phase margin	no
"loop" delay	limits bandwidth	easily compensated by same delay on the beam path
non-linearity of the error function	usually not a problem	can degrade efficiency
lock loop stability	possibly critical	irrelevant (except saturation)
efficiency assessment	measure error signal PSD or RMS	requires extra error measurement
finding the correct settings	generally not critical	critical if high efficiency expected
		ideal if actuator has a flat gain !
	(*) UGF = unit gain frequency	
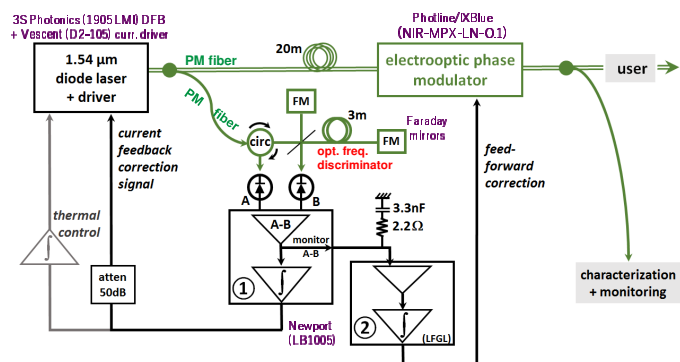
implementation — and — characterization
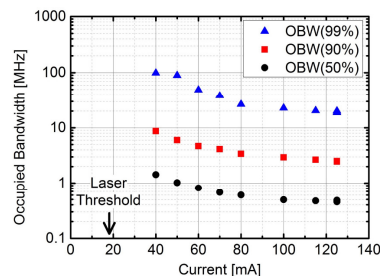

Spectral narrowing @ 125mA

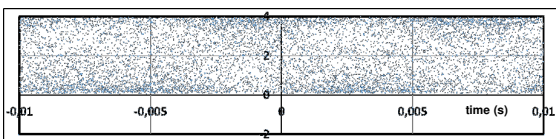### Spectral narrowing vs laser diode current

"occupied bandwidth" of the free-running laser
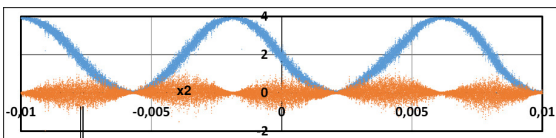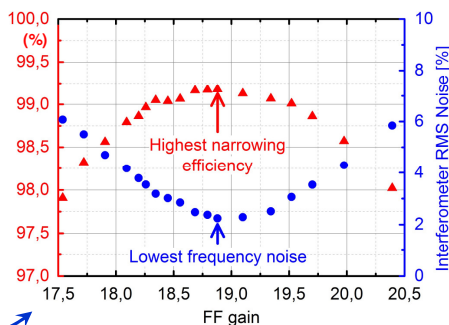

"monitor interferometer" signal ...

without feed-forward

with feed-forward active

high-passed signal x2, measures residual freq. noise

... helps in finding the optimum FF settings

Highest narrowing efficiency

Lowest frequency noise

conclusions

Feed-forward is the ideal frequency control when using large bandwidth electrooptic phase modulator: control bandwidth >15MHz, 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 readjusted => a "monitor" interferometer helps in finding new optimum settings

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