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Microwave-optical fiber lasers stabilized by frequency-shifted feedback



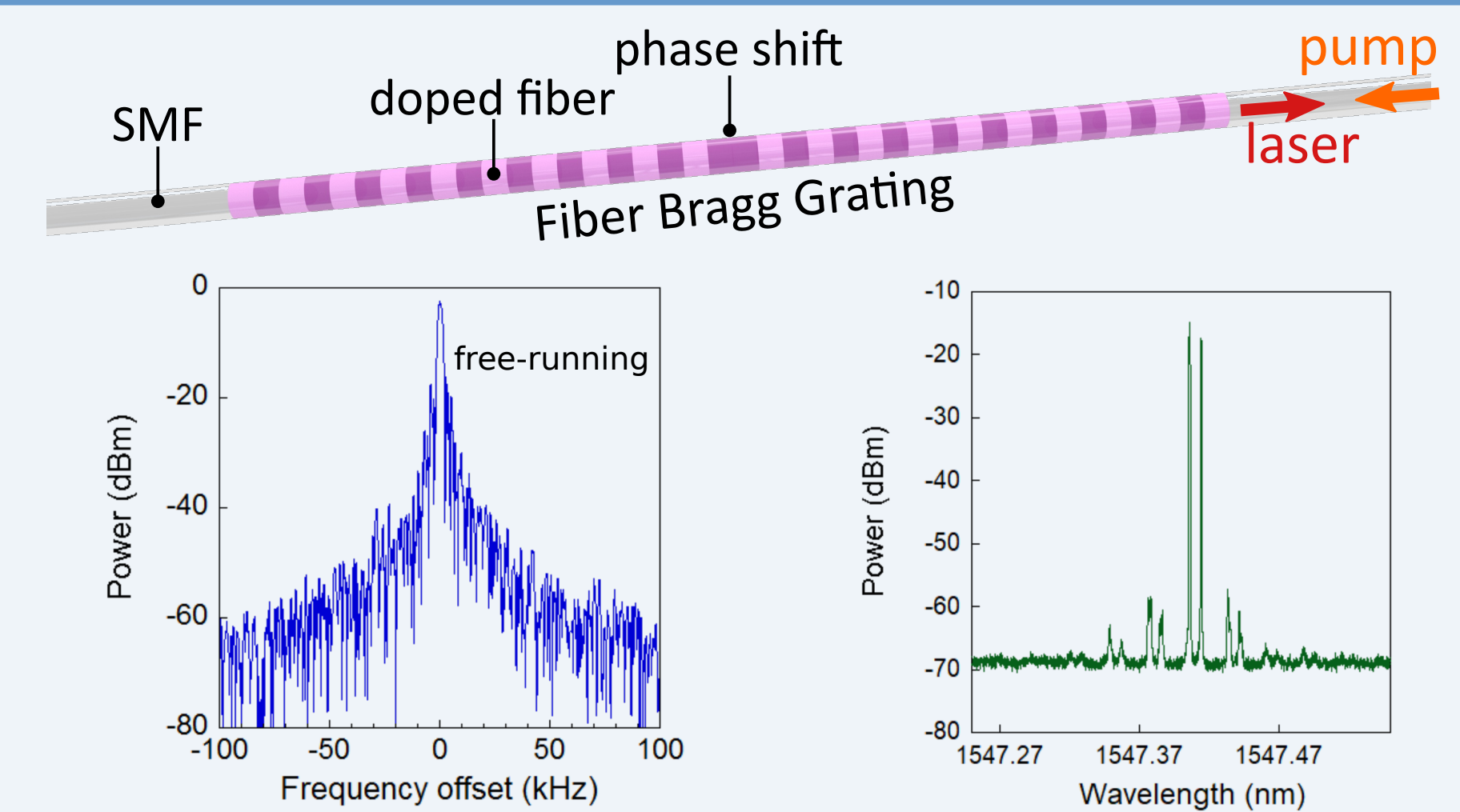
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Distributed-feedback (DFB) fiber lasers can sustain the oscillation of two orthogonal polarizations[1]. Such dual-frequency fiber lasers could be used as sensors or as a microwave optical source.

➡ Phase stabilization needed for microwave photonics applications.

Solutions ? OPLL[2] but uses pump power as the actuator.

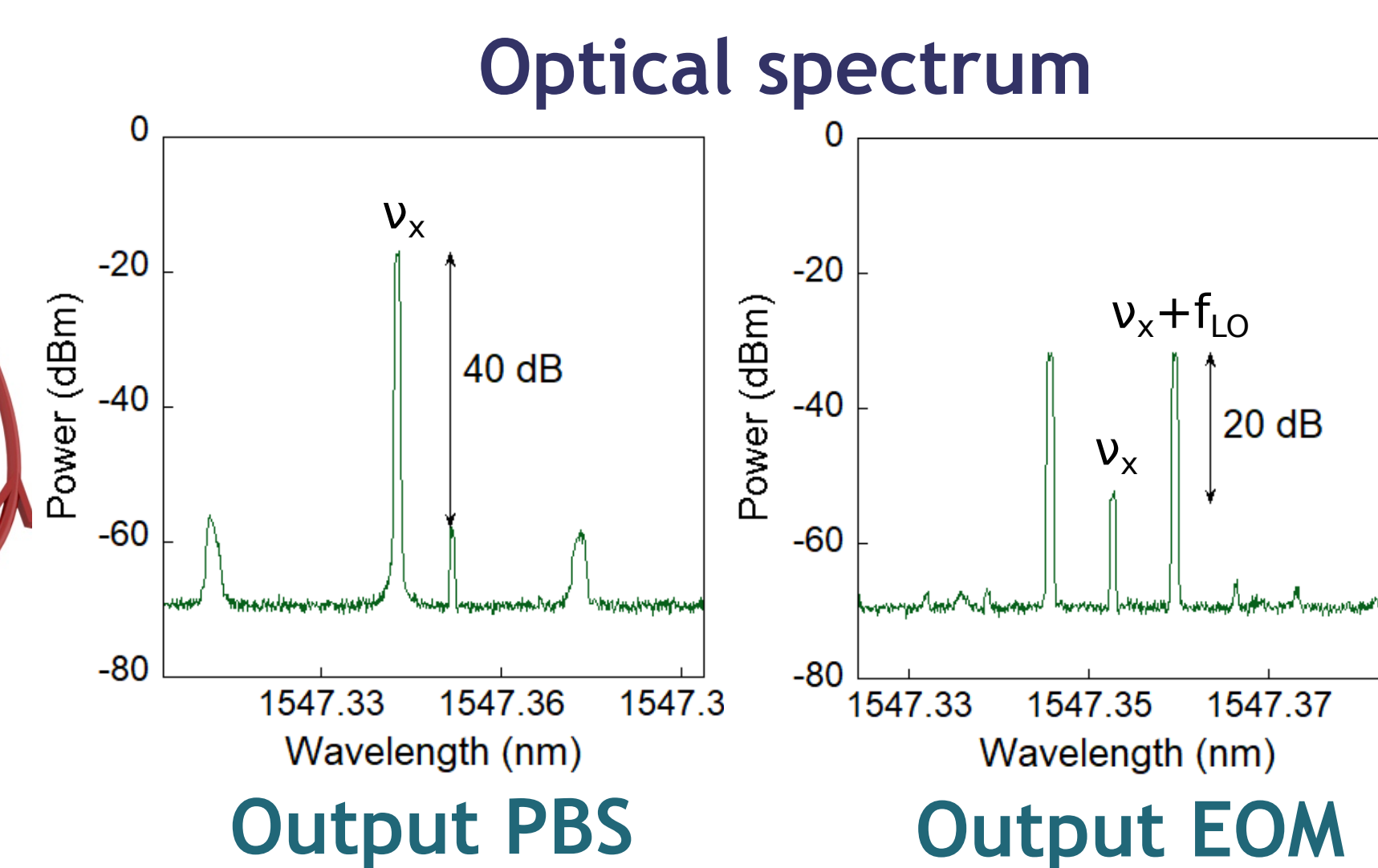
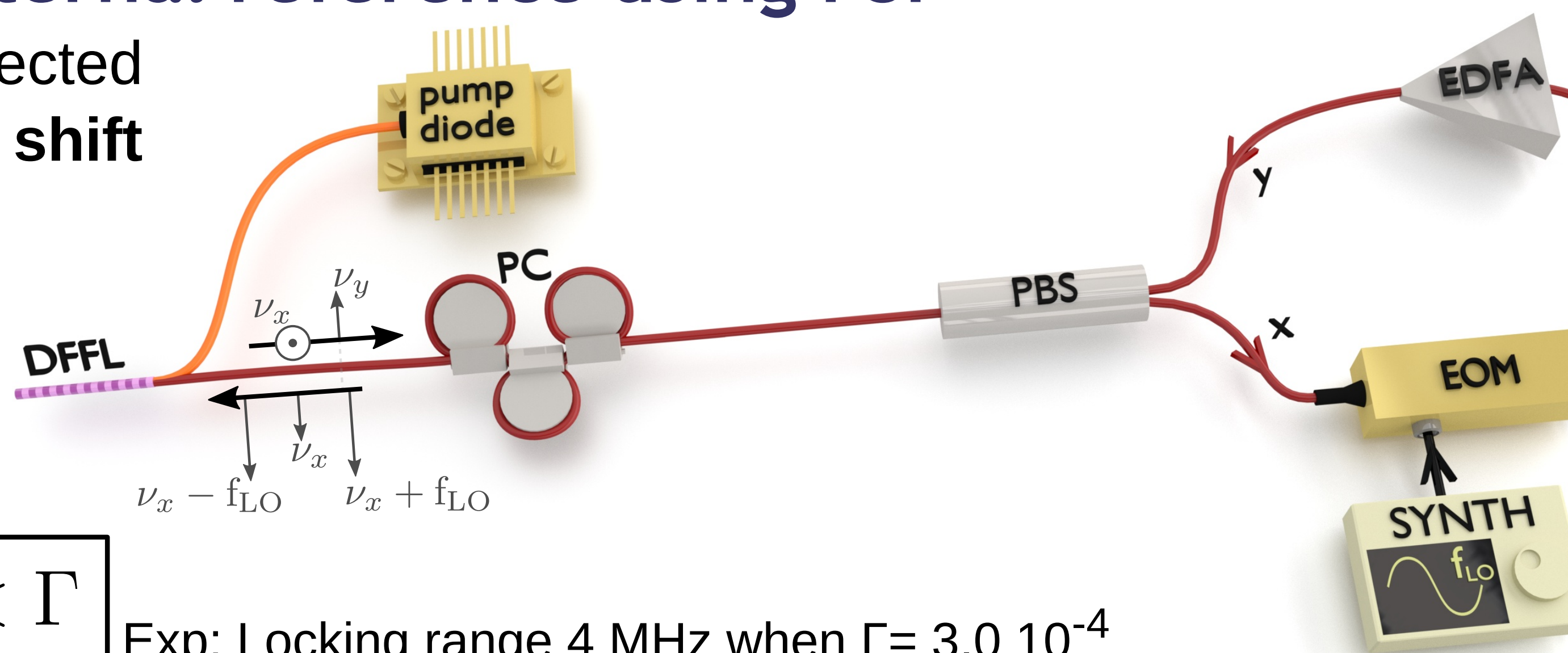
➡ Frequency-shifted feedback (FSF) as in bulk lasers[3]?



Stabilization on an external reference using FSF

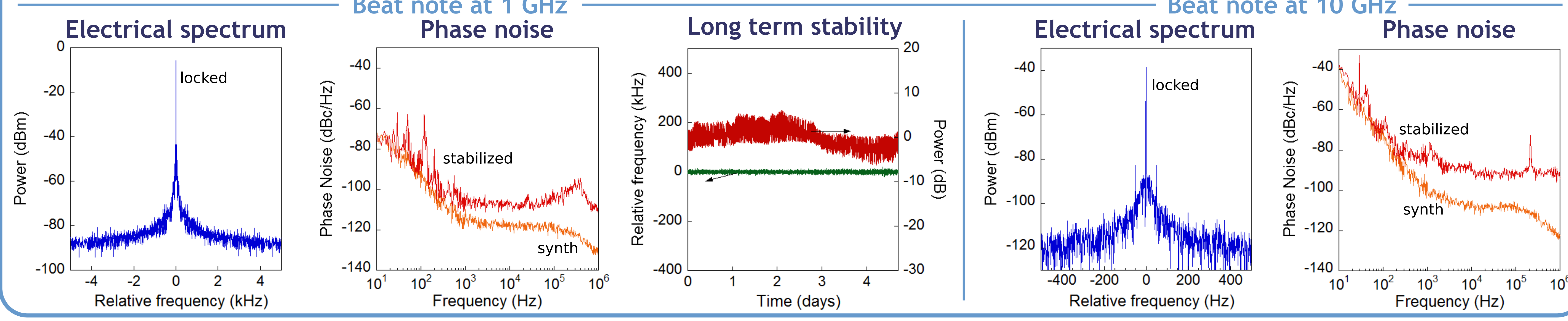
One laser mode (x) is re-injected in the laser after frequency shift and polarization rotation

Detuning: Δ
 $\Delta = \nu_y - (\nu_x + f_{LO}) = f_b - f_{LO}$
 Reinjection rate: Γ



Frequency locked if $\Delta < \Gamma$ Exp: Locking range 4 MHz when $\Gamma = 3.0 \cdot 10^{-4}$

Results for two different DFBs

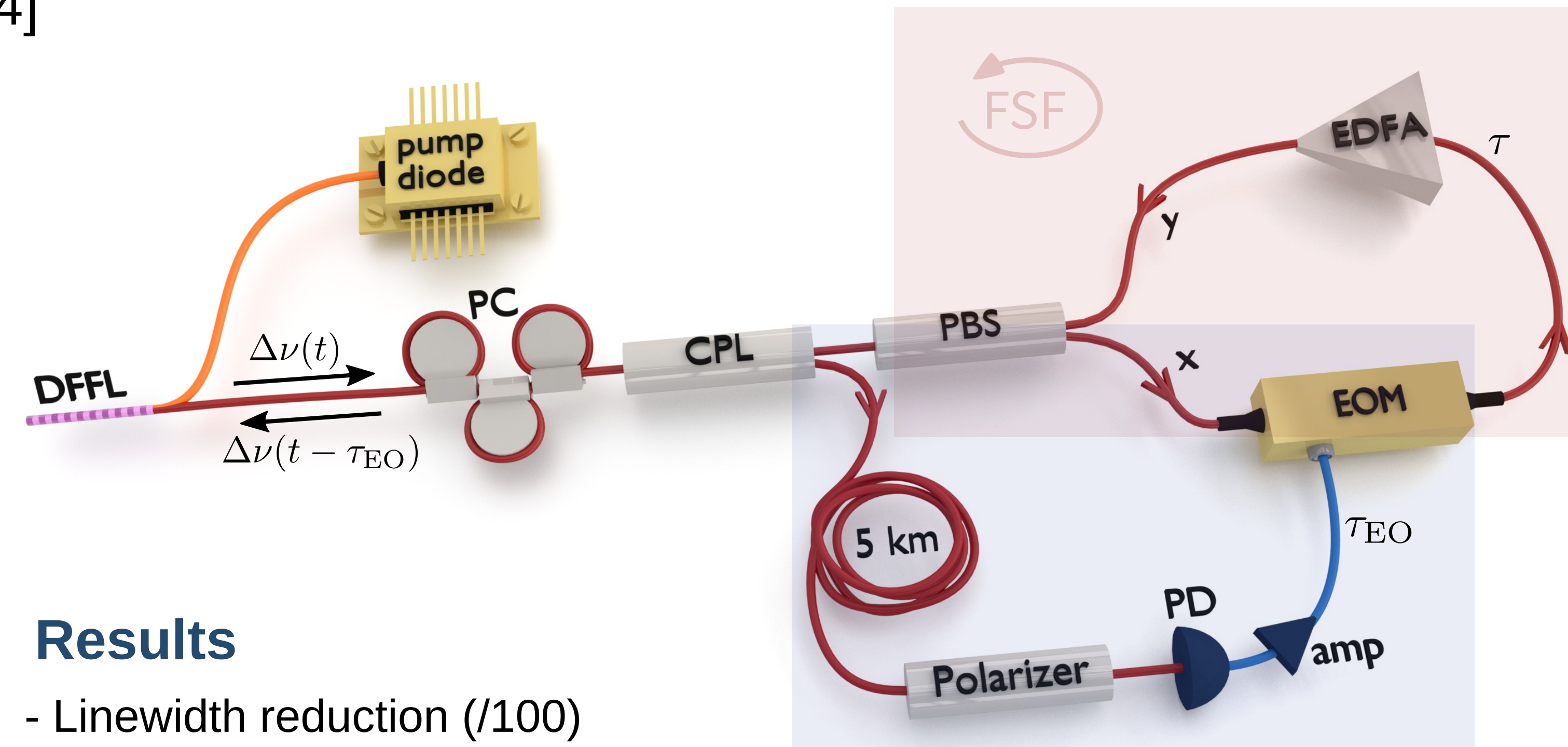


Self-stabilization using FSF and a delay-line

Hybrid opto-electronic (OEO) scheme[4]

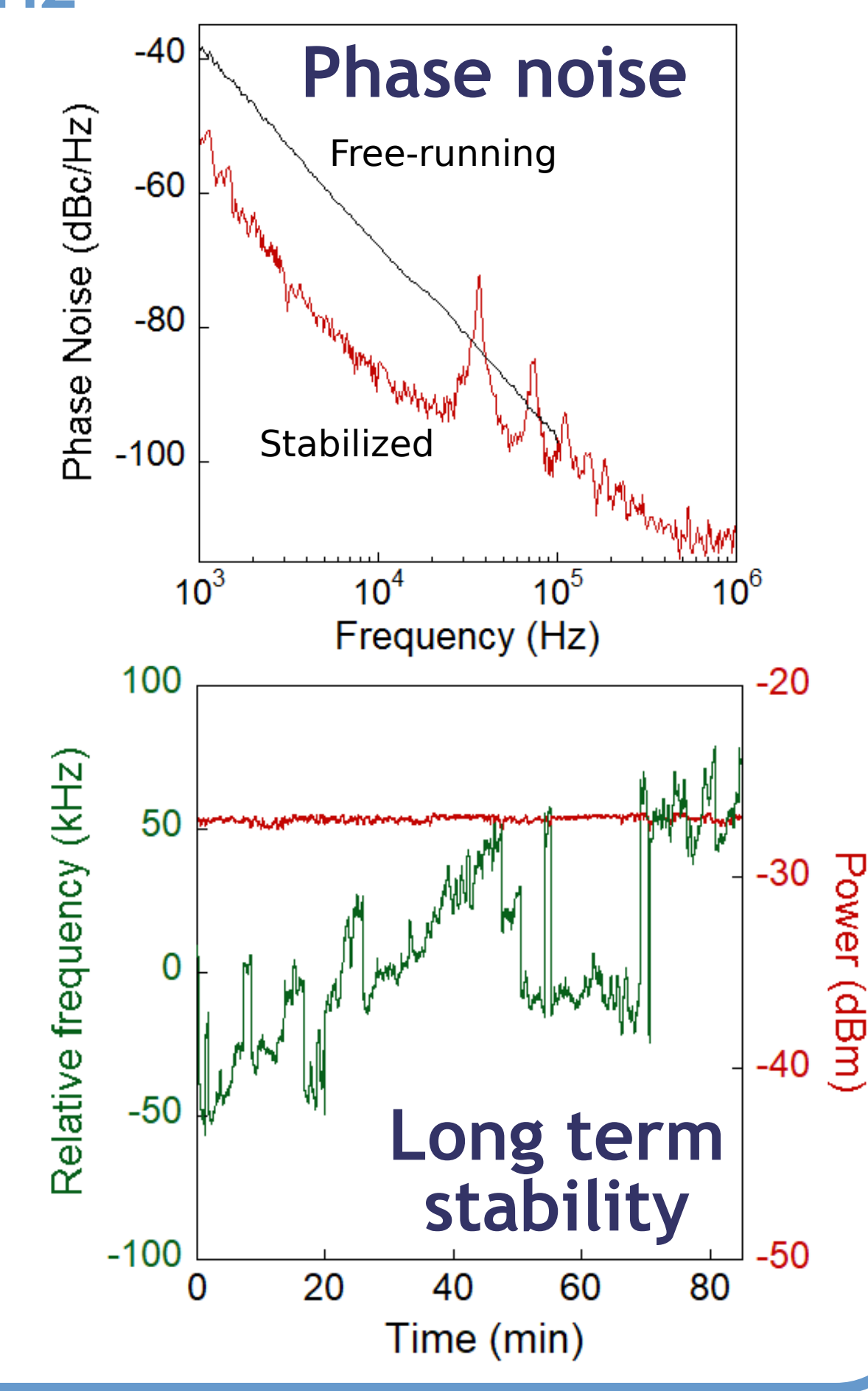
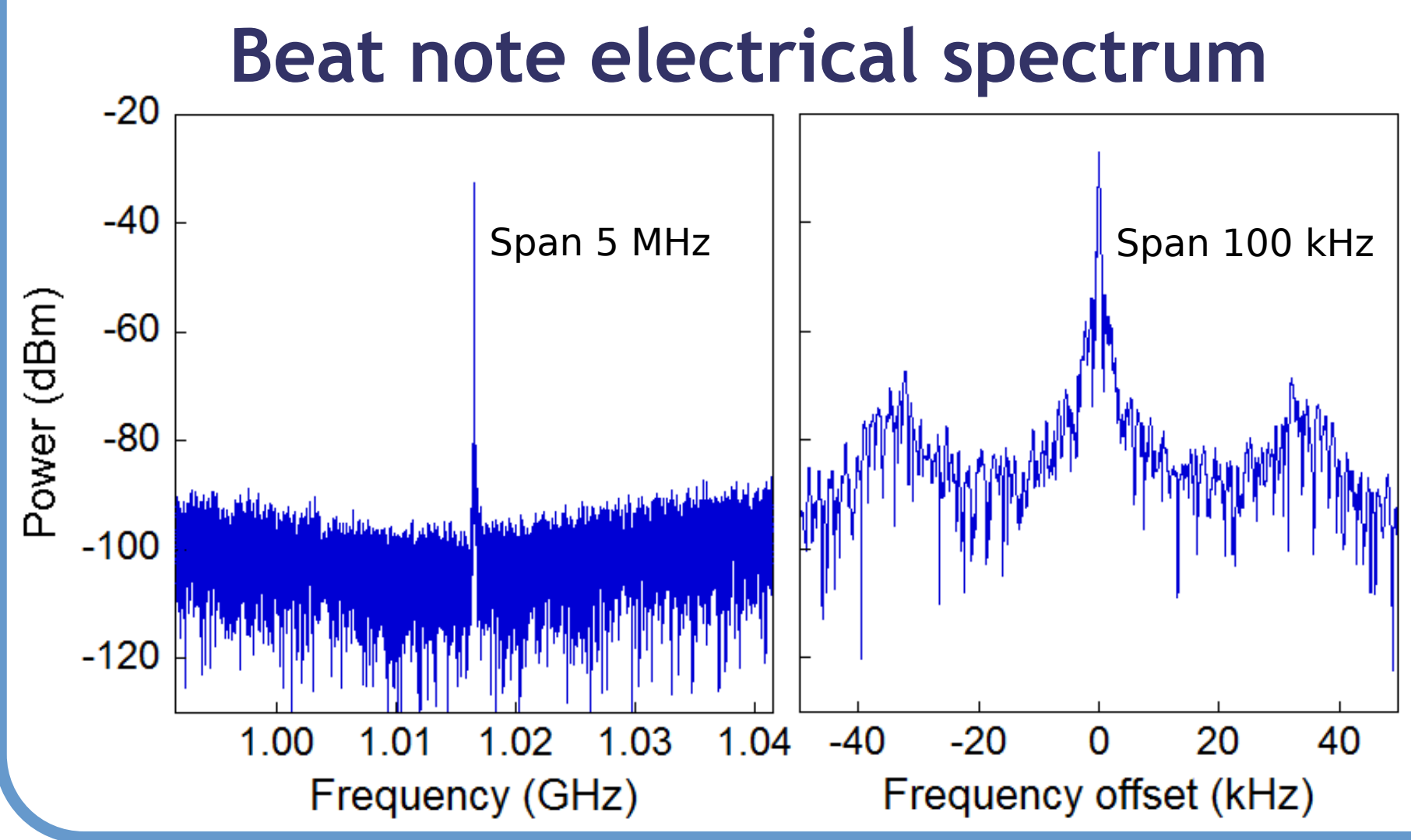
Dynamics governed by:

Relaxation oscillation	$\tau_r \approx 5 \mu s$	200 kHz
FSF loop	$\tau = 50 ns$	20 MHz
OEO delay line	$\tau_{EO} = 25 \mu s$	40 kHz



Results

- Linewidth reduction (/100)
- Few mode hops (40 kHz)
- No RF filter needed (20 MHz resonances filtered by the laser)



Conclusions

- Proof-of-principle of both methods validated
- Methods are independent of the carrier (within limit of EOM bandwidth)
- Reduction of linewidth (at least 100 times) and phase noise (better results on external reference than in the OPLL case)

Perspectives

- Simulation of the laser dynamics with a rate-equation model ✓
- Study on different fiber laser architectures (DBR) ✓
- Increase the beat note for communication application (5G)

References

[1] W. H. Loh and R. I. Laming, "1.55 μm phase-shifted distributed feedback fibre laser", *Electron. Lett.* 31(17), 1440-1442 (1995).
 [2] L. Keruevan *et al.*, "Beat note jitter suppression in a dual-frequency laser using optical feedback", *Opt. Lett.* 32(9), 1099-1101 (2007).
 [3] M. Guionie *et al.*, "Beat note stabilization in dual-polarization DFB fiber lasers by an optical phase-locked loop", *Opt. Express* 26(3), 3483-3488 (2018).
 [4] M. Vallet *et al.*, "Self-stabilized optoelectronic oscillator using frequency-shifted feedback and a delay-line", *IEEE Photon. Technol. Lett.* 28(10), 1088-1091 (2016).

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