Dual-polarization DFB fiber laser stabilized by frequency-shifted feedback

Marie Guionie[1], Aurélien Thorette[1], Marco Romanelli[1], Emmanuel Pinsard[2], Laurent Lablonde[2], Benoît Cadier[2], Marc Vallet[1], Marc Brunel[1]

1. Univ Rennes, CNRS, Institut FOTON - UMR 6082, F-35000 Rennes, France

2. iXBlue Photonics, Rue Paul Sabatier, 22300 Lannion, France

Distributed-feedback (DFB) fiber lasers can sustain the oscillation of two orthogonal polarizations at different frequencies, due to the fiber Bragg grating UV-induced birefringence [1]. Such dual-frequency fiber lasers (DFFL) are promising as heterodyne sources but, in the context of microwave photonics, the stabilization of the beat frequency becomes necessary. Locking the beat frequency of a dual-frequency laser to a local oscillator by optical frequency-shifted feedback (FSF) has been proved to be efficient [2], and can be applied in principle to any dual-polarization laser. Here we investigate this FSF method to an Er^{3+}- doped DFB fiber laser, resulting in an all-fibered 1.5µm system emitting a stabilized beat note at 1 GHz.

The set-up is depicted in Fig. 1(a). The DFFL is pumped at 976 nm through the WDM and emits at 1547 nm two orthogonal polarizations (with associated frequencies ν_x and ν_y). The free-running beat note is around 1 GHz; its line-width is equal to 3 kHz and presents a drift of a few MHz over hours [3]. The polarization-maintaining FSF loop is based on a polarization beam splitter whose output ports are closed on one another after passing through the frequency shifter, here an intensity modulator EOM driven at f_{LO}, and an optical isolator. The polarization controller PC permits to select one of the polarization states, say ν_x ($\nu_x < \nu_y$), which is re-injected into the laser. The EOM thus generates two sidebands at frequencies $\nu_x \pm f_{LO}$. Hence, for a small detuning $\Delta\nu = f_{LO} - (\nu_y - \nu_x)$, the re-injected field contains an optical sideband resonant with ν_y. Intracavity coupling can then lead to frequency locking between ν_y and the $\nu_x + f_{LO}$ component of the reinjected field. This results in the transfer of the spectral purity from f_{LO} to the beat frequency (ν_y - ν_x).

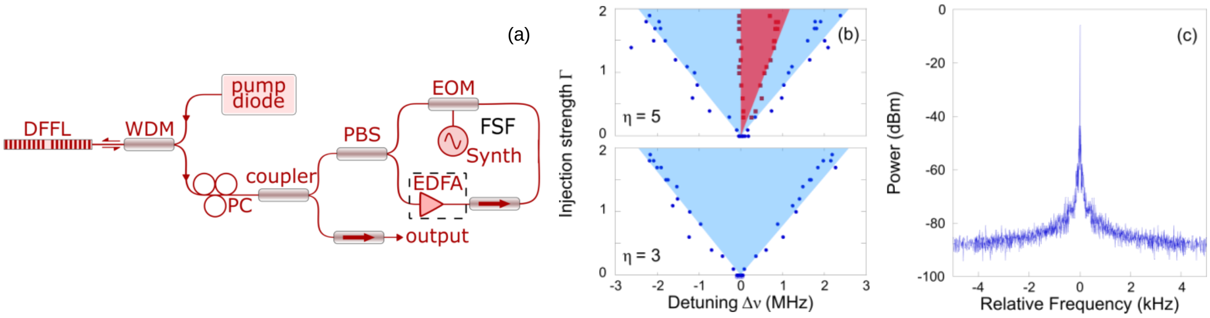

Fig. 1 (a) Experimental scheme. The optional EDFA permits here to control the re-injected power. **(b)** Normalized injection strength Γ with respect to the detuning Δν at two different excitation ratios η. Colored areas delimit the different regimes. White: unlocked, blue: locked, red: intensity modulated. **(c)** RF Spectrum of the locked DFFL beat.

The observed dynamics depend on both detuning Δν and injection strength Γ. First, we find a frequency locking between the beat note and the synthesizer, delimited by the experimental blue points (see Fig. 1(b)), over a 4 MHz range at maximum injection strength. Then, at larger excitation rates, the laser may display a complicated, possibly chaotic dynamics on the $\Delta\nu > 0$ side (delimited by the red points). In the locking zones, the stabilized beat frequency exhibits a narrow linewidth, smaller than 1 Hz (see Fig. 1(c)). The associated phase noise is measured to be –100 dBc/Hz at 1 kHz from carrier. The laser remains phase-locked for days in laboratory conditions.

Such stabilization scheme based on an EOM is advantageous in terms of carrier tuning, compactness and integration, and could find application in, e.g., radio-over-fiber. To this aim, similar studies on DFFL at higher frequencies are under investigation. Finally, it is interesting to note that the linewidth enhancement factor of such lasers could be measured using this stabilization scheme [4].

References

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