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High-Definition Optical Frequency Comb Detection

Passively mode-locked lasers are well known in the ultrafast laser community to intrinsically produce a free-running and clean frequency comb, which can be converted into a fully stabilized comb by providing feedback on two parameters, f_{CEO} and f_{rep}. Frequency combs with line spacing at 1 GHz has been demonstrated [1], nevertheless individual comb lines are unresolved with standard OSA.

We describe here how the MENHIR-1550 laser with 1 GHz comb line spacing can be directly and easily characterized using the Brillouin Optical Spectrum Analyzer (BOSA) from Aragon Photonics [2]. The BOSA is capable of 10 MHz absolute resolution with unprecedent repeatability. Combined with the passive stability of the MENHIR-1550, individual comb lines of the laser are resolved allowing to detect precise changes on f_{CEO} and f_{rep} without the need for additional optical sources.

Menhir Photonics' product strengths

Excellent passive repetition rate stability

Compact all-in-one design

Aragon Photonics' product strengths

Full spurious-free dynamic range

10 MHz pure optical resolution

Application use case

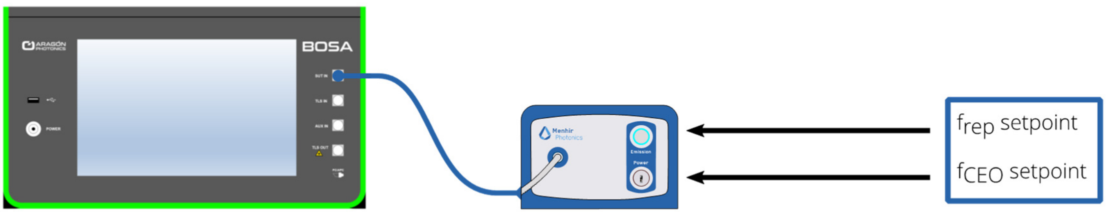

Figure 1 — The MENHIR-1550 is directly connected to the BOSA which can sustain directly the 50 mW laser output. f_{CEO} and f_{rep} setpoint can be programmed by computer in the MENHIR-1550 hardware. The BOSA measures the performance of the free-running MENHIR-1550.

Wide- and short-band spectrum

The BOSA is a high-resolution spectrum analyzer based on the Stimulated Brillouin Scattering (SBS). This technology creates a very narrow pure optical filtering effect of 10 MHz in the fiber optic that is used to scan the system under test with unmatched spurious-free dynamic range (80 dB). The Figure 2 shows the large-scale spectrum of the MENHIR-1550 when directly plugged into the BOSA. The overall spectrum follows the $sech^2$ shape as it is expected from passive mode-locked lasers. Zooming into a portion of the spectrum (in red in Figure 2) allows to unveil the capacity of the BOSA in resolving the individual comb-lines of the MENHIR-1550 (1 GHz = 0.008 nm spacing in that case). This is possible thanks to the high stability of the MENHIR-1550 which ensures that the f_{CEO} and f_{rep}, the two parameters defining the output comb, are not varying with time. Although the intrinsic linewidth of an individual comb-line (<10 kHz) is below the 10 MHz resolution of the BOSA, all the spectral lines of the comb can be assessed as the frequency separation between spectral lines is much higher.

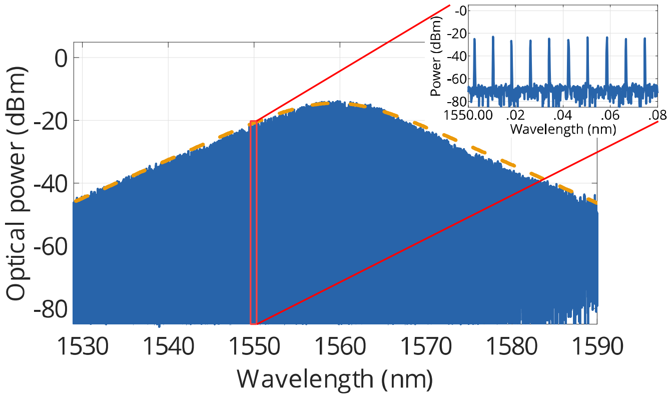

Figure 2 — Full-scale spectrum measurement of the MENHIR-1550 laser. The overall shape follows the sech² shape (orange dashed-line) as expected for mode-locked oscillators. SNR of more than 60 dBm is shown. Inset: Zoom into the red portion of the main graph. Thanks to the high free-running stability of the MENHIR-1550, individual comb line separated by 1 GHz (0.008 nm = 8.1 pm) are resolved.

Changing the repetition rate f_{rep}

The MENHIR-1550 femtosecond laser has all the inputs to stabilize the two comb parameters (f_{rep} and f_{CEO}). Each comb line is defined exactly by $f = f_{CEO} + n\, f_{rep}$, in which n is an integer with a value close to 200'000. Figure 3 depicts the effect of a slight variation of the repetition rate of +1 kHz to the base repetition rate frequency of the laser of 1.0 GHz exactly. The orange trace compared to the blue one is displaced to higher frequencies (i.e. smaller wavelength), due to the slightly more spaced comb lines at constant f_{CEO}.

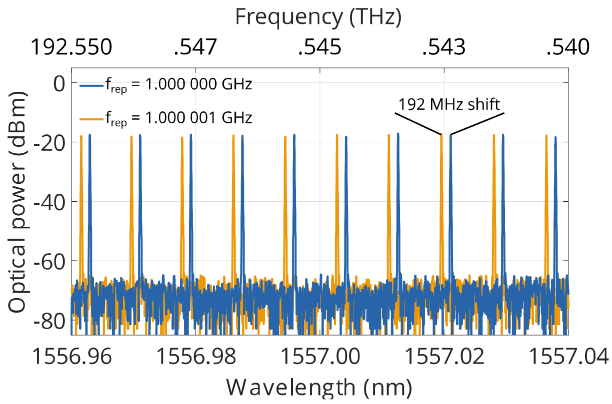

Figure 3 — By changing f_{rep} by a small amount of +1 kHz, i.e. 1 ppm, each comb line has a small additional spacing between them. At optical frequencies of 192 THz, this incremental spacing is observed as a shift of 192 MHz of the comb toward higher frequencies, i.e. smaller wavelengths.

References

1. D. M. B. Lesko, A. J. Lind, N. Hoghooghi, A. Kowligy, H. Timmers, P. Sekhar, B. Rudin, F. Emaury, G. B. Rieker, S. A. Diddams, *Fully phase-stabilized 1 GHz turnkey frequency comb at 1.56 µm*, OSA Continuum **3**, 2070 (2020)
2. J. M. Subías Domingo, J. Pelayo, F. Villuendas, C. D. Heras, and E. Pellejer, *Very High Resolution Optical Spectrometry by Stimulated Brillouin Scattering*, IEEE Photonics Technol. Lett. **17**, 855 (2005)

Related product

MENHIR-1550 at 1.0 GHz		BOSA 400	
Repetition rate	1.0 GHz	Resolution	10 MHz
Average power	> 50 mW	SFDR	>80 dB
Central wavelength	1555 +/- 10 nm	Band cover	S, C, L & O bands
Spectral bandwidth at -3 dB	> 10 nm	Wav. repeatability	± 0.5 pm

Contact & Info

For further information, please contact Menhir Photonics at contact@menhir-photonics.com, or Aragon Photonics at info@aragonphotonics.com. Find more videos and tutorials on this topic in our Youtube channel.