

stretched-pulse regime. The RIN of mode-locked fiber lasers obtained at zero cavity dispersion and negative cavity dispersion is lower than that of positive cavity dispersion in the high offset frequency (>30 kHz), which is similar to the timing jitter measurement results shown in Fig. 3. The lowest RIN can be obtained at close-to-zero intracavity dispersion conditions (-0.004 ps² to 0 ps² range), which is consistent with the recent study in [24]. The lower RIN at slightly negative dispersion might be due to the soliton-like pulse formation effect in negative dispersion as explained in [28].

5. Conclusion and discussion

In this paper, we characterized the high-frequency timing jitter and RIN of free-running, stretched-pulse Yb-fiber lasers operating at close-to-zero intracavity dispersion. The measured lowest rms timing jitter is 175 as when integrated from 10 kHz to 40 MHz offset frequency. To our knowledge, this result corresponds to the lowest high-frequency timing jitter from mode-locked fiber lasers so far. This result demonstrates that standard free-running, NPE-based fiber lasers can achieve timing jitter (and equivalent phase noise) performance comparable to solid-state crystal lasers [15,16] and the best commercial microwave sources (such as sapphire-loaded cavity oscillators) with much reduced cost and engineering complexity. Another interesting finding is that both the lowest timing jitter and RIN can be obtained in a narrow range of close-to-zero dispersion (in this work, from -0.004 ps² to 0 ps²), which is fairly consistent with the recent study on the optimization of f_{ceo} noise at zero dispersion [24]. Since choosing the right mode-locking condition at a given intracavity dispersion is also important for the optimization of timing jitter, the BOC method can be used as an ultra-sensitive, real-time jitter monitor to find and maintain the best performance. Note that the Yb-fiber laser used in this work is not fully optimized for the lowest possible timing jitter operation because of the low cavity Q (four bounces on grating pair in one round-trip contribute 85% power loss). Higher Q fiber lasers (e.g., all-fiber implementation) operating at close-to-zero cavity dispersion are expected to have timing jitter well below 100 as in the near future.

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