All-fiber mode-locked nanosecond laser employing intracavity chirped fiber gratings

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Abstract: We demonstrate that nanosecond pulses are generated directly from an all-fiber mode-locked ytterbium-doped fiber laser. A pair of Chirped Fiber Gratings (CFGs) with different sign of dispersion is employed for intracavity dispersion management. Self-starting stabilized mode-locking operation is achieved by nonlinear polarization evolution (NPE). The 1.27 ns pulses are obtained after one CFG with large positive dispersion. The pulse energy is up to 15 nJ at a repetition rate of 3.48 MHz.

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References and links

environmental stability can be improved via polarization-maintaining fiber based laser cavity and real saturable absorbers such as carbon nanotubes.

In the process of experiment, we turned the cavity length from 28 m to 75 m and the net dispersion changed from $-0.62332 \text{ ps}^2$ to $0.41973 \text{ ps}^2$ at 1055 nm correspondingly. Mode-locking could still be obtained in such a dispersion region. However, as the absolute value of the net dispersion in the cavity increased over 0.13 $\text{ ps}^2$, mode-locking became unstable in our fiber laser. It is believed that stable mode-locking can only be obtained with the balance of dispersion and nonlinearity. It was also found that once stable mode-locking was obtained, the pump powers could be decreased to a relatively low level while maintaining mode-locking. The width of the spectrum as well as pulse duration stayed almost unchanged with the decrease of pump powers.

For the long cavity nanosecond fiber lasers, the intracavity fiber of ultra-long length induces a high nonlinear phase shift in the optical pulse, and may thus lead to wave-breaking or multiple-pulsing phenomena [21, 22]. To reduce the intracavity nonlinearity and maintain stable mode-locking in such fiber lasers, peak power of the pulse should be limited to a reasonable level, which thereby results in relatively low single pulse energy [11, 12]. In our nanosecond fiber laser, by employing CFG with negligible nonlinearity instead of a segment of ultra-long fiber, the intracavity nonlinearity is effectively confined to a lower level and the pulse energy is possible to be further increased. The single pulse energy of the nanosecond pulse reaches 15 nJ. Peak power of the pulse is below the threshold of stimulated Raman scattering (SRS), as confirmed by the output spectrum. It is believed that the pulse energy in our fiber laser can be further increased by injecting higher pump powers or employing CFGs with lower loss.

Strongly chirped pulses have been suggested as suitable for compression by anomalous dispersion compensation [9], and compression has been demonstrated in a short cavity [4]. The time-bandwidth product of the 1.27 ns pulse is estimated to be 1180, which indicates giant chirp. The nanosecond pulse is dechirped partly to picosecond pulse of 340 ps in the cavity mainly by CFG2 of negative dispersion, indicating partial pulse compressibility. However, dechirping such giant chirped pulse outside the cavity requires careful design of compressor and needs further work.

4. Conclusion

In conclusion, we demonstrated a self-starting all-fiber Yb-doped nanosecond laser. The dispersion management was performed by two carefully designed chirped fiber gratings in the ring oscillator. Self-starting, stable mode-locked, 1.27 ns pulses with single pulse energy up to 15 nJ at a repetition rate of 3.48 MHz were directly generated without external pulse stretching or amplification. This is, to the best of our knowledge, the first result of nanosecond pulse generation directly from an all-fiber mode-locked giant-chirped laser with CFGs. This fiber laser may be beneficial to all-fiber CPA systems. The pulse energy and pulse duration could be further increased via employing CFGs with lower loss and larger dispersion. The strong nonlinear effects that lead to wave-breaking may limit the single pulse energy. Further work will be devoted to the compression of the nanosecond pulse with large positive chirp.

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