Noise Properties of Mode-Locked Microjoule Thin-Disk Oscillators

V. L. Kalashnikov[1], C. Teisset[2], A. Sugita[2], O. Pronin[2], A. Apolonski[3]

1. *Institut für Photonik, TU Wien, Gusshausstr. 27/387, A-1040 Vienna, Austria*
2. *Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching, Germany*
3. *Department für Physik der Ludwig-Maximilians-Universität München, Am Coulombwall 1, 85748, Germany*

Oscillators generating tens up to hundreds of μJ femtosecond pulses at the MHz repetition rate [1] nowadays allow experiments such as direct gas ionization [2,3], where the level of intensity reaches and exceeds 10^{14} W/cm^2. One can expect soon the pump-probe experiments with short electron pulses and direct high-harmonic generation in gases, parametric mixing of the femtosecond pulses from different oscillators, coherent enhancement of the femtosecond pulses in an empty cavity [4] etc. All these experiments will benefit from low pulse timing jitter.

It is known that timing jitter for low-energy (nJ) oscillators can be as small as femtoseconds or even smaller. In this work, the issue of noise of over-μJ thin-disk oscillators operating in both negative- (NDR) and positive- (PDR) regimes is addressed for the first time to our knowledge. In agreement with the experiment, numerical simulations based on the generalized nonlinear complex Ginzburg-Landau model demonstrate 0.6-1 ps solitonic pulses with 5-7 μJ energies from an air-filled thin-disk Yb:YAG oscillator operating in the NDR at 11.6 MHz repetition rate (numerical pulse envelope and spectrum are shown in Fig. 1). It is found that variations of the pulse velocity inside the active medium have the main contribution to the resulting timing jitter. The source of the group velocity variation is the dispersion of comparatively narrow (<6 nm) gain band. Due to pump power noise (≈5%), the nosily variation of dispersion induced by gain band causes the pulse timing jitter ranging within 300-500 fs, which agrees with the measurement. The lower values of timing jitter correspond to broader pulses and larger gain/loss ratio.

In the PDR, same energy levels can be achieved for the substantially lower dispersions (see Figure) due to large stretching (≈4 ps) of the chirped pulse. Broader spectrum allows compressing the pulse down to sub-picoseconds. It should be noted, that the truncated spectrum in the PDR is asymmetric as a results of dispersion induced by gain band. A very important observation is that the timing jitter is substantially reduced (<100 fs) in the PDR. One can interpret such a result as a manifestation of strong negative passive feed-back, which is formed due to stronger spectral filtering of the chirped pulse in comparison with that of the soliton in the NDR.

In conclusion, the timing jitter of an over-μJ thin-disk oscillator operating in the NDR and the PDR is studied both experimentally and theoretically. One can conclude that the jitter ranging within 300-500 fs in the NDR results from the pump power noise affecting the dispersion, which is induced by comparatively narrow gain band. In the PDR, the timing jitter of the stretched pulse with truncated and extra-broaden spectrum is found to be suppressed substantially.

The work was supported by the Austrian National Science Fund (FWF project P20293) .

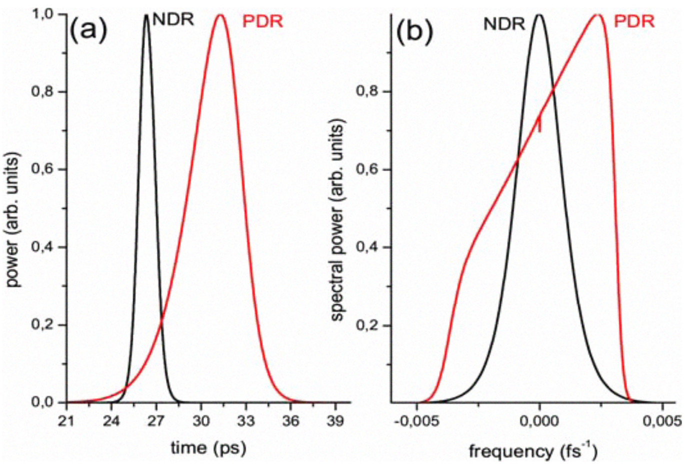

Fig. 1 The results of numerical simulations for the pulse profiles (a) and spectra (b) from the thin-disk Yb:YAG oscillator operating in the NDR (black, GDD = –22000 fs^2) and the PDR (red, GDD = 2500 fs^2).

References:

[1] T.Südmeyer, S.V.Marchese, S.Hashimoto, C.R.E.Baer, G.Gingras, B.Witzel, U.Keller, Nature Photonics **2**, 599 (2008).
[2] Ch. Gohle, Th. Udem, M. Herrmann, J. Rauschenberger, R. Holzwarth, H.A. Schuessler, F. Krausz, Th.W. Hänsch, Nature **436**, 234 (2005).
[3] Y.Lin, S.Tschuch, A.Rudenko, M.Dürr, M.Siegel, U.Morgner, R.Moshammer, J.Ullrich, Phys. Rev. Lett. **101**, 053001 (2008).
[4]. A.Ozawa, J.Rauschenberger, Ch,Gohle, M.Herrmann, D.R.Walker, V.Pervak, A.Fernandez, R.Graf, A.Apolonski, R.Holzwarth, F.Krausz, T.W.Hänsch, Th.Udem, Phys. Rev. Lett. **100**, 253901 (2008).

978-1-4244-4080-1/09/$25.00 ©2009 IEEE