Carbon nanotube saturable absorber with electrical gating for control over pulse generation regime.

Yu. Gladush[1], A. Mkrtchyan[1], V. Iakovlev[1], D. Kopylova[1], A. Khegay[2], M. Melkumov[2], A. Nasibulin[1,3]
[1] *Skolkovo Institute of Science and Technology, Nobel str. 3, Moscow, 143026, Russia*
[2] *Fiber optics research center, Vavilov str. 38, Moscow, Russia*
[3] *Aalto University, Department of Applied Physics, 00076, Aalto, Finland*
y.gladush@skoltech.ru

Abstract

Passive mode-locking is a method to produce ultra-short (from picosecond to femtosecond) pulses in laser. For its implementation one should simply insert the material with saturable absorption on laser working wavelength inside the laser resonator. It is well known that single walled carbon nanotubes (SWCNT) work perfectly as a saturable absorber for fiber laser. Conventional methods imply mixing of SWCNTs with polymer to produce a composite tabled that is clamped between two connectors. This method has a drawback of a small thermal damage threshold of a hosting polymer compared to SWCNTs. Another approach is to deposit a SWCNTs from the liquid directly on the surface of the fiber – facet, side-polished surface or tapered fiber – by thermosdiffusion or any other method. In this case one have to do additional steps SWCNT solution preparation.

In our work we use a dry transfer technic to deposit SWCNTs on a side-polished fiber [1]. For this we use SWCNTs grown by aerosol synthesis and collected on the filter. Produced SWCNT film do not have any contamination nor polymer support. This result in high stability towards thermal damage due to heating by the short pulse train propagating through the SA in laser resonator.

Another advantage is possibility of control of the absorbance of SWCNT film by ionic liquid gating. For this we have prepared an electrochemical cell in three electrode scheme where working electrode covers the surface of side-polished fiber. By applying on a working electrode voltage below 1 V we can reduce the SWCNT absorbance up to 2dB. Control over absorbance of SA allows to switch between different generation regimes [2]. We show switching of the pulse generation regimes for both anomalous and normal net dispersion laser resonators. In anomalous net dispersion regime we can change between 400 fs pulses in mode-lock regime to 2 um pulses in Q-switch regime. To take advantage of high thermal stability of SA on the side-polished fiber we also investigate pulse generation switching in normal net dispersion regime. Dissipative solitons in resonators with high normal net dispersion can have much higher energy per pulse compared to conservative soliton. We show that in this regime pulse generation can also undergo switching between mode-locking and Q-switch by changing absorption of the saturable absorber. We attribute the mechanism of the switching to change of the modulation depth of the saturable absorber: when voltage is applied the transmission of the SWCNT film increases mostly due to the saturable part of the absorption.

[1] S Kobtsev et. al., Ultrafast all-fibre laser mode-locked by polymer-free carbon nanotube film Optics Express **24**, 28768 (2016)
[2] Lee E. J. et al., Active control of all-fibre graphene devices with electrical gating. Nature Communications **6**, 6851 (2015)