Soliton molecules in a dispersion-managed Tm-doped fiber laser utilizing black phosphorus

Q. Zhang[1], M. Zhang[1*], X. Jin[1], Z. Zheng[1, 2]

[1] *School of Electronic and Information Engineering, Beihang University, Beijing, 100191, China*
[2]*Beijing Advanced Innovation Center for Big Date-based Precision Medicine, Beihang University, Beijing, 100083, China*
**Email: mengzhang10@buaa.edu.cn*

Abstract: We report the experimental observation of soliton molecules in a dispersion-managed thulium-doped (Tm-doped) fiber laser mode-locked by a black phosphorus saturable absorber (BP-SA), exhibiting both loosely bound dispersion-managed soliton pairs and three-pulse molecules.

1. Introduction

Ultrafast fiber lasers are essential tools facilitating for a variety of scientific and industrial applications, such as high precision spectroscopy, metrology and material processing[1, 2]. The management of the interplay of intracavity dispersion, nonlinearity and filtering effect has permitted the development of ultrafast lasers with various types of pulse shape. Among different pulse shapes, soliton molecules, also frequently termed as soliton-bound states, have attracted intense studies for many applications, including optical communication and logic system[3]. Soliton molecules can be experimentally observed in different dispersion regimes. Conventional soliton molecules[4] and the dissipative soliton molecules[5] are reported to be formed in the anomalous-dispersion regime and the normal-dispersion regime, respectively. Compared with these dispersion regimes, mode-locked lasers operating in the dispersion managed regime are of great importance to address the dynamics of the pulse-pulse interaction due to the large breathing ratio of dispersion-managed soliton (DMS). Here, we develop a dispersion-managed Tm-doped fiber laser mode-locked with a BP-SA, exhibiting various molecule evolutions. DMS molecules with equal separations are obtained, including loosely bound DMS pairs and three-pulse bound states.

2. Experimental setup and results

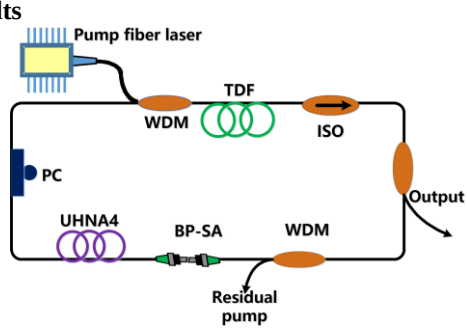

Fig.1. Schematic diagram of the Tm-doped dispersion-managed soliton laser utilizing a BP-SA

The schematic diagram is depicted in Fig. 1, including a length of thulium-doped fiber (Nufern SM-TSF-5/125) as the gain medium, co-pump by a continuous-wave 1569 nm fiber laser through a 1550/1950 nm wavelength-division multiplexer (WDM), an isolator to ensure unidirectional operation, and a 50:50 fiber optical coupler (OC). A polarization controller (PC) is used to precisely adjust the intracavity birefringence, and a length of UHNA4 is used to compensate the intracavity dispersion. The net group velocity dispersion of the cavity is estimated as 0.002 ps^2.

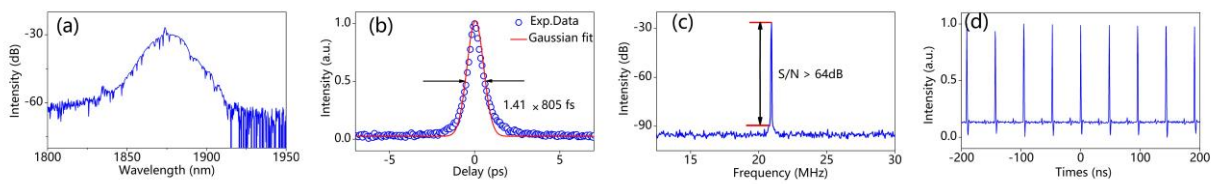

Fig. 2. Experimental results of DMS singlets: (a) optical spectrum, (b) autocorrelation trace, (c) RF spectrum, (d) oscilloscope trace.

Self-starting dispersion-managed mode-locking pulses are observed at a pump power of 490 mW. Figure 2 shows the features of the DMS at a pump power of 820 mW. The optical spectrum of the DMS singlet with a central wavelength of 1875.1 nm and a 3 dB bandwidth of 17 nm is shown in Fig. 2(a). The corresponding pulse duration of