Nonlinear optical gain modulation: a novel approach towards high performance ultrafast Raman fiber laser

J. Zhou[1,2,3,*], Y. Feng[3,4]

[1] *Wangzhijiang Innovation Center for Laser, Aerospace Laser Technology and System Department, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

[2] *Key Laboratory of Space Laser Communication and Detection Technology, Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences*

[3] *Center of Materials Science and Optoelectronics Engineering, University of Chinese Academy of Sciences*

[4] *Hangzhou Institute for Advanced Study, University of Chinese Academy of Sciences*

[*] *E-mail: jqzhou@siom.ac.cn*

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Ultrafast Raman fiber lasers have proven effective in generating laser pulses at special wavelength. Once pump laser with appropriate wavelength is provided, laser output at any target wavelength within the transparent window of conventional optical fibers can be achieved with high conversion efficiency. Such laser pulses with flexible wavelength would expand applications in industry and biomedical field as well as for scientific research [1].

Mode-locking and synchronously-pumping are two conventional methods for ultrafast Raman fiber lasers, both of which are based on a structure of oscillators. This brings problems such as involvement of long Raman gain fiber under continuous-wave (CW) pump [2]; or synchronization difficulty under pulsed pump [3]. The idea is whether oscillators can be replaced with single-pass amplifiers so that synchronization is not necessary under pulsed pump.

In this regard, we proposed a novel method to generate ultrafast Raman pulses, named as nonlinear optical gain modulation (NOGM). The concept of ultrafast Raman pulse generation by NOGM is illustrated in Fig. 1, which uses stimulated Raman scattering (SRS) to modulate single-frequency (SF) laser into ultrafast Raman pulses. The input signal is a SF CW laser, which is amplified and reshaped temporally and spectrally in a piece of optical fiber. The optical fiber, providing nonlinear optical gain by SRS, is pumped by ultrafast pulses. The ultrafast pump laser, served as a modulation driver, can offer an ultrafast modulation to reshape the CW signal. In the temporal domain, the CW laser would be reshaped into pulsed laser; while in the spectral domain, the single longitudinal mode of the CW laser would be modulated and new spectral components would be generated by nonlinear optical effects, forming a shape of frequency comb.

Pumping with a 1064 nm mode-locked laser with a pulse duration of 14 ps, the NOGM setup can generate 436 fs highly coherent laser at 1120 nm with an optical efficiency of 69.4%, as shown in Fig. 2 [4]. Cascaded NOGM processes were also demonstrated, which can produce femtosecond 1178 nm or 1319 nm 2nd-order Stokes pulses in a piece of conventional single-mode fiber or phosphorus-doped fiber respectively [5, 6]. Recent research progress on gain-switched diodes pumped NOGM system will also be introduced in this talk, which can generate femtosecond Raman pulses with both repetition-rate and wavelength agility.

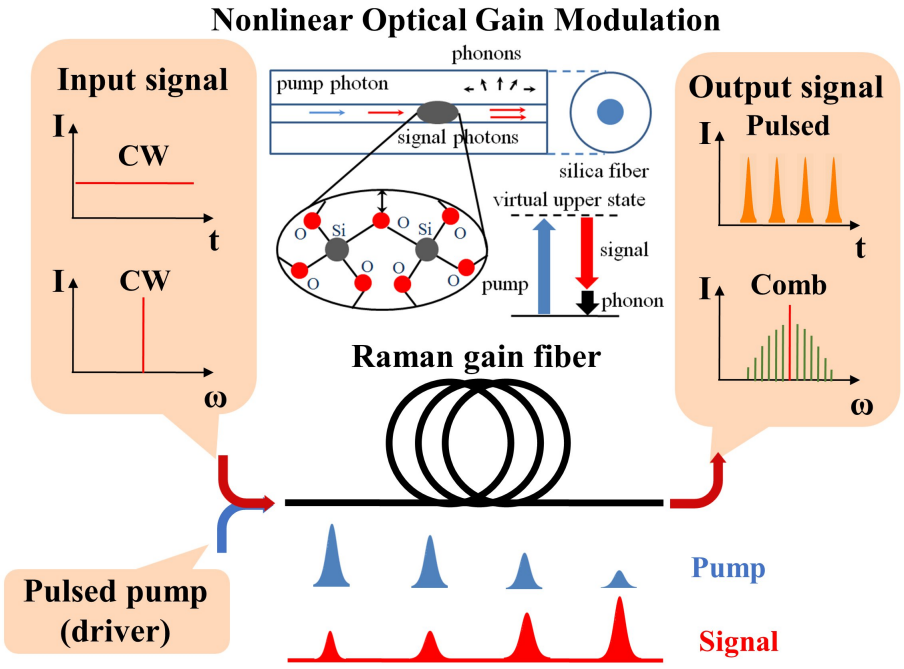

Fig. 1. Principle of nonlinear optical gain modulation

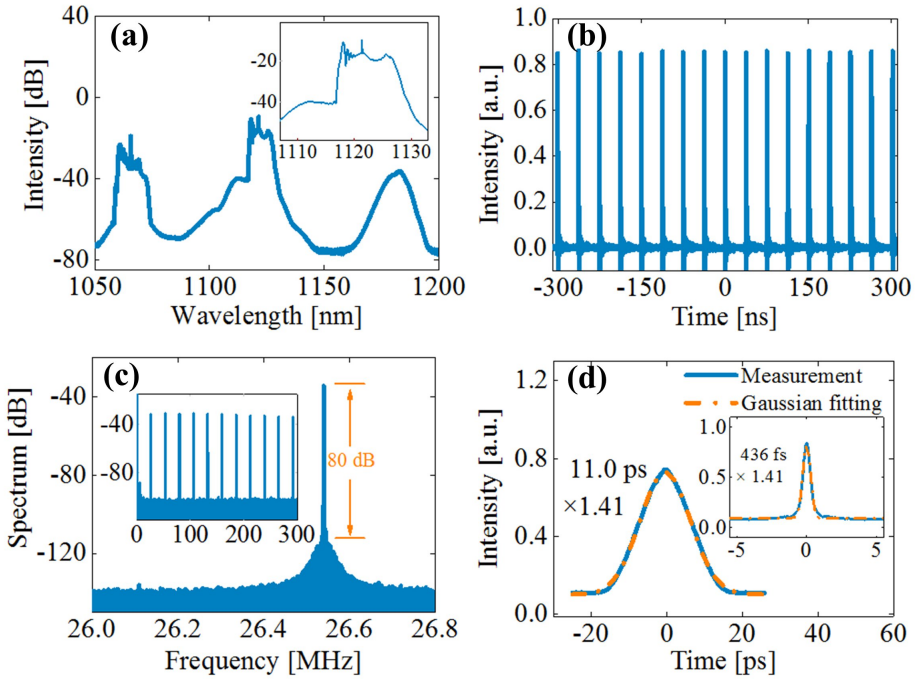

Fig. 2. Characteristics of the measured 1120 nm NOGM 1st-order Stokes pulses: (a) spectrum, (b) pulse train, (c) RF spectrum and (d) autocorrelation traces.

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