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Cascaded Raman Scattering by a Q-switched and Mode-Locked pulses through Yb^{3+}-doped Fiber Amplifier

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Raman scattering (RS) effect, a nonlinear optical phenomenon for the frequency down-shifted stokes wave generation, has attracted a lot of attention due to its large potential applications in broadband optical amplifiers, tunable lasers and telecommunications, etc. As reported, the RS effect has been generated in all normal dispersion fiber by an amplified gain switched laser diode or a picosecond pulsed master oscillator power amplifier (MOPA) system at 1064 nm [1, 2]. Recently, all normal dispersion passively mode-locked Yb-doped fiber lasers (YDFLs) have been reported to generate high energy pulses [3]. Besides, the Q-switched and mode-locked (QML) pulses have been reported in YDFL systems by decreasing the pulse repletion rate to increase the pulse energy [4]. In this work, we investigate the cascaded RS based on a nonlinear Yb^{3+}-doped silicate fiber amplifier, seeded by a QML fiber laser.

The schematic setup of the all-normal dispersion Yb^{3+}-doped fiber ring laser as well as the YDFA is shown in Fig. 1(a). The gain medium of the seed laser was a 30 cm long Yb^{3+} doped fiber, pumped by a 974 nm laser diode. The QML pulses were produced based on nonlinear polarization evolution mechanism using two polarization controllers (PCs) and a polarization dependent optical isolator. The isolator was employed to ensure the uni-directional laser operation and an 80/20 fiber coupler was chosen as the output coupler. The QML seed laser is then amplified by a 974-nm pumped fiber amplifier, constructed by a 20-m single-mode Yb^{3+}-doped silicate fiber with a core diameter of 3.25 μm, numerical aperture (NA) of 0.25 and core absorption coefficient of 4 dB/m at 974 nm.

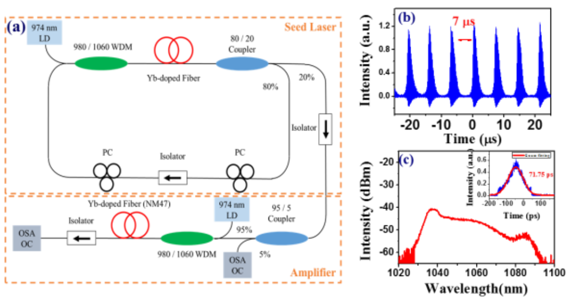

Fig.1 (a) Experimental setup of the QML Yb^{3+} doped fiber MOPA system, (b) the time trace of the QML pulse train, and (c) the corresponding optical spectrum and autocorrelation trace.

With proper adjustments of the PCs, the seeded laser can be operated at QML state. [10] Time trace and optical spectrum of the generated QML pulses are shown in Figs. 1(b) and 1(c). In Fig. 1(b), the mode-locked pulses were modulated by the Q-switched envelope. The time interval between each Q-switched envelope is 7 μs, corresponding to a repetition rate of 142.9 kHz. As shown in Fig. 1(c), the output wavelength at the QML state covers the range from 1024 nm to 1094 nm with the central wavelength at 1062 nm and 3 dB bandwidth of 5.6 nm. With an autocorrelator, the pulswidth of a single ML pulse, shown in inset of Fig. 1(c), was measured as ~72 ps. Then, we used the QML pulse as the seed of the Yb^{3+}-doped silicate fiber amplifier. With the high peak power QML pulses, output spectrum of the amplifier was extended from 1010 nm to 1650 nm As shown in Fig. 2, the interval between wavelength peaks is about 12.7 THz, which verifies that those peaks are generated through cascaded RS.

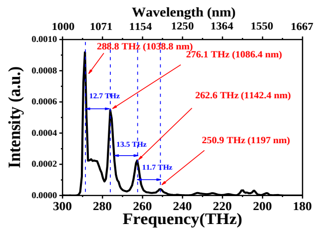

Fig.2 The optical spectrum reveal the cascaded Raman sattering.

In this work, we investigate the cascaded RS scattering from Yb^{3+}-doped silicate fiber amplifier with the seed of QML pulses from an all-normal-dispersion Yb^{3+}-doped fiber laser based on the NPE technique. After the YDFA, the continuous spectral ranging from 1010 nm to 1650 nm in near IR and spectral bands in the visible and UV are experimentally demonstrated. The interval between wavelength peaks is about 12.7 THz, which verifies that those peaks are generated through cascaded RS in the Yb^{3+}-doped silicate fiber amplifier.

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