Abstract: All-fiber Raman fiber source emitting at 1254 nm was realized. For the first time to pump Raman converter we have applied Yb:Bi pulsed fiber laser. The P-doped fiber was used as an active medium of the Raman converter. The conversion slope efficiency of 70% and the peak power of 12 W were observed.

All-fiber pulsed Raman source based on Yb:Bi fiber laser

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1. Introduction

Q-switched fiber lasers have found a number of applications such as medical treatment, micromachining, diagnostics and others. Up to now several approaches were suggested to get Q-switching for the all fiber design. Self Q-switched regime was realized in [1–4], where the pulsed lasing was provided by Rayleigh and stimulated Brillouin scattering. Another approach exploits fiber saturation absorbers placed into the laser cavity. It was suggested to use Cr-doped [5] or Sm-doped [6] fiber by way of a saturated absorber. An oscillation wavelength of realized laser was determined by the active fiber used, namely it was in a range of 980–1180 nm for Yb-fiber laser [7] and 1530–1560 nm for Er-fiber laser. At the same time a number of applications, for instance medicine, require a pulsed emission at other wavelength within near IR range. In paper [8] the intracavity spectral conversion of self-Q-switched ytterbium-doped fiber laser was demonstrated, however it was made without a spectral selection of the converted emission.

In this paper we present all-fiber pulsed Raman source based on a new type of the pulsed Yb-doped fiber laser with Bi-doped fiber saturated absorber [9].

2. Experimental scheme

Scheme of the source is shown in Fig. 1. It consists on two main parts: pulsed fiber laser and Raman converter. Yb-Bi fiber lasers were made using GTWave Yb-doped phosphosilicate laser fiber [10] and Bi-doped aluminosilicate fiber. The Yb-doped fiber with a length of 20 m had a cut-off at 1400 nm and a core-cladding refraction index difference of 0.009. Cladding pumping of the Yb-doped fiber was performed by a diode laser operating at 975 nm wavelength fabricated by “Milon Laser”. Laser cavity was

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Figure 1 Experimental scheme

Figure 2 Pulse train at 1254 nm

closed by two Bragg gratings written in germanosilicate fibers spliced with the active medium.

The Bi-doped fiber was used as a saturated absorber. It had an absorption level of 300 dB/km measured at 1075 nm and a passive loss about 15 dB/km estimated at 1300 nm. It should be noted that active centers lifetime is too long, ~1 ms, so it should lead to its poor efficiency at a high repetition rate exceeding ~1 kHz. To overcome this drawback we placed the saturation absorber in a separate resonator to achieve a laser action in it and consequently to decrease the lifetime of active centers in the excited state. The resonator was closed by two Bragg gratings having a high reflection. The Bi-doped fiber had a cut-off wavelength of 900 nm and a refraction index difference of 0.005.

The P-doped fiber was used as an active medium of the Raman converter. An application of phosphosilicate fibers allows one to get the high spectral shift using a minimum number of the conversion stages due to the large Raman shift (1330 cm$^{-1}$) [11,12]. We used the fiber having the optical losses of 1.6 and 1 dB at 1075 and 1254 nm, respectively. The Raman gain coefficient was of approximately 5.3 dB/W km at 1254 nm. The fiber length in Raman converter was of 500 m. A cavity of the converter was formed by Bragg gratings. It should be noted that in contrast to CW Raman converter, our scheme doesn’t contain the output reflector for the laser emission. Usually such Bragg reflector is used to return the unconverted emission of Yb-laser. In the case of the pulsed laser an application of this reflector increases a feedback disturbing the lasing regime.

3. Results and discussion

Without Raman converter the laser generated a stable pulse train. Maximum output average power of 3 W was achieved for a pump power of 7 W that corresponded to the peak power of 60 W. Maximum frequency was of 35 kHz for the maximum pump power of 7 W at 975 nm. It can be noted that the laser characteristics are similar to parameters obtained for Sm-fiber saturable absorber [5].

An application of the converter based on P-doped fiber allowed us to obtain the stable pulse train at the wavelength of 1254 nm illustrated by Fig. 2. Secondary peaks of less intensity in the train are caused by the reflection of the main pulse from the output grating. Time delay between the main and second pulses corresponds to the double pass of P-doped fiber. The train frequency corresponded to the pump laser frequency. Pulse duration was of 3 microseconds.

Fig. 3 illustrates the output spectrum of the realized source. It consists on several emission bands: Yb-laser emission (1075 nm), Bi-laser emission (1160 nm), Raman converter emission (1254 nm) and two wide bands corresponding to Raman scattering in silica (1135, 1337 nm). Nevertheless, the peak centered at the wavelength of 1254 nm contains of 70% of the total output power. The maximum average power of 1.4 W and the lasing threshold of 1 W were observed. The output average power versus the pump average power is shown in Fig. 4. This dependence corresponds to a conversion slope efficiency of
Average power at 1254 nm

Figure 4 The output average power versus the pump average power

70%. The peak power can be estimated as 12 W, pulse energy – 0.04 mJ.

4. Resume

For the first time we have applied Yb:Bi pulsed fiber laser and P-doped fiber to build the fiber Raman converter. That allowed us to obtain a source emitting microsecond pulses at 1254 nm with a pulse power of 12 W.

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References