Experimental demonstration of the wideband double-pass discrete Raman amplifiers based on a gold-film reflector

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We experimentally demonstrate a wideband double-pass discrete Raman amplifier using a gold-film. In this Raman amplifier (RA), by using a one-end gilded fiber as the broadband reflector, signals and multi-pump are simultaneously reflected to propagate through the gain fiber for a second time in the opposite direction of the input. An increase in net gain of more than 150% has been achieved compared with that in the typical co-pumped Raman amplifier. The noise and polarization dependent gain (PDG) characteristics of such a RA are also investigated.

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Wide-band fiber amplifiers are indispensable for wide-band and long-distance dense wavelength divison multiplexing(DWDM) systems[1,2]. Discrete Raman amplifiers (RA) have potential use in extending new gain bandwidth as S-band or L-band[3,4]due to the wavelength independence of Raman gain. However, the low Raman efficiency makes the amplifiers require high-power pump lasers and long gain fiber to achieve an enough gain. Therefore, it is important to enhance the gain efficiency when designing a discrete Raman amplifier. A double-pass discrete RA based on fiber Bragg grating (FBG) has recently been demonstrated to enable improved gain efficiency[5]. But the limited reflection bandwidth of FBG limits the bandwidth of such a Raman amplifier and also baffles to increase the gain efficiency further more.

In this paper, we experimentally demonstrate, for the first time to our knowledge, a wideband double-pass discrete Raman amplifier using a gold-film with a high flat reflectivity over more than 200 nm. In this RA configurations, signals and multi-pump are both reflected to propagate through the gain fiber for a second time in the opposite direction of the input. We show that compared with a backward-pumping Raman amplifier, this double-pass discrete RA can improve gain more than two times within the range of 1530—1610 nm. Its noise and polarization dependent gain (PDG) characteristics are also investigated experimentally.

The experimental setup of the wideband double-pass discrete RA is shown as Fig. 1. A tunable laser source (TLS) with wavelength ranging from 1530–1610 nm was used as an input signal source. The signal power was −10 dBm. Pumping wavelengths have been set to be 1426, 1440, 1454, 1472, and 1496 nm. A one-end gilded fiber was used as the broadband reflector that has a relative high and flat reflectivity over more than 200 nm .

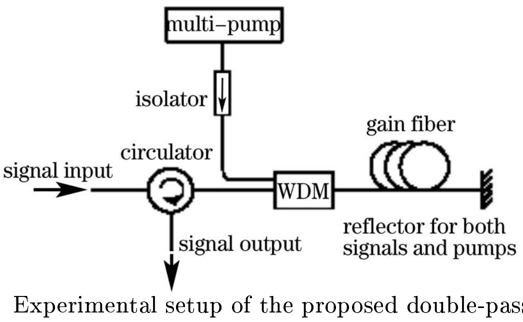

Fig. 1. Experimental setup of the proposed double-pass RA.

This kind of reflectivity cannot be easily achieved by using a FBG or a chirped FBG. Besides this, the cost of this reflector is much lower. Figure 2 shows the measured reflectivity spectrum covering the wavelength range of 1420–1620 nm, in which the reflectivity varies smoothly from 93% to 98%. 10-km standard single mode fiber (SSMF) was used as the gain medium.

To further show the gain advantage of this double-pass discrete RA, we also measured gain and noise figure of other three RA configurations: 1) only pumps were reflected; 2) only signals covering C+L band were reflected; 3) the typical backward-pumping scheme. The experimental setups of configuration 1) and 2) are shown in Figs. 3 and 4 respectively. In the measurements, pump conditions, fiber length, and signal power were all kept same.

The measured net gain and noise figure of the proposed double-pass RA and other three configurations are given

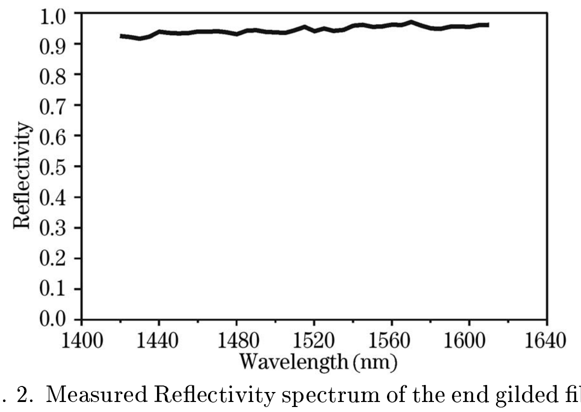

Fig. 2. Measured Reflectivity spectrum of the end gilded fiber.

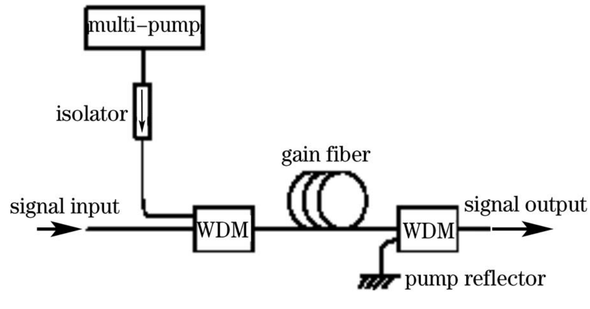

Fig. 3. Experimental setup of RA with only pumps reflected.

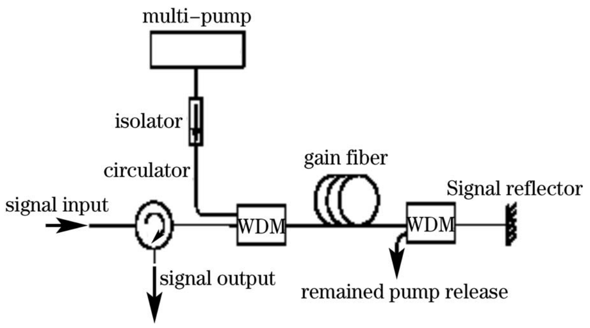

Fig. 4. Experimental setup of RA with only signals reflected.

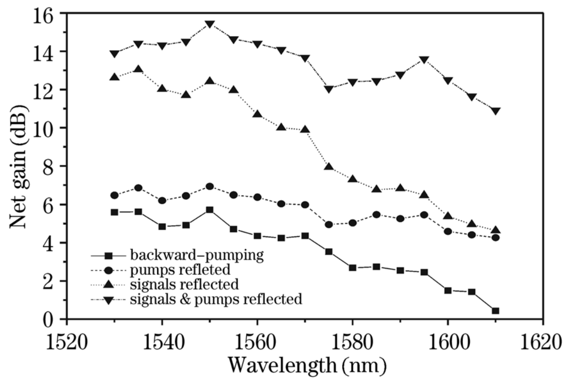

Fig. 5. Net gain of the three double-pass RA configurations and a forward-pumped one.

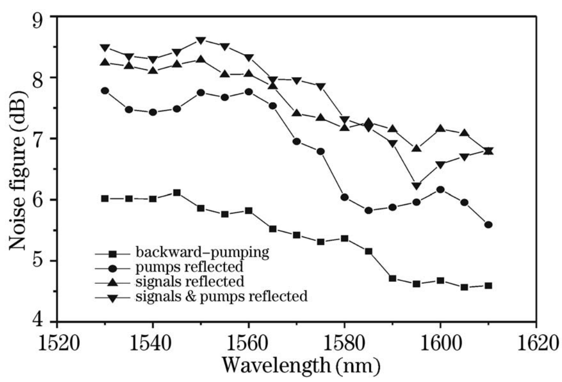

Fig. 6. Noise figure of the three double-pass RA configurations and a forward-pumped one.

in Figs. 5 and 6, respectively. It is shown that although reflection of either pumps or signals can enhance gain efficiency, the configuration of reflection of both two can increase the gain to a much higher level.

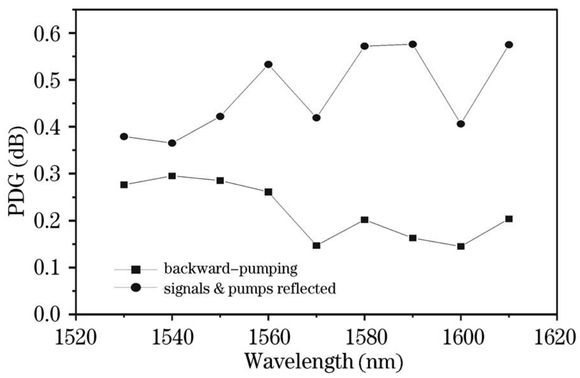

Fig. 7. The measured PDGs of the double-pass discrete RA and a backward-pumping RA.

However, the reflection of pumps or signals causes the degradation of noise figure about 2 dB because more lightwaves existed in the fiber. Figure 7 shows the measured PDG of the double-pass discrete RA and a backward-pumping RA. The reflection of both signals and pumps increases PDG from about 0.3 to 0.6 dB.

In conclusion, a wideband double-pass discrete Raman amplifier based on a gold film reflector is demonstrated, and its gain, noise figure, and PDG performance are investigated. It is shown that the double-pass configuration with both signals and pumps being reflected can improve gain efficiency of more than 2 times than the backward-pumping one. Further improvements in performance of such a double-pass RA can be expected with using other kind of gain fiber, such as DCF or DSF.

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