# A multi-wavelength fiber laser based on superimposed fiber grating and chirp fiber Bragg grating for wavelength selection*

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In this paper, a new type of multi-wavelength fiber laser is proposed and demonstrated experimentally. Superimposed fiber grating (SIFG) and chirp fiber Bragg grating (CFBG) are used for wavelength selection. Based on gain equalization technology, by finely adjusting the stress device in the cavity, the gain and loss are equal, so as to suppress the modal competition and achieve multi-wavelength lasing at room temperature. The experimental results show that the laser can output stable multi-wavelength lasers simultaneously. The laser coupling loss is small, the structure is simple, and it is convenient for integration, so it can be widely used in dense wavelength division multiplexing (DWDM) system and optical fiber sensors.

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Multi-wavelength fiber laser has a great potential in the areas of wavelength division multiplexing (WDM) optical fiber communication system[1,2], optical sensing[3-5], microwave generation[6-8] and optical measurement[9,10]. At present, the most key technology of multi-wavelength laser is to overcome the homogeneous broadening and cross gain saturation effect of erbium-doped optical fiber at room temperature[11,12], and to suppress the mode competition and jump[13,14]. Therefore, a stable multi-wavelength fiber laser is needed.

Based on the gain equalization technology[15], multi-wavelength erbium-doped fiber lasers with dual-wavelength and three wavelengths superimposed fiber grating (SIFG) and chirp fiber Bragg grating (CFBG) are proposed in this paper. The experimental results show that the laser can output stable multi-wavelength lasers simultaneously, and the 3 dB line width is less than 0.1 nm.

The schematic diagram of experimental devices of the fiber laser based on SIFG and CFBG is shown in Fig.1. The 980 nm laser diode (LD) is a semiconductor laser with the maximum output power of 750 mW, the Nufern company EDFC HP-980-C-band erbium-doped fiber (EDF) is used, the AQ6370C type spectrum analyzer with the minimum wavelength resolution ratio of 0.02 nm is adopted as the optical spectrum analyzer (OSA) for measuring the output spectrum, and both sides of CFBG assemble the stress adjusting devices. All these devices are non-polarization maintaining.

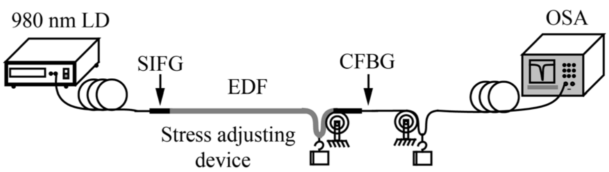


**Fig.1 Experimental devices of the proposed fiber laser based on SIFG and CFBG**

SIFG is a kind of important optical element with a lot of advantages, such as a small length, flexible wavelength interval and reflectivity, and consistent temperature and strain responses. SIFG is also a kind of novel fiber laser wavelength selection device with small size. It can realize the rapid and exact wavelength selection, and has good stability.

The reflection spectrum of the prepared dual-wavelength SIFG is shown in Fig.2.

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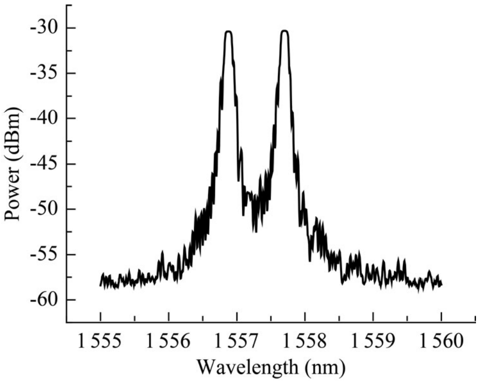


**Fig.2 Reflection spectrum of the dual-wavelength SIFG**

Fig.2 shows that the reflectivities of SIFG are 99.21% and 99.50% at two peak wavelengths of 1 556.872 nm and 1 557.700 nm, respectively, the 3 dB bandwidths of SIFG at two peaks are both 0.15 nm, and the wavelength interval between the two gratings is 0.828 nm, which meets the nanometer or sub-nanometer channel spacing unit requirements in communication.

The transmission spectrum of the prepared SIFG with three wavelengths is shown in Fig.3.

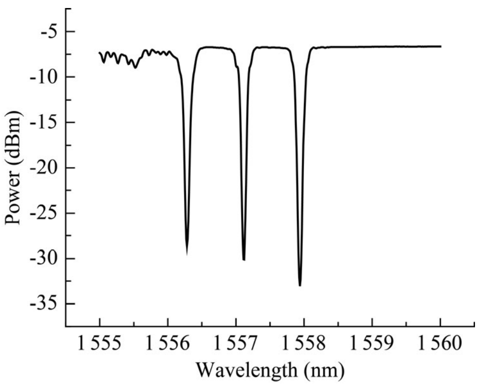


**Fig.3 Transmission spectrum of the three-wavelength SIFG**

Fig.3 shows that the reflectivities of SIFG are 99.37%, 99.50% and 99.60% at the peak wavelengths of 1 556.280 nm, 1 557.120 nm and 1 557.940 nm, respectively, and the 3 dB bandwidths of SIFG at three peaks are all 0.1 nm. The wavelength interval between two gratings with wavelengths of 1 556.280 nm and 1 557.120 nm is 0.84 nm, and that between two gratings with wavelengths of 1 557.120 nm and 1 557.940 nm is 0.82 nm, which meets the nanometer or sub-nanometer channel spacing unit requirements in communication.

Set up a dual-wavelength fiber laser system according to Fig.1, in which the length of EDF is 1 m, the length of cavity is 1.1 m, and the dual-wavelength SIFG is adopted. When the pump power is 1.25 mW, the output power spectrum is shown in Fig.4.

With the increase of the pump power, the output power increases gradually as shown in Fig.5.

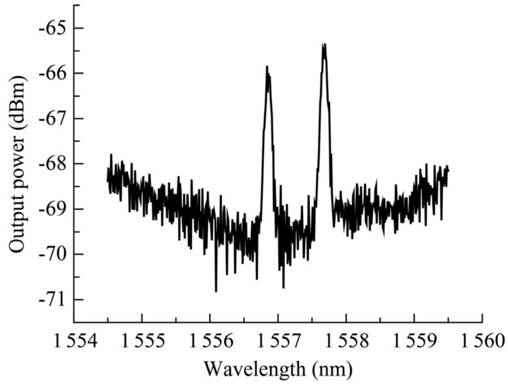


**Fig.4 Output power spectrum of the dual-wavelength fiber laser with pump power of 1.25 mW**

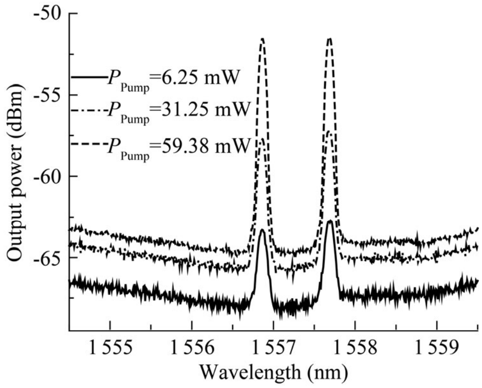


**Fig.5 Output power spectra of the dual-wavelength fiber laser with different pump powers**

It can be seen from Fig.5 that when the pump powers are 6.25 mW, 31.25 mW and 59.38 mW, there are two output peak wavelengths, which are 1 556.860 nm on the left and 1 557.700 nm, 1 557.690 nm and 1 557.680 nm on the right, respectively. With the increase of pump power from 6.25 mW to 59.38 mW, the output peak powers are −63.31 dBm, −57.71 dBm and −57.71 dBm at left peak wavelength, and −62.72 dBm, −57.22 dBm and −51.45 dBm at right peak wavelength, respectively. Analysis of the above data shows that the output power is increased with the increase of the pump power. Under different pump powers, the two output peak wavelengths almost have no change, SIFG is good for wavelength selection, and the center wavelength is also stable. With the increase of the pump power, the output laser line width almost has no change, 3 dB bandwidth of each lasing is less than 0.1 nm, and the line width is narrow.

In order to investigate the long-term stability of laser output, the output spectra with peak wavelengths of 1 556.840 nm and 1 557.690 nm are measured for 10 times at room temperature (25 °C) with time interval of 3 min, when the pump power is 12.5 mW, as shown in Fig.6.

It can be seen from Fig.6 that the 3 dB line width of the dual-wavelength laser is less than 0.1 nm, and the stability of output spectra is good.

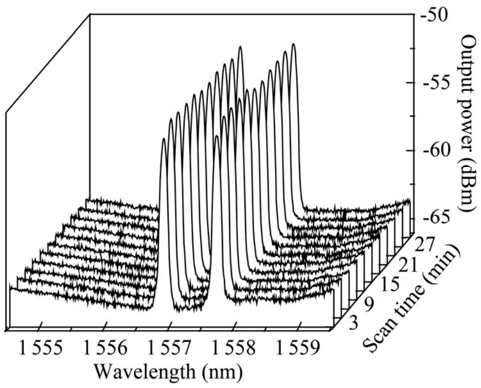


**Fig.6 Continuous scanning output spectra of the dual-wavelength laser at pump power of 12.5 mW for 10 times**

To further increase the pump power, when the pump power is 13 mW or higher, the laser output presents obvious mode jump phenomenon, and the output power starts to become unstable. This is because with the increase of pump power, the mode competition is severe, and the stress adjustment device is unable to precisely hold the balance between gain and loss in the laser cavity, resulting in the mode jump phenomenon.

Then set up another fiber laser system according to Fig.1, in which the length of EDF is 1 m, and the three-wavelength SIFG is adopted. When the pump power reaches 60 mW, it begins to have laser output. Using CFBG with weight of 20 g, the output spectra of the three-wavelength laser with pump powers of 125 mW and 150 mW are shown in Fig.7.

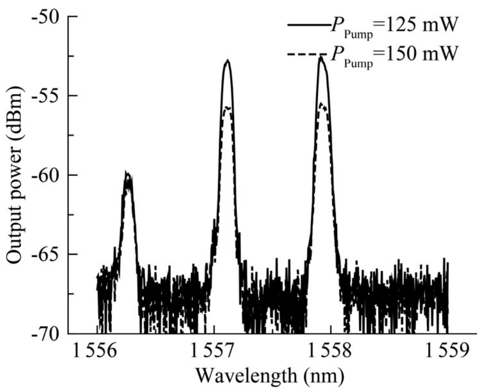


**Fig.7 Output power spectra of the three-wavelength laser with different pump powers**

From Fig.7, firstly, with the increase of the pump power, the output power is also increased; secondly, at different pump powers, the peak wavelengths of output spectra have no change, SIFG is good for wavelength selection, and the center wavelength is stable; thirdly, with the increase of pump power, the 3 dB line width of output laser nearly has no change, that of each lasing wavelength is less than 0.1 nm, and the line width is narrow.

In this paper, based on gain equalization technique, the multi-wavelength fiber lasers based on SIFG and CFBG are proposed. The experimental results show that by finely adjusting the device to realize equal gain and loss at resonance wavelength in the cavity, the mode competition can be inhibited, and finally the laser output is stable.

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