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# Development of C-Band Single Longitudinal Mode Fiber Laser and Analysis and Measurement of Distributed Fiber Sensing


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***Abstract :*** The primary research directions in this doctoral study focus on the development of single longitudinal mode fiber lasers and the analysis and measurement of distributed fiber sensing. Optical fiber has become the foundational technology for information transmission and various photonic applications.

Topic 1：High-quality light sources are especially critical to optical systems. This research aims to develop single-longitudinal-mode (SLM) fiber lasers based on multiple sub-ring configurations, with applications not only in optical communications but also in optical sensing.

Topic 2：Optical fiber sensing technology is currently one of the most effective sensing technologies. This research specifically integrates phase-sensitive optical time-domain reflectometry (φ-OTDR) and Brillouin optical time-domain analysis (BOTDA) distributed sensing systems to enable the detection of temperature, stress, and vibration.



**Keywords** :*Erbium-doped fiber laser (EDFL); Sub-Ring Cavities Arrayed Waveguide Grating (AWG); Single longitudinal mode ；Distributed fiber sensing.*


## Topic 1: single longitudinal mode fiber laser

As shown in Fig.1, Initially, we utilize EDFA as the output light source. the light entering the 1x8 AWG, where different wavelengths are filtered out through different channels. Channel switching is achieved by adjusting OSW. Subsequently, the light is split into 90% and 10%, with the 10% portion serving as the output of the EDFL, while the 90% enters the NPR structure. Then, 80% of the light enters the resonant structure of the PTSR through OC2, while the remaining 20% to re-enter EDFA for resonance cycling.

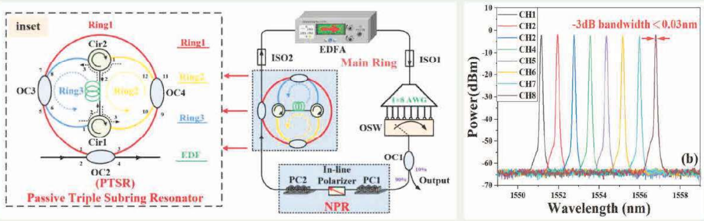


**Fig. 1. (a)Experimental setup; (b)The measured spectra of the eight channels**

In Fig.2, the laser exhibits three parameters: wavelength, OSNR, and output power. when CH1 outputs were selected, with intervals of 2 minutes, the fluctuations in output power and wavelength over one hour were 0.01 dB and 0.005 nm, respectively, indicating high stability even without protective measures during the experiment.

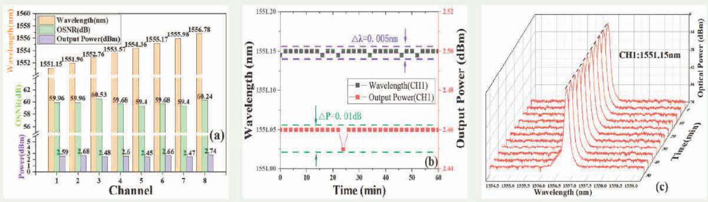


**Fig. 2. (a)wavelength, OSNR, and power of different channels; (b)The stability of laser power and wavelength for CH1; (c)The laser output spectra of CH1 in 5-minute intervals.**

In Fig.3(a), the frequency spacing between adjacent peaks for laser output, measured without PTSR in the DSHMS, is approximately 3.07 MHz. Fig.3(b) illustrates RF beat frequencies of the laser outputs, measured with a resolution bandwidth of 1 MHz within a 1 GHz range. the linewidth measurement results for the eight different channels of the laser are shown in Fig.3(c).

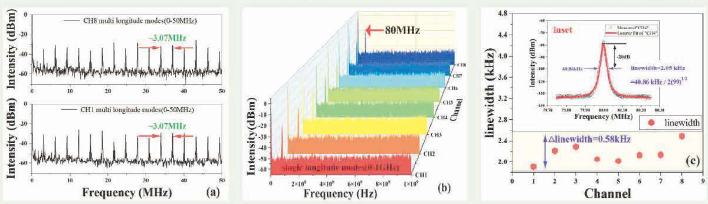


**Fig. 3. RF beating spectra results measured for (a) 0-50 MHz span without PTSR; (b) 0-1 GHz span with PTSR. (c) Linewidth of eight different channels of the laser.**

## Topic 2: distributed fiber sensing

As shown in Fig.1, In the BOTDA part, the focus is on temperature and strain analysis. In the φ-OTDR section, accurate identification of vibration points is achieved through differential demodulation based on the Mach-Zehnder Interferometer (MZI) system. This presentation introduces comprehensive experiments, demonstrating the ability to achieve multi-parameter sensing on a single optical fiber using the hybrid system, all within a low-cost framework.

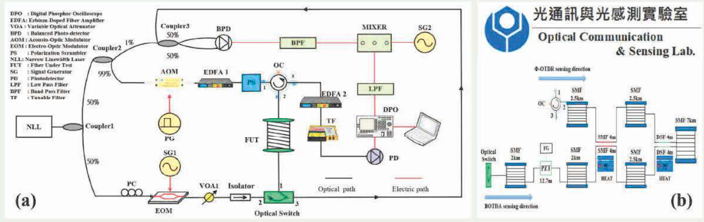


**Fig. 1. (a) Experimental Setup; (b) The setup of the FUT in experiments.**

Fig.2 show the 3D and 2D plots of the scanning frequency, Four distinct peaks can be observed due to temperature and strain drift. T1 and T2 correspond to the Brillouin frequency shift (BFS) generated by heating the SMF (130°C), while dispersion shifted fibers (DSF1) and DSF2 representthe BFS generated by simulating strain.

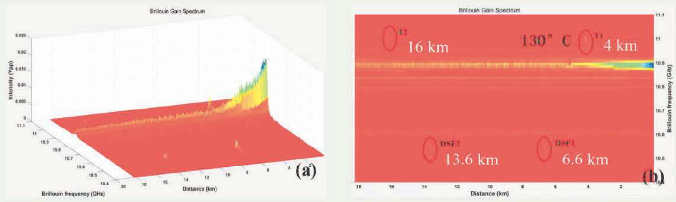


**Fig. 2. (a) 3D and (b) 2D Brillouin gain spectra, with the BFS swept from 10.88 GHz to 10.52 GHz.**

Fig.3(a) shows the overlay plot of 100 consecutive backscattered Rayleigh curves. By performing a differential operation on the 100 consecutive curves, we obtained Fig.3(b), which reveals the location of the vibration point at 16.37km. SNR = 10log ($V_{signal}/V_{noise}$) =3.65dB. Fig.3(c) displays the signal demodulation result of the 120Hz signal.

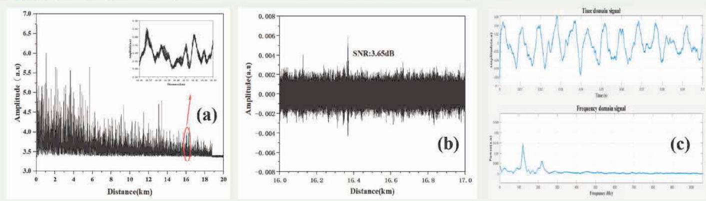


**Fig 3. (a) Rayleigh backscattering 100 trace; (b) SNR in 16.37km vibration sensing distance. (c) Demodulated 120Hz signal time domain and frequency domain diagram.**


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