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Controlled spectral emission of fiber lasers using two external cavities

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ABSTRACT

A multi mode channeled emission spectrum of Nd^{3+} and Er^{3+} doped fiber lasers with two symmetric free space external cavities is experimentally demonstrated. An optical Vernier effect depending on the relative length difference between the two end cavities leads to a controlled number of clusters of oscillating modes.

INTRODUCTION

Nd^{3+} and Er^{3+} doped fiber lasers (NDFL and EDFL) with long Fabry-Perot cavities usually provide both a broad and erratic emission spectrum¹. Several techniques have been reported for achieving the spectral emission control in rare-earth-doped fiber lasers: i) use of Bragg reflection gratings²; ii) intra-cavity optical filters like narrow-band width filters³; iii) intra-cavity birefringence filters⁴. Optical feedback mode-selection by external Fabry-Perot cavity has also been reported⁵. Most of the solutions cited above concern single longitudinal mode operation and tuning of the fiber laser emission. Here we are interested in fiber lasers that have a channeled emission spectrum composed of a number of discrete cluster peaks: every cluster contains several longitudinal lasing modes⁶. We propose a new spectral emission control technique based on an optical Vernier effect between two symmetric external cavities coupled to the doped fiber laser. In this communication we present the experimental results on Nd^{3+} and Er^{3+} doped fiber lasers. A detailed theoretical analysis of this effect using the optical Airy function in frequency domain has been reported elsewhere⁷.

EXPERIMENT

The experimental set up is shown in figure 1. Two 30 cm external free space cavities ($M_{1\text{ext}}$ - M_1 and M_2 - $M_{2\text{ext}}$) are coupled to the main laser cavity by means of M_1 and M_2 mirrors. The second external mirror $M_{2\text{ext}}$ can be moved by a step by step micropositioner ($1\mu\text{m}/\text{step}$) creating a controlled difference length $\Delta=d_1-d_2$ between the two end cavities. For each signal wavelength (1080 nm or 1550 nm) two antireflection-coated microscope objectives (MO_1 and MO_2) were used in order to collimate and focus the light.

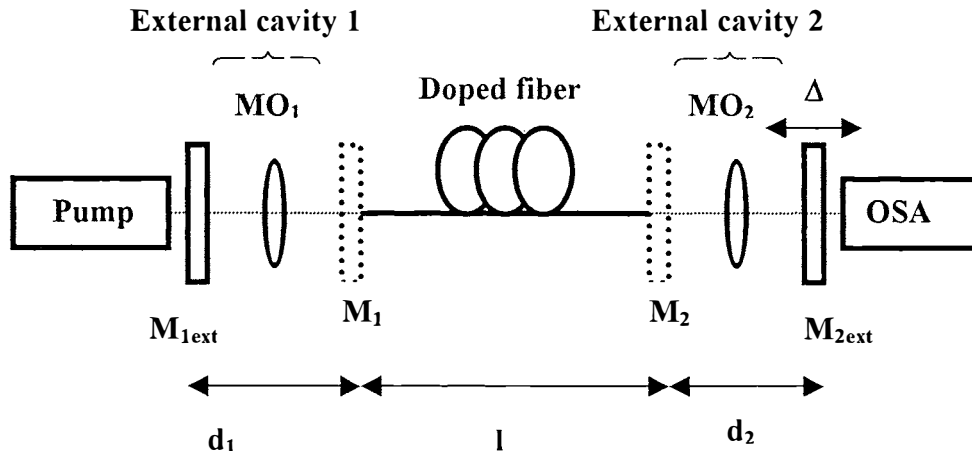


Fig 1. Experimental set up.

Two different amplifying media, a 10m long NDF and respectively a 13m long EDF were used. To obtain the channeled spectrum emission of the fiber lasers the reflectivity of external mirrors at the signal wavelength must be much greater than the reflectivity of the mirrors M_1 and M_2 . The optical spectrum analyzer (OSA) used in the experiment had 0.1 nm resolving power and a logarithmic scale.

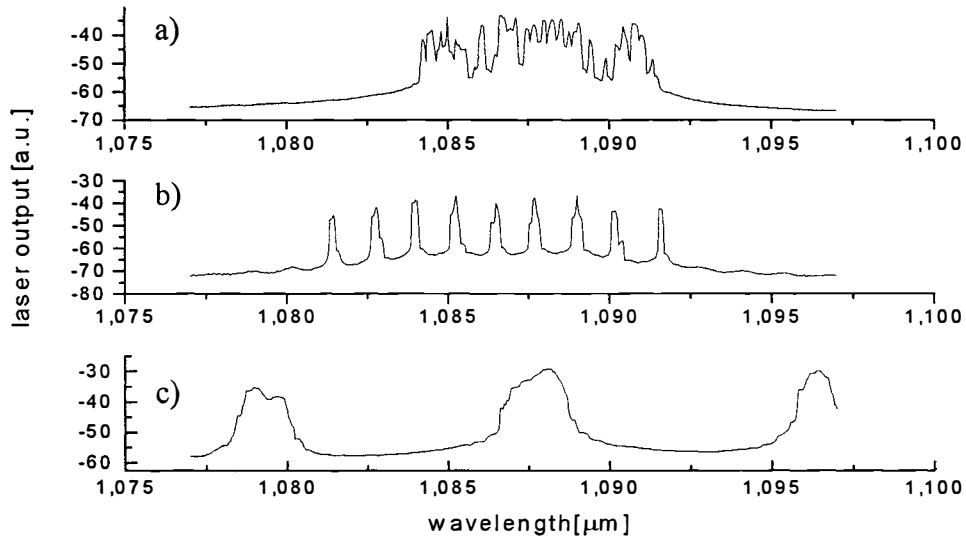


Fig. 2 Neodymium doped fiber laser emission spectrum for different cavity configurations: a) without external cavities; b) with external cavities and $\Delta = 300 \mu\text{m}$; c) with external cavities and $\Delta = 100 \mu\text{m}$.

A broad and erratic spectrum of the NDFL without external cavities is presented in figure 2 a. When the external cavities are added, the laser spectrum became more stable and exhibits a channeled spectral selection illustrated in figures 2 b and 2 c. All measurements were done for a ratio of two between the pumping power and the lasing threshold power. One sees that the longitudinal modes are bunched together in clusters separated by free spectral regions. Changing the absolute length difference Δ between the two external cavities by moving the $M_{2\text{ext}}$ mirror, an important variation of the free spectral range between cluster peaks in laser emission can be observed. A bigger Δ gives an increasing number of clusters in laser spectra. Similarly results were obtained in EDFL case.

To summarize, we have experimentally demonstrated a spectral emission control mechanism in fiber lasers that uses two external symmetric cavities. An optical Vernier effect depending on the relative length difference between the two end cavities leads to a channeled emission spectrum with a variable number of clusters of longitudinal modes.

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