CThM35

Multiwavelength Fiber Laser Source with a Hybrid Gain Medium

D. N. Wang, F. W. Tong, Xiaohui Fang, W. Jin, *P. K. A. Wai and J. M. Gong

Department of Electrical Engineering

*Department of Electronic and Information Engineering

The Hong Kong Polytechnic University

Hung Hom, Kowloon, Hong Kong

P. R. China

ceednwg@polyu.edu.hk

Abstract

A semiconductor optical amplifier and an erbium-doped fiber are incorporated in a ring cavity to form a hybrid gain medium. Stable multi-wavelength laser operation using such a medium is predicted theoretically and confirmed experimentally.
Summary

The number of operating wavelengths of the fiber laser is limited by the homogeneous line broadening of erbium ions, and its spectral power fluctuation is caused by mode competition, which can be effectively suppressed if inhomogeneous gain medium such as semiconductor laser amplifier (SOA) is employed. However, SOA processes relatively large insertion loss and high sensitivity to polarization. Recently, various approaches for multiwavelength fiber laser operation at room temperature are proposed, including the use of a multimode fiber [1], injection of Brillouin pump power [2] or incorporation of a frequency shifter into the laser cavity [3].

In this paper, a fiber laser by incorporating an SOA into the erbium-doped fiber ring cavity to form a hybrid gain medium is proposed. Theoretical analysis and experimental demonstration of a stable multiwavelength laser operation at room temperature have been carried out.

For an erbium-doped fiber amplifier (EDFA), the coupled intensity growth equation is given by [4]

$$\frac{dI_i}{dt} = \alpha_e I_i - \kappa \sum_{j=1}^{N} I_j I_j$$  \hspace{1cm} (1)

and that for an SOA, it has

$$\frac{dI_i}{dt} = (\alpha_s - \beta) I_i I_i$$  \hspace{1cm} (2)

where \( I_i \) is the intensity of the \( i \)-th wavelength, \( t \) is time, \( \alpha_e \) and \( \alpha_s \) are the overall gains for EDFA and SOA respectively, \( \kappa \) and \( \beta \) are cross and self-saturation coefficients respectively and are always positive. EDFA and SOA are assumed to be purely homogeneous and inhomogeneous respectively and the intensity change in each of the \( N \) wavelengths per round trip is small [5], then

$$\frac{dI_i}{dt} = (\alpha - \beta) I_i I_i - \kappa \sum_{j=1}^{N} I_j I_j$$  \hspace{1cm} (3)

where \( \alpha = \alpha_e + \alpha_s \). The steady state solution of Eq. (3) is given by \( I_i = \alpha/(N\kappa + \beta) \), \( i = 1, 2, \ldots, N \). The roots of the characteristic polynomial for the \( N \) wavelengths are \(-\alpha\) and \(-\beta\alpha/(N\kappa + \beta)\) with the second solution \((N-I)\) degenerate. Thus a hybrid gain medium can support multiwavelength operation as long as \( \alpha > 0 \).
The experimental setup is shown in Fig. 1. The amplified spontaneous emission (ASE) from the SOA passes through a Mach-Zehnder interferometer which acts as a comb filter. The interferometer output is amplified by the EDFA and then introduced to the SOA. Because of the spectral hole burning effect associated with the inhomogeneous broadened medium, the multiwavelength elements are enhanced. A large portion of the multiwavelength power is reintroduced to the EDFA and is reinforced. Such a process will continue until overall gain is equal to the loss of the cavity.

The system output is demonstrated in Fig. 2, where 22 lasing wavelengths with signal-to-noise ratio (SNR) of 25 dB were observed within a 3 dB bandwidth. The experimentally obtained results with only an SOA in the laser cavity is also shown in Fig. 3.

10 successive scans of the system output within 10 minutes were carried out at room temperature and the results obtained were recorded in Fig. 4. The maximum peak intensity fluctuation was less than 1.5 dB.

In conclusion, a hybrid gain medium has been used in an erbium-doped fiber ring laser cavity to enable multiwavelength lasing at room temperature.

*This work is supported by Hong Kong Polytechnic University Research Grant No. G-YC89.

EDFA - Erbium-doped fiber amplifier
SOA - Semi-conductor amplifier
MZI - Mach-Zehnder interferometer
OSA - Optical spectrum analyzer
P.C. - Polarization controller

Fig. 1  Schematic of the experimental setup

Fig. 2  Output spectrum from the fiber ring laser source with hybrid gain medium (with EDFA driving current of 72 mA and SOA driving current of 120 mA)
Fig. 3  Output spectrum from the fiber ring laser source with only SOA as the gain medium

(SOA driving current of 120 mA)

Fig. 4  System output monitored over 10 minutes