

# Multi-pumped Raman Amplifier for Long-Haul UW-WDM Optical Communication Systems: Gain Flatness and Bandwidth Enhancements

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**Abstract**—Fiber Raman amplifiers in ultra wideband wavelength division multiplexing (UW-WDM) systems have recently received much more attention because of their greatly extended bandwidth and distributed amplification with the installed fiber as gain medium. It has been shown that the bandwidth of the amplifier can be further increased and gain spectrum can be tailored by using pumping with multiple wavelengths. In this paper, the distributed multi-pumping Raman amplifier has been studied and analyzed by testing two designed algorithms of amplifier to obtain the gain of maximum flatness and bandwidth. Also we have investigated the effects of many parameters on the gain and bandwidth of Raman amplifier such as: pumping wavelength, offset wavelength, the relative refractive index difference and the number and location of the cascaded units used in the amplifier model design. The gain is computed over the spectral optical wavelengths ( $1.45\mu\text{m} \leq \lambda_{\text{signal}} \leq 1.65\mu\text{m}$ ). The differential gain of each unit of the amplifier is obtained according to the straight line-exponential model of a small maximum constant gain of  $7.4 \times 10^{-14}$  m/W over an optical wavelength interval of 16 nm.

**Keyword**—Distributed multi-pumping Raman amplifier (DMRA), Raman gain, ultra wideband-wavelength division multiplexing (UW-WDM).

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