Simulation and Experimental Validation of Gain Saturation in Raman Fiber Amplifier

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Abstract-In this paper, the effect of the large signal power on the Raman amplification is simulated utilizing OptiSystem. Two types of Raman amplification systems are simulated; average power Raman amplifier model (APA-RFA) and bidirectional-fiber Raman amplifier model (Bi-Fiber RFA). A comparison is made between these two kinds of amplifiers under the same input power condition. As a result the saturation mechanism due to the large input signal is recognized in bidirectional fiber Raman amplifier model. This saturation is due to the stimulated Brillouin scattering that occurred once the input signal power exceeds the stimulated Brillouin scattering threshold (SBS_{TH}). On the other hand, the average power Raman amplifier model exhibits constant Raman gain with the input signal power variation as the stimulated Brillouin scattering is not considered in this model. Finally, experimental results show significant agreement with the simulation results of the bidirectional fiber Raman amplifier model.

I. INTRODUCTION

Fiber Raman amplification is one of the enabling technologies for next-generation long haul and ultra long haul high capacity fiber optic transmission systems [1]. Using distributed Raman amplifiers in standard single mode fiber (SMF) as a gain medium improved the noise figure and reduced the nonlinear penalty of dense wavelength division multiplexing (DWDM) systems [2–4].

Furthermore, in the past few years the stimulated Brillouin scattering (SBS) effect on the gain saturation have been investigated theoretically [5, 6], and experimentally [7] in Raman fiber amplifier.

In simulation program, the Raman fiber amplifier-average power model (APA-RFA) is used to decrease the computational time required to solve Raman amplifier differential equations. In this model, pump-to-pump, signal-to-signal and pump-to-signal Raman interactions, spontaneous Raman emission and its temperature dependency, stimulated Raman scattering (SRS), pump depletions due to Raman energy transfer; high-order Stokes generation, multiple Rayleigh backscattering, fiber loss and spontaneous emission noise, all these parameters are considered [8]. In addition, this model is used as a gain medium for RFA [8, 9]. While the stimulated Brillouin scattering (SBS) effects, are not included in APA-RFA model. In other word, the gain saturation in RFA due to the large signal power that causes SBS effects is not included in this model.

In this paper, a simulation programs for Raman fiber amplifier are built for two different RFA models; APA-RFA and bidirectional fiber RFA (Bi-Fiber RFA) model. The effect of the large signal on the gain saturation is studied for both models for the first time to the best our knowledge. The experimental results show a good agreement with Bi-Fiber RFA model.

II. SIMULATION MODEL AND EXPERIMENTAL VALIDATION

A. Simulation Model

The simulation layout of average power model and bidirectional fiber of 25km length co-pumped RFA is illustrated in Fig.1. In APA-FRA, the output port of the pump coupler at point (a) is connected to the input port of the APA at point (b), while in Bi-Fiber RFA; point (a) is connected to the input port of Bi-Fiber at point (c).

The required parameters for Bi-Fiber FRA are entered in the main menu and sub menus of the program. The gain and the backward Brillouin signal can be obtained as a function of the input signal swept from -7 to 8 dBm at 1580 nm wavelength, and the Raman pump power swept from 200 to 500 mW in step of 100 mW at 1480 nm wavelength. The Bi-Fiber RFA parameters for the simulations are listed in Table-I.

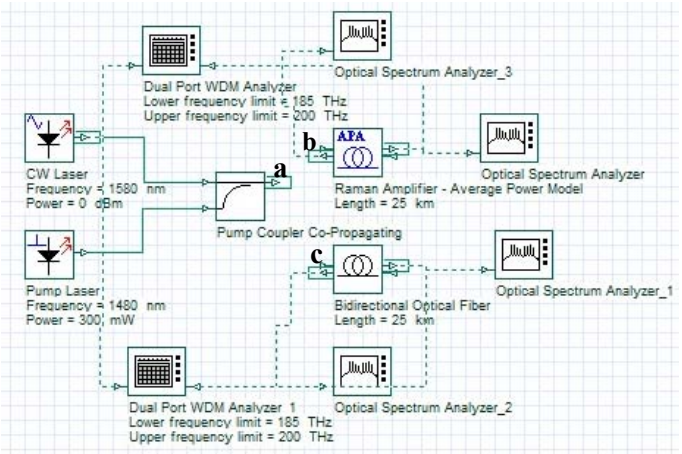

Fig.1. Simulation layout, APA and Bi-Fiber RFA