INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Thulium doped fiber amplifiers (TDFAs) can provide high power optical amplification in the wavelength range of 1460 nm--1545 nm (S and near-C bands). They can be potentially employed for dense wavelength division multiplexing (DWDM) in optical fiber communication over a broad range, unlike the Erbium-doped fiber amplifiers (EDFAs), which are active only in the conventional ``Erbium Window" of 1550 nm in the C-band. This research-work presents overmodulation of signal and gain dynamics on TDFAs using the EDFA's Bononi and Rusch model, making it the first approach of its kind on TDFAs. It portrays the overmodulation of digital optical communication signal, of which, the amplitude is modulated by low-frequency (~100 kHz), for line-surveillance and management control of optical information in DWDM TDFA systems. Signal-to-signal and signal-to-amplified spontaneous emission transfer functions are derived to predict the system performance under high input signal power conditions and its variation on the input modulation index. Overmodulation sensitivity for various levels of input signal power is investigated to demonstrate the undesirable increment in the output modulation index at 8 dBm and 1490 nm signal wavelength respectively at the corner frequency. It also provides a methodical testbed to analyze the signal wavelength effect, using MatLab-Simulink, resulting in the development of a simulator. The thesis proposes the phenomenon of modulation instability (MI) in TDFAs operating at a calculated optimum wavelength of 1460 nm. It focuses on the loss parameter and non-linear effects when the continuous wave signal is allowed to amplify inside TDFAs and perturbed with weak modulation signals. Analytical model starting from the non-linear Schrödinger-wave equation for the integrated gain including loss effects has been uniquely presented. The analysis is carried out to predict the frequency range for which MI could be invoked in TDFAs. The loss and non-linear factor analysis have been presented and a comparison of the frequency shift with and without losses has been done. Optimum TDFA length is also calculated and the parameters are compared to the existing state-of-the-art EDFAs. A special case is solved numerically as an example of a non-ideal case showing the MI's applicability as an active saturable absorber in building TDFA based femtosecond pulse-width lasers. Moreover, the pulse splitting effect through MI with variation in frequency chirp parameter of the input pulses and non-linear TDFA length is modeled, numerically solved, and simulated for various parameters. The input pulses considered are *sech*, *Gaussian,* and *super-Gaussian* type in a

1050 nm pumped heavily doped TDFA. The model is computationally solved on MatLab and the results are verified by incorporating similar conditions and parameters on OptiSystem simulation platform. The findings conclude the optimum non-linear length and the chirp parameter which has to be taken so as to obtain continuous-time domain pulse train as well as linearly spaced frequency combs for various applications. The optical conversion efficiency of TDFAs is dependent on parameters like Thulium-ion concentration, pump power, fiber length, dopant area, signal wavelength, and ion-ion interaction mechanisms (IM). This thesis also focuses on the analytical formulation and simulation of IM effects involving homogeneous up-conversion and pair induced quenching on TDFA gain characteristics. The beneficial aspects of IM effects are perceived in the selection of optimum pump power and TDFA gain. The findings on optimum doping radius, TDFA length, and an added advantage of a single wavelength (1050 nm) pump further assist to evaluate and establish the performance of TDFAs for S and near-C band optical fiber networks for the future.