Faculty of Electrical Engineering & Computer Science
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HOCHSCHULE BREMEN
UNIVERSITY OF APPLIED SCIENCES

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Amruta Gandhe

Polarization Independent All Optical Wavelength Conversion of DQPSK Signals using Highly Nonlinear Fiber

ABSTRACT - Masterthesis

FWM based parametric amplification and wavelength conversion initiated in HNLF, enables data rate and modulation format transparent wavelength conversion. The efficiency of the wavelength converted signal (idler) is mainly dependent on the pump power, which is limited by stimulated Brillouin scattering (SBS) inside the fiber. Enhancement of the usable pump power is possible by spectral broadening of the pump via pump-phase modulation. In conventional configurations, where only a single pump is used for FWM, the pump phase modulation introduces strong phase distortions on idler, which is critical for phase modulated data signals like DQPSK. Such phase distortions can be suppressed in dual pump configuration if the two pumps are phase modulated 180° out of phase with each other (counterphased).

Such a dual pump arrangement was realized in this thesis work and was tested in a polarization diversity configuration to realize polarization independent wavelength conversion. Several HNLFs were characterized for its basic properties and respective gain bandwidths to select the best candidate for dual pump investigations. With dual pump setup, it was possible to realize a flat gain bandwidth over a wide signal wavelength range with wavelength conversion efficiencies up to 22dB. Fiber dispersion plays important role in positioning of the pumps and signal relative to the zero dispersion wavelength of the fiber in order to minimize the phase mismatch, thereby leading to high conversion efficiencies over large bandwidth. Along with the optimum pump powers, the choice of perfect signal power is also necessary to avoid the operation in nonlinear regime due to gain saturation. Such an optimum wavelength converter setup (dual pump-straight configuration) resulted in a 3 dB conversion bandwidth of 18nm with more than 20dB conversion efficiency. Later, the fiber was tested under polinsensitive (dual pump loop configuration) wavelength converter setup and the 8nm polinsensitive gain bandwidth was realized. It was observed that, as signal gain increases polinsensitive bandwidth reduces, because polarization dependent gain (PDG) fluctuations increase with increasing pump powers. Still, over the wavelength range of 8nm PDG fluctuations were observed to be < 0.3dB; which can be regarded as almost polarization independent.

The characterized dual pump setup was then deployed to system experiments with 28GBaud-RZ-DQPSK signal to evaluate its susceptibility to data modulated signals. The DQPSK signal was passed through straight configuration AOWC and evaluated at the receiver; where the BER measurement was analyzed. The recorded OSNR penalties for varied signal gains indicated the signal degradations in AOWC because of pump induced nonlinear phase noise. Subsequently the performance was also tested for polinsensitive AOWC. In the entire thesis experimentation work, all the straight configuration measurements were done as the best-case comparison for polinsensitive loop configuration to allow for determining the influence of the loop configuration on the degradations.

The OSNR penalty recorded for highest signal gain 25dB in straight configuration was 0.5dB whereas for lower gains it was around 0.3dB. These penalties can be attributed to XPM from pump known as pump induced nonlinear phase noise. Another reason for high penalties for high gains was confirmed to be increasing nonlinear phase noise of the pumps with increasing gains. This was verified by testing 28-GBaud DQPSK signal with different pump OSNR values (53dB, 50dB and 46dB). It was found that lower pump OSNR values increase the signal degradations confirming the dependency an the pump quality. However, exact same penalties were observed for signal and idler for same signal gain which emphasizes the success of SBS suppression with counterphased pumps. Even small deviations from optimum pump counterphase setting lead to increased penalties.

While testing the polinsensitive setup, to address the arbitrary change in the polarization of signal, a polarization scrambler was used which generated arbitrary polarizations over the time. The highest signal gain tested in loop configuration was 20dB with OSNR penalty of 0.8dB which is higher than the straight configuration. The obvious reason behind it is the decreased pump OSNR due to Rayleigh scattering inside the loop. Also, it should be noted that, highest signal gain that was tested in loop configuration is lower than the highest signal gain in straight configuration to assure the operation in linear gain regime. Following the polarization scrambled signal, polarization insensitive wavelength conversion performance was tested for different signal polarization arrangements (single polarization) for example entire signal in clockwise or in counterclockwise direction of the loop, signal split in power 50/50 in both the direction. The performance of 50/50 signal splitting was better than CW and CCW signal splitting. Subsequently, to achieve higher data rates a time interleaved POLMUX signal was realized, which accommodated 112Gbit/s data rate. When polmuxed signal was applied to the polinsensitive wavelength converter, the OSNR penalties were similar to the single polarization. The BER measurements for wavelength converted signal (idler) shows similar performance in all the cases again indicating the excellent performance of the wavelength conversion. For all polarization independent BER measurements, fluctuations in PDG were observed to be <0.3dB over the time and over quite acceptable wavelength range which signifies the signal polarization independence of the wavelength converter.

With respect to till date published research experiments on polarization independent wavelength conversion of phase-modulated data signals (see section state of the art), the conversion efficiency has been pushed to positive value up to 20dB in this work. The residual polarization independency (<0.3dB) was comparable to previously published results.

The aim of the thesis is achieved.

Because of the excellent results of the conversion efficiencies, the demonstrated dual pump polindependent setup is capable of accommodating still higher data rates with other advanced modulation formats. Besides, to obtain larger signal tunability, cascading of the wavelength converters is feasible. But in this case, special efforts should be taken to achieve considerably high wavelength conversion efficiencies.