# SOA-based, Idler-free Phase Quantiser

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Energy consumption, system complexity and potential for integration are important factors when considering the suitability of all-optical processing, and depend upon both the scheme used and the medium in which it is performed. We have recently proposed a simple, wavelength-converting phase quantising scheme based on an idler-free phase-sensitive amplifier, notable for its flexibility of operating power and relative compactness [1]. We have demonstrated its performance for QPSK regeneration using an operating power of 24 dBm in 300 m of highly nonlinear fibre (HNLF). Despite offering low loss and high net nonlinearity, the size and geometry of the HNLF do not make it suitable for integration in a photonic device. Semiconductor optical amplifiers (SOAs) on the other hand, offer a particularly compact medium for nonlinear signal processing, combining an amplifier and nonlinear medium in one device. BPSK phase regeneration has been demonstrated in SOAs [2]; in this paper we experimentally demonstrate, to our knowledge, the first realisation of QPSK phase regeneration in SOAs, making use of the above idler-free scheme to realise a compact and more easily integrated QPSK regenerator.

The scheme, whose spectral configuration is illustrated in Fig. 1-a, makes use of two continuous wave pumps (P1 and P2), asymmetric in power and spectrally located such that conjugated signal photons (with phase $-\phi$) are coherently added to the signal's 3$^{rd}$ phase harmonic, resulting in a phase quantised signal appearing at the 3$^{rd}$ harmonic channel [3]. In the experiment, the pumps are provided by an optical frequency comb (with 40 GHz spacing) and phase locking is achieved through the use of a fibre stretcher operated in a feedback loop. After modulation, the 10 GBaud QPSK signal is combined with the pumps, which are all amplified with an EDFA and launched into the SOAs. Two cascaded SOAs were used, each with a length of about 0.5 mm, both operating with a current of 350mA, with total launch powers of 6dBm and 9dBm in the first and second SOA, respectively. The power of P1was kept as high as possible to maximise saturation of the SOAs' gain, which reduces the non-parametric gain, noise level and improves the squeezing of the QPSK signal and idlers. The relative power levels of the signal and P2 were optimised for best phase squeezing possible at the output.

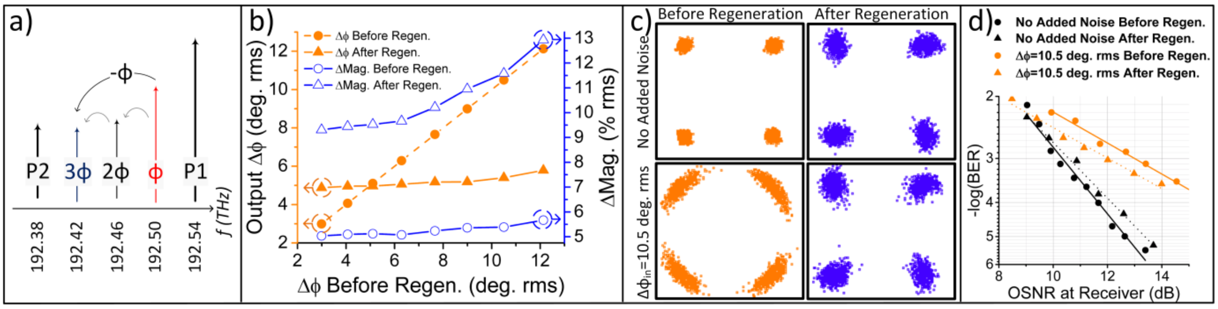


**Fig. 1** a) Wavelength converting, idler-free scheme; b) Phase and magnitude noise before and after regeneration versus input phase noise; c) Constellation plots before and after regeneration for two different noise levels; d) BER before and after regeneration both without additional phase noise and with 10.5 deg. rms phase noise.

Different broadband phase noise levels were artificially added to the signal with a phase modulator. These preliminary results show that the regenerator decreases phase noise in the 10.5 deg. rms case, albeit with an increase in amplitude noise. Fig. 1-b provides plots of phase and magnitude noise versus input phase noise before and after phase regeneration for a range of input phase noise levels. It can be seen that the output phase noise is relatively constant (~5.25 deg. rms) regardless of input phase noise, constituting an approximately 50% reduction in phase noise for high noise levels. This reduction is associated with an increase in amplitude noise, as typical for non-saturating phase regenerators. Fig. 1-c provides some examples of constellation plots before and after regeneration, both without additional noise, and with 10.5 deg. rms (highest level). Bit error rate measurements (BER) were also taken using an optical modulation analyser for a range of input phase noise levels, before and after regeneration (Fig. 1-d). With no added phase noise, the phase regenerator results in a power penalty of 0.25 dB for a BER of $10^{-3}$. With an input phase noise of $\Delta\phi_{in} = 10.5$ deg. rms, the regenerator improves receiver sensitivity by 1 dB for a BER of $10^{-3}$. We expect performance to improve through the use of a longer length of SOA and further optimisation of the launch powers into the SOAs.

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## References

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