Conversion efficiency and bandwidth of inter-modal four wave mixing in two-mode optical fibres

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FWM is a non-linear process where two or more wave propagating throughout a fibre result in a production of frequencies different to that of the input waves. Space division multiplexing and in particular mode division multiplexing (MDM) have shown promises in overcoming the capacity limit of single-mode fibres for optical telecommunications. Over long distances MDM systems would result in processes like inter modal FWM (IM-FWM). If such systems are to be used commercially, they will require methods of switching data signals between wavelengths and spatial modes. An attractive solution is provided by four-wave mixing (FWM) where two strong pump fields convert the signal into an idler field at another wavelength. However, applications of intermodal FWM (IM-FWM) for telecommunications in multimode fibres are relatively new. Recently, two potentially interesting IM-FWM processes have been identified: phase conjugation (PC) and Bragg scattering (BS) [Essiambre *et al*., IEEE Photon. Technol. Lett. 25, 539 (2013)].

Here we investigate conversion efficiencies and spectral bandwidths of PC and BS in a two-mode optical fibre as potential mode/wavelength conversion systems using two numerical models and compare with experimental results.

The first model uses the coupled amplitude equations for FWM [Agrawal, Nonlinear fiber optics, Academic Press (2013)] which take into account self and cross phase modulation and FWM between the four wavelength channels involved. This model was found to agree with experimental results of the PC idler. However discrepancies are found for BS, which we attribute to simultaneous and/or cascaded FWM processes within the same fibre. Thus we use a second, more sophisticated model, the multi-mode nonlinear Schrödinger equation [Poletti & Horak, JOSAB 25, 1645 (2008)] which, contrary to the first model, includes all third order nonlinear processes simultaneously and is additionally able to predict cascaded FWM processes that occur throughout the spectrum. We compare the differences between the two models, analyse the contributions to the BS and PC idlers from multiple FWM processes within the spectrum, and finally present comparisons to experimental results.