Short pulse sources based on erbium doped fibres

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The invention of the erbium doped fibre amplifier (EDFA) has led to a revolution in telecommunications permitting data transfer at rates previously unimaginable with conventional regenerator technology. With the problem of loss largely eliminated it is now dispersion and nonlinearity that represent the principle barriers to utilizing the enormous bandwidth offered by optical fibre. Soliton transmission in which the nonlinear and dispersive effects within the fibre can be made to balance and effectively cancel provide one means of getting access to more of that potential transmission capacity. As the field has advanced further limiting issues have been identified, e.g. Gordon Haus jitter [1], soliton interactions [2], acousto-optic interactions [3] etc., requiring more advanced solutions such as soliton control [4-6] to be sought.

The rapid development of amplifier technology and associated components has also led to rapid advances in other technically relevant areas; not least in the development of a wide range of novel short pulse generation techniques. Controlled access to optical gain in conjunction with nonlinear and dispersive effects within a fibre circuit permit a wide range of possibilities for the generation of optical pulse forms. The main focus of attention has concerned actively [7] and passively mode-locked lasers [8,9], however, a number of other powerful, non resonator based pulse generation schemes based on soliton effects have been proposed and demonstrated [10,11]. Pulse repetition rates from KHz to THz, pulse durations from 30fs-10 ns and pulse energies from pJ to mJ levels have all been demonstrated illustrating the enormous versatility of the medium.

At first glance a laser based soliton generator would perhaps seem to have little in common with a soliton transmission line, however, in both systems solitons undergo periodic loss and amplification, and experience the same nonlinear and dispersive effects. The principle difference between the two systems is that within a laser the losses are generally discrete, whereas in a transmission system they are generally distributed. This difference however is not significant in instances where average soliton dynamics apply and consequently the underlying physics is extremely similar. Almost all effects and concepts appropriate to one system manifest themselves in the other, albeit usually over different physical and temporal length scales.

One of the most striking examples of the strong linkage between the two research areas has been recently demonstrated in experiments with passively harmonically mode-locked ring lasers. It is now known that the propagating soliton excites a weak acoustic wave (via the electrostriction effect) causing a perturbation of refractive index and which repeats every 20 nanoseconds due to reflection from the fibre cladding [3]. Thus each propagating soliton affects propagation of the subsequent pulses and results in the so called long-range soliton interaction [12]. This detrimental acousto-optic effect first observed in soliton transmission lines may be used to good effect to harmonically mode-lock a soliton fibre laser, when the laser repetition rate coincides with eigen-frequency of the acoustic waves [13].

Another example of the similarity between fibre soliton lasers and soliton transmission systems comes from the recent experiments with mode-locked fibre lasers with fast saturable absorbers. The key idea of such lasers - to provide additional loss for low-intensity radiation by way of saturable absorbtion [14] -is completely applicapable to soliton transmission systems where undesirable non-soliton components can be successfully suppressed by appropriately placed saturable absorbers, resulting in substantial improvements in the system performance [15].

We also discuss the unique and enormous versatility of erbium based short pulse sources for the generation of ultra short pulses. To further illustrate this we describe our recent results on the generation and measurement of high frequency bright and dark optical solitons [16].

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