# Similaritons and Chirped Fibre Lasers

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**Abstract**

Self similar solutions of nonlinear partial differential equations are chirped solutions which maintain their mathematical form, whilst being scaled in time or amplitude. Standard techniques for finding such solutions have been developed with applications in nonlinear acoustics, plasma physics and other areas. Recently these techniques have been applied to locate new solutions of the nonlinear Schrödinger equation (NLSE), which are finding increasing applications in high power amplifiers and mode locked fibre lasers. Of particular interest are the solitary pulse solutions which are known as similaritons. The various different similariton solutions applying to pulse propagation under the influence of the NLSE and the LSE provide a route to the development of stable pulsed lasers, with the potential to generate much higher power pulse energies than are available through soliton laser systems.

There are three different experimental regimes areas where self similar propagation is important. These are propagation in the linear regime, and nonlinear propagation in the normal and the anomalous dispersion regimes. In the normal dispersion regime the NLSE supports the development of expanding parabolic similaritons as an asymptotic solution, whilst in the anomalous dispersion regime it has an exact compressing hyperbolic secant similariton solution.

The first demonstration of the existence of parabolic pulses was made using a high power amplifier at 1μ wavelength, using a seed pulse of about 200fs duration [1]. The asymptotic nature of the solution ensures that it forms regardless of the input pulse shape given sufficient gain and propagation length, but a short unchirped seed pulse facilitates rapid evolution to the asymptotic form. It is important for the fidelity of the similariton, that the amplifier has sufficient gain bandwidth to support the steadily increasing bandwidth of the developing pulse, but both Raman and rare earth doped fibre amplifiers have been shown to support their development experimentally[2]. Early on, it was clear that the possibility of constructing a laser yielding the parabolic shaped chirped output pulse was attractive, instead of developing it in a single pass amplifier from a separate seed pulse, although this has proved challenging.

Recently, similariton lasers of varying design have been constructed by different groups. In our laboratories the construction of these lasers has benefited materially from the development of a full theoretical model of their operation. Since the evolution of the similariton in the high gain region involves extensive spectral and temporal reshaping, the main challenge is to recover a suitable seed pulse from the output parabolic pulse, which has a wide bandwidth and strong linear chirp.

We have constructed fibre lasers which produce both parabolic and non parabolic output pulses depending upon the details of the laser design [3,4]. The lasers which produce a non parabolic pulse output are related to so called “ANDi” and “giant chirp” lasers which are the subject of much development currently, and whilst the output pulse does not have a parabolic shape, the propagation within some sections of the laser is still self similar.

**References**

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