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Chirped-pulse supercontinuum generation with a long-cavity Ti:sapphire oscillator

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ABSTRACT We demonstrate chirped-pulse supercontinuum generation in a conventional fibre with a relatively narrow-band, long-cavity, chirped-pulse Ti:sapphire oscillator delivering 200 nJ pulses. The inherent chirp of the outcoupled pulses were overcompensated by a 4-prism compressor to overcome damage threshold problems at the fibre entrance. The resulting fibre output spectrum corresponds to a pulse length of 7 fs in the transform-limit. The experimentally observed highly efficient spectral broadening process of negatively chirped pulses in the fibre is supported by simulation data.

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1 Introduction

Merging Ti:sapphire laser oscillator technology with the so-called long-cavity, chirped-pulse oscillator concept has brought significant advances in recent years [1–3]. The main objective of these development efforts was the increase of the pulse energy of femtosecond laser pulses directly available from oscillators. Thus several strong-field light-matter interaction experiments that were previously driven by oscillator-amplifier systems came within reach with relatively simple oscillators in an extremely cost-efficient manner [4]. Current state-of-the-art corresponds to pulse energies approaching the μJ frontier [3–5] and focused intensities exceeding 10^{14} W/cm^2 [4]. Moreover, further development efforts that combine this concept with cavity dumping [5] promise the possibility of the construction of μJ-level Ti:S oscillators.

Current chirped pulse oscillator technology exploits the following solutions: i) the resonator length of these lasers is increased with a so-called Herriott-cell (an imaging system with a unity ABCD matrix [6]). Since in mode-locked lasers such a cavity extension results in a decrease of the repetition rate (while the average output power usually stays the same) the energy of the outcoupled pulse can be increased. ii) However, a drastic increase that could be conceived easy by an arbitrarily huge cavity lengthening is limited by nonlinearities arising from the interaction of the focused pulses with the laser crystal. The result is pulse splitting, double pulsing and other unwanted phenomena that clamp the maximum intracavity pulse intensity in solitonically mode-locked oscillators. This drawback can be overcome by setting the net cavity dispersion either at a high negative value [1] or slightly positive [2–5] (as opposed to the slightly negative net cavity dispersion regime in which traditional soliton-like mode locking comes about). As a result, circulating mode-locked pulses in the oscillator become longer and (in the latter case) heavily chirped, and therefore they possess a lower peak intensity hindering the appearance of the above-mentioned nonlinearities. As a consequence, outcoupled pulses of a positive dispersion oscillator are also heavily chirped, but their phase modulation can be compensated for by e.g. a simple prismatic pulse compressor. iii) Since it was also noticed that an increase in cavity length results in the destabilization of the oscillator and hinders easy starting of mode-locking a saturable Bragg reflector (SBR) is introduced in the cavity which enables easy build-up and stabilization of the mode-locked operation [7, 8].

In spite of these solutions proliferating in the past 2–3 years there are some unresolved issues when it comes to the utilization of these lasers. Since their bandwidth is limited by the group delay dispersion oscillations of the chirped mirrors in the Herriott-cell and the SBR bandwidth, the shortest pulse duration available from the laser (and the subsequent linear extracavity pulse compressor) is limited to 30–60 fs [1–5]. A way to overcome this limitation is to evacuate the cavity thereby eliminating the need for chirped mirrors, however, the bandwidth in that case was also limited to 30–35 nm [4]. Even though the corresponding spectral content of these oscillators is sufficient for several novel experiments, such as material processing and nanofabrication, there are some particular spectroscopic, pump-probe and strong-field light-matter interaction experiments which call for broadening the output spectrum (and eventually pulse compression, if few-cycles pulses are necessary).

Therefore, an extracavity nonlinear element is needed for these applications in which spectral broadening of the output pulses can be carried out. Several solutions have been demonstrated in the past to achieve this for input laser pulses covering a wide range of parameter regimes. Very first demonstrations involved spectral broadening of ns pulses in single mode fibres [9] and this technique has also proven very efficient

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