Whitepaper

Shortest CEP stabilised Ti:Sapphire pulse

Abstract: A dual-output, self-synchronised, CEP-stabilised Ti:sapphire oscillator is presented, with a pulse duration of 4.4fs and a CEP phase noise of < 100 mrad using a Finesse 6 Pure pump laser.

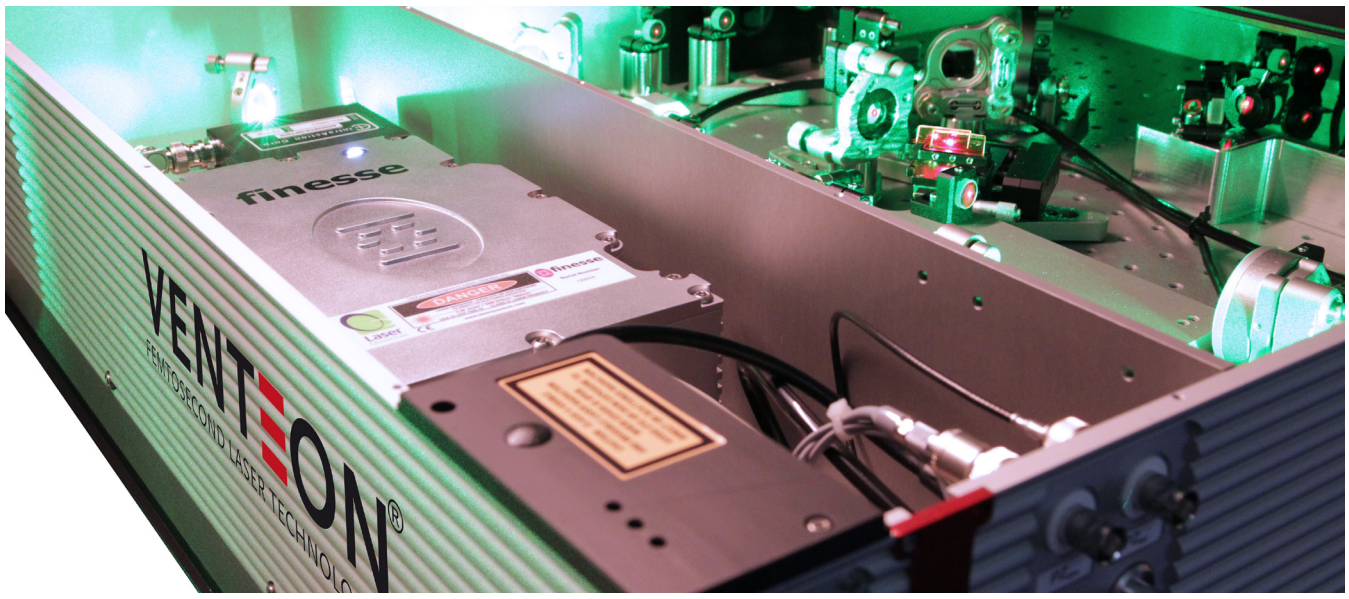

Figure 2: An image of the Finesse 6 Pure (Laser Quantum Ltd) pumping an octave-spanning VENTEON | PULSE : ONE femtosecond oscillator

Since the first demonstration of the gain material Ti:sapphire as a tuneable laser medium, there has been much interest in the exploitation of its broadband optical output, chief among which is the generation of ultra-short optical pulses. Since the pulse duration is inversely proportional to the optical bandwidth supported by the Ti:sapphire oscillator, careful attention must be paid to the optical design to compensate for dispersive effects.

The generation of sub-20 femtoseconds pulses (fs or 10^{-15} seconds) is now routinely demonstrated and has been commercially available for several years. In recent years, however, the pulse duration has been driven down to sub-10 fs by exploiting the full bandwidth of the Ti:sapphire crystal. Once the pulse duration is reduced to sub-6 fs, there are only approximately two cycles of the electric field within the envelope of the optical pulse. Figure 1 shows a comparison of two femtosecond pulses, their pulse envelope plotted with the corresponding electric field oscillation.

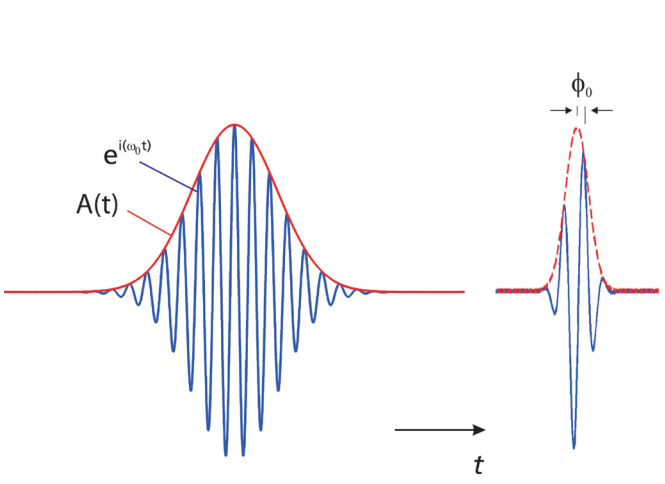

Figure 1: A comparison of two femtosecond pulses with the corresponding electric field oscillations. In the few-cycles pulse shown, the Ti:sapphire centre frequency of 375 THz, a wavelength of 800 nm respectively, the period of the electric field oscillation is 2.7 fs.

It can be seen that the number of contributing field oscillations supported by the longer pulse - which is already as short as 15 fs - is significantly higher than for the few-cycle femtosecond pulse. By stabilizing the carrier envelope phase (CEP, ϕ_0), the electric field of such few-cycle pulses can be controlled opening up for novel, significant ultrafast experiments such as high harmonic generation and attosecond science.

Using a Finesse Pure 6 W pump source at 532 nm from Laser Quantum Ltd, integrated into a common water-cooled platform, VENTEON Laser Technologies GmbH has demonstrated an octave-spanning direct CEP-stabilised output of well below 5 fs without the need for additional spectral broadening (Figure 2).

This system delivers the shortest commercially available pulses directly from a Ti:sapphire oscillator, with a SPIDER characterised pulse as short as 4.4 fs as shown in Figure 3.

The CEP phase noise of those pulses is less than 100 mrad. This requires a minimal amplitude noise of the Finesse Pure within the whole noise spectrum. With RMS noise significantly less than 0.03% (10 Hz to 100 MHz), the Finesse Pure is ideally suited to this purpose.

This laser system is directly applicable for optical parametric chirped pulse amplification (OPCPA) applications, since its octave-spanning spectral bandwidth allows the system to be equipped with two separate outputs which are intrinsically self-synchronised with ultra-low timing jitter. The first output can provide CEP-stable broadband sub-6 fs signal pulses; the second narrowband output at a centre frequency of 1030 nm can deliver a pulse energy of > 30 pJ in a spectral bandwidth of 10 nm (FWHM) and is an ideal seed for Yb-doped amplifier stages used for pumping NOPA stages of an OPCPA amplifier system.

In such an OPCPA amplifier system, the ultrashort pulse duration of the sub-6 fs signal seed pulses can be preserved and amplified up to multi-µJ pulse energies making an ideal source for high harmonic generation and ultrafast spectroscopy.

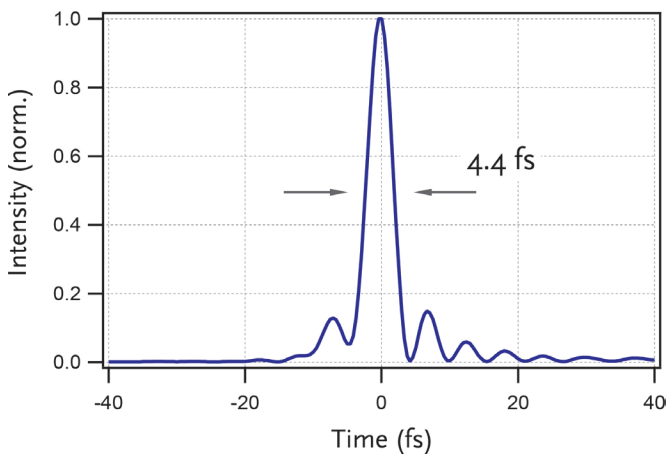

Figure 3: A SPIDER characterized pulse of 4.4 fs is shown: the shortest commercially available pulse from a CEP-stabilised Ti:sapphire laser.

Acknowledgements: Dr Stefan Rausch and Dr Thomas Binhammer of VENTEON Laser Technologies GmbH and Dr Lawrie Gloster of Laser Quantum Ltd.

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