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New approaches to the generation and characterization of few-cycle laser pulses

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NEW APPROACHES TO THE GENERATION AND CHARACTERIZATION OF FEW-CYCLE LASER PULSES

Habilitationsschrift

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ABSTRACT

With a gain bandwidth ranging from 650 nm to well above 1000 nm Ti:sapphire lasers offer a vast bandwidth supporting pulses of 5 fs duration. In this work, nearly the entire bandwidth could be utilized for mode-locking with pulse durations of 5.8 fs obtained directly from the laser. Important component in this type of lasers are chirped mirrors for dispersion compensation. Here a new generation of chirped mirrors is introduced. The approach of back-side coating the chirped mirror structure inherently avoids the impedance matching problem of previous chirped mirror generations and holds the potential to achieve dispersion compensation for octave-spanning spectra, which makes this technique particularly interesting for compression of white-light continua. A careful theoretical analysis is presented, followed by experiments with a mode-locked Ti:sapphire laser. Pulses from this laser are currently still the shortest well-characterized laser pulses from an oscillator. Measurement of such short pulses is an extremely important task. In this work several variants of frequency-resolved optical gating and spectral phase interferometry for direct electric-field reconstruction are described. These methods contributed much to the success of the work on the oscillator. With pulses as short as two optical cycles, the relative phase between carrier and envelope starts to become an important parameter in optics. A method to measure this parameter is described, relying on harmonic generation out of different part of the mode-locked laser comb and subsequent heterodyning. The phase noise of this quantity is carefully analyzed, and the laser is finally phase-locked to a reference oscillator with a residual rms phase jitter of only about 20 mrad. In the final part of this thesis, a novel method is described to generate short pulses by frequency doubling them in an aperiodic quasi-phase matching grating structure. An experimental demonstration yielded blue pulses as short as 5.3 fs. This sets a new record for the shortest pulse ever generated with second-harmonic generation and at oscillator repetition rates in the blue spectral range.