



UMEÅ UNIVERSITY

Near-single-cycle laser development

and applications in nanophotonics

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Academic dissertation

Which, with the due permission of the Vice-Chancellor of Umeå University for the examination for the Degree of Doctor of Philosophy in Science, is presented for public defence in NAT.D.480 on Thursday, 11 June, 2026 at 09:00.

The thesis will be defended in English.

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Organisation
Umeå University
Physics

Document type
Doctoral thesis

Date of publication
21 May 2026

Author
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Title
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Abstract

Throughout the history of laser development, the generation of ultrashort pulses has always been one of the most active frontiers. The generation of visible light pulses that contain only a few optical cycles is therefore a major achievement of modern physics. Femtosecond laser pulses now find applications across science, medicine, industrial manufacturing, and telecommunications, impacting many aspects of modern life.

This thesis presents the generation, characterization, and application of few-cycle light pulses. It includes the development of the Light Wave Synthesizer 100, one of the pioneering systems for waveform-controlled ultrafast optics. Throughout my thesis, this system was upgraded to facilitate higher peak intensities, shorter pulses and carrier-envelope phase (CEP) stabilization. A key contribution of this thesis is the development of a new compression chamber layout.

The broad spectra required for few-femtosecond pulses can give rise to spatio-spectral couplings. To characterize and control these effects, reliable measurement techniques are necessary. The simplified INSIGHT method is presented and evaluated against HASO multispectral, a commercially available device to whose development our research group, the RELativistic Attosecond physics Laboratory (REAL), contributed.

There are fundamental limits to how short a pulse of a given spectrum can be, commonly referred to as the Fourier transform limit. Different approaches are demonstrated how this limitation can be circumvented, supported by both simulations and experimental results.

Finally, one of the main applications of ultrashort pulses is the field of ultrafast spectroscopy. A central component of this work is the development of a degenerate pump-probe setup with exceptional sub-5-fs time resolution. This experimental platform is applied to a strongly coupled exciton-cavity system to observe the ultrafast generation and decay of polaritons, as well as excitons in WS₂, a semiconducting transition metal dichalcogenide.

Keywords: Laser, Nanophotonics, Ultrafast, Spectroscopy, Pump-probe, Polariton, Exciton, Strong coupling, Spatio-temporal, Spatio-spectral, Temporal superresolution

Language
English

ISBN
978-91-6850-002-7 (print)
978-91-6850-003-4 (pdf)

Number of pages
137 + 6 delarbeten/papers