DOCTORAL STUDIES COURSE UNIT DESCRIPTION

Name of subject	Scientific Field	Faculty	Center/Institute/ Department
Optics of Femtosecond Pulses (8 ECTS credits)	Physics N 002	Faculty of Physics	Laser Research Center
Student's workload	Hours	Student's workload	Hours
Lectures		Consultations	8
Individual study	192	Seminars	

Course annotation

Femtosecond light pulses in dispersive linear media.

Wave packet description methods. Propagation of the light beams. Time and space analogy. The light pulse models. Dispersive wave packet broadening. Dispersion theory approximations. Wave packet Fourier optics. Femtosecond light pulse propagation in optical systems: pulse filtering, lenses, mirrors, diffraction gratings and interferometers. Matrix description. Femtosecond pulses diffraction. Light wave-packets in optical fibers. Optical matrices for dispersive systems.

Light pulse self-action: self-phase-modulation, self-compression, solitons.

Self-action physics: the origin of nonlinear refractive index, conversion of amplitude modulation into the phase. Quasi-static cubic response and the nonlinear refractive index. Equations of nonlinear optics describing light propagation dynamics in medium with cubic nonlinearity. Self-phase-modulation of regular pulses. Shock envelope waves. Self-focusing of the femtosecond pulses. Super-broadening of spectrum, continuum generation, spectral description of self-phase-modulation. Stationary pulses - soliton propagation.

Light-matter interaction. Coherence.

Description of light-matter interaction by density matrix. Pulse shaping in resonance media. Nonlinear and non-resonance processes, their description methods. Coherent and non-coherent interaction. Maxwell-Bloch equations, the population, the evolution equation. Multiphoton interactions.

Femtosecond pulse parametric interaction and coherent scattering.

Physics of the femtosecond pulse nonlinear parametric interaction. Femtosecond pulse frequency doubling. Parametric amplification of ultra-short pulses. Sum frequency generation. Parametric solitons. Difference frequency generation and infrared femtosecond pulse Cherenkov radiation. Stimulated Raman scattering of the ultrashort pulses.

Fast control of the phase. The light pulse compression and generation.

Nonlinear optical phase modulators. Optical compressors and compression optimization. Self-phase-modulation in dispersive medium. Spectral filtering and random pulse compression. Femtosecond pulse duration and shape control, self-action and compression features.

Optical solitons.

Optical soliton formation. Single-soliton and multi-soliton solutions of Schroedinger equation. Experimental demonstration of optical solitons. The powerful ultrashort pulse self-compression: opportunities and challenges. Solitons propagation disturbing factors. The inverse-scattering transform method for nonlinear equation solutions.

Femtosecond laser system.

General principles for the development of laser systems. Solid-state lasers. Tunable femtosecond laser systems. Optical parametric chirped pulse amplification (OPCPA). The powerful femtosecond pulse amplification and generation. Far infrared femtosecond pulses.
Diagnostic methods.
Intensity and interferometric correlation. Measurement techniques. Pulse amplitude and phase reconstruction. Measurement Techniques of femtosecond spectroscopy. Data deconvolution. Transient absorption spectroscopy. Transient polarization rotation. Transient grating techniques. Femtosecond resolved fluorescence. Imaging technique.

List of literature

1. A.Akhmanov, V.A.Vysloukh, A.S.Chirkin, Optics of femtosecond laser pulses, American Institute of Physics, New York, 1992, 366 p.
2. J. C. Diels, W. Rudolph, Ultrashort laser pulse phenomena, London, Academic Press ,2006. 652 p.
3. A.P.Stabinis, G.Valiulis, Ultratrumpųjų šviesos impulsų netiesinė optika, TEV, Vilnius, 2008, 242 p.
4. R. W. Boyd, Nonlinear optics, Academic Press, USA, 2008, 640 p.
5. G. Cerullo and S. De Silvestri, Ultrafast optical parametric amplifiers, Rev. Sci. Instrum., vol. 74, 1–18 (2003).
6. D. Brida, C. Manzoni, G. Cirmi, M. Marangoni, S. Bonora, P. Villoresi, S. De Silvestri, and G. Cerullo, Few-optical cycle pulses tunable from the visible to the mid-infrared by optical parametric amplifiers, J. Opt. A 12, 013001 (2010).

Consulting teachers	Scientific degree	Pedagogical name	Main scientific works published in a scientific field in last 5 year period
Gintaras Valiulis	Dr. (HP)	Prof.	1. R. Šuminas, G. Tamošauskas, G. Valiulis, A. Dubietis, Spatiotemporal light bullets and supercontinuum generation in β-BBO crystal with competing quadratic and cubic nonlinearities, Opt. Lett., 41, 2097 (2016). 2. R. Šuminas, G. Tamošauskas, G. Valiulis, V. Jukna, A. Couairon, A. Dubietis, Multi-octave spanning nonlinear interactions induced by femtosecond filamentation in polycrystalline ZnSe, Appl. Phys. Lett. 110, 241106 (2017).
Vygandas Jarutis	Dr.	Doc.	1. Julius Vengelis,Vygandas Jarutis, and Valdas Sirutkaitis, "Visible supercontinuum generation in photonic crystal fiber using various harmonics of subnanosecond Q-switched laser", Optical Engineering 55(9), 096107 (September 2016). 2. Vygandas Jarutis, Karolis Jurkus, Valerijus Smilgevičius, Temperature tuned doubly resonant OPO: Peculiarities, Optics Communications 382, 405-409 (2017). 3. Julius Vengelis, Vygandas Jarutis, Valdas Sirutkaitis, "Estimation of photonic crystal fiber dispersion by means of

			supercontinuum generation", Optics Letters, Vol. 42, No. 9, 1844-1847, May 1 2017. 4. Julius Vengelis,Adomas Tumas, Ieva Pipinytė, Miglė Kuliešaitė, Viktorija Tamulienė,Vygandas Jarutis, imantas Grigonis, Valdas Sirutkaitis, Characteristics of optical parametric oscillator synchronously pumped by Yb:KGW laser and based on periodically poled potassium titanyl phosphate crystal, Optics Communications 410, 774–781 (2018). 5. Julius Vengelis, Vygandas Jarutis, and Valdas Sirutkaitis, Extension of supercontinuum spectrum, generated in polarization-maintaining photonic crystal fiber, using chirped femtosecond pulses, Optical Engineering 57(1), 016102 (January 2018). 6. Julius Vengelis, Vygandas Jarutis, and Valdas Sirutkaitis, Measurement of the phase refractive index of a photonic crystal fiber mode, Optics Letters, Vol. 43, No. 11, 2571-2574, June 1 2018. 7. Julius Vengelis, Vygandas Jarutis, Marius Franckevičius, Vudmantas Gulbinas, Valdas Sirutkaitis, Investigation of supercontinuum generated in the cladding of highly nonlinear photonic crystal fiber, Journal of the Optical Society of America B, Vol. 36, No. 2, A79-A85, February 2019. 8. Ieva Pipinytė, Julius Vengelis, Vygandas Jarutis, Mikas Vengris, Rimantas Grigonis, Valdas Sirutkaitis, Investigation of continuum generation in the non-zero dispersion-shifted fiber pumped by femtosecond nanojoule pulses in 1450–1800 nm spectral range, Results in Physics 17 (2020) 103064.
Certified during Doctoral Committee session 02/02/2022, protocol No. (7.17 E) 15600-KT-32			
Committee Chairman prof. S. Juršėnas			