Ultrafast Optical Physics II
SS 2015

Term Paper Assignment

We will have a term paper instead of a final examination. The purpose of this paper is to give you an opportunity to do independent reading and study in order to apply the theoretical concepts that you have learned in class.

Please submit a proposal for the term paper till **June 19, 2015**.

The proposal should contain a title, a half page abstract and 2-3 references on which the term paper will be based. The topic of the paper should be related to the general topic of the class. The paper can have several formats. It can be a summary and review of a few selected journal articles on a particular theme of interest covered also to some extend in the Ultrafast Optical Physics class, or it can be related to a problem you are addressing in your research.

The constraints are that the topic of the paper should be understandable to your peers and that it should be written such that it is self-contained, and understandable without additional references. Therefore, the paper must have an appropriate introduction that presents the topic in a clear scientific context. In addition, the paper must use to some extent the material we covered in class or relates to it.

The papers do not have to contain original research.

The paper should be submitted electronically in Word or pdf format. The file size should not be larger than 1 MB. The paper should be emailed with copies to the following addresses: franz.kaertner@cfel.de, guoqing.chang@cfel.de, and Christine.berber@cfel.de. The final term paper should be about 10 pages in length and is due on **July 10th, 2015, the last class.**

Possible topics:

1. **Limitations on Phase and Transmission of Filters (Output Couplers) due to Kramers-Krönig Relations.**
    1. G. Lenz, B. J. Eggleton, C. R. Giles, C. K. Madsen, and R. E. Slusher "Dispersive Properties of Optical Filters for WDM Systems," IEEE J. Quantum Electron. 34, 1390 – 1402 (1998).
    2. R. Unbehauen, Systemtheorie, Oldenbourg Verlag, 5. Auflage, Section 6.2.

2. **Kerr-Lens Modelocking**
    3. G. Cerullo, S. De Silvestri, V. Magni, L. Pallaro, "Resonators for Kerr-lens mode-locked femtosecond Ti:sapphire lasers", Opt. Lett. 19, pp. 807 — 809 (1994).
    4. G. Cerullo, S. De Silvestri, V. Magni, "Self-starting Kerr Lens Mode- Locking of a Ti:Sapphire Laser", Opt. Lett. 19, pp. 1040 — 1042 (1994).
    5. Hermann A. Haus, James G. Fujimoto, Erich P. Ippen " Analytic Theory of Additive Pulse and Kerr Lens Mode Locking", IEEE J. Quantum Electron., Vol. 28, No. 10 2086(1992)

3. **Strong Field Emission of Electrons from metal tips**
    6. P. Hommelhoff, Y. Sortias, A. Aghajani-Talesh, and M. A. Kasevich, "Field Emission Tip as a Nanometer Source of Free Electron Femtosecond Pulses," Phys. Rev. Lett. 96, 077401 (2006).
    7. P. Hommelhoff, C. Kealhofer, and M. A. Kasevich, "Ultrafast Electron Pulses from a Tungsten Tip Triggered by Low-Power Femtosecond Laser Pulses," Phys. Rev. Lett. 97, 247402 (2006).

8. C. Ropers, D. R. Solli, C. P. Schulz, C. Lienau and T. Elsaesser, "Localized Multiphoton Emission of Femtosecond Electron Pulses from Metal Nanotips," Phys. Rev. Lett. 98, 043907 (2007).
9. R. Bormann, M. Gulde, A. Weismann, S. V. Yalunin, and C. Ropers, "Tip-Enhanced Strong-Field Photoemission," Phys. Rev. Lett. 105, 147601 (2010)

4. Optical Atomic Clocks

10. M. Takamoto, F. L. Hong, R. Higashi, and H. Katori, "An optical lattice clock", *Nature* **435**, 321 (2005).
11. M. M. Boyd, A.D. Ludlow, S. Blatt, S. M. Foreman, T. Ido, T. Zelevinsky, and J. Ye, "Sr-87 lattice clock with inaccuracy below 10^{-15}", *Phys. Rev. Lett.* **98**, 083002 (2007).
12. J. Ye, H. J. Kimble, and H. Katori, "Quantum state engineering and precision metrology using state-insensitive light traps", *Science* **320**, 1734 (2008).
13. C. W. Chou, D. B. Hume, J. C. J. Koelemeij, D. J. Wineland, and T. Rosenband, "Frequency Comparison of Two High-Accuracy Al+ Optical Clocks," Phys. Rev. Lett. 104, 070802 (2010)

5. Optical Parametric Pulse Amplification

14. P. Maine, D. Strickland, P. Bado, M. Pessot, and G. Mourou, "Generation of ultrahigh peak power pulses by chirped pulse amplification", *IEEE J. Quantum Electron* **24**, 398 (1988).
15. G. Cerullo and S. De Silvestri, "Ultrafast optical parametric amplifiers", *Review of Scientific Instruments* **74**, 1 (2003).
16. A. Dubietis, R. Butkus, and A. P. Piskarskas, "Trends in chirped pulse optical parametric amplification", *IEEE J. Quantum Electron* **12**, 163 (2006).

6. Attosecond Pulse Generation

17. A. Scrinzi, M. Y. Ivanov, R. Kienberger, and D. M. Villeneuve, "Attosecond physics", *Journal of Physics B* **39**, R1 (2006).
18. E. Goulielmakis, V. S. Yakovlev, A. L. Cavalieri, M. Uiberacker, V. Pervak, A. Apolonski, R. Kienberger, U. Kleineberg, and F. Krausz, "Attosecond control and measurement: Lightwave electronics", *Science* **317**, 769 (2007).
19. P. B. Corkum, and F. Krausz, "Attosecond science", *Nature Physics* **3**, 381 (2007).

7. Femtosecond Enhancement Cavities

24. R. J. Jones and J. Ye, "Femtosecond pulse amplification by coherent addition in a passive optical cavity," Opt. Lett. 27, 1848–1850 (2002).
25. R. J. Jones and J. Ye, "High-repetition-rate coherent femtosecond pulse amplification with an external passive optical cavity," Opt. Lett. 29, 2812–2814 (2004).
26. R. J. Jones, K. D. Moll, M. J. Thorpe, and J. Ye, "Phase-coherent frequency combs in the vacuum ultraviolet via high-harmonic generation inside a femtosecond enhancement cavity," Phys. Rev. Lett. **94**, 193201 (2005).
27. A. Cingöz, D. C. Yost, T. K. Allison, A. Ruehl, M., Fermann, I. Hartl, and J. Ye, "Direct frequency comb spectroscopy in the extreme ultraviolet," Nature **482**, 68 (2012).
28. I. Pupeza, S. Holzberger, T. Eidam, H. Carstens, D. Esser, J. Weitenberg, P. Russbüldt, J. Rauschenberger, J. Limpert, T. Udem, A. Tünnermann, T. Hänsch, A. Apolonski, F. Krausz, and E. Fill, "Compact high-repetition-rate source of coherent 100 eV radiation," Nat. Photonics **7**, 608 (2013).

8. Enhancement of Nonlinear Effects due to slow light structures

29. K. Tajima, "All-Optical Switch with Switch-Off Time Unrestricted by Carrier Lifetime", *Jpn. J. Appl. Phys.*, **32**, pp. L1746-L1749, December 1993.
30. M. Soljacic, et. al., "Photonic-Crystal Slow-Light Enhancement of Nonlinear Phase Sensitivity", J. Opt. Soc. Am. B, 19(9), pp. 2052-2059, September 2002.

9. Laser Acceleration

31. Tajima, T. & Dawson, J. M. Laser electron accelerator. Phys. Rev. Lett. 43, 267–270 (1979).
32. Modena, A. et al. Electron acceleration from the breaking of relativistic plasma waves. Nature 337, 606–608 (1995).
33. C. G. R. Geddes, Cs. Toth, J. van Tilborg, E. Esarey, C. B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary and W. P. Leemans: "High-quality electron beams from a laser wakefield accelerator using |plasma-channel guiding," and following articles in Nature 431, p. 538 -550, 2004.

10. Designs and Applications of Optical Coatings for Femtosecond Lasers

34. R. Szipöcs and A. Koházi-Kis, "Theory and design of chirped dielectric mirrors", Appl. Phys. B 65, 115 (1997).
35. F. X. Kärtner et al., "Ultrabroadband double-chirped mirror pairs for generation of octave spectra", J. Opt. Soc. Am. B 18 (6), 882 (2001).
36. V. Pervak et al., "High-dispersive mirrors for femtosecond lasers", Opt. Express 16 (14), 10220 (2008).

11. High-intensity Laser Filamentation

37. S. L. Chin, "Some fundamental concepts of femtosecond laser filamentation," J. Korean Phys. Soc. 49, 281 (2006).
38. S.L. Chin, et al., "Filamentation nonlinear optics." Appl. Phys. B 86, 477–483 (2007),.
39. A. Couairon and A.Mysyrowicz, "Femtosecond filamentation in transparent media", Phys. Rep. 441, 47–189 (2007).
40. A. Couairon, J. Biegert, C. P. Hauri, W. Kornelis, F. W. Helbing, U. Keller, and A. Mysyrowicz," Self-compression of ultra-short laser pulses down to one optical cycle by filamentation," J. Mod. Opt. 53, 75 (2005).

12. Supercontinumm generation using dispersion-managed fibers

41. T. A. Birks et al., "Supercontinuum generation in tapered fibers", Opt. Lett. 25 (19), 1415 (2000)
42. J. M. Dudley et al., "Supercontinuum generation in air–silica microstructure fibers with nanosecond and femtosecond pulse pumping", J. Opt. Soc. Am. B 19 (4), 765 (2002)
43. J. Dudley et al., "Supercontinuum generation in photonic crystal fiber", Rev. Mod. Phys. 78, 1135 (2006)
44. J. M. Dudley and J. R. Taylor, "Ten years of nonlinear optics in photonic crystal fibre", Nature Photon. 3, 85 (2009)

13. Coherent Control of Femtosecond Lasers

45. A. M. Weiner, "Femtosecond pulse shaping using spatial light modulators," Rev. Sci. Instrum. 71, 1929–1960 (2000).
46. Z. Jiang, C.-B. Huang, D. E. Leaird, and A. M. Weiner, "Optical arbitrary waveform processing of more than 100 spectral comb lines," Nat. Photonics 1(8), 463–467 (2007).
47. T. Brixner and G. Gerber, "Femtosecond polarization pulse shaping," Opt. Lett. 26, 557-559 (2001).

14. Femtosecond Laser Micromachining

48. R. R. Gattass and E. Mazur, "Femtosecond laser micromachining in transparent materials," Nat. Photonics 2(4), 219-225 (2008).
49. G. Della Valle, R. Osellame, and P. Laporta, "Micromachining of photonic devices by femtosecond laser pulses," J. Opt. A, Pure Appl. Opt. 11(1), 013001 (2009).

15. Femtosecond-Laser-Based Imaging Techniques

50. D. Huang, E. A. Swanson, C. P. Lin, J. S. Schuman, W. G. Stinson, W. Chang, M. Hee, T. Flotte, K. Gregory, C. Puliafito, and J. Fujimoto, "Optical coherence tomography," Science 254, 1178–1181 (1991)
51. P. J. Campagnola, H.A. Clark, W.A. Mohler, A. Lewis and L.M. Loew, "Second-harmonic Imaging Microscopy of Living Cells," J. Biomed. Opt. 6, 277-286 (2001)

52. W.R. Zipfel, R.M. Williams, and W.W. Webb, “Nonlinear magic: multiphoton microscopy in the biosciences,“ Nature Biotech. 21, 1369-1377 (2003)

16. Microresonator based frequency comb

53. T. J. Kippenberg, R. Holzwarth, S. A. Diddams, “Microresonator-Based Optical Freqeuncy Combs,“ Science 29, Vol. 332 no. 6029 pp. 555-559 (2011), DOI: 10.1126/science.1193968
54. C. Y. Wang, et al. “Mid-infrared optical frequency combs at 2.5 micron based on crystalline microresonators,“ Nature Communications 4, 1345 (2012), doi:10.1038/ncomms2335

17. Ultrafast Coherent Nonlinear Microscopy:

55. Martin Aeschlimann et al., “Coherent Two-Dimensional Nanoscopy,” Science 333, 1723 (2011)
56. Richard Hildner, Daan Brinks & Niek F. van Hulst, “Femtosecond coherence and quantum control of single molecules at room temperature,” Nature Physics 7, 172 (2011)
57. K. E. Sheetz and J. Squier, “Ultrafast optics: imaging and manipulating biological systems,” Journal of Applied Physics 105, 051101 (2009)