

Femtosecond Molecular Fieldoscopy

By Dr. Hanieh Fattahi

Abstract:

Femtosecond Fieldoscopy is a novel metrology for detecting the electric field of light with high detection sensitivity, dynamic range, upto petahertz detection bandwidth, and high spatial resolution. These criteria offer unprecedented prospects in label-free spectroscopy and microscopy. In this talk, I present our recent results on the development of the ultrashort source required for Femtosecond Fieldoscopy, highly sensitive detection of water molecules in the gas and liquid phase, and a roadmap toward high-resolution spectro-microscopy.



Personal details

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Education

2008-2015 Ph. D. in Physics with *summa cum laude/ highest distinction*, Max Planck Institute of Quantum Optics and Ludwig-Maximilians-University, Munich, Germany; Chair of Prof. Ferenc Krausz
2005-2007 M.Sc. in Physics, Sharif University of Technology, Teheran, Iran
2001-2005 B.Sc in Physics, University of Zanjan, Zanjan, Iran

Scientific career

2020, Independent Group Leader (W2 equivalent position), Max Planck Institute for the Science of Light, Erlangen, Germany
2022-2023 Visiting Assistant Professor, University of Rochester, Rochester, USA
2019-2020 Visiting Scientist, Harvard University, Cambridge, USA; Chair of Prof. Sunney Xie
8.2017-2.2018 Visiting Scientist, Oxford University, Oxford, UK; Chair of Prof. Philipp Kukura
6.2017-7.2017 Konstanz University, Konstanz, Germany; Chair of Prof. Alfred Leitenstorfer
2017-2019 MINERVA Group Leader, Max Planck Institute of Quantum Optics, Munich, Germany
2015-2017 Postdoctoral Scientist, Max Planck Institute of Quantum Optics, Munich, Germany; Chair of Prof. Ferenc Krausz

Research topics

Mid-infrared, overtones, and stimulated Raman fieldoscopy/ Advancing sensitive, field-resolved metrologies/ Development of mid-infrared and near-infrared few-cycle sources/ Development of nonperturbative, non-invasive (sub)-cellular imaging techniques/ High field physics, solotronics and quantum material.

Four major research accomplishments

Femtosecond molecular Fieldoscopy

Detecting the electromagnetic field of molecular responses when excited by near-infrared femtosecond pulses for the first time.

Petahertz field-resolved technology

Advancing the frontiers of ambient-air field-resolved technology to petahertz frequencies.

Third-generation femtosecond technology

Advancing the frontiers of high-energy few-cycle pulses towards sub-cycle regime by field synthesis.

Advancing Yb:YAG thin-disk laser technology

towards the higher peak and average power.

Publishing impact

Number of citations: 1303

H-index: 12

Awards and appointments

2021, Member of the [Max Planck Quantum Alliance](#), Germany
2020, Fellow of [Max Planck School of Photonics](#)
2019, Max Planck Research Group Leader, Erlangen, Germany
2019 Selected as the best lecturer by students in the Siegman international summer school on lasers, Rochester
2018, Selected as a member of the [Elisabeth-Schiemann Kolleg](#), Max Planck Society
2017-2019 Minerva fast-track position of Max Planck Society, Munich, Germany

- 2016-2019 Co-coordinator of the International Max Planck Research School of Advanced Photon Science ([IMPRS-APS](#)), Munich, Germany
- 2016, Fellow of [Max Planck Center for Extreme and Quantum Photonics](#), Ottawa, Canada
- 2008-2012 PhD scholarship, International Max Planck Research School of Advanced Photon Science

Professional activities

- 2023 Member of the technical program committee of UFO XIII, Bariloche
- 2022 Member of the technical program committee of IEEE Photonics Conference, Vancouver
- 2021 Member of the technical program committee of EOSAM, Rome
- 2021 Member of the technical program committee of IEEE Photonics Conference, Vancouver
- 2021 Member of the technical program committee of CLEO Europe, Munich
- 2020 Member of the technical program committee of IEEE Photonics Conference, Vancouver
- 2019 Co-organizer of a special symposium, CLEO-Europe: Novel techniques for molecular sensing
- 2018 Organizer of the Theodor Maiman seminars at Max Planck Institute of Quantum Optics
- 2018 Organizer of the PhD carrier day, Ringberg castle in Munich
- 2017 Member of the technical program committee for UFO XI, Jackson Hole
- 2016 Co-organizer of a special symposium, CLEO US: Ultrafast Dynamics in Solids, San Jose
- 2016 Co-organizer of a special workshop, CLEO US: Attosecond Nonlinear Optics, San Jose
- 2015 Organizer of trilogy workshops: [Future of Ultrashort Pulses](#)
- Founder of the [Green room Book Club](#)
- Co-founder of the podcast series: [LIGHT WAVE](#)

Invited talks

- 2022, Sep "Femtosecond Fieldoscopy: A novel spectro-microscopy technique", ICO25, Dresden
- 2022, June Bothe Colloquium, MPI for Nuclear Physics, Heidelberg
- 2022, May "Ultrashort pulses for Sensing and Microscopy", Colloquium, Caltech
- 2022, May "Ultrashort pulses for Sensing and Microscopy", Colloquium, University of Rochester
- 2022, April "Femtosecond Fieldoscopy", Invited talk, SPIE meeting, Strasbourg
- 2021, Oct "Ultrashort pulses for Sensing and Microscopy", Schawlow-Towns Symposium, Ottawa
- 2020, July Invited lecturer in the Siegman international summer school on lasers, Virtual
- 2020, June "Towards spectro-microscopy at extreme limits", Colloquium, Virtual, Stuttgart
- 2020, May "Sub-cycle pulse generation: from petahertz to terahertz", Photonics North, Virtual
- 2019, Oct "Femtosecond Molecular Fieldoscopy", Max Planck Society section symposium, Berlin
- 2019, July Invited lecturer in the Siegman international summer school on lasers, Rochester
- 2019, May "Advanced laser technology for fs- and as-spectroscopy," CLEO, San-Jose
- 2018, Oct "Molecular Fieldoscopy," Attosecond Physics at the Nanoscale, Daejeon
- 2017, Dec "Towards high energy, sub-cycle pulses at PHz frequency," Imperial College London
- 2017, Oct "High energy, sub-cycle pulses at PHz frequency," UFO XI, Wyoming
- 2016, Oct "Towards attosecond pulse generation in the X-ray regime," FIO, Rochester
- 2015, May "Third-generation femtosecond technology," CLEO, San Jose

Professional affiliations

- 2016, Member of the German Physical Society (DPG)
- 2015-2021 Member of the executive committee of Short Wavelength Sources and Attosecond /High Field Physics Technical Group of Optical Society of America (OSA)
- 2015-2017 Young Professional member of the Optical Society of America (OSA)
- 2009, Member of the Optical Society of America (OSA)

Patents

- H. Fattahi, "Method and apparatus for creating a microscopic sample image of a molecular vibrational response of a sample," PCT/EP2020/075849.
- H. Fattahi, F. Krausz, "Pulse light source device and method for creating cep stable fs laser pulses," PCT/EP2016/000965, WO2017211374A1.
- H. Fattahi, F. Krausz, M. Huber, I. Pupeza, M. Zigman "Methods and devices for measuring changes in the polarization response of a sample by time-domain infrared spectroscopy," PCT/EP2017/056705, WO2018171869A1.

Book chapters

- 2016 H. Fattahi, "High energy and short pulse lasers", ISBN 978-953-51-4758-9
2015 H. Fattahi, "Third-generation femtosecond technology", ISBN 978-3-319-20024-8
2013 R. Tahvildari, H. Fattahi, A. Amjadi, "Cataract Surgery", ISBN 978-953-51-0975-4

Publication list

- G. Barbiero, H. Wang, M. Graßl, S. Gröbmeyer, D. Kimbaras, M. Neuhaus, V. Pervak, T. Nubbemeyer, H. Fattahi, M. F Kling, "Efficient nonlinear compression of a thin-disk oscillator to 8.5 fs at 55 W average power," *Optics Letters*, 53, 125601 (2021). <https://doi.org/10.1364/OL.440303>
- G. Barbiero, H. Wang, J. Brons, B. Chen, V. Pervak, H. Fattahi, "Broadband terahertz solid-state emitter driven by Yb:YAG thin-disk oscillator," *Journal of Physics B*, 46 (21), 5304 (2020). <https://doi.org/10.1088/1361-6455/ab8049>
- Alismail, H. Wang, G. Barbiero, N. Altwaijry, S. Hussain, V. Pervak, W. Schweinberger, A. Azzeer, F. Krausz, H. Fattahi, "Multi-octave, CEP-stable source for high-energy field synthesis," *Science Advances* 6, eaax 3408 (2020). DOI: [10.1126/sciadv.aax3408](https://doi.org/10.1126/sciadv.aax3408)
- H. Wang, A. Alismail, G. Barbiero, R. N. Ahmad, H. Fattahi, "High Energy, Sub-Cycle, Field Synthesizers," *IEEE Journal of Selected Topics in Quantum Electronics*, (2019). DOI: [10.1109/JSTQE.2019.2924151](https://doi.org/10.1109/JSTQE.2019.2924151)
- Alismail, H. Wang, G. Barbiero, S. A. Hussain, W. Schweinberger, F. Krausz, and H. Fattahi, "Near-infrared molecular fieldoscopy of water," *Proceedings Volume 10882, Multiphoton Microscopy in the Biomedical Sciences XIX*; 1088231 (2019). DOI: [10.1109/CLEOE-EQEC.2019.8872880](https://doi.org/10.1109/CLEOE-EQEC.2019.8872880)
- M. Wendl, M. Hoegner, H. Fattahi, "Theoretical Study: High Harmonic Generation by Light Transients," *Applied Science* 8, 728 (2018). <https://doi.org/10.3390/app8050728>
- H. Fattahi, Z. Fattahi, A. Ghorbani, "Prospects of Third-generation Femtosecond Laser Technology in biological spectromicroscopy," *Journal of Optics* 20, 5 (2018). DOI: [10.1088/2040-8986/aab79a](https://doi.org/10.1088/2040-8986/aab79a)
- Alismail, H. Wang, J. Brons, H. Fattahi, "20 mJ, 1 ps Yb:YAG Thin-disk Regenerative Amplifier," *J. Vis. Exp.* 125, 55717 (2017). DOI: [10.3791/55717](https://doi.org/10.3791/55717)
- H. Wang, A. Alismail, G. Barbiero, M. Wendl, H. Fattahi, "Cross-polarized, multi-octave supercontinuum generation," *Optics Letters* 42, 2595 (2017). <https://doi.org/10.1364/OL.42.002595>
- Alismail, H. Wang, N. Altwaijry, H. Fattahi, "Carrier-envelope phase stable, 5.4 μ J, broadband, mid-infrared pulse generation from a 1-ps, Yb:YAG thin-disk laser," *Applied Optics* 56, 4990 (2017). <https://doi.org/10.1364/AO.56.004990>
- G. Vampa, H. Fattahi, J. Vučković, and F. Krausz, "Nonlinear optics: Attosecond nanophotonics," *Nature Photonics* 11, 210 (2017). <https://doi.org/10.1038/nphoton.2017.41>
- T. Nubbemeyer, M. Kaumanns, M. Ueffing, M. Gorjan, A. Alismail, H. Fattahi, J. Brons, O. Pronin, H. G. Barros, Z. Major, T. Metzger, D. Sutter, and F. Krausz, "1 kW, 200 mJ picosecond thin-disk laser system," *Optics Letters* 42, 1381 (2017). <https://doi.org/10.1364/OL.42.001381>
- H. Fattahi, H. Wang, A. Alismail, G. Arisholm, V. Pervak, A. Azzeer, and F. Krausz, "Near-PHz-bandwidth, phase-stable continua generated from a Yb:YAG thin-disk amplifier," *Optics Express* 24, 24337 (2016). <https://doi.org/10.1364/OE.24.024337>
- H. Fattahi, "Sub-cycle light transients for attosecond, X-ray, four-dimensional imaging," *Invited Article, The Contemporary Physics Journal*, 57, 1 (2016). <https://doi.org/10.1080/00107514.2016.1231870>
- T. Amotchkina, H. Fattahi, A. Yuriy, M. Trubetskov, and V. Pervak, "Broadband beamsplitter for high intensity laser applications in the infra-red spectral range," *Optics Express* 24, 16752 (2016). <https://doi.org/10.1364/OE.24.016752>
- A. Sommer, E. M. Bothschafter, S. A. Sato, C. Jakubeit, T. Latka, O. Razskazovskaya, H. Fattahi, M. Jobst, W. Schweinberger, V. Shirvanyan, V. S. Yakovlev, R. Kienberger, K. Yabana, N. Karpowicz, M. Schultze, and F. Krausz, "Attosecond nonlinear polarization and energy transfer in dielectrics," *Nature* 534, 86 (2016). <https://doi.org/10.1038/nature17650>

- T. Buberl, A. Alismail, H. Wang, N. Karpowicz, and H. Fattahi, "Self-compressed, spectral broadening of Yb:YAG thin-disk amplifier," *Optics Express* 24, 10286 (2016). <https://doi.org/10.1364/OE.24.010286>
- H. Fattahi, A. Alismail, H. Wang, J. Brons, O. Pronin, T. Buberl, L. Vámos, G. Arisholm, A. M. Azzeer, and F. Krausz, "High-power, 1-ps, all Yb:YAG thin-disk regenerative amplifier," *Optics Letters* 41, 1126 (2016). <https://doi.org/10.1364/OL.41.001126>
- H. Fattahi, A. Schwarz, X. T. Geng, S. Keiber, D. Kim, F. Krausz, and N. Karpowicz, "Decoupling chaotic amplification and nonlinear phase in high-energy thin-disk amplifiers for stable OPCPA pumping," *Optics Express* 22, 31440 (2014). <https://doi.org/10.1364/OE.22.031440>
- H. Fattahi, H. Barros, M. Gorjan, T. Nubbemeyer, B. Alsaif, C. Y. Teisset, M. Schultze, S. Prinz, M. Haefner, M. Ueffing, A. Alismail, L. Vámos, A. Schwarz, O. Pronin, J. Brons, X. T. Geng, G. Arisholm, M. Ciappina, V. S. Yakovlev, D. Kim, A. M. Azzeer, N. Karpowicz, D. Sutter, Z. Major, Thomas Metzger, and F. Krausz, "Third-generation femtosecond technology," *Optica* 1, 45 (2014). <https://doi.org/10.1364/OPTICA.1.000045>
- H. Fattahi, A. Schwarz, S. Keiber, and N. Karpowicz, "Efficient, octave-spanning difference-frequency generation using few-cycle pulses in simple collinear geometry," *Optics Letters* 20, 4216 (2013). <https://doi.org/10.1364/OL.38.004216>
- Y. Deng, A. Schwarz, H. Fattahi, M. Ueffing, X. Gu, M. Ossiander, T. Metzger, V. Pervak, H. Ishizuki, T. Taira, T. Kobayashi, G. Marcus, F. Krausz, R. Kienberger, and N. Karpowicz, "Carrier-envelope-phase-stable, 1.2 mJ, 1.5 cycle laser pulses at 2.1 μm ," *Optics Letters* 37, 4973 (2012). <https://doi.org/10.1364/OL.37.004973>
- H. Fattahi, C. Y. Teisset, O. Pronin, A. Sugita, R. Graf, V. Pervak, X. Gu, T. Metzger, Z. Major, F. Krausz, and A. Apolonski, "Pump-seed synchronization for MHz repetition rate, high-power optical parametric chirped pulse amplification," *Optics Express* 20, 9833 (2012). <https://doi.org/10.1364/OE.20.009833>
- A. Schwarz, M. Ueffing, Y. Deng, X. Gu, H. Fattahi, T. Metzger, M. Ossiander, F. Krausz, and R. Kienberger, "Active stabilization for optically synchronized optical parametric chirped pulse amplification," *Optics Express* 20, 5557 (2012). <https://doi.org/10.1364/OE.20.005557>
- R. Tahvildari, H. Fattahi, and A. Amjadi, "Thermal analysis of different tips for various operating modes of phacoemulsification system," *Journal of Biomedical Science and Engineering* 03, 727 (2010). DOI: [10.4236/jbise.2010.37097](https://doi.org/10.4236/jbise.2010.37097)