Stanford

Matthias Kling

Professor of Photon Science and, by courtesy, of Applied Physics

Photon Science Directorate

Bio

BIO

Matthias Kling is a Professor of Photon Science and (by courtesy) of Applied Physics at Stanford University and the Director of the Science, Research and Development (SRD) Division at the Linac Coherent Light Source (LCLS) at the SLAC National Accelerator Laboratory. Kling received a Diploma in Physics in 1998 and a PhD in Physical Chemistry in 2002 from Goettingen University in Germany. He subsequently was a postdoctoral researcher at the University of California at Berkeley and at AMOLF in Amsterdam, The Netherlands. From 2007 Kling led the Research Group on Attosecond Imaging at the Max Planck Institute of Quantum Optics (MPQ) in Garching, Germany, and was Assistant Professor at Kansas-State University from 2009 until 2013. In 2013, he became Professor of Physics at the Ludwig-Maximilians-Universität (LMU) in Munich in Germany and was appointed as Max Planck Fellow at MPQ in 2019. Kling joined Stanford University in 2021, leading the Research Group on Ultrafast Electronics and Nanophotonics and serving as the Director of the SRD Division at LCLS at SLAC.

ACADEMIC APPOINTMENTS

- Professor, Photon Science Directorate
- Professor (By courtesy), Applied Physics
- Member, Bio-X
- Member, Stanford PULSE Institute

ADMINISTRATIVE APPOINTMENTS

- Professor of Photon Science & Applied Physics (by courtesy), Stanford University, (2021- present)
- SRD Division Director, LCLS, SLAC, (2021- present)
- Max Planck Fellow, Max Planck Institute of Quantum Optics, Germany, (2019-2023)
- Professor of Physics, LMU Munich, Germany, (2013-2021)
- Assistant Professor of Physics, Kansas-State University, (2009-2013)
- Max Planck Group Leader, Max Planck Institute of Quantum Optics, Germany, (2007-2013)

HONORS AND AWARDS

- OPTICA Fellow, OPTICA (2024)
- APS Fellow, American Physical Society (2019)
- Max Planck Fellow, Max Planck Society (2019)
- ERC Starting Grant, European Research Council (2013)
- Early Career Award, Department of Energy (2012)
- Heisenberg Fellow, German Research Foundation (2012)

- Nernst-Haber Bodenstein Prize, German Bunsen Society (2012)
- Roentgen Prize, Giessen University (2011)
- Emmy-Noether Fellow, German Research Foundation (2007)
- Marie-Curie Fellow, European Research Council (2004)
- Feodor-Lynen Fellow, Alexander von Humboldt foundation (2003)

PROFESSIONAL EDUCATION

- Ph.D., University of Goettingen, Germany , Physical Chemistry (2002)
- Certificate, Jena University, Germany , Laser Physics (2000)
- Diploma, University of Goettingen, Germany , Physics (1998)

LINKS

- Ultrafast Electronics and Nanophotonics Group: https://uen.stanford.edu
- LCLS/SLAC: https://lcls.slac.stanford.edu/
- Stanford PULSE Institute: https://ultrafast.stanford.edu/
- SLAC National Laboratory: https://www6.slac.stanford.edu/

Research & Scholarship

CURRENT RESEARCH AND SCHOLARLY INTERESTS

The fastest timescale of electron motion within nanostructures is attoseconds (1 attosecond = 10-18 seconds). We have pioneered the field attosecond nanophotonics and are currently conducting research to extend the state-of-the-art to multi-dimensional spectroscopies, x-ray emission and scattering using intense attosecond XFEL pulses. We aim to explore the dynamics of many-electron effects, including correlation-driven and collective effects. A particularly important open question is the transition from many-body quantum physics to classical dynamics. This will largely impact applications of nanosystems in optoelectronic devices used in ultrafast electronics and computing. As an example, ultrafast plasmonic circuitry can overcome current limitations in resistive electronics and might open an avenue towards quantum computing at ambient temperature.

We also address the question, how aerosolized particles can enable and catalyze light-induced chemical processes. Reaction nanoscopy is a powerful method that is developed in our group for analyzing the surface chemistry on aerosols with nanometer spatial and femtosecond temporal resolution. We aim to advance this technique to solve fundamental questions in astro- and atmospheric chemistry. Among these are the mechanisms of chemical transformations under extreme conditions, where such particles are exposed to high-intensity or high-energy radiation.

We aim to develop, expand, and exploit field-resolved spectroscopies towards higher frequencies in the THz and PHz domains. Opening up these frequency ranges will enable sensitivity to a manyfold of vibrational and electronic transitions in organic electronics and 2D-materials. Field-resolved spectroscopy is a powerful technique that permits addressing the sub-cycle response of a solid to a lightfield. Exploring and controlling many-body excitations and scattering dynamics opens a path for optimized energy conversion in optoelectronic devices. The sub-cycle control of a device builds the basis for lightwave electronics, which may push the speed of computing to its ultimate limit.

We engage in the development of high-average and high-peak power ultrashort light sources. These include optical-parametric chirped pulse amplifiers (OPCPAs) driven by high-power fiber, thin-disk and Innoslab amplifiers. We focus on ultrashort few-cycle pulse generation in the visible and mid-infared spectral region with stable and controllable electric field waveforms. The R&D efforts also include nonlinear tools for pulse characterization. Such capabilities are instrumental in addition to the facility-based light sources in our research on ultrafast nanophotonics, lightwave electronics, and ultrafast x-ray science.

Teaching

COURSES

2023-24

- Synchrotron Radiation and Free Electron Lasers: Principles and Applications.: APPPHYS 325 (Aut)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Paris Franz, Jun Wang

Postdoctoral Faculty Sponsor

Daniel Jost, Tom Linker, Ilana Porter, Vandana Tiwari

Doctoral Dissertation Advisor (AC)

Samuel Sahel-Schackis, Selene She

Publications

PUBLICATIONS

- **Propagation effects in polarization-gated attosecond soft-X-ray pulse generation.** *Optics express*
  Mitra, S., Schotz, J., Zhang, C., Hyuk Ko, D., Chang, Z., Corkum, P. B., Staudte, A., Kling, M. F.
  2024; 32 (2): 1151-1160
- **49 W carrier-envelope-phase-stable few-cycle 2.1 & mu;m OPCPA at 10 kHz** *OPTICS EXPRESS*
  Seeger, M. F., Kammerer, D., Bloechl, J., Neuhaus, M., Pervak, V., Nubbemeyer, T., Kling, M. F.
  2023; 31 (15): 24821-24834
- **Resonance Effect in Brunel Harmonic Generation in Thin Film Organic Semiconductors** *ADVANCED OPTICAL MATERIALS*
  Li, W., Saleh, A., Sharma, M., Huenecke, C., Sierka, M., Neuhaus, M., Hedewig, L., Bergues, B., Alharbi, M., ALQahtani, H., Azzeer, A. M., Graefe, S., Kling, et al
  2023
- **Enhanced cutoff energies for direct and rescattered strong-field photoelectron emission of plasmonic nanoparticles** *NANOPHOTONICS*
  Saydanzad, E., Powell, J., Summers, A., Robatjazi, S., Trallero-Herrero, C., Kling, M. F., Rudenko, A., Thumm, U.
  2023
- **Reaction nanoscopy of ion emission from sub-wavelength propanediol droplets** *NANOPHOTONICS*
  Rosenberger, P., Dagar, R., Zhang, W., Majumdar, A., Neuhaus, M., Ihme, M., Bergues, B., Kling, M. F.
  2023
- **Linear and Nonlinear Optical Properties of Iridium Nanoparticles Grown via Atomic Layer Deposition** *COATINGS*
  Schmitt, P., Paul, P., Li, W., Wang, Z., David, C., Daryakar, N., Hanemann, K., Felde, N., Munser, A., Kling, M. F., Schroeder, S., Tuennermann, A., Szeghalmi, et al
  2023; 13 (4)
- **Light-Induced Subnanometric Modulation of a Single-Molecule Electron Source.** *Physical review letters*
  Yanagisawa, H., Bohn, M., Kitoh-Nishioka, H., Goschin, F., Kling, M. F.
  2023; 130 (10): 106204
- **Ion microscopy with evolutionary-algorithm-based autofocusing** *ENGINEERING RESEARCH EXPRESS*
  Haniel, F. E., Hedewig, L., Schroeder, H., Kling, M. F., Bergues, B.
  2023; 5 (1)
- **Broadband Photoconductive Sampling in Gallium Phosphide** *ADVANCED OPTICAL MATERIALS*
  Altwaijry, N., Qasim, M., Mamaikin, M., Schoetz, J., Golyari, K., Heynck, M., Ridente, E., Yakovlev, V. S., Karpowicz, N., Kling, M. F.

2023

- **Ultrafast quantum dynamics driven by the strong space-charge field of a relativistic electron beam** *OPTICA*
  Cesar, D., Acharya, A., Cryan, J. P., Kartsev, A., Kling, M. F., Lindenberg, A. M., Pemmaraju, C. D., Poletayev, A. D., Yakovlev, V. S., Marinelli, A.
  2023; 10 (1): 1-10

- **Strong-field physics with nanospheres** *ADVANCES IN PHYSICS-X*
  Seiffert, L., Zherebtsov, S., Kling, M. F., Fennel, T.
  2022; 7 (1)

- **Relaxation dynamics in excited helium nanodroplets probed with high resolution, time-resolved photoelectron spectroscopy** *PHYSICAL CHEMISTRY CHEMICAL PHYSICS*
  LaForge, A. C., Asmussen, J. D., Bastian, B., Bonanomi, M., Callegari, C., De, S., Di Fraia, M., Gorman, L., Hartweg, S., Krishnan, S. R., Kling, M. F., Mishra, D., Mandal, et al
  2022: 28844-28852

- **Strong-Field Control of Plasmonic Properties in Core-Shell Nanoparticles** *ACS PHOTONICS*
  Powell, J. A., Li, J., Summers, A., Robatjazi, S., Davino, M., Rupp, P., Saydanzad, E., Sorensen, C. M., Rolles, D., Kling, M. F., Trallero, C., Thumm, U., Rudenko, et al
  2022

- **Complementary dispersive mirror pair produced in one coating run based on desired non-uniformity** *OPTICS EXPRESS*
  Chen, Y., Li, W., Wang, Z., Hahner, D., Kling, M. F., Pervak, V.
  2022; 30 (18): 32074-32083

- **Spatiotemporal sampling of near-petahertz vortex fields** *OPTICA*
  Bloechl, J., Schoetz, J., Maliakkal, A., Sreibere, N., Wang, Z., Rosenberger, P., Hommelhoff, P., Staudte, A., Corkum, P. B., Bergues, B., Kling, M. F.
  2022; 9 (7): 755-761

- **Imaging elliptically polarized infrared near-fields on nanoparticles by strong-field dissociation of functional surface groups** *EUROPEAN PHYSICAL JOURNAL D*
  Rosenberger, P., Dagar, R., Zhang, W., Sousa-Castillo, A., Neuhaus, M., Cortes, E., Maier, S. A., Costa-Vera, C., Kling, M. F., Bergues, B.
  2022; 76 (6)

- **All-optical nanoscopic spatial control of molecular reaction yields on nanoparticles** *OPTICA*
  Zhang, W., Dagar, R., Rosenberger, P., Sousa-Castillo, A., Neuhaus, M., Li, W., Khan, S. A., Alnaser, A. S., Cortes, E., Maier, S. A., Costa-Vera, C., Kling, M. F., Bergues, et al
  2022; 9 (5): 551-560

- **Fifth-order nonlinear optical response of Alq(3) thin films** *RESULTS IN PHYSICS*
  Saleh, A., Li, W., ALQahtani, H., Neuhaus, M., Alshehri, A., Bergues, B., Alharbi, M., Kling, M. F., Azzeer, A. M., Wang, Z., Alharbi, A. F.
  2022; 37

- **Few-femtosecond resolved imaging of laser-driven nanoplasma expansion** *NEW JOURNAL OF PHYSICS*
  Peltz, C., Powell, J. A., Rupp, P., Summers, A., Gorkhover, T., Gallei, M., Halfpap, Antonsson, E., Langer, B., Trallero-Herrero, C., Graf, C., Ray, D., Liu, Q., et al
  2022; 24 (4)

- **Electro-optic characterization of synthesized infrared-visible light fields** *NATURE COMMUNICATIONS*
  Ridente, E., Mamaikin, M., Altwaijry, N., Zimin, D., Kling, M. F., Pervak, V., Weidman, M., Krausz, F., Karpowicz, N.
  2022; 13 (1): 1111

- **The emergence of macroscopic currents in photoconductive sampling of optical fields.** *Nature communications*
  Schotz, J., Maliakkal, A., Blochl, J., Zimin, D., Wang, Z., Rosenberger, P., Alharbi, M., Azzeer, A. M., Weidman, M., Yakovlev, V. S., Bergues, B., Kling, M. F.
  2022; 13 (1): 962

- **Attosecond coherent electron motion in Auger-Meitner decay.** *Science (New York, N.Y.)*
  Li, S., Driver, T., Rosenberger, P., Champenois, E. G., Duris, J., Al-Haddad, A., Averbukh, V., Barnard, J. C., Berrah, N., Bostedt, C., Bucksbaum, P. H., Coffee, R. N., DiMauro, et al
  1800: eabj2096

- **Efficient nonlinear compression of a thin-disk oscillator to 8.5 fs at 55 W average power** *OPTICS LETTERS*

Barbiero, G., Wang, H., Grassl, M., Groebmeyer, S., Kimbaras, D., Neuhaus, M., Pervak, V., Nubbemeyer, T., Fattahi, H., Kling, M. F.

2021; 46 (21): 5304-5307

- **Onset of charge interaction in strong-field photoemission from nanometric needle tips** *NANOPHOTONICS*

  Schoetz, J., Seiffert, L., Maliakkal, A., Bloechl, J., Zimin, D., Rosenberger, P., Bergues, B., Hommelhoff, P., Krausz, F., Fennel, T., Kling, M. F.

  2021; 10 (14): 3769-3775

- **Tunable isolated attosecond X-ray pulses with gigawatt peak power from a free-electron laser** *NATURE PHOTONICS*

  Duris, J., Li, S., Driver, T., Champenois, E. G., MacArthur, J. P., Lutman, A. A., Zhang, Z., Rosenberger, P., Aldrich, J. W., Coffee, R., Coslovich, G., Decker, F., Glownia, et al

  2020; 14 (1): 30-+

- **Attosecond transient absorption spooktroscopy: a ghost imaging approach to ultrafast absorption spectroscopy.** *Physical chemistry chemical physics : PCCP*

  Driver, T., Li, S., Champenois, E. G., Duris, J., Ratner, D., Lane, T. J., Rosenberger, P., Al-Haddad, A., Averbukh, V., Barnard, T., Berrah, N., Bostedt, C., Bucksbaum, et al

  2019

- **Generation and Characterization of Attosecond Pulses from an X-ray Free-electron Laser**

  Li, S., Rosenberger, P., Champenois, E. G., Driver, T., Bucksbaum, P. H., Coffee, R., Gatton, A., Hartmann, G., Helml, W., Huang, Z., Knurr, J., Kling, M. F., Lin, et al

  IEEE.2019

- **Roadmap on plasmonics** *JOURNAL OF OPTICS*

  Stockman, M. I., Kneipp, K., Bozhevolnyi, S. I., Saha, S., Dutta, A., Ndukaife, J., Kinsey, N., Reddy, H., Guler, U., Shalaev, V. M., Boltasseva, A., Gholipour, B., Krishnamoorthy, et al

  2018; 20 (4)