

The Dantus Research Group: Ultrafast Science, Sources, and Applications

Research Interests

Ultrafast lasers, with pulse durations shorter than 10^{-13} s—pulse duration shorter than it takes for atoms to move, have already led to two Nobel Prizes and more can be expected.

Our group has three well-funded thrust areas of scientific leadership:

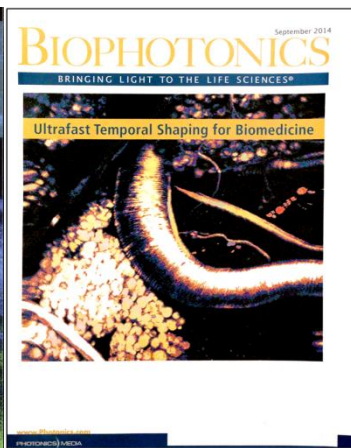
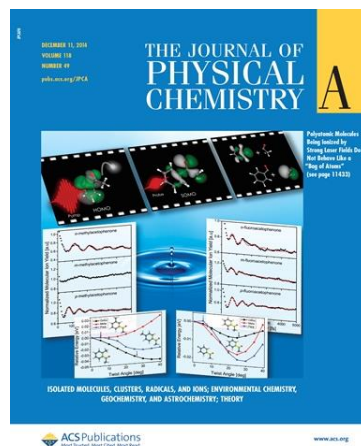
(a) **Control of strong-field laser matter interactions:** Exploring molecular dynamics at energies ranging from 10^{15} to 10^{20} W/cm².

(b) **Biomedical imaging and sensing:** Label free biomedical imaging and explosives detection.

(c) **Source development:** New laser sources, pulse shapers, and technology combining both.

Progress in these three areas requires fundamental advances in science, often questioning established dogmas and accomplishing what others have determined to be impossible.

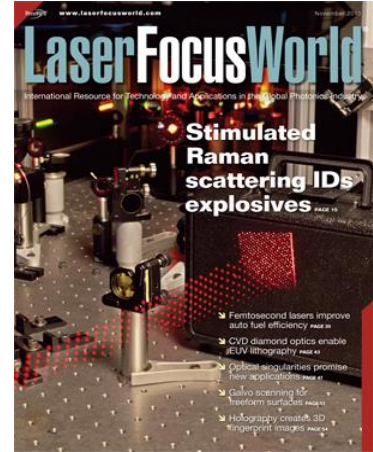
Control of strong-field laser matter interactions: Ultrafast lasers can exert enormous pressures and temperatures on the top few nanometers of materials on a time-scale that is faster than atomic motion. Studying chemical changes induced by these strong fields in gas, liquids, and solids is of great interest. We are particularly intrigued by intensities at which the response of the electrons to the field becomes relativistic. At this intensities, the electrons ‘push-back’ on the pulse causing compression and wavelength shifts towards the x-ray regime. We plan to take advantage of our unique laser sources to explore this exciting regime. Our projects include exotic chemical reactions, chemical transformations, and exploring relativistic pulse compression to achieve high efficiency conversion of femtosecond pulses into attosecond pulses.



Biomedical Imaging and Sensing:

Whether the goal is to detect cancer or the trace quantities of explosives, the challenge is one of chemically resolved imaging. Our group has been pioneering laser technology for unstained imaging and for standoff detection of explosives. In both areas, developments from our group are leading world efforts thanks to our combination of fundamental scientific advances with source development. We routinely collaborate with a number of medical centers and with DOD agencies.

Source development: Our group has revolutionized how ultrashort pulses are measured and compressed (technology patented, commercialized, and used around the world). The fundamental science behind this breakthrough technology is based on coherent control of quantum mechanical process. The technology is known as Multiphoton Intrapulse Interference Phase Scan, and it has allowed the generation of intense (0.5mJ) sub-two cycle pulses (2008), as well as record performance from ultrafast fiber lasers. Our work on source development includes nonlinear optics studies in particular self-action processes (when the pulse modifies the material and the material modifies the pulse). We are also working on novel combinations of spatial and temporal shaping of ultrafast laser pulses. Our work in source development fuels advances in many of our other research directions, for example standoff detection of explosives.



Some of our ongoing collaborations:

- Chong-Yu Ruan (MSU, ultrafast electron diffraction)
- Frank Wise (Cornell, fiber laser design)
- Stephen Boppart (UIUC, developing chemical imaging medical instruments based on our technology)
- Manoochehr Koochesfahani (MSU, Mechanical Engineering)
- Stefano Bonora (Univ. Padova Italy, Electrical Engineering, working on adaptive optics)
- Dana Spence (MSU, Working on methods to image red blood cells)
- Warren Beck (MSU, Working on 3D resolved 2D coherent spectroscopy)
- Conor Evans (Harvard Medical School, Working on nonlinear optical imaging of red blood cells)
- Bruce Tromberg (UC Irvine, Beckman Laser Institute, Working on melanoma imaging)
- Toshiki Tajima (UC Irvine, Physics, Relativistic optics theory)
- Gerard Mourou (Ecole Polytechnique, France, Zeptosecond, Zettawatt lasers)
- Shaul Mukamel (UC Irvine, Nonlinear optics theory)