AFOSR Overview

03 APR 2012

Riq Parra
Program Manager
AFOSR/RSE
Air Force Research Laboratory

Integrity ★ Service ★ Excellence

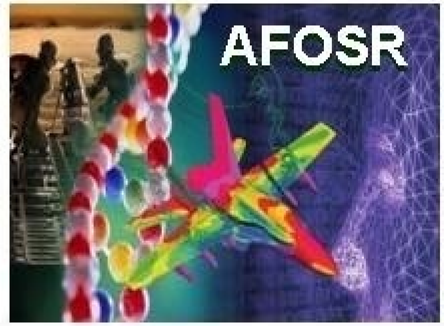
AFOSR Mission

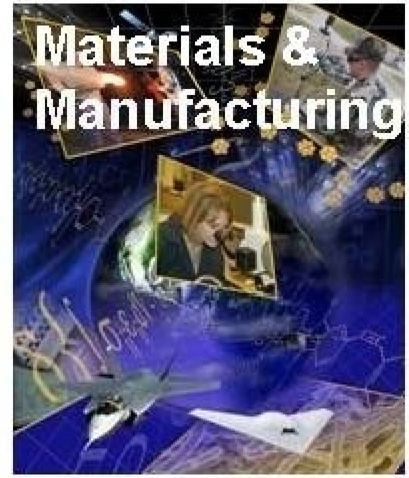
Discover, shape, and champion basic science that profoundly impacts the future Air Force

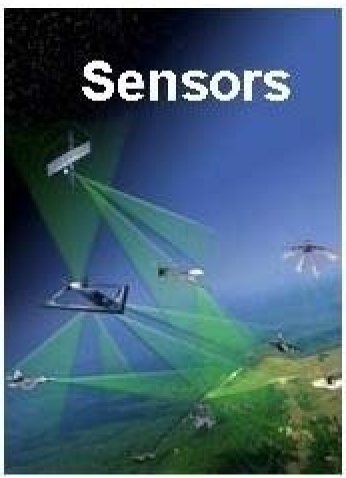
- ID Breakthrough Research Opportunities – Here & Abroad
- Foster Revolutionary Basic Research for Air Force Needs
- Transition Technologies to DoD and Industry

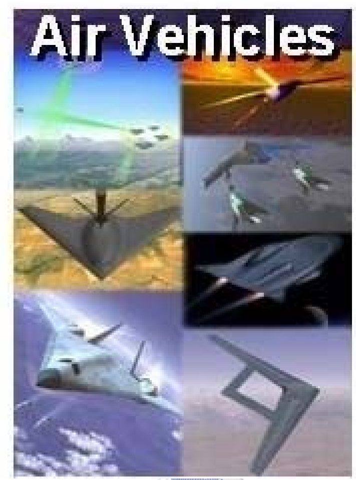
TODAY'S BREAKTHROUGH SCIENCE FOR TOMORROW'S AIR FORCE

AFRL Technical Directorates

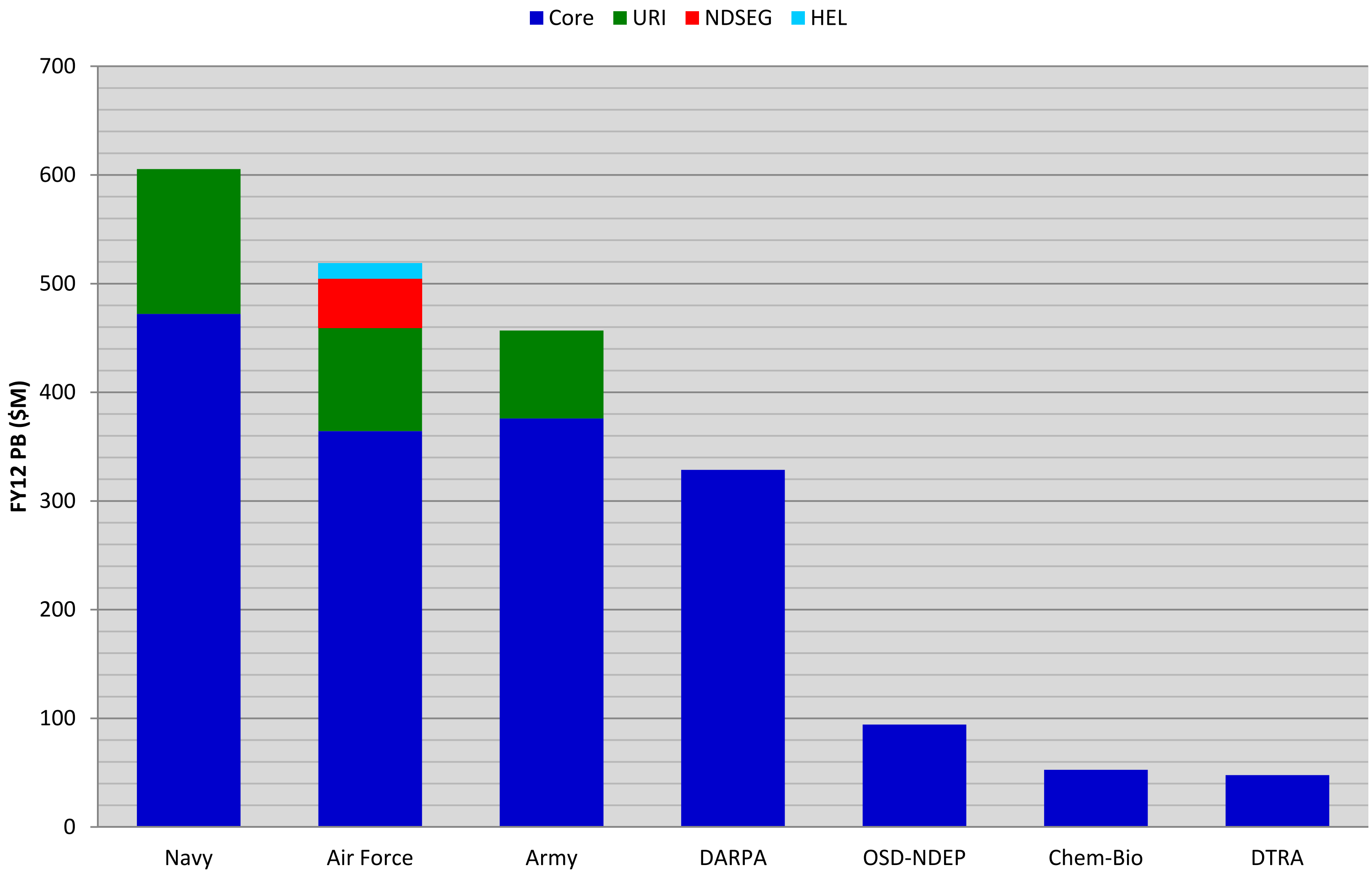








DoD Basic Research Enterprise

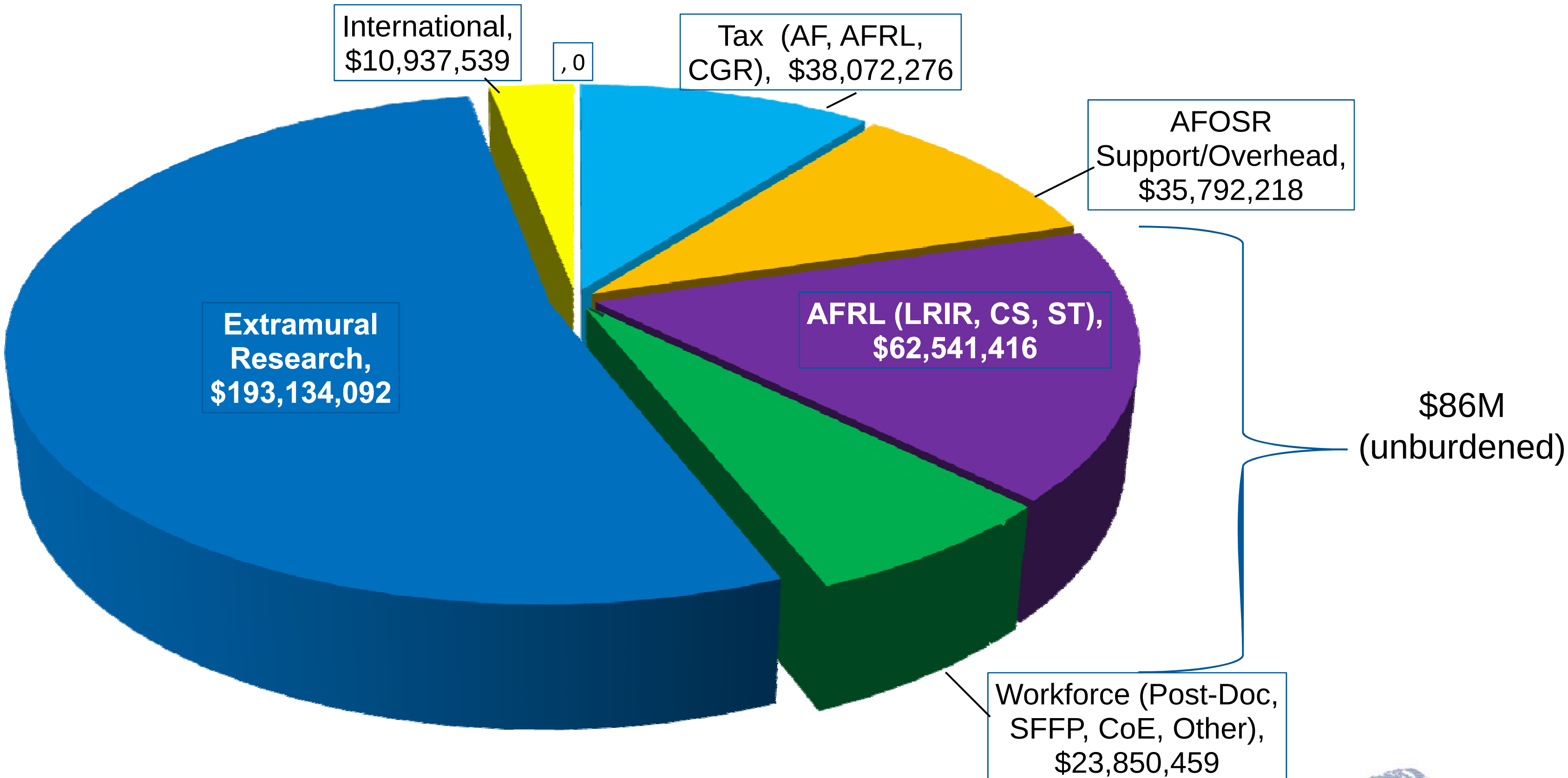


DoD Total FY12 Basic Research Budget = $2.12B

AFOSR FY12 Budget Plan

Program Element	FY 2011	FY 2012	FY 2013*	FY 2014*
61102F (Core)	348,910	364,328	361,787	374,267
61103F (URI)	135,601	140,273	141,153	138,747

* Estimate



61102F budget break-out

Shaping the Research Portfolio

Goals for AFOSR to strengthen the Air Force basic research program as defined in AF S&T Strategic Plan:

- **Provide scientific leadership for the AF basic research enterprise**
- **Attract the Nation's/World's best S&Es to contribute to and lead AF/DoD research**
- **Ensure the coherence and balance of the AF basic research portfolio**
- **Foster connections between AFRL researchers and the National/International basic research community**
- **Maximize the discovery potential of the defense research business environment**

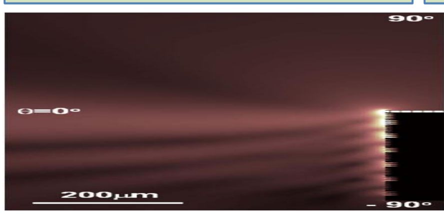
Focus on the Future AF with the ultimate goal to make Today's AF and Tomorrow's AF Obsolete!

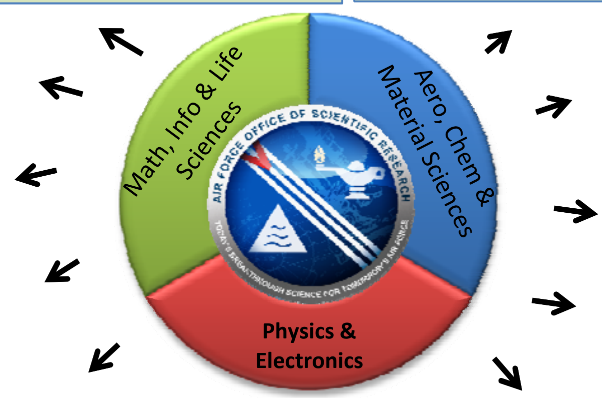
Shaping the Research Portfolio

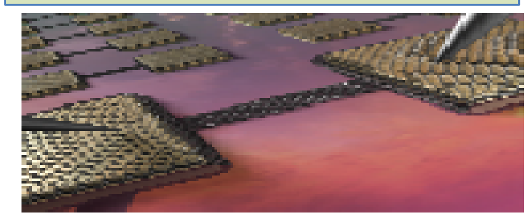
Though a principal source of new scientific opportunities is bottom up from the scientific community through AFOSR PMs, we also consider the assessment of opportunities by AF and OSD

AF/ST "Technology Horizons"

Inherently Intrusion-Resistant Cyber Networks	Trusted Highly-Autonomous Decision-Making Systems	Hyper-Precision Air Delivery in Difficult Environments	Fractionated, Composable, Survivable Remote-Piloted Systems







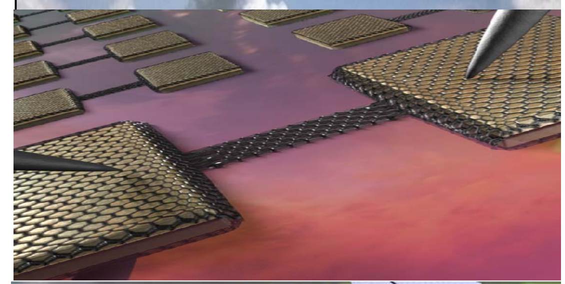
Metamaterials and Plasmonics	Quantum Information Science	Cognitive Neuroscience .	Nanoscience and Nanoengineering	Synthetic Biology .	Computational Models of Human Behavior

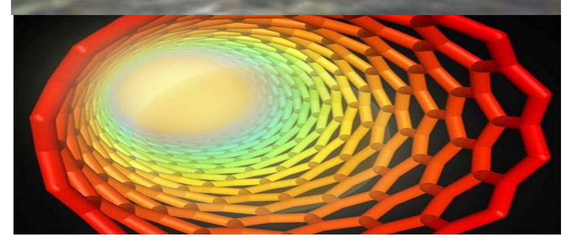
ASD(R&E) "Six Disruptive Basic Research Areas"

Trends in AFOSR Emphasis

- Advanced Mathematics
- Hypersonics (Turbulence Control)
- Complex, Multi-Functional Materials
- High-Temperature Superconductivity
- Info Assurance and Network Sciences
- Micro Air Vehicles (Autonomy, Adaptive Aero)
- Interfacial Sciences (Thermal, Tribology)
- Counter-Directed Energy Weapons
- Robust Decision-Making, Info Fusion
- Socio-Cultural Modeling, Minerva
- Quantum Information Sciences
- Space Situational Awareness
- *fs*-Laser Material Interactions
- Artificial Intelligence

RED = PBD709 (OSD Interest)
BLUE = AF Tech Horizons Grand Challenges
GREEN = Both

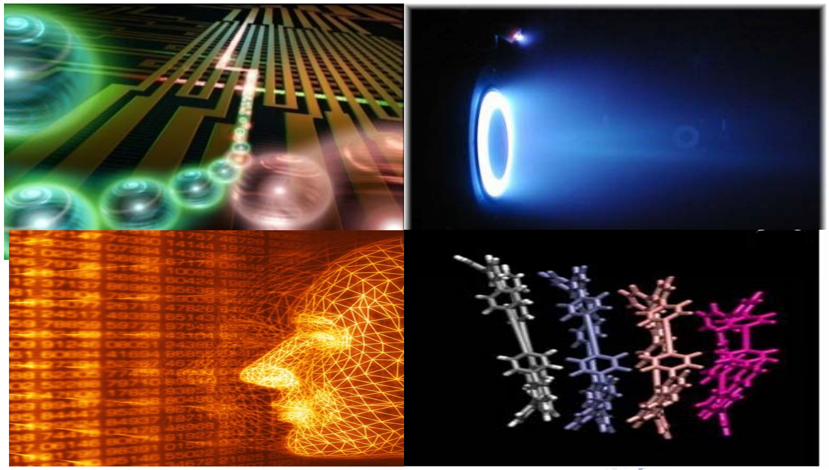


Invest in AF "Technology Horizons" Research Areas

- **PBD 709 Topic Enhancements**
  - Information Assurance
  - Interacting Complex Networks
  - Artificial Intelligence
  - Socio-Cultural Modeling
- **Materials and Processes Far from Equilibrium**
  - Physics and Chemistry of Surfaces in Highly Stressed Environments
  - Small Molecule Activation
  - Extreme Optics
- **Transformational Computing**
  - Neural Computing
  - Bio-Inspired Distributed Control Sys.
  - Beyond Moore's Law Electronics
  - Multiscale Modeling

Tech Horizons Grand Challenges

1. Inherently Intrusion-Resistant Cyber Networks
2. Trusted Highly-Autonomous Decision-Making Systems
3. Fractionated, Composable, Survivable Remote-Piloted Systems
4. Hyper-Precision Air Delivery in Difficult Environments



Basic Research Initiative Program

- The Basic Research Initiative program provides a mechanism to fund new Projects aligned to identified emphasis areas.
- Funded by a 10% assessment on the prior year budgets of all research portfolios (PE61102F funding)
- Program managers nominate research topics that are reviewed for scientific merit and alignment to the AFOSR technical strategy
- New research areas identified via a broad agency announcement

FY12 BRI Topics

- Ultra-cold and strongly coupled plasmas
- Micro-resonator-based optical frequency combs
- Origami design for the integration of self-assembling systems
- Active, functional nanoscale oxides
- Reliance optimization for autonomous systems
- Bio-nanocombinatorics
- Design under uncertainty of complex engineering systems

New BRI Topics for Potential Collaborations

1. Layered structured 2D-materials for extreme environment
2. Autonomic material systems utilizing biomolecular transduction
3. Transformational computing via co-design of high-performance algorithms and hardware
4. High peak power, ultrashort laser ablation of solids
5. Sustainable alloy design: Rare earth materials challenge
6. Catalytic reactions in endothermic cooling systems
7. Foundations of energy transfer in multi-physics flow phenomena
8. Cyber trust and suspicion
9. Ultra-scale and fault-resilient algorithms: Mathematical algorithms for ultra-pararallel computing

AFOSR Ten Focus Areas

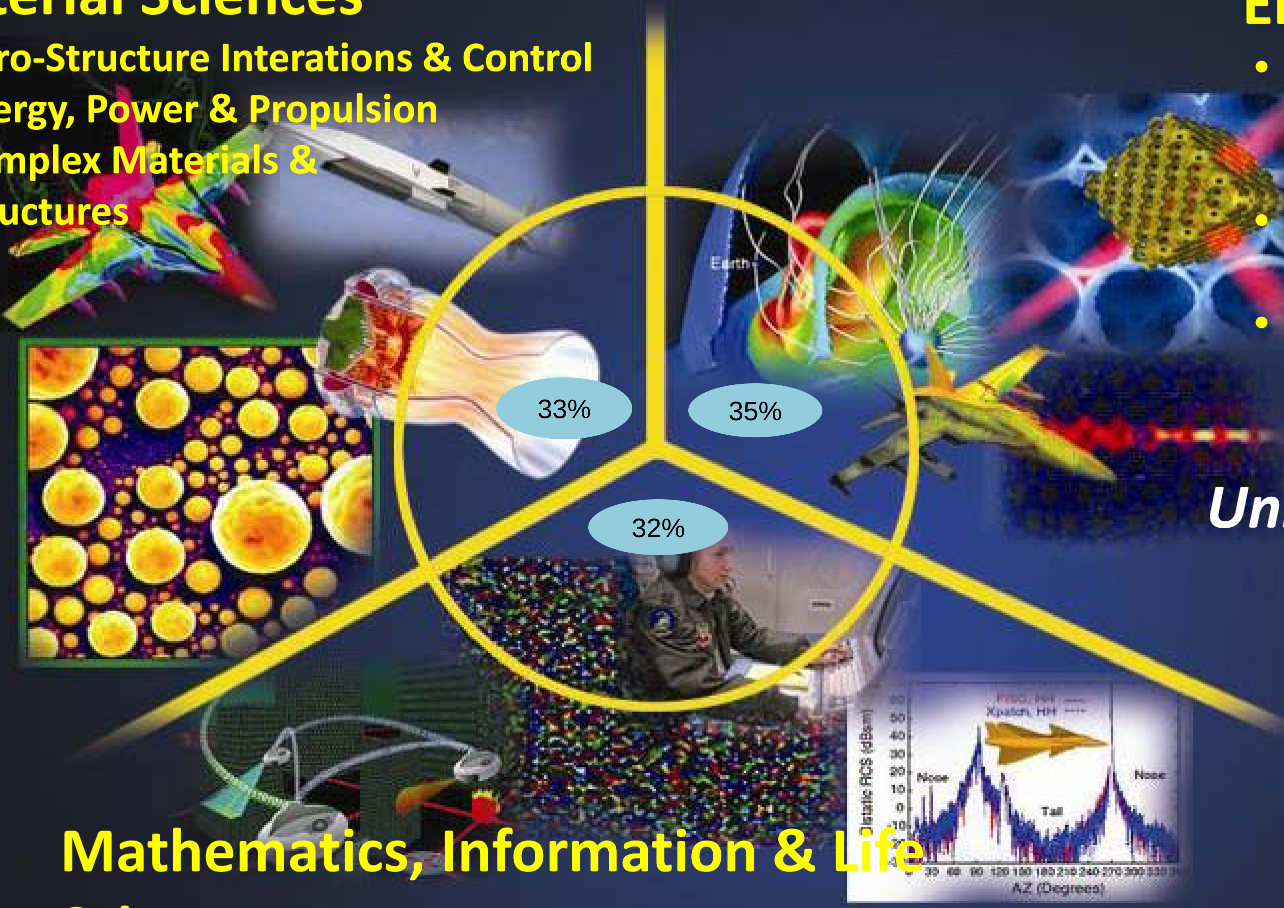
(*FY12* - $364.3M)

Aerospace, Chemical & Material Sciences

- Aero-Structure Interations & Control
- Energy, Power & Propulsion
- Complex Materials & Structures

Physics & Electronics

- Complex Electronics & Fundamental Quantum Processes
- Plasma Physics & High Energy Density
- Optics, EM, Comm, Signals Processing



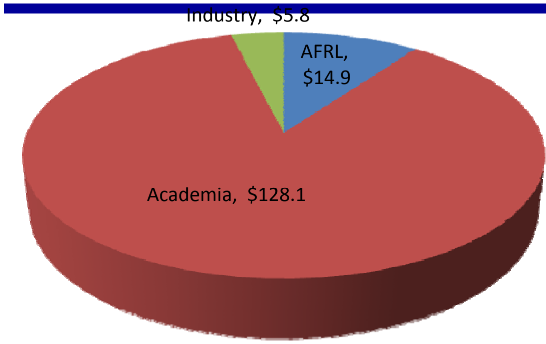
University Research Initiatives

(*FY12*- $140.3M)

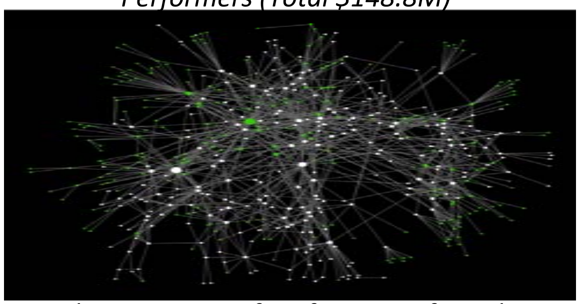
Mathematics, Information & Life Sciences

- Info & Complex Networks
- Decision Making
- Dynamical Sys, Optimization & Control
- Natural Materials & Systems

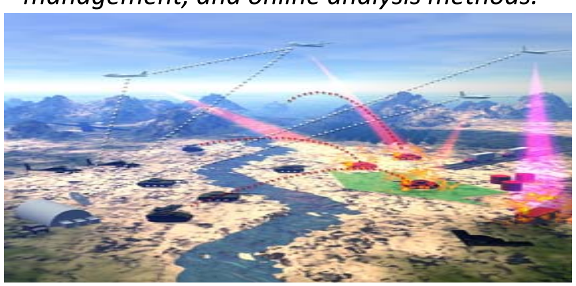
Mathematics, Information & Life Sciences



Performers (Total $148.8M)



Math guarantees of performance for policy, protocol, and security using new coding, management, and online analysis methods.



Enabling distributed control of flexibly autonomous agents for performing single or multiple tasks and missions.

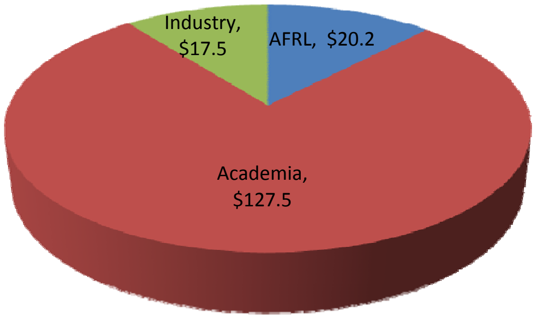
Information and Complex Networks:
- Science of cyber security
- Mathematics of complex networks
- Software/algorithms for advance computational architectures

Decision-Making:
- Robust computational intelligence
- Mathematical basis for neurobiological processes
- Trust, autonomy, and the human-machine interface
- Effect of culture on influence

Dynamical Systems, Optimization and Control:
- Multiagent, networked control
- Uncertain, information-rich, dynamic environments
- Contested environments
- Dynamic, data-driven control

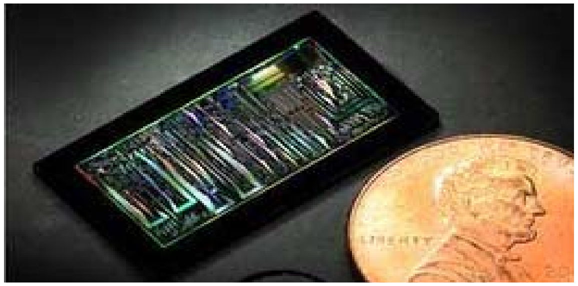
Natural Materials and Systems:
- Bio-inspired materials
- Bio-derived materials including energy
- Bio-sensing
- Extremophiles

Physics & Electronics



Performers (Total $165.2M)

Diocles laser, which produces the most intense light on earth.



Combining low-cost silicon chips with tiny lasers to send bits of data using light rather than pulses of electricity.

Complex Electronics and Fundamental Quantum Processes:

- Ultracold Atoms & Molecules
- Metamaterials & Graphene
- Dielectric and Magnetic Materials
- High Temperature Superconductors
- Novel Sensing Devices and Architectures
- Non-linear Optical Materials,Optoelectronics, and Nanophotonics

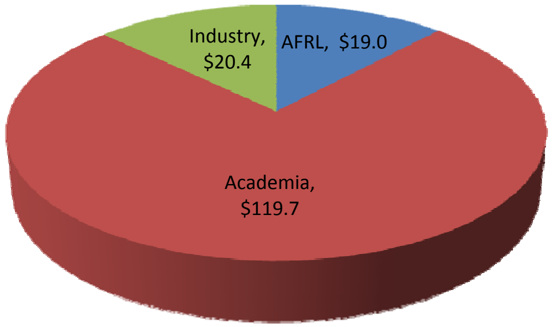
Plasmas & High Energy Density Nonequilibrium Processes:

- Space weather
- High power microwave devices
- Cold, dense, degenerate plasmas
- RF propagation and RF-plasma interaction
- Plasma discharges & non-equilibrium chemistry
- Plasma control of boundary layers in turbulent flow

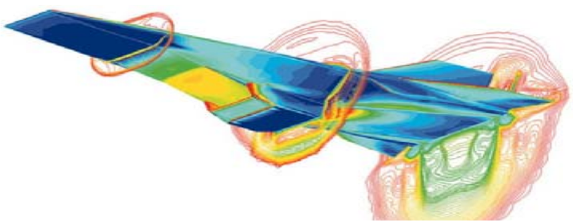
Optics, Electromagnetics, Communication, & Signal Processing:

- Information fusion
- Lasers and non-linear optics
- RF and EO signal processing
- Novel RF devices and communication architectures

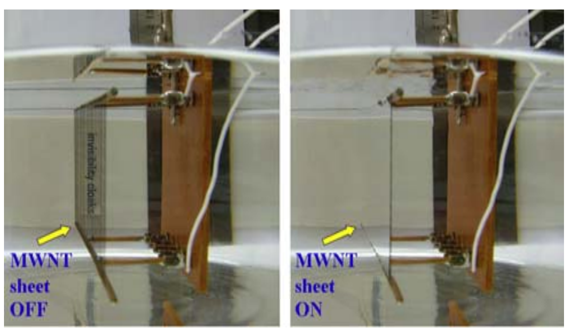
Aerospace, Chemical, and Material Sciences



Performers (Total $159.1M)



Model-free simulations of >Mach 3 shock turbulent boundary layer interactions



Application of a nanotube sheet as a mirage based concealment cloak is demonstrated in water.

Time Magazine List of Best Inventions for 2011

Aero-Structure Interactions and Control:

- Turbulence and laminar-turbulent transition
- Unsteady aerodynamics and flow control
- Aero-elasticity and structural dynamics
- Integrated Modeling

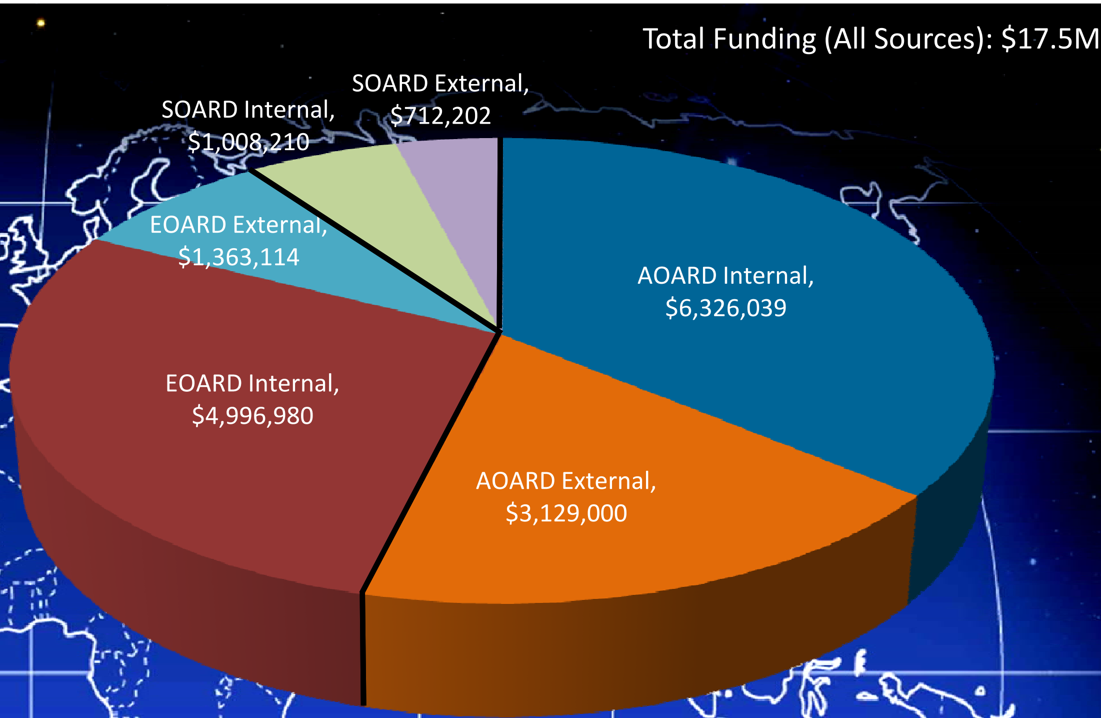
Energy, Power and Propulsion:

- Novel energetic materials
- Combustion and catalysis chemistry
- Thermal science
- Novel means of producing, collecting and storing energy
- System-level analysis and modeling

Complex Materials and Structures:

- Novel lightweight materials
- Materials with tunable properties
- Reconfigurable structures
- Multifunctional materials and structures

AFOSR International Enterprise



- ***Building international goodwill***
- ***Strengthening partnerships***
- ***Avoiding technological surprise***
- ***Accelerating S&T achievements and transitions to the U.S.***

AOARD	EOARD	SOARD
ASIAN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT	EUROPEAN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT	SOUTHERN OFFICE OF AEROSPACE RESEARCH AND DEVELOPMENT
Tokyo	London	Santiago

The Sun Never Sets on AFOSR

Summary

AFOSR continues to *discover, shape, and champion basic science that profoundly impacts the future Air Force*

- **Supporting world-class basic research**
- **Educating tomorrow's scientific leaders**
- **Providing meaningful transitions and for future**
- **Enhance mutual understanding of AFOSR and other organizations missions, roles, programs, priorities**
- **Ensure current investments are fully coordinated and opportunities for leveraging are exploited**

"Innovation also demands basic research. Today, the discoveries taking place in our federally-financed labs and universities could lead to … New lightweight vests for cops and soldiers that can stop any bullet. Don't gut these investments in our budget. Support the same kind of research and innovation that led to the computer chip and the Internet."
- President Obama, State of Union Speech, 24 January 2012

Social Media

www.facebook.com/afosr

www.twitter.com/afosr

www.youtube.com/TheAFOSR

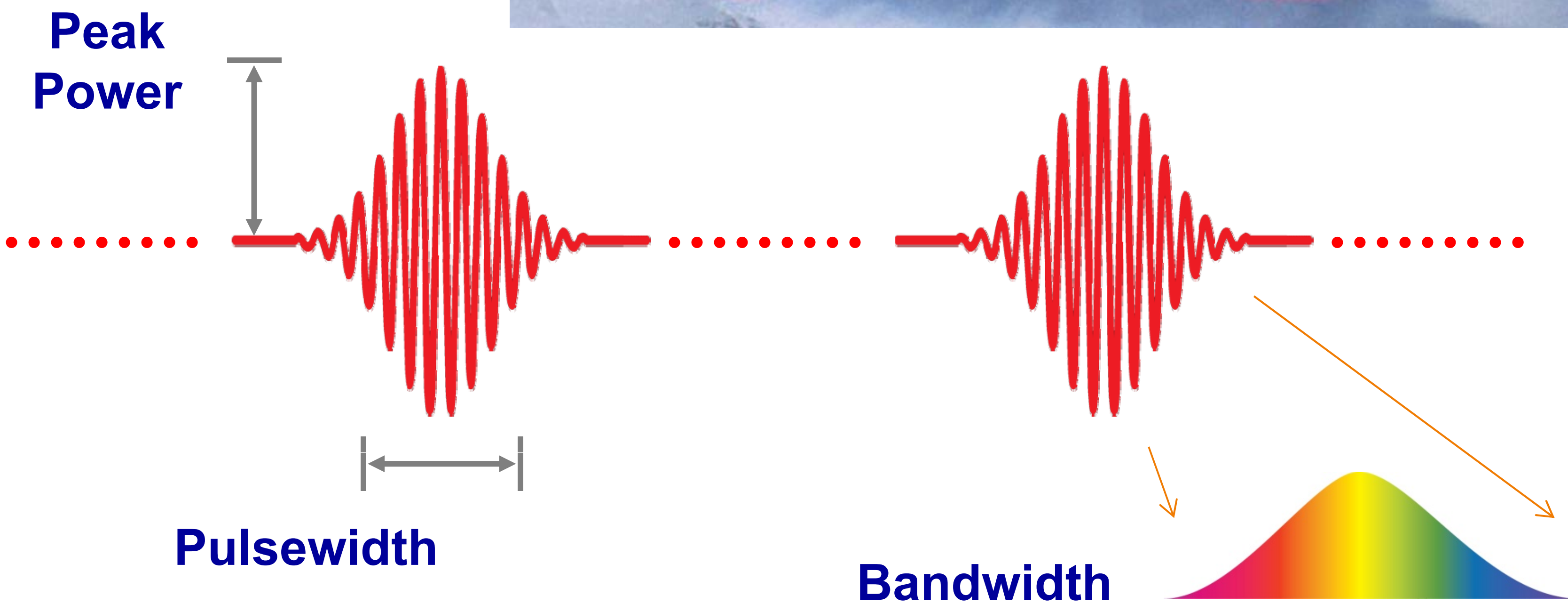
Ultrashort Pulse (USP) Laser-Matter Interactions

03 APR 2012

Riq Parra
Program Manager
AFOSR/RSE
Air Force Research Laboratory

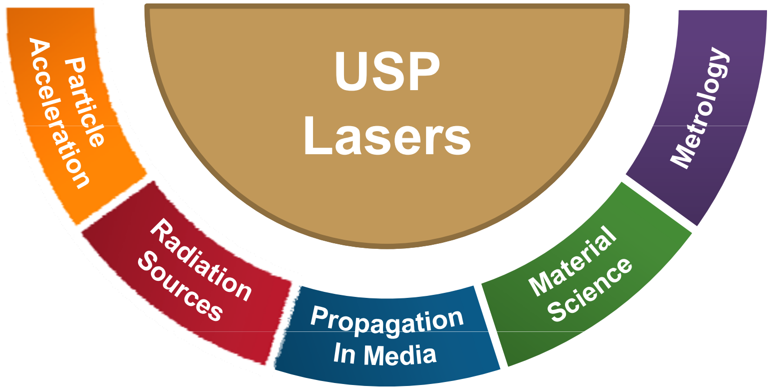
Integrity ★ Service ★ Excellence

Characteristics of short pulse lasers



- **The program aims to understand and control light sources exhibiting extreme bandwidth, peak power and temporal characteristics.**
- **Portfolio sub-areas: optical frequency combs, high-field science, attosecond physics.**

Applications of USP Lasers



Particle Acceleration
ultrahigh electric field gradients

- Table-top GeV electron accelerators
- MeV ion sources for imaging
- Isotope production
- Hadron tumor therapy
- Proton-based fast ignition

Metrology
stabilized, ultra-wide bandwidth

- Ultra-stable freq sources
- Arb waveform generation
- High precision spectroscopy
- Frequency/time transfer
- Ultra-wideband comms
- Coherent LIDAR
- Optical clocks
- Calibration

Secondary Radiation Sources
generation of particle & photons

- High power THz generation
- Extreme ultraviolet lithography
- Biological soft x-ray microscopy
- Non-destructive evaluation
- Medical imaging/therapy

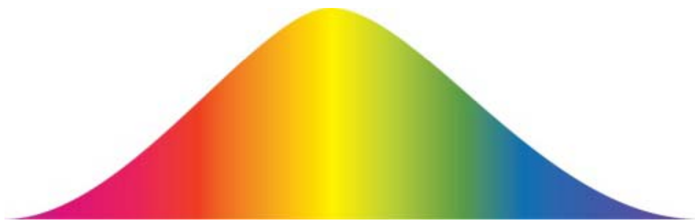
Propagation in media
self-channeling

- Remote sensing
- Remote tagging
- Directed energy
- Electronic warfare
- Countermeasures
- Advanced sonar

Material Science
ultrashort, high peak power

- Surgery
- Chemical analysis (LIBS)
- Surface property modification
- Non-equilibrium ablation
- Micromachining
- Ultrafast photochemistry
- Attochemistry

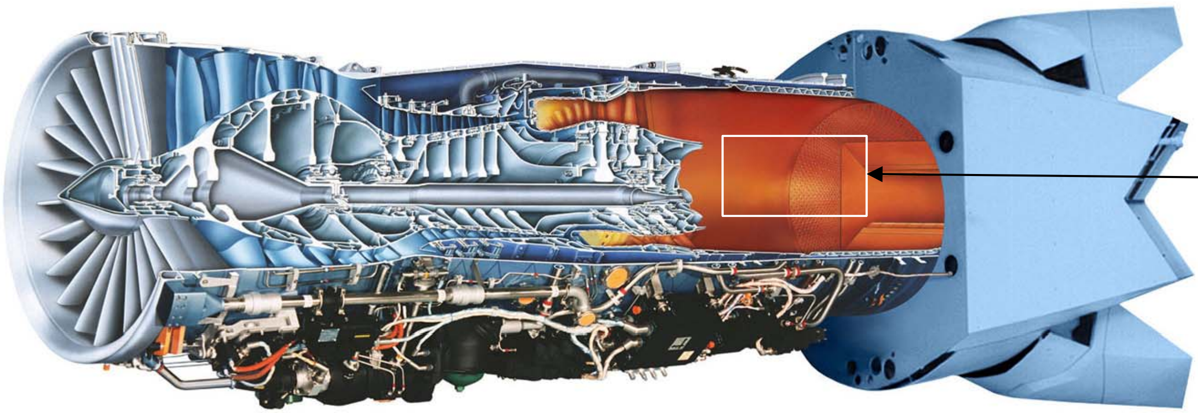
Mode-locked lasers as broadband phase-coherent optical sources (optical frequency combs)

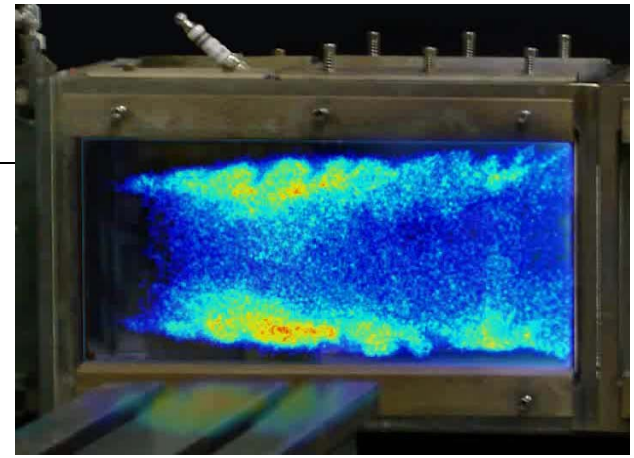


Advancing Ultrafast Lasers for High-Bandwidth 4D Metrology

Pratt & Whitney F119

PI: James Gord, AFRL/RZ



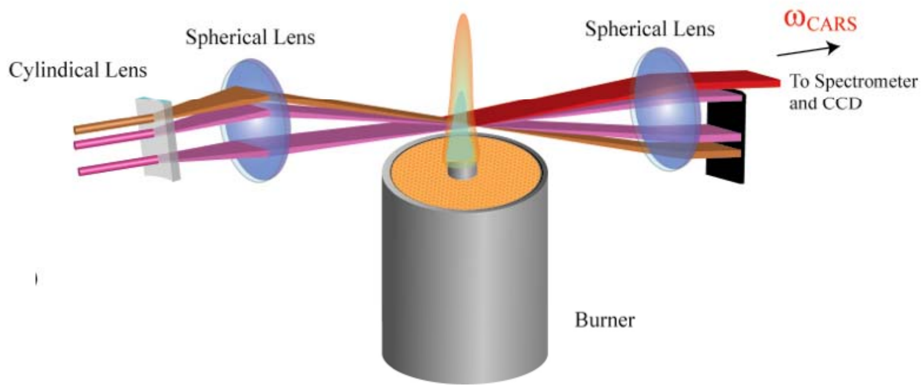


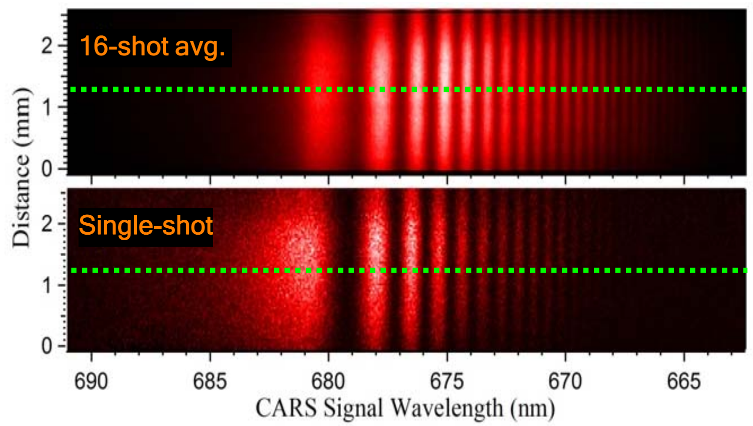
- **Ultrashort pulses for propulsion measurements**
  - **Ultrafast laser–based spectroscopic techniques for investigating the physics and chemistry of reacting flows.**
- **Generate top-quality data for**
  - **advanced concept development and model validation (R&D)**
  - **propulsion-system performance assessment (T&E)**
  - **weapon-system active combustion control (ACC)**
- **Measure everything, everywhere, all the time…**

Spectrally Resolved Femtosecond CARS 1D Line Imaging

Single-shot, one-dimensional thermometry in flames

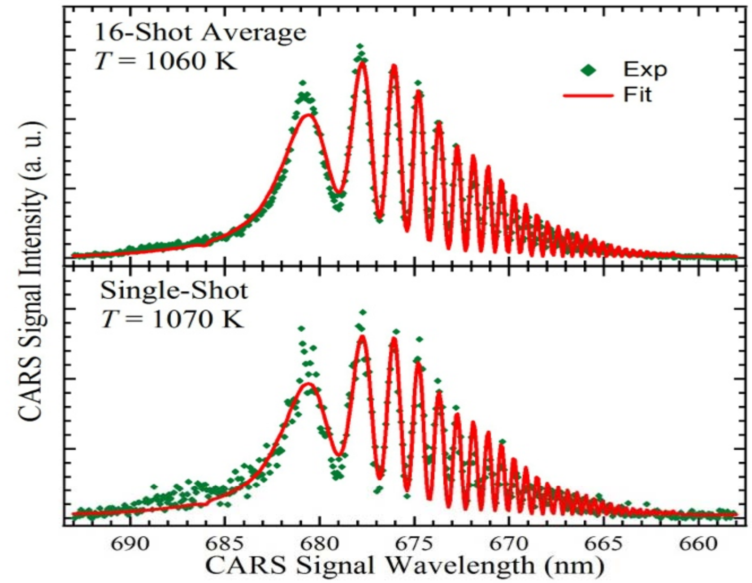
PI: James Gord, AFRL/RZ





Key fs-CARS advantages

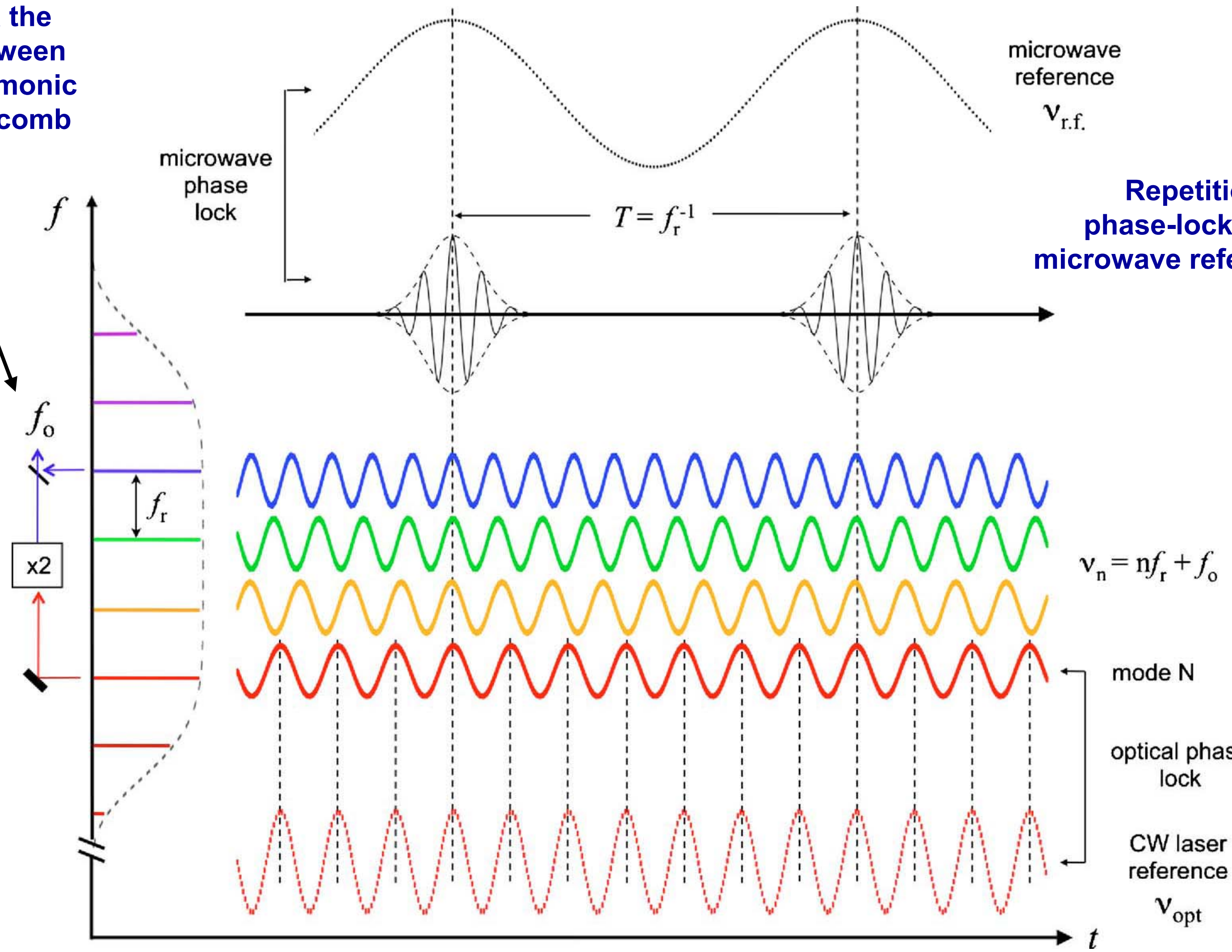
- **>3 OOM faster data acquisition**
- **1D line vs. point measurements**
- **Free from collisional broadening**
- **Nonresonant-background control**
- **Strong coherences**
- **Improved accuracy, precision**
- **Species-selective [n] and T**
- **Multiple-species excitation**



An optical frequency comb

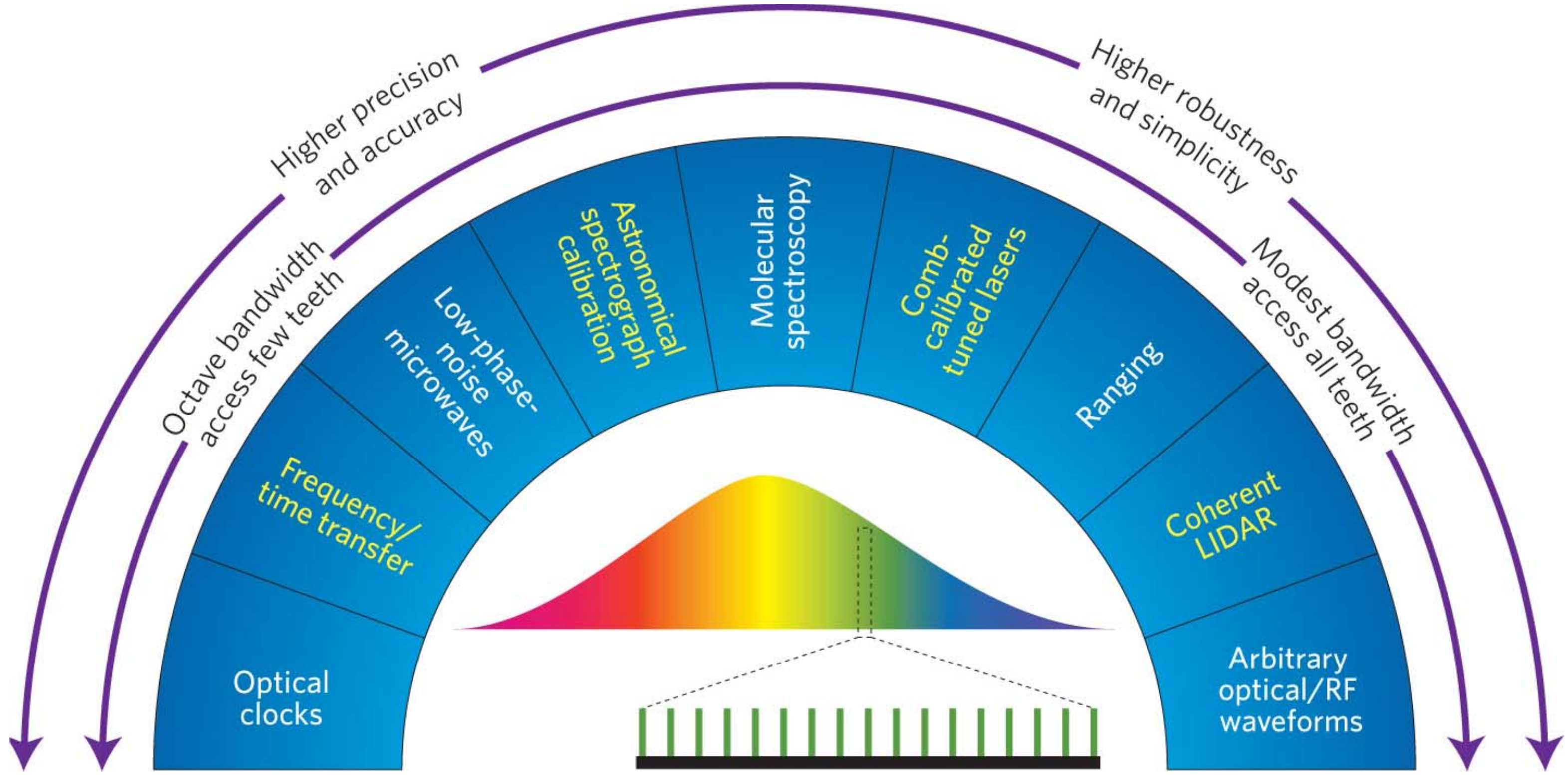
f_o measured via the heterodyne between the second harmonic of the IR & VIS comb components.

Repetition rate phase-locked to a microwave reference.



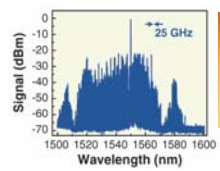
Source: Diddams, JOSA B (2010)

Metrological applications of optical frequency combs

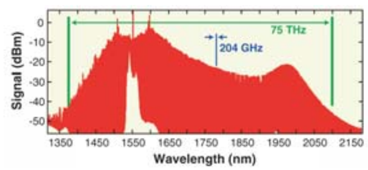


Source: Newbury, Nature Photonics (2011)

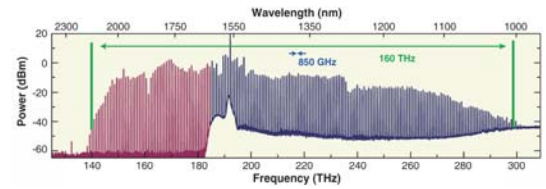
Microresonator frequency combs

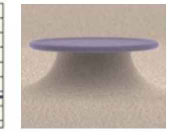


CaF2

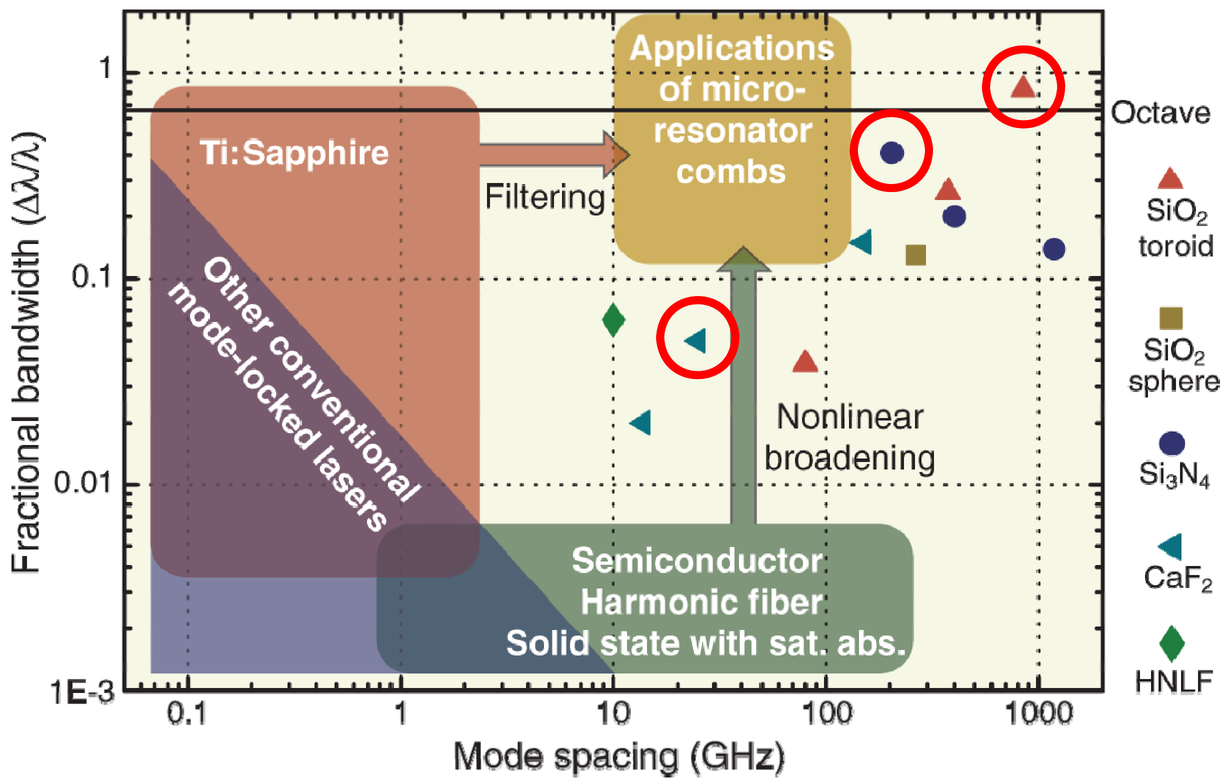


SiN rings





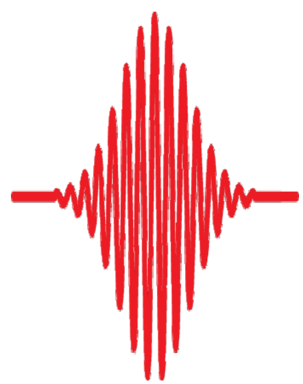
Silica toroids



FY2012 Basic Research Initiative (BAA-AFOSR-2012-02)

Source: Kippenberg et al., Science (2011)

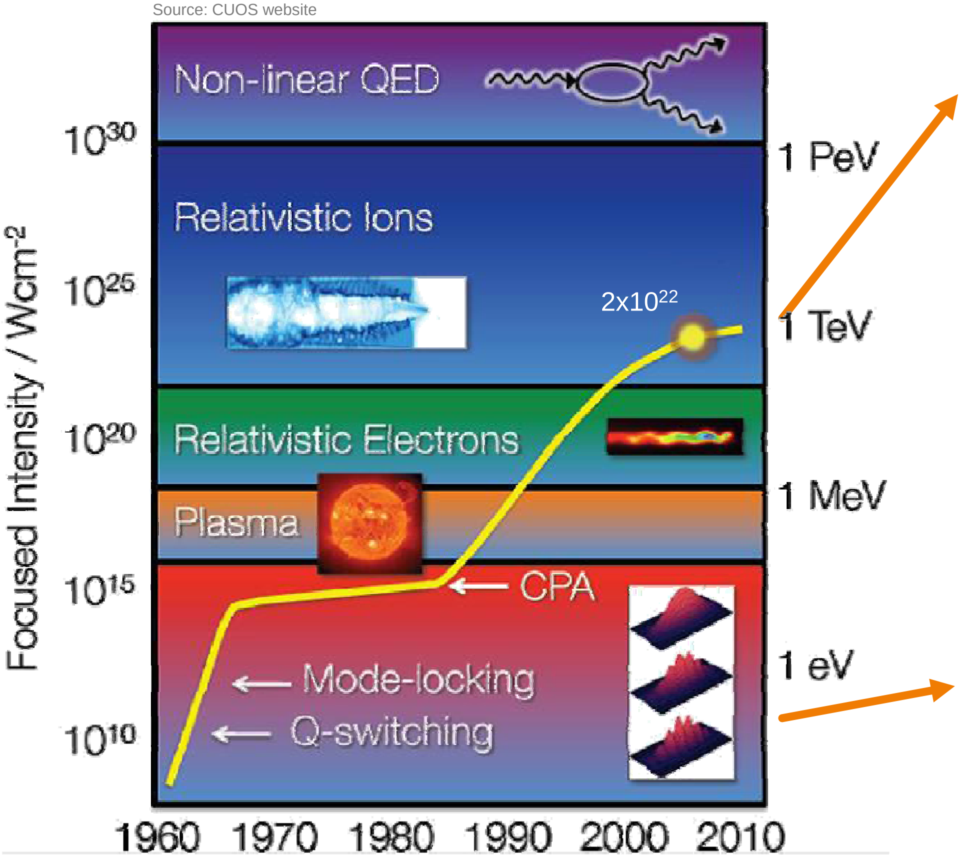
Mode-locked lasers as high peak power sources (high field science)



Progress in peak intensity

- **Over the last two decades, a 6 order of magnitude increase in achieved focused intensities in table-top systems.**

Source: CUOS website



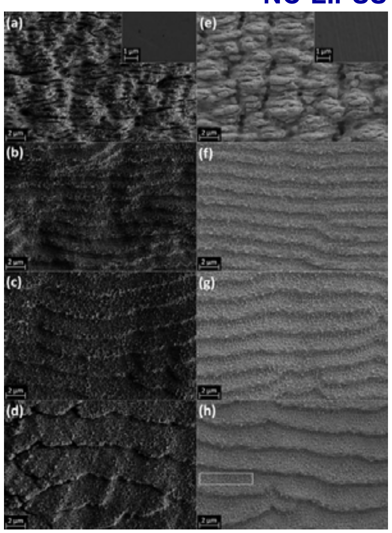
Phenomena	Relevance
Thomson scattering	**Gamma rays source**
Laser wakefield acceleration	**Compact e$^-$ accelerators**
Particle and x-ray emission from solids	**Proton & x-ray sources**
High harmonic generation	**Coherent EUV sources**
Filamentation	**Propagation of EM pulses**
Laser ablation of solids	**Laser machining & patterning**

Laser micromachining & patterning

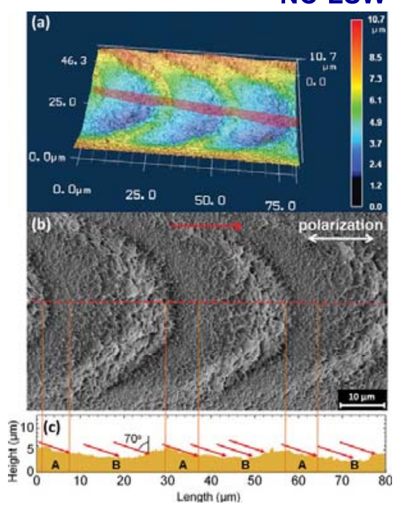
PI: Chunlei Guo, U of Rochester

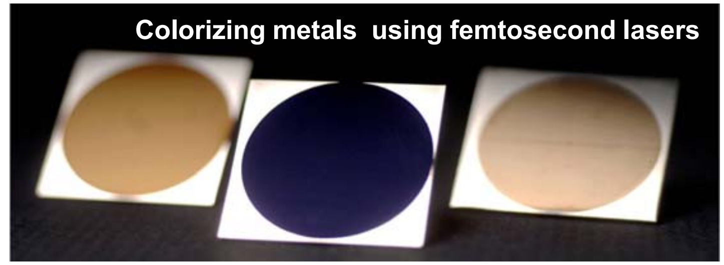
- Ultrashort laser pulses open up novel possibilities and mechanisms for laser-solid interactions.
- Demonstrated femtosecond laser processing and surface texturing techniques to engineer surface structures & properties (e.g. darkened & colored metals, super wicking surfaces).
- Studied nanostructure-covered laser-induced periodic surface structures (NC-LIPSS) & nanostructure-covered large scale waves (NC-LSW).

NC-LIPSS

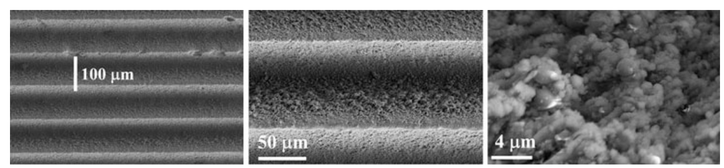


NC-LSW




Colorizing metals using femtosecond lasers

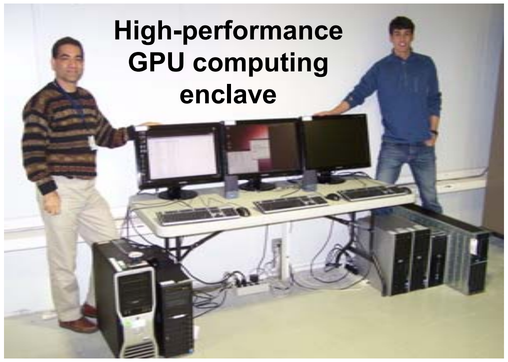

Super wicking surfaces: Array of parallel microgrooves generates strong capillary force.



Propagation of high-intensity USPL pulses

PI: William P Roach, AFRL/RD

- Propagation of localized high-intensity laser pulses is of interest for remote sensing, imaging, communications and remote interactions.
- Such propagation in air leads to self-channeling (i.e. filaments) and plasma formation.
- AFRL/RDLA Filamentation Team is engaged in an experimental, theoretical and computational effort to:
    - Develop computational models for long-distance fs propagation as an extended free space waveguide.
    - Study filament propagation for long distances (2, 5 & 7 km test sites available).
    - Characterize fs-laser filament physics necessary for coupling/confining external EM-Fields.
    - Understand filamentation induced electrical shorting.

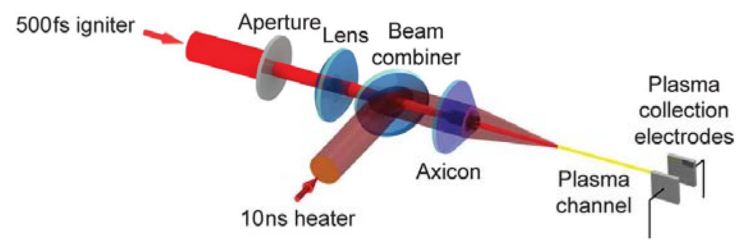

High-performance GPU computing enclave

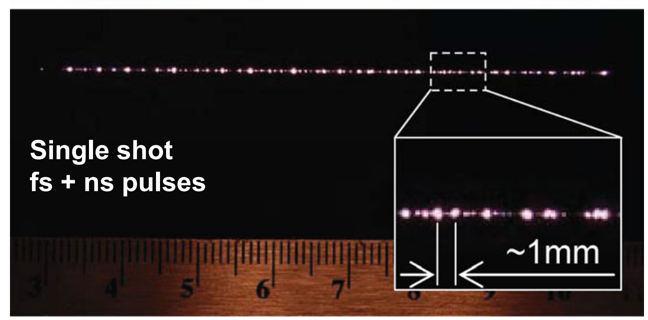

9-inch filament bundle propagation through kV-level E-Field

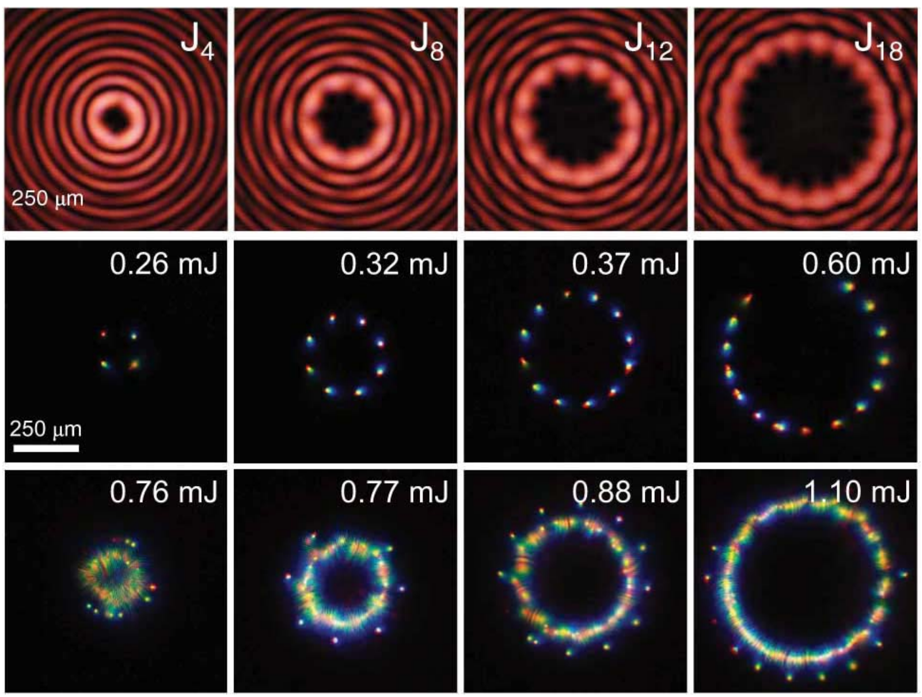
Optical breakdown of air triggered by femtosecond laser filaments

PI: Pavel Polynkin, Arizona

- **Generation and 200x enhancement of dense plasma channels at range via dual-pulse femtosecond-nanosecond laser excitation.**
- **Control of femtosecond laser filamentation through laser beam engineering. Extended bottle-like plasma-channel distributions using vortex beams and high order Bessel beams.**



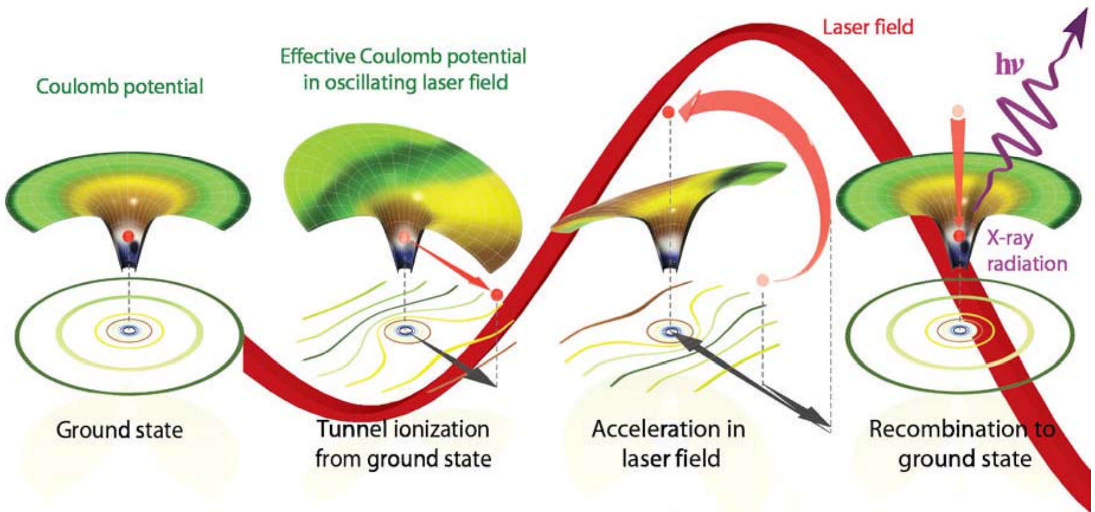




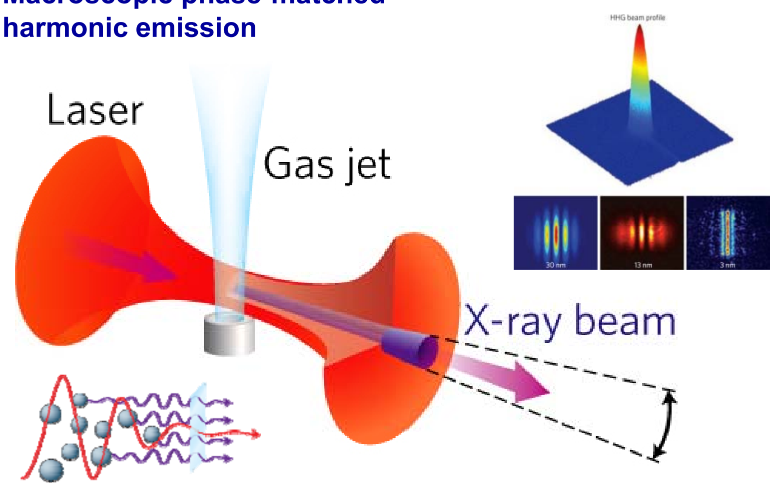
Bottle-like filament patterns produced by vortex beams in water

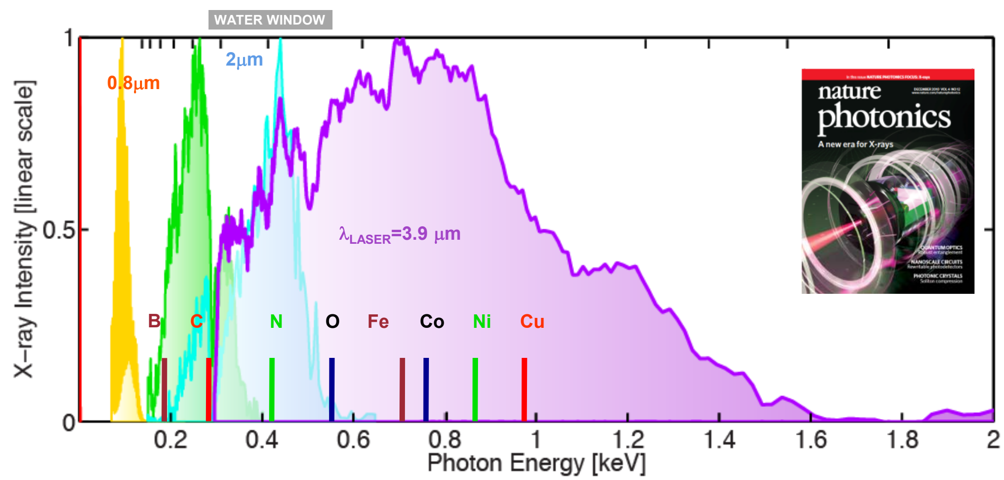
High Harmonic Generation (HHG)

Microscopic single-atom physics of HHG



Macroscopic phase-matched harmonic emission



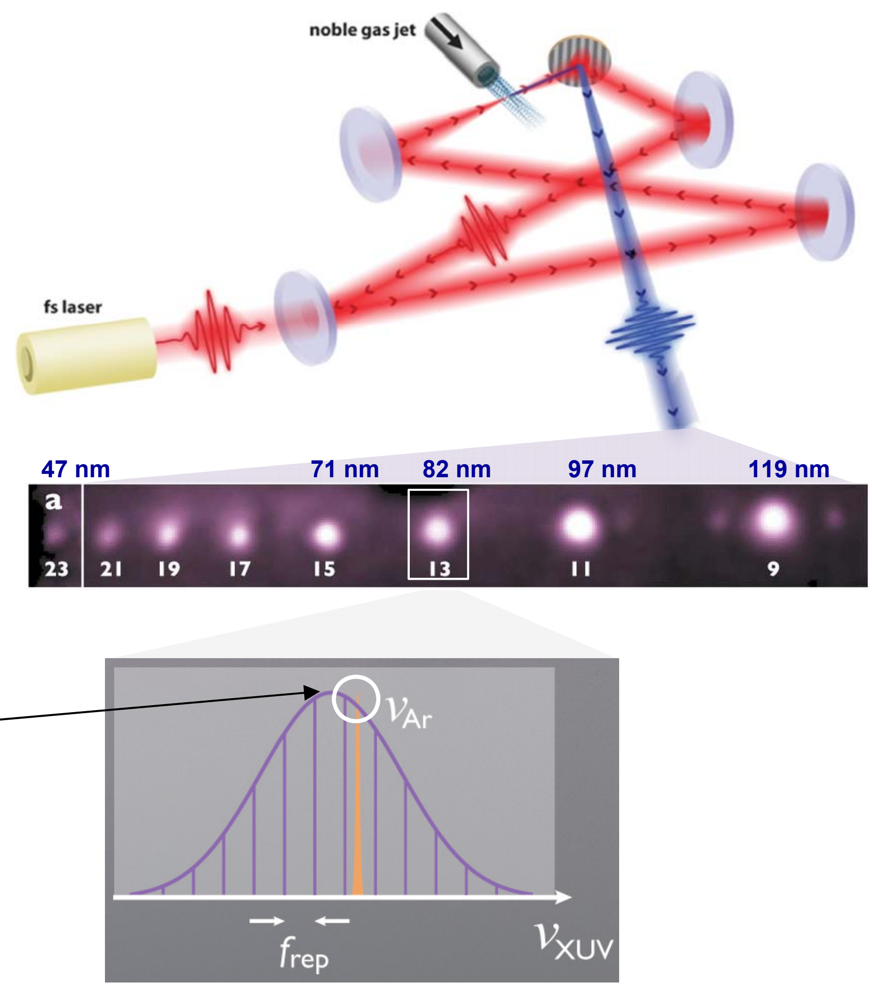


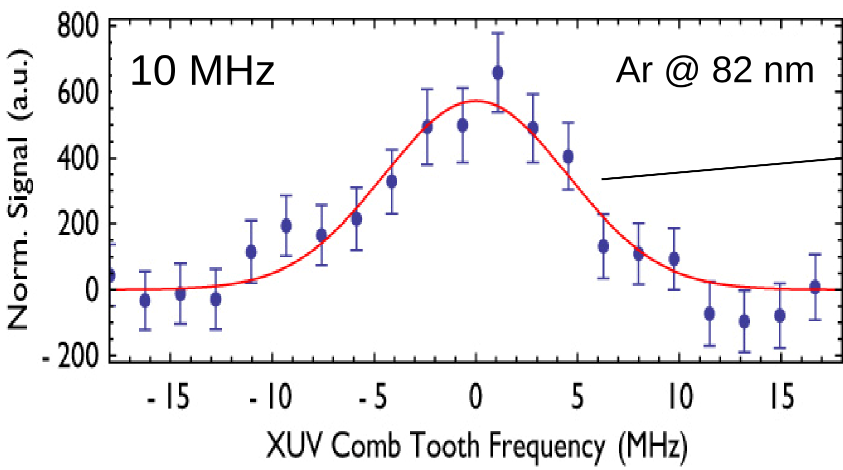
Source: Popmintchev et al., Nat Photonics (2010), Popmintchev et al., CLEO postdeadline (2011)

Direct Frequency Comb Spectroscopy in the Extreme Ultraviolet

PI: Jun Ye, U of Colorado

- **Generating frequency combs in the extreme ultraviolet (XUV) via high harmonic generation (HHG) in a femtosecond enhancement cavity.**
- **Demonstrated generation of >200 µW per harmonic down to 50 nm.**
- **Ultrahigh precision spectroscopy below the 100 nm spectral region:**
- **Direct frequency comb spectroscopy of Argon transition at 82 nm with resolved 10 MHz linewidth (atomic thermal motion limited).**

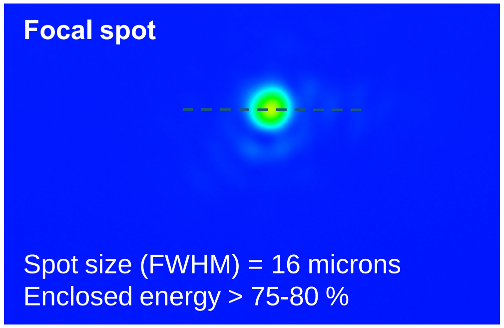


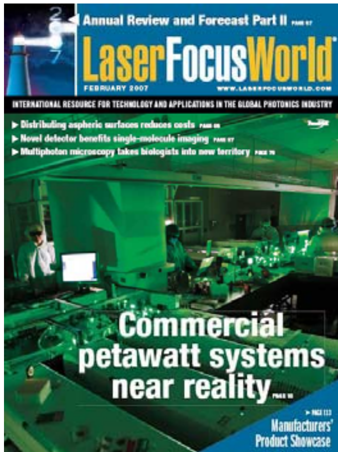


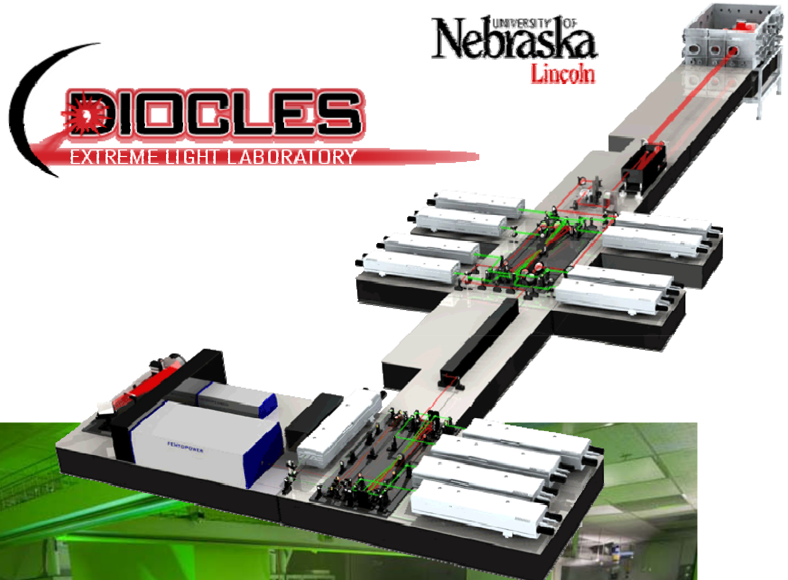
Diocles 100 TW laser system

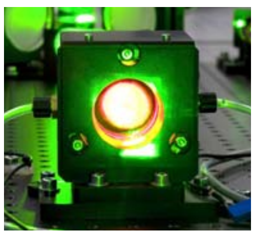
PI: Donald Umstadter, U of Nebraska

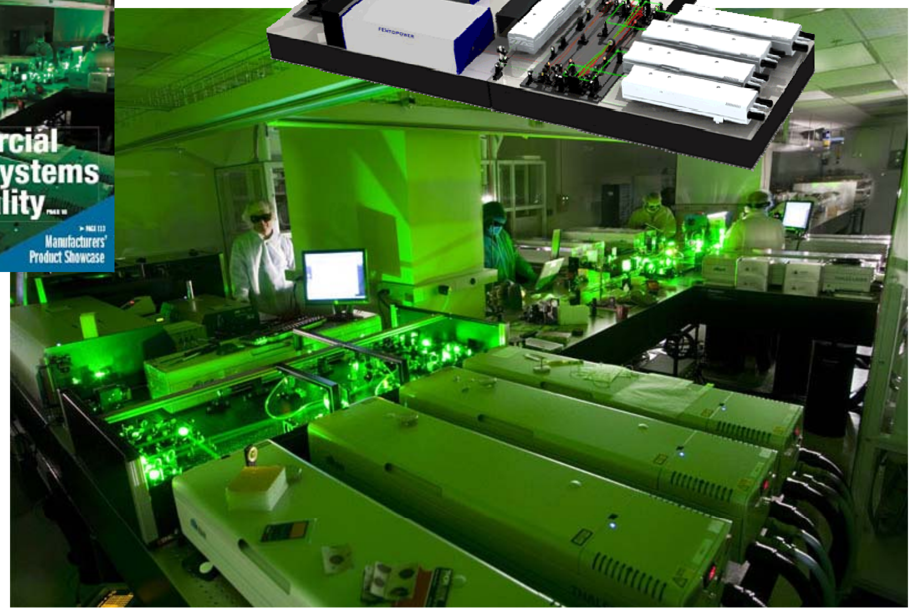
- **Nd:YAG pumped Ti:Sapphire**
- **3.5 J in < 30 fs, 100 TW @ 10 Hz**







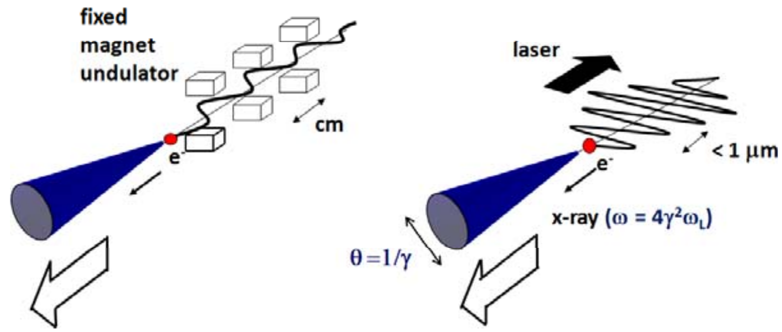


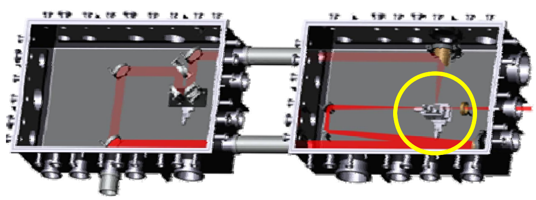


Laser-driven x-rays generation (0.1 – 10 MeV)

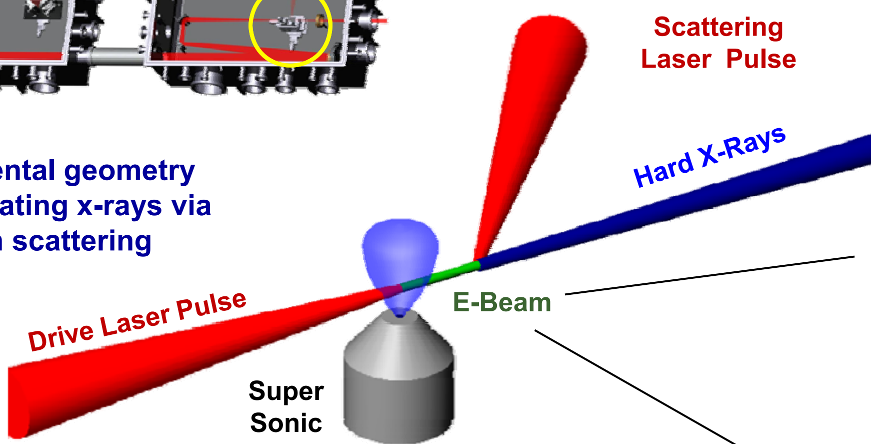
PI: Donald Umstadter, U of Nebraska

- **Scattering from a 300 MeV electron beam can Doppler shift a 1-eV energy laser photon to 1.5 MeV energy.**
- **Demonstrated > 710 MeV electron beams with no detectable low-energy background.**

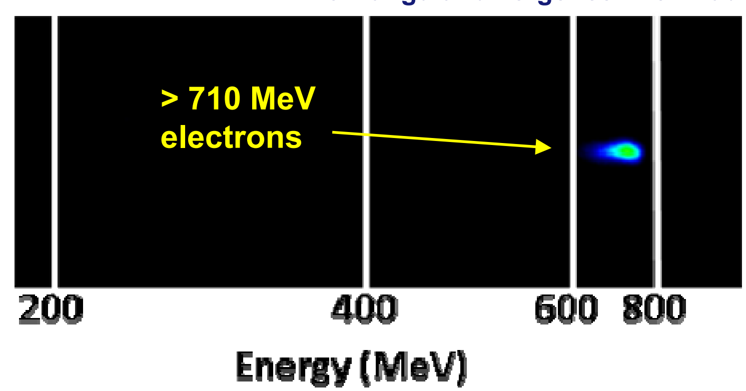




Experimental geometry for generating x-rays via Thomson scattering



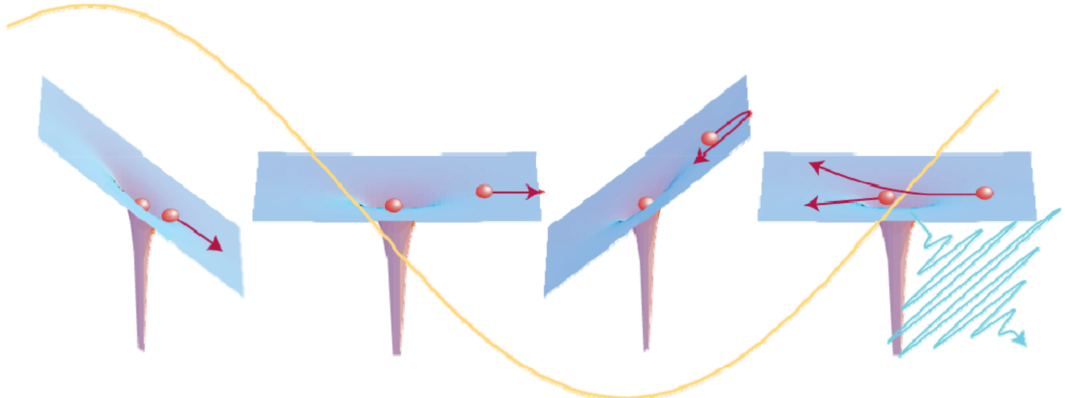
Energy tunability from 0.1 – 0.8 GeV.
Monoenergetic: ΔE/E ~ 10 %
Low angular divergence: 1-5 mrad

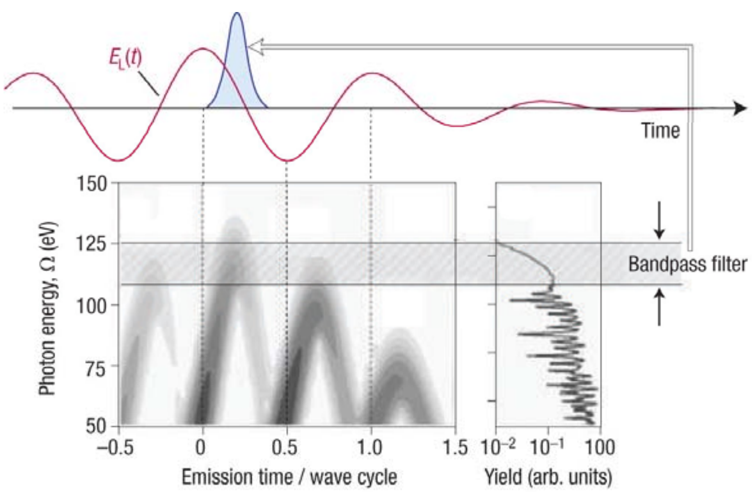


- **Proof-of-principle experiments are underway.**

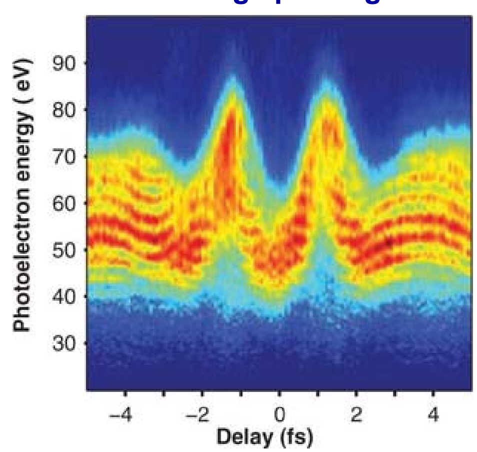
Mode-locked lasers as sources of ultrashort EM pulses (attosecond physics)

Generation of single attosecond photon pulses

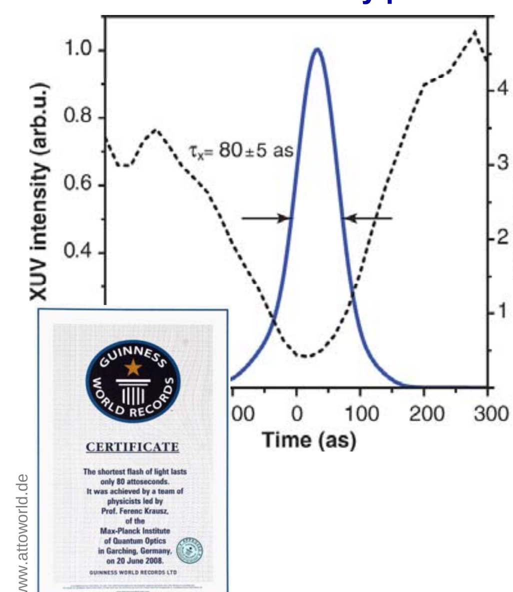




Streaking spectrogram

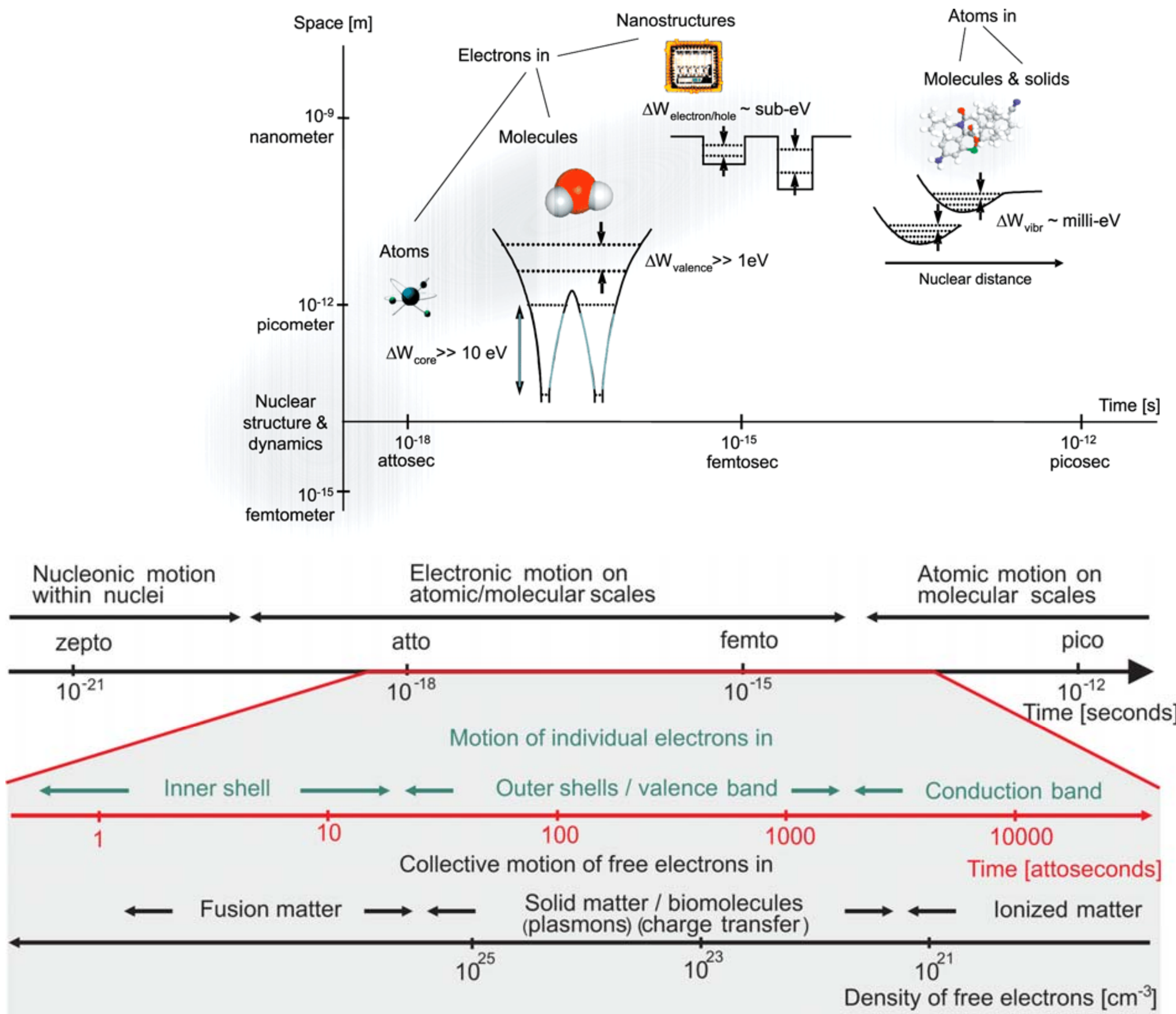


Retrieved intensity profile



Source: Corkum, Nature Physics (2007), Goulielmakis, Science (2008)

Attosecond pulses provide a new set of metrology tools



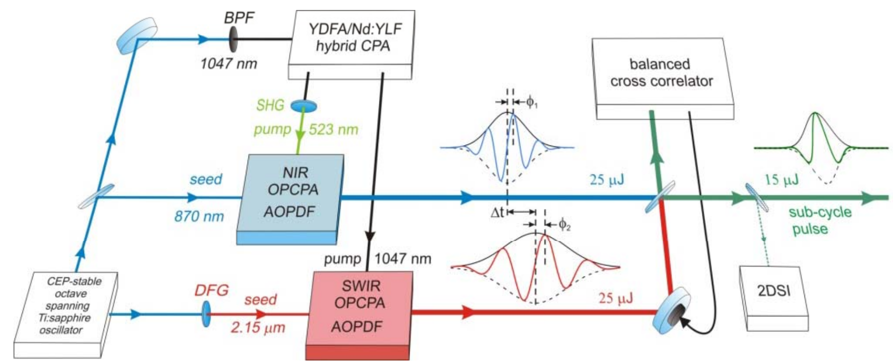
Source: Krausz, RMP (2009)

Sub-cycle optical pulses for isolated attosecond pulse generation

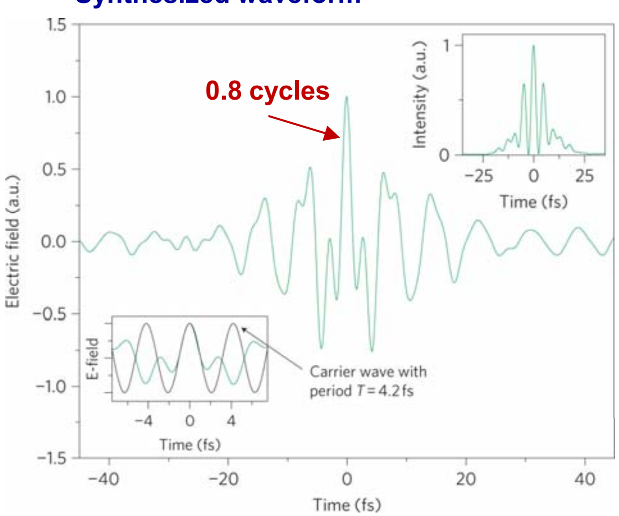
PI: Franz Kaertner, MIT

- **Coherent wavelength multiplexing of high energy pulses, spanning two octaves, into a non-sinusoidal waveform with sub-cycle features.**
- **Shortest high-field transient lasts 0.8 cycles of the carrier frequency.**
- **Unique, scalable approach to higher energies and rep rates for high average power sources of isolated attosecond pulses.**

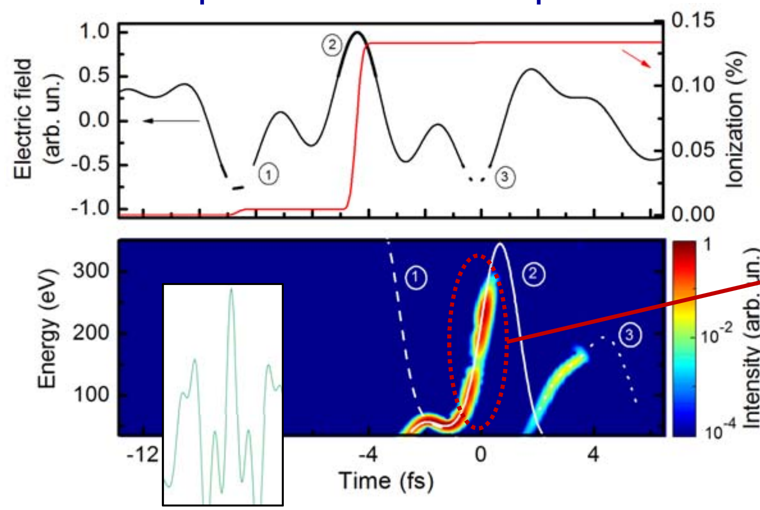
High-energy optical waveform synthesizer



Synthesized waveform

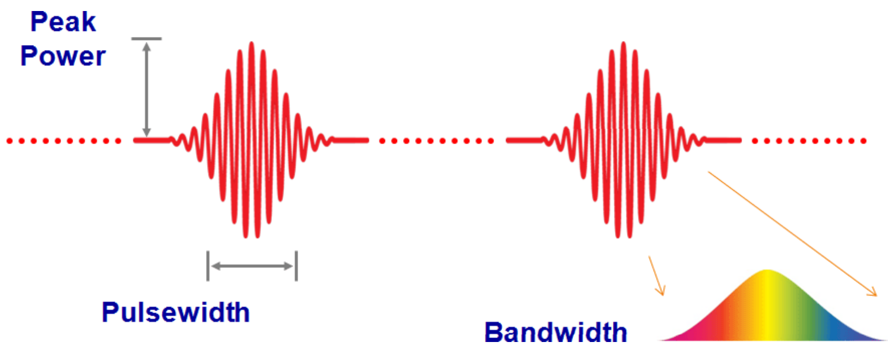


Computed isolated attosecond pulse



Waveform supports directly isolated soft X-ray pulse with 150 as duration (with no gating).

Summary and outlook



The program aims to understand and control light sources exhibiting extreme temporal, bandwidth and peak power characteristics.

Optical frequency combs
ultra-wide bandwidths

- **Spectral coverage to exceed an octave with high power/comb.**
- **Coherence across EUV-LWIR.**
- **Novel resonator designs (e.g. micro-resonator based).**
- **Ultra-broadband pulse shaping.**
- **…**

High-field laser physics
high peak powers

- **Laser-solid interactions.**
- **Fs propagation in media.**
- **Sources of secondary photons.**
- **Compact particle accelerators.**
- **High peak power laser architectures.**
- **High repetition rates.**
- **New wavelengths of operation.**
- **…**

Attosecond science
ultrashort pulsewidths

- **Efficient, high-flux generation.**
- **Pump-probe methods.**
- **Probe atoms/molecules & condensed matter systems.**
- **Attosecond pulse propagation.**
- **Novel attosecond experiments.**
- **Fundamental interpretations of attosecond measurements.**
- **…**