Integrity ★ Service ★ Excellence

Ultrashort Pulse Laser-Matter Interactions Program Overview

2 April 2013

Riq Parra
Program Officer
AFOSR
Air Force Research Laboratory

AFOSR Mission

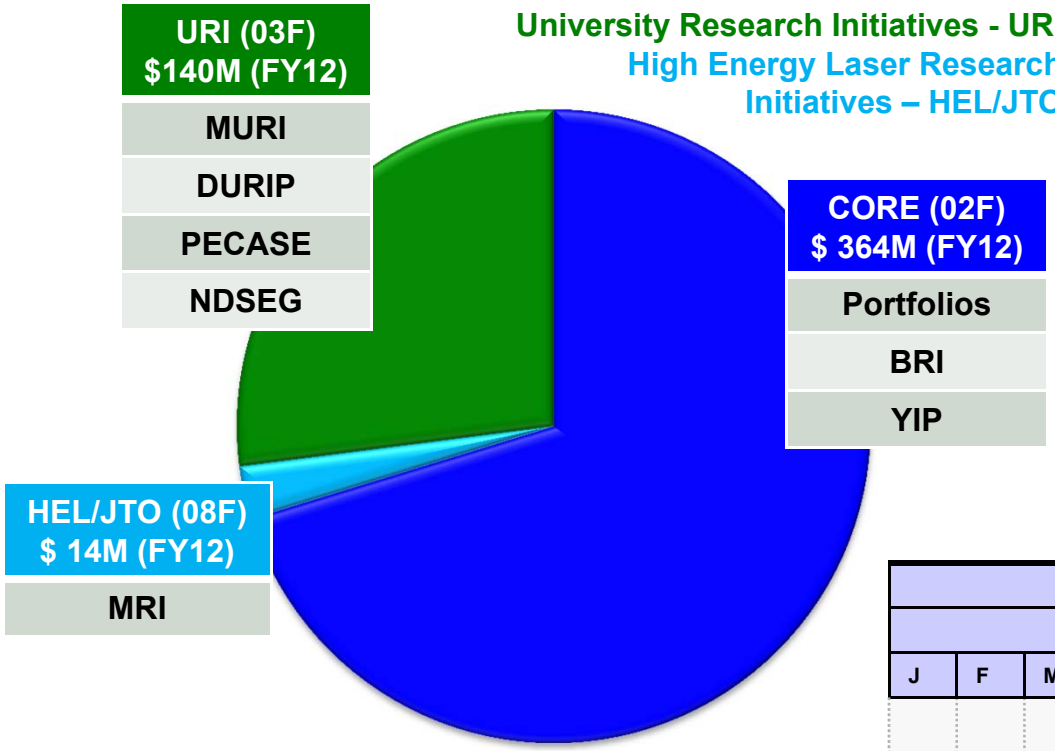
Discover, shape, and champion basic science that profoundly impacts the future Air Force

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

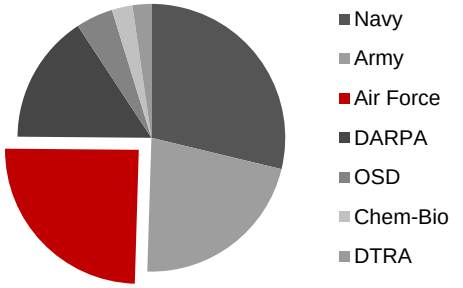
TODAY'S BREAKTHROUGH SCIENCE FOR TOMORROW'S AIR FORCE

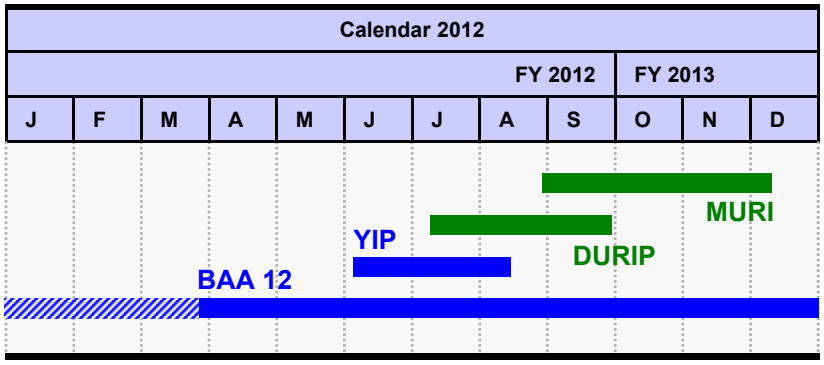
Basic Research at AFOSR

Defense Research Sciences - CORE
University Research Initiatives - URI
High Energy Laser Research Initiatives – HEL/JTO



DoD Total FY12 Basic Research Budget = $2.12B



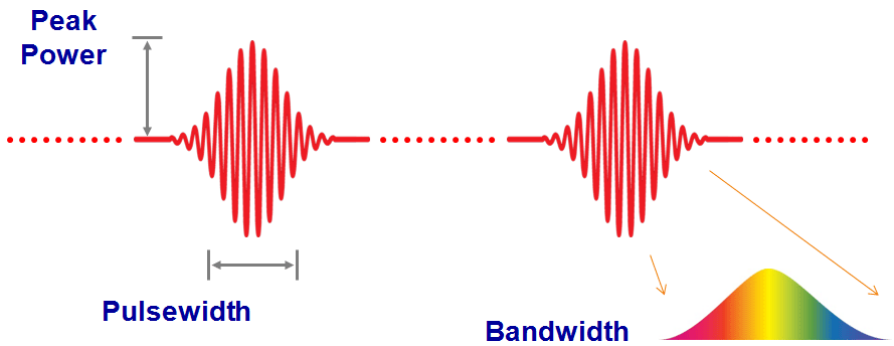


ONR-BAA-12-020	**MURI**
PA-AFOSR-2012-0004	**DURIP**
BAA-AFOSR-2012-0005	**YIP**
BAA-AFOSR-2012-0001	**BAA12**

AFOSR at-a-glance

- **40 core portfolios, 5 new departments:**
  - **RTA – Dynamical Systems and Control (8)**
  - **RTB – Quantum and Non-Equilibrium Processes (7)**
    - Atomic and Molecular Physics (Curcic)
    - Electromagnetics (Nachman)
    - Laser and Optical Physics (Schlossberg)
    - Plasma and Electro-Energetic Physics (Luginsland)
    - Remote Sensing and Imaging Physics (Miller)
    - Space Sciences (Miller)
    - **Ultrashort Pulse Laser-Matter Interactions (Parra)**
  - **RTC – Information, Decision and Complex Networks (11)**
  - **RTD – Complex Material and Devices (9)**
  - **RTE – Energy, Power and Propulsion (5)**

Ultrashort Pulse Laser-Matter Interactions



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.
- Novel laser diagnostics.
- …

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.
- …

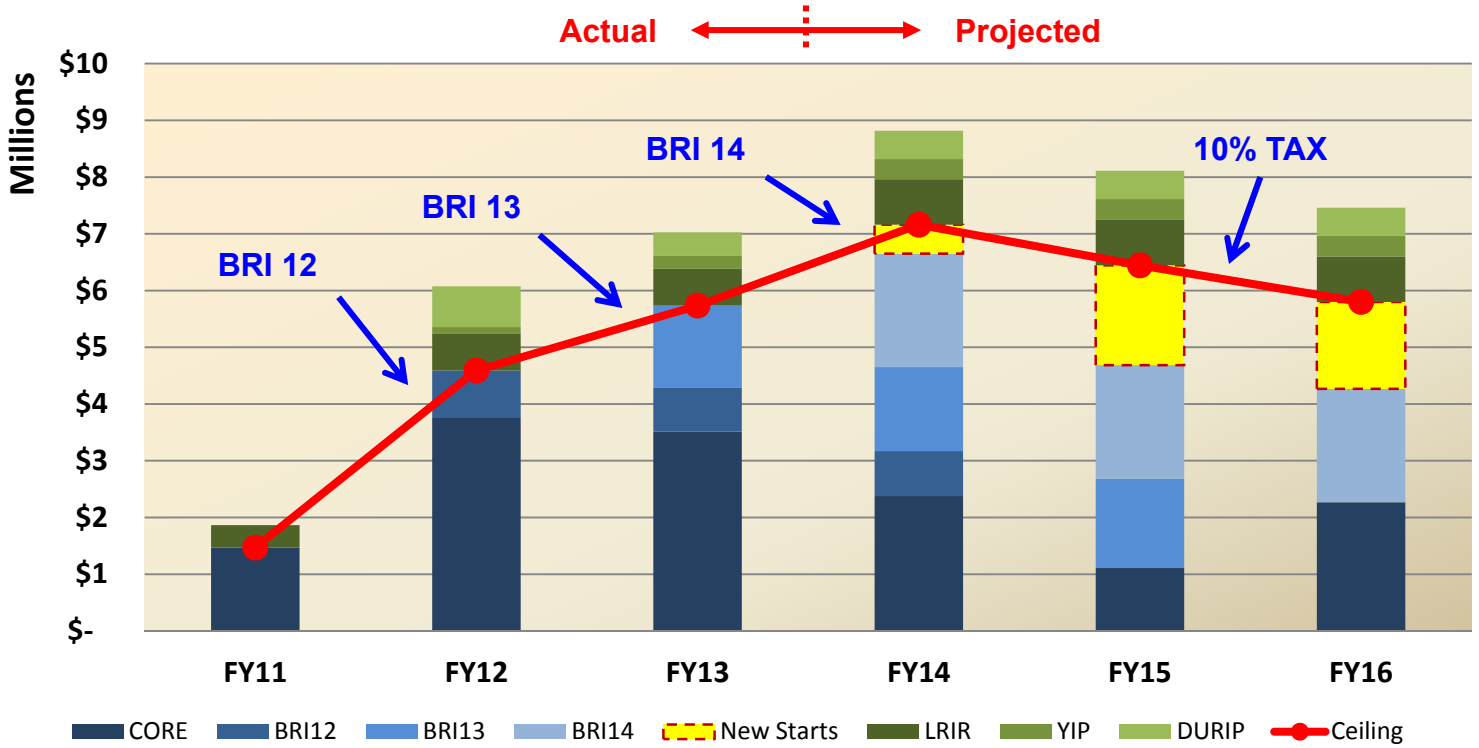
Core Portfolios and Basic Research Initiatives

- **Core research portfolios**
  - **40 portfolios, 5 new departments (RTA,RTB,RTC, RTD, RTE)**
  - **FY12 BAA-AFOSR-2013-0001 (posted Jan 29, 2013, remains open until superseded)**

- **Basic Research Initiatives (BRI) program**
  - **New mechanism to fund new projects aligned to identified emphasis areas**
  - **Funded by a 10% assessment on the prior year budgets of all research portfolios**
  - **PMs nominate research topics that are reviewed for scientific merit and alignment to the AFOSR technical strategy**
  - **BRI topics identified in annual AFOSR BAA**

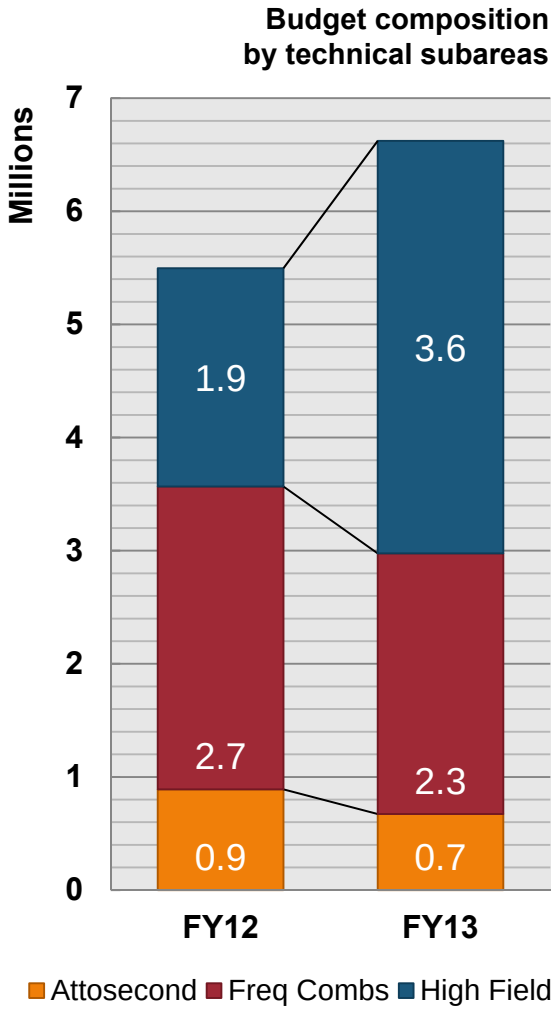
Program Budget

- **Budget subject to compounding annual 10% tax replenished by Basic Research Initiatives (BRIs)**



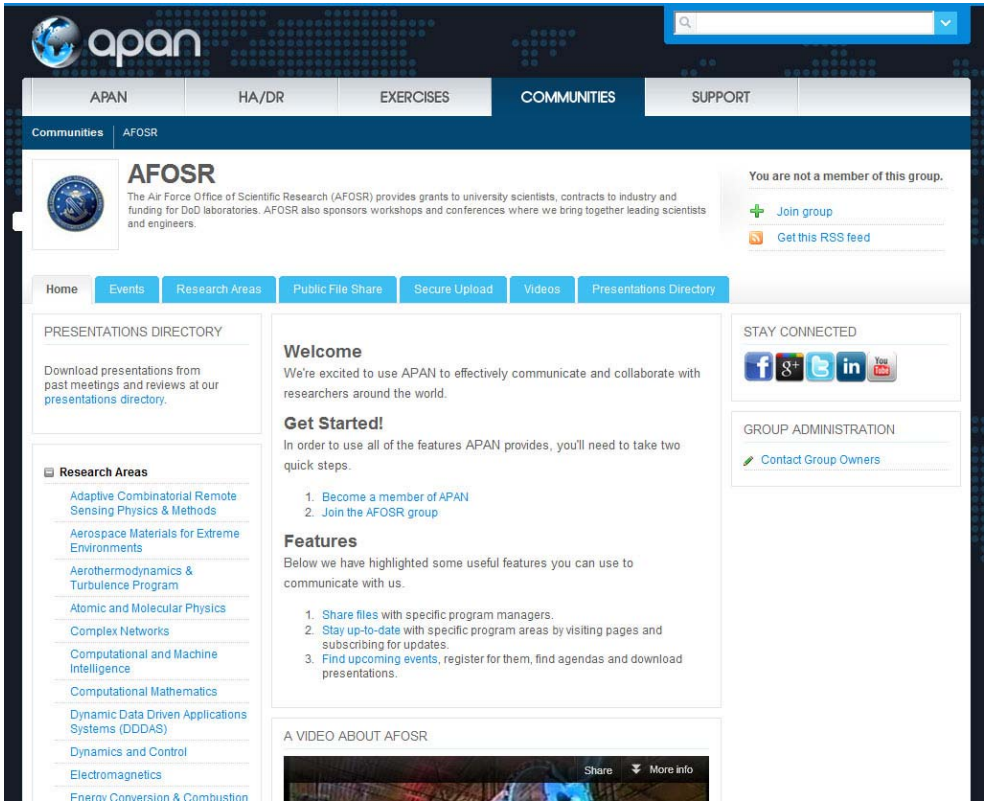
Program Composition

- **Current composition driven by BRI topic areas:**
  - **BRI12 Micro-resonator-based optical frequency combs ($0.8M)**
  - **BRI13 High peak power, ultrashort laser ablation of solids ($1.6M)**
  - ***BRI14 Relativistic optics ($2.0M)***



APAN collaboration website

https://community.apan.org/afosr



Research Areas	Program Managers
Molecular Dynamics and Theoretical Chemistry	Dr. Michael Berman
Space Power and Propulsion	Dr. Mitat Birkan
Complex Networks	Dr. Robert Bonneau
Foundations of Information Systems	Dr. Robert Bonneau
Systems and Software	Dr. Robert Bonneau
Human Performance and Biosystems	Dr. Patrick Bradshaw
Atomic and Molecular Physics	Dr. Tatjana Curcic
	ca Darema
	e Long
	Fahroo
	Fahroo
	ller
	n Harrison
	Hearn
	L. Herklotz
	Hwang
	e
	Li
	ginsland
	Lyons
	ller
	ller
Computational and Machine Intelligence	Dr. Jay Myung

December 2012			
Event	**Dates**	**Location**	**Contact**
Natural Materials, Systems and Extremophilles Program Review More Information Registration	Dec. 3-7, 2012	TBD	Dr. Hugh DeLong hugh.delong@afosr.af.mil
Distributed Intelligence & Information Fusion Program Review More Information Registration	Dec. 4-6, 2012	Arlington, VA	Dr. Tristan Nguyen tristan.nguyen@afosr.af.mil
4th Asia-Pacific Workshop on Structural Health Monitoring More Information	Dec. 5-7, 2012	Melbourne, Australia	Dr. Kenneth Caster kenneth.caster@us.af.mil
International Conference on Hypersonic Aerothermodynamics More Information	Dec. 9-13, 2012	Bangalore, India	Lt Col Tammy Low tammy.low@us.af.mil
Third International Symposium on Terahertz Nanoscience (TeraNano III) More Information	Dec. 10- 12, 2012	Hawaii, USA	Dr. Seng Hong seng.hong@us.af.mil

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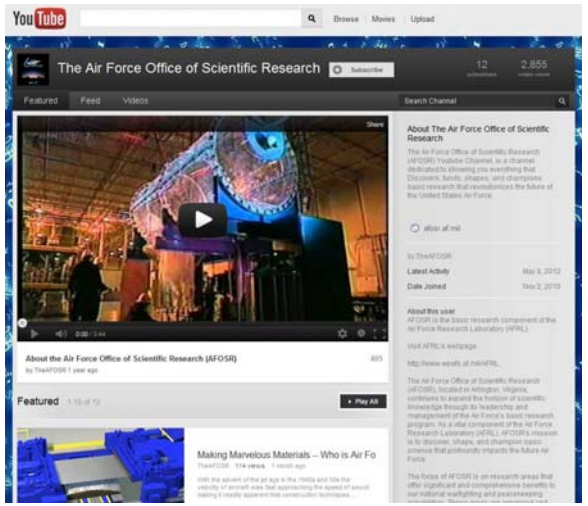


What's keeping us up at night?

- **Efficient spending measures**
- **FY14 budget**
- **Continuing resolutions**
- **Sequestration**

Supplemental Material

FY12 BRI Topics (7)

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

(FY12 BRI) Microresonator-based optical frequency combs


S. Diddams
NIST


Q. Lin
University of Rochester

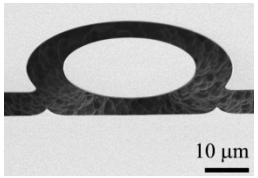

A. Gaeta
Cornell

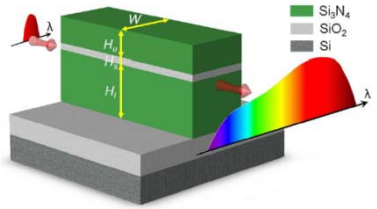

A. Matsko
OEwaves


A. Weiner
Purdue University


A. Willner
USC Optical Communications Laboratory

- **Initiative aimed at exploring the fundamental physics of microresonator comb generation.**
- **Six efforts exploring:**
  - **Spatio-temporal field mapping and control**
  - **Silicon-carbide microdisks**
  - **Silicon nitride resonators**
  - **Mid-IR microresonators**
  - **Time domain characterization**
  - **Dispersion tailoring via slotted waveguides**

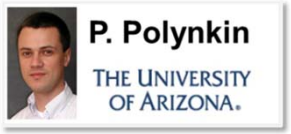




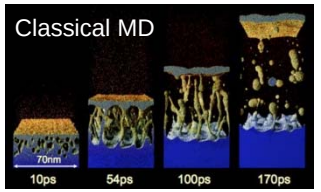
FY13 BRI Topics (9)

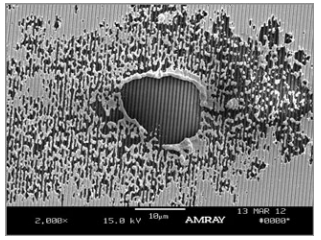
1) Layered structured 2D-materials for extreme environment
2) Autonomic material systems utilizing biomolecular transduction
3) Transformational computing via co-design of high-performance algorithms and hardware
4) High peak power, ultrashort laser ablation of solids
5) Sustainable alloy design: Rare 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-parallel computing

(FY13 BRI) High peak power, ultrashort pulse laser processing of materials

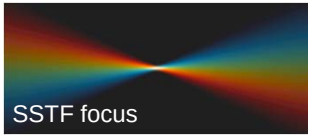


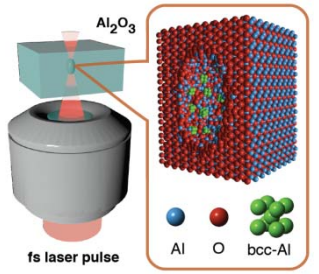
- **Initiative aimed at developing a fundamental understanding of intense field laser ablation/damage in the femtosecond regime.**
- **Three multi-PI efforts exploring:**
  - **Dynamics of ionization**
  - **Fundamental dynamics of laser ablation**
  - **Effect of structures on laser damage**
  - **First principle-based models, non-adiabatic quantum MD, classical MD**
  - **Vary λ = 400 nm – 4 μm, τ = 5 – 1000 fs**
  - **Complex beam shapes (Bessel, Airy, vortex, SSTF beams)**
  - **Novel laser-matter interaction geometries (confined microexplosions, SSTF excitation, few-cycle pulses)**





Gratings



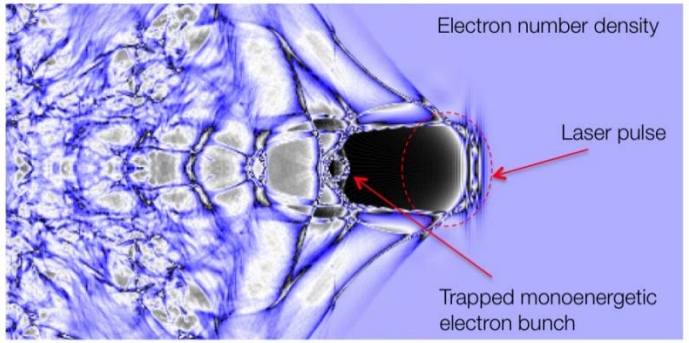


FY14 BRI Topics (13)

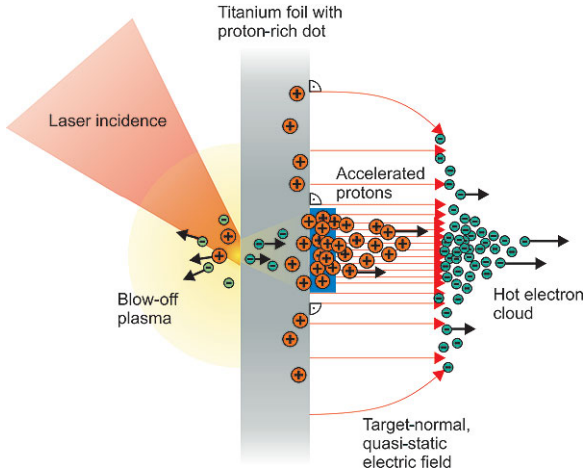
1) 2D Materials and Devices beyond Graphene
2) Bio-Sensing of Magnetic Fields
3) Development and Verification of Effective First Principles Modeling (Maxwell-Bloch Equations) of Semiconductor Lasers Under Non Equilibrium Operating Conditions
4) Laser-matter Interactions in the Relativistic Optics Regime
5) Lasers Physics for Scaling of Single Fibers to High Beam Quality and High-power
6) Metal Dielectric Interface - Charge Transfer in Heterogeneous Media under Extreme Environments
7) Nanoscale Building Blocks for Novel Materials
8) Perceptual and Social Cues in Human-like Robotic Interactions
9) Plasma – Surface Interactions in Reactive Environments
10) Socio-Digital Influence
11) Theory-based Engineering of Biomolecular Circuits in Living Cells
12) Understanding the Interaction of Coronal Mass Ejections with the Solar-Terrestrial Environment
13) Understanding the Psychological/Behavioral Effects of Advanced Weaponry

(FY14 BRI) Laser-matter interactions in the relativistic optics regime

- **Laser-driven electron acceleration**
  - **Laser Wakefield Acceleration: Electrons are accelerated to gigaelectronvolt (GeV) energies over centimeters distances**
  - **Direct Light Acceleration**
- **Ion acceleration**
  - **Protons and ions are accelerated to megaelectronvolt (MeV) energies by a mechanism known as 'target normal sheath acceleration' (TNSA)**
- **X-ray radiation sources**
  - **keV to MeV x-rays via non-linear Thomson Scattering**
  - **Kα monochromatic emission**
  - **Bremsstrahlung broadband radiation**
- **Neutron sources**
  - **Protons incident on a secondary target (e.g. Lithium) can produce MeV neutrons**
- **QED physics**



Electron density distribution and generation of quasi-monoenergetic electron bunches observed in PIC simulations.



Target Sheath Normal Acceleration: Laser acceleration of protons from the back side of a microstructured target.