RA4-FA1: X-ray Induced Blow-off and Plasma

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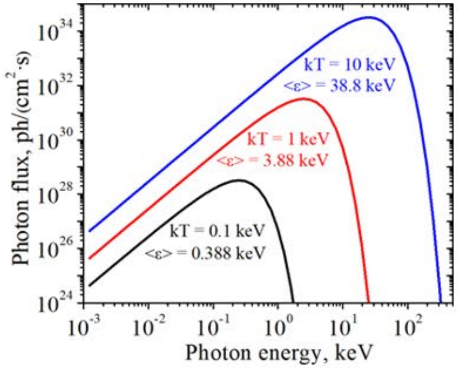
MSEE | MATERIALS SCIENCE IN EXTREME ENVIRONMENTS UNIVERSITY RESEARCH ALLIANCE

DEFENSE THREAT REDUCTION AGENCY • UNITED STATES OF AMERICA

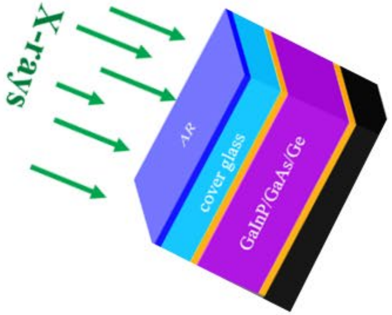
Problem and Challenges

exo-atmospheric nuclear blast

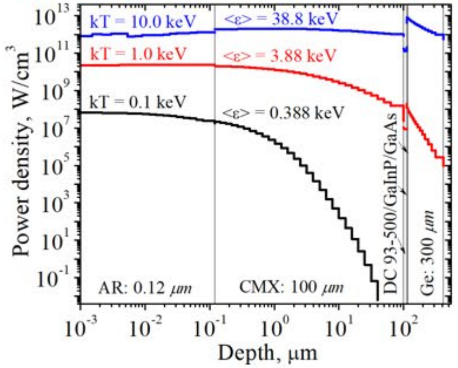
high flux of blackbody X-rays



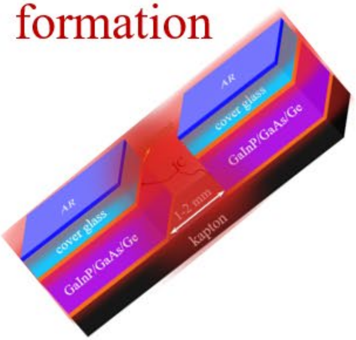
X-ray transport in multi-layer structure



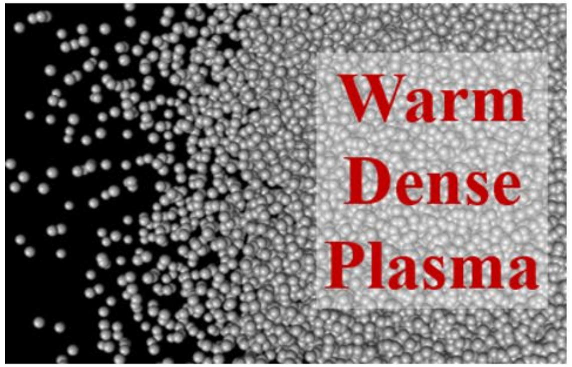
X-ray deposited power density in multi-layers



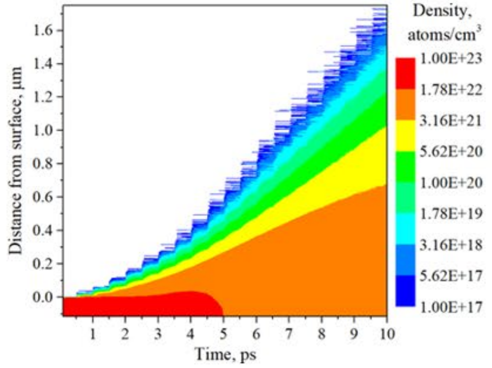
ablation, blow-off, WDP formation

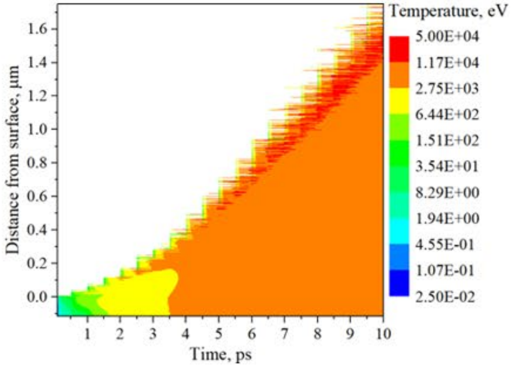


WDP expansion

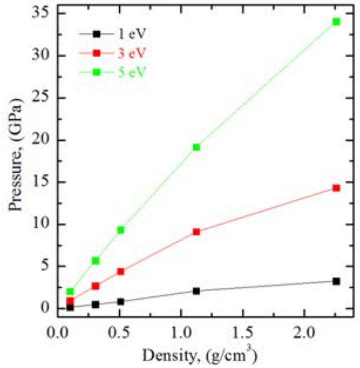


evolution of density & temperature of WDP





equation of state of WDP



- multi-physics and multi-scale processes, high X-ray number, micron size layers of materials, enormous absorbed power density, blow-off into a vacuum

Scientific Drivers

SCIENTIFIC DRIVERS:

- Predict & understand the interaction of high intensity x-ray fluxes with near-surface materials
- Develop use of high-power lasers and tamper materials to simulate x-ray blow-off and thermomechanical shock

Thrust 1: X-RAY INDUCED BLOW-OFF

HIGH INTENSITY X-RAYS INTERACTION
Material ablation; black body radiation; power density; solar cells

TRANSPORT
Layer targets; warm dense matter; conductivity

PARTICLE GENERATION
Electrons; photons; equation of state

Thrust 2: DIRECT LASER IMPULSE

LASER PLASMA INTERACTION
Phase plates; laser spot sizes; energy absorption; shock generation

TAMPER MATERIALS
Optically designed films; shock energy deposition

NUCLEAR EFFECTS
Damage; shock propagation across boundaries; material damage

Thrust 3: DIAGNOSTICS AND PREDICTIVE MODELING

DIAGNOSTICS
Spectroscopy; imaging; Velocity Interferometer System for Any Reflector (VISAR)

MODELING
Prediction of laser and x-ray irradiation; synthetic diagnostics

← OPTICAL AND X-RAY IRRADIATION →

Personnel

Investigators and Collaborators	Position	Institution
Gena Miloshevsky	**FA Coord**	**VCU**
Farhat Beg	Collaborator	UCSD
Hari Harilal	Collaborator	PNNL
Debbie Levin	Collaborator	UIUC
Mike Shields	Collaborator	JHU
Jacob Calkins	Collaborator	DTRA

Long-term Goals and Strategies

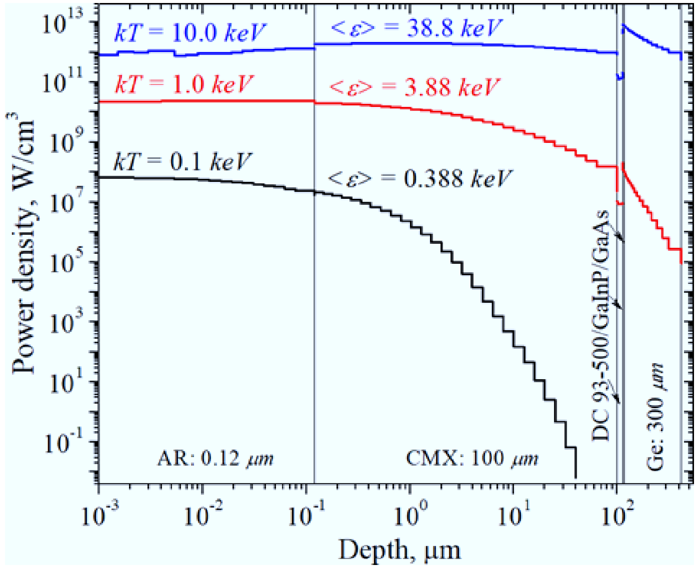
- Long-term Goals
  - high-fidelity modeling, prediction, and understanding the interaction of high-intensity X-rays with the exposed surfaces of DoD space and strategic systems
    - X-ray absorption, surface ablation, blow-off, and generation of Warm Dense Plasma (WDP)
- Strategies
  - development of accurate physics models and their applications to predict and possibly mitigate X-ray induced blow-off and WDP generation
    - bi-weekly meetings to discuss progress and research activities within FA
    - Craedl account at JHU for the data storage, sharing, and information exchange needs
    - virtual meetings with collaborators from NRL and DTRA to guide investigations

IPP Goals and Strategies

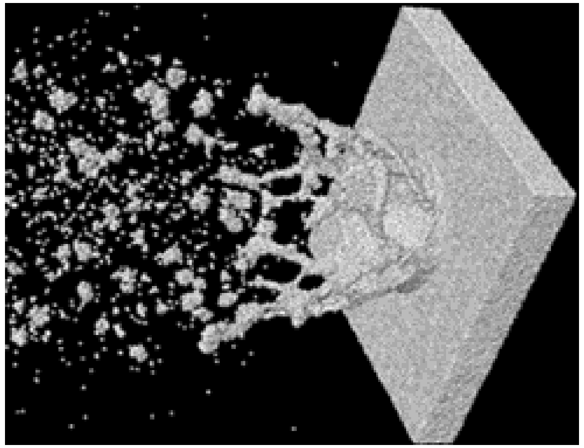
- IPP Goals
  - development of a canonical model for parametric studies of X-rays fluences and space and strategic materials
  - quantification of X-ray thermal sources and X-ray interactions with specific satellite materials within the canonical model
- IPP Strategies
  - daily management control necessary to monitor the progress of the work
    - assure schedule, reporting, budget requirements, resource allocation, scope, and milestones
    - bi-weekly meetings to ensure completion of tasks or any needed FA adjustments
    - seminars to discuss various aspects, results, and progress of FA

What is Revolutionary and/or Unique About this Research

- MIRDIC-GEANT4 code developed by FA coordinator in collaboration with the NASA’s Marshal Space Flight Center
    - transport of blackbody photons from EUV to hard X-rays in satellite materials, generation of secondary photons and electrons, and their energy deposition

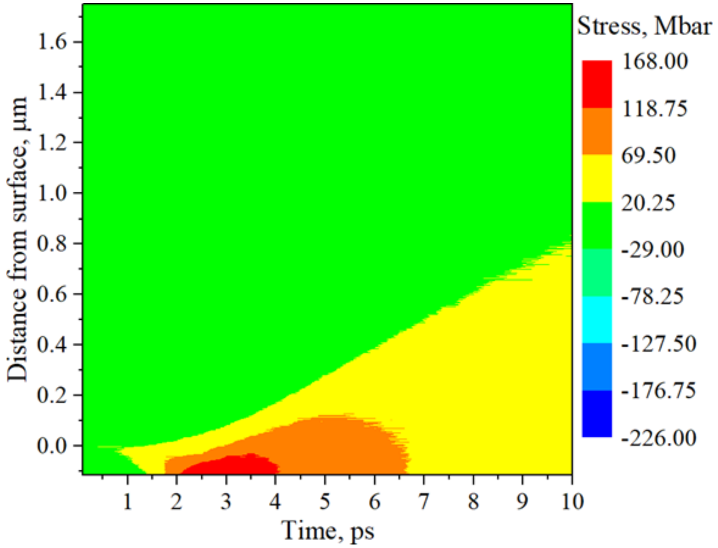


- MSM-LAMMPS code developed by FA coordinator for the modeling of laser-material interactions in collaboration with PNNL
    - X-ray induced shock generation, material ablation, and blow-off into a vacuum

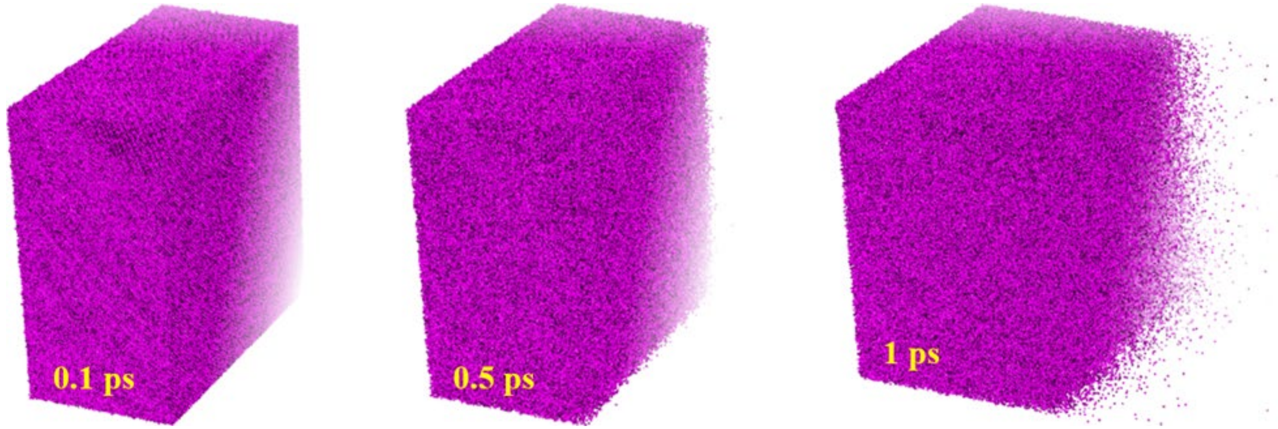


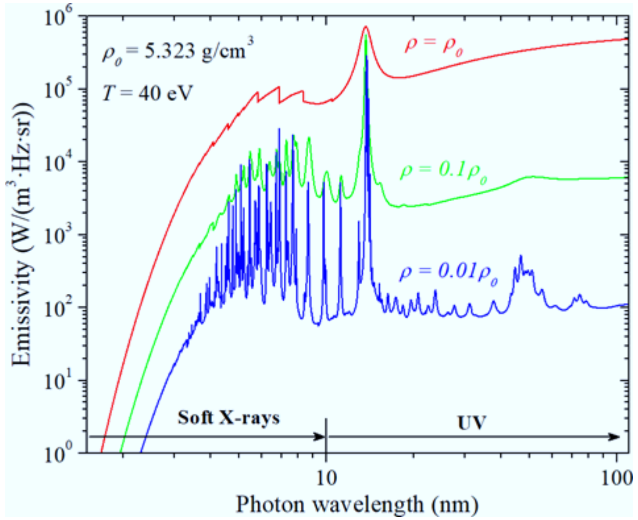
What is Revolutionary and/or Unique About this Research

- unique opportunity to implement new physics models for solving specific FA problems by developing and adapting both codes



- possibility for revealing new physical phenomena and providing a knowledge base for new technologies





Description of PI Activities

- construction of constitutive models of representative space and strategic materials of interest to DTRA within a framework of canonical model
  - general geometry of components, list of materials and compounds
- creation of input data files for MIRDIC-GEANT4 computer code
  - mass fractions, parameters characterizing geometry and properties of materials
- development of parametric model describing relevant flux and fluence of X-rays and implementation into MIRDIC-GEANT4
  - energy spectrum, duration, width, and shape of X-ray pulse

Description of PI Activities

- revision and improvement of fluorescence models used in GEANT4 to account for shell structure of relevant atoms in this FA
  - emission of secondary photons and Auger electrons
- outcomes of IPP
  - canonical model of materials, geometry of components, parametric X-ray fluxes
  - input data files for MIRDIC-GEANT4 code with material composition, properties of materials, and geometry of representative space and strategic components
  - upgraded MIRDIC-GEANT4 code implementing time-dependent spectral energy function, temporal shape and parameters of parametric X-ray pulses
  - improved models describing X-ray interactions with electronic shells of atoms

Plans for Collaborative Exchanges

- TBD (NRL)
  - development of canonical model for materials, geometries, and X-ray sources
- Farhat Beg (UCSD)
  - materials, their properties, and geometries to be used in laboratory experiments
- Hari Harilal (PNNL)
  - diagnostics and characterization of material states under extreme loads and irradiation conditions
- Jacob Calkins (DTRA)
  - refinement of canonical model for materials, geometry, and characteristic parameters of X-ray pulse

Collaborative Exchanges w/CCRI

- Mike Shields (JHU)
  - formalizing and disseminating an initial general strategy and standard practices of the CCRI for uncertainty quantification (UQ) in this FA
  - FA coordinator is a member of the UQ Subgroup