



Nonlinear Optics at the U.S. Army Research Laboratory's Weapons and Materials Research Directorate

by Anthony Valenzuela, Andrew Porwitzky, and Chase Munson

ARL-SR-222

March 2011

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Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5066

ARL-SR-222

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**Anthony Valenzuela, Andrew Porwitzky, and Chase Munson
Weapons and Materials Research Directorate, ARL**

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14. ABSTRACT We provide an overview of efforts and interest in studying directed energy and ultrashort pulse lasers in the U.S. Army Research Laboratory's Weapons and Materials Research Directorate (WMRD). WMRD's interest in nonlinear optics lies primarily in target effects of filaments impacting on solid surfaces. In addition, we are keenly interested in on-going work in the theory and modeling of the basic physical understanding of propagation through atmosphere and particulates.					
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Contents

List of Figures	iv
1. Introduction	1
Distribution List	9

List of Figures

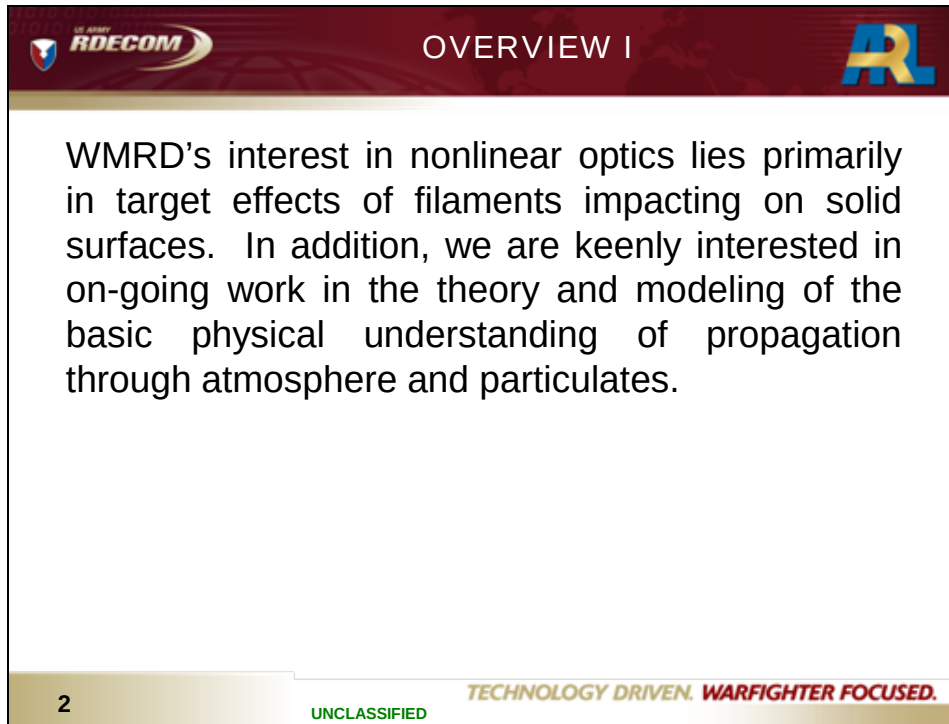
Figure 1. Nonlinear optics at the U.S. Army Research Laboratory - Weapons and Materials Research Directorate.....	1
Figure 2. Overview I.	2
Figure 3. Overview II.....	2
Figure 4. Overview III.	3
Figure 5. Overview IV.	3
Figure 6. Ablation I.....	4
Figure 7. Ablation II.	4
Figure 8. EM generation.	5
Figure 9. Plasma diagnostics I.	5
Figure 10. Plasma diagnostics II.....	6
Figure 11. Plasma diagnostics III.....	6
Figure 12. Filament propagation.....	7
Figure 13. Collaboration.	7
Figure 14. Contact information.....	8
Figure 15. Original poster.	8

1. Introduction

The following slides were presented at the Nonlinear Optics Meeting sponsored by the U.S. Air Force Office of Scientific Research (AFOSR) that was held at Albuquerque, NM, in September 2010. The purpose of the meeting was to act as both review of AFOSR sponsored nonlinear optics (NLO) works and also as a kick-off to the FY10 Multidisciplinary University Research Initiative “Propagation of Ultrashort Laser Pulses Through Transparent Media.” The slides are taken from a poster presented at the meeting to inform the U.S. Department of Defense (DOD) and related academic community about the NLO and ultrashort pulse laser efforts at the U.S. Army Research Laboratory’s Weapons and Materials Research Directorate. The goal is to encourage sharing of resources and establish collaborations that are mutually beneficial to the Army and DOD as well as prepare avenues for the translation of basic research to more applied research to meet protection and lethality needs.



Figure 1. Nonlinear optics at the U.S. Army Research Laboratory - Weapons and Materials Research Directorate.

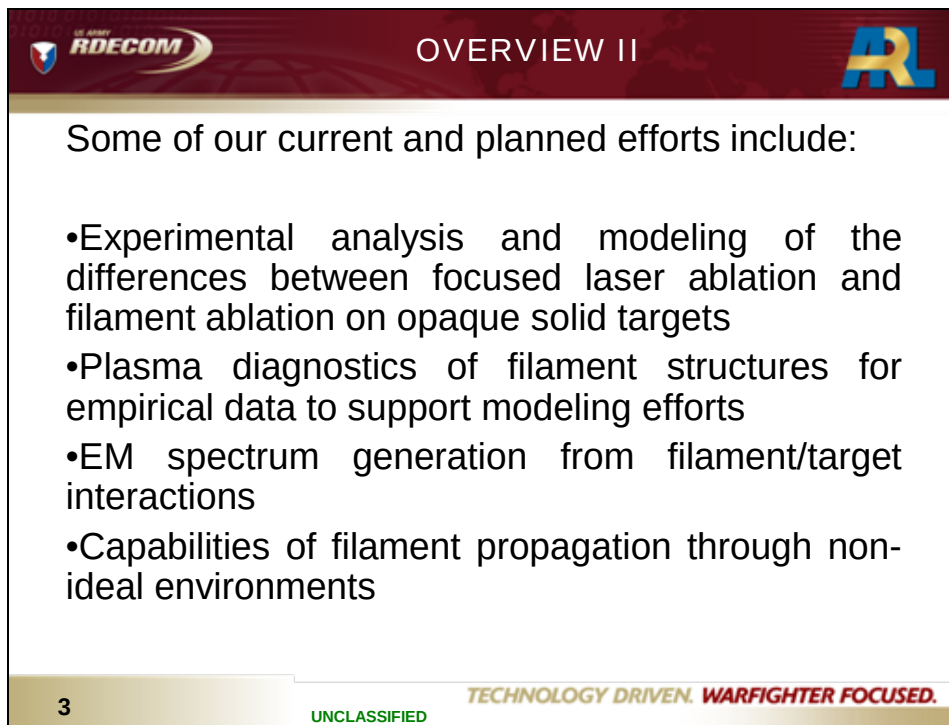
The slide has a dark red header with the US Army RDECOM logo on the left, the title "OVERVIEW I" in the center, and a stylized "AR" logo on the right. The main content area is white with black text. The footer is a gold bar containing the number "2", the word "UNCLASSIFIED", and the slogan "TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED." in red.

US ARMY RDECOM OVERVIEW I AR

WMRD's interest in nonlinear optics lies primarily in target effects of filaments impacting on solid surfaces. In addition, we are keenly interested in on-going work in the theory and modeling of the basic physical understanding of propagation through atmosphere and particulates.

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Figure 2. Overview I.

The slide has a dark red header with the US Army RDECOM logo on the left, the title "OVERVIEW II" in the center, and a stylized "AR" logo on the right. The main content area is white with black text, including a list of four bullet points. The footer is a gold bar containing the number "3", the word "UNCLASSIFIED", and the slogan "TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED." in red.

US ARMY RDECOM OVERVIEW II AR

Some of our current and planned efforts include:

- Experimental analysis and modeling of the differences between focused laser ablation and filament ablation on opaque solid targets
- Plasma diagnostics of filament structures for empirical data to support modeling efforts
- EM spectrum generation from filament/target interactions
- Capabilities of filament propagation through non-ideal environments

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Figure 3. Overview II.



OVERVIEW III



Beyond our core mission, we are interested in advances in:

- fs laser development
- Propagation modeling
- Non-Gaussian beam dynamics
- Remote laser induced breakdown spectroscopy

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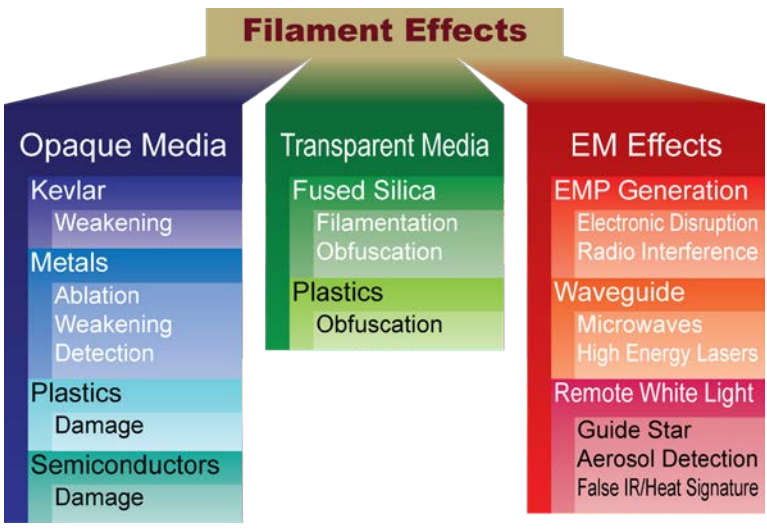
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Figure 4. Overview III.



OVERVIEW IV





Filament Effects		
Opaque Media	Transparent Media	EM Effects
Kevlar	Fused Silica	EMP Generation
Weakening	Filamentation	Electronic Disruption
Metals	Obfuscation	Radio Interference
Ablation	Plastics	Waveguide
Weakening	Obfuscation	Microwaves
Detection		High Energy Lasers
Plastics		Remote White Light
Damage		Guide Star
Semiconductors		Aerosol Detection
Damage		False IR/Heat Signature

5

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Figure 5. Overview IV.

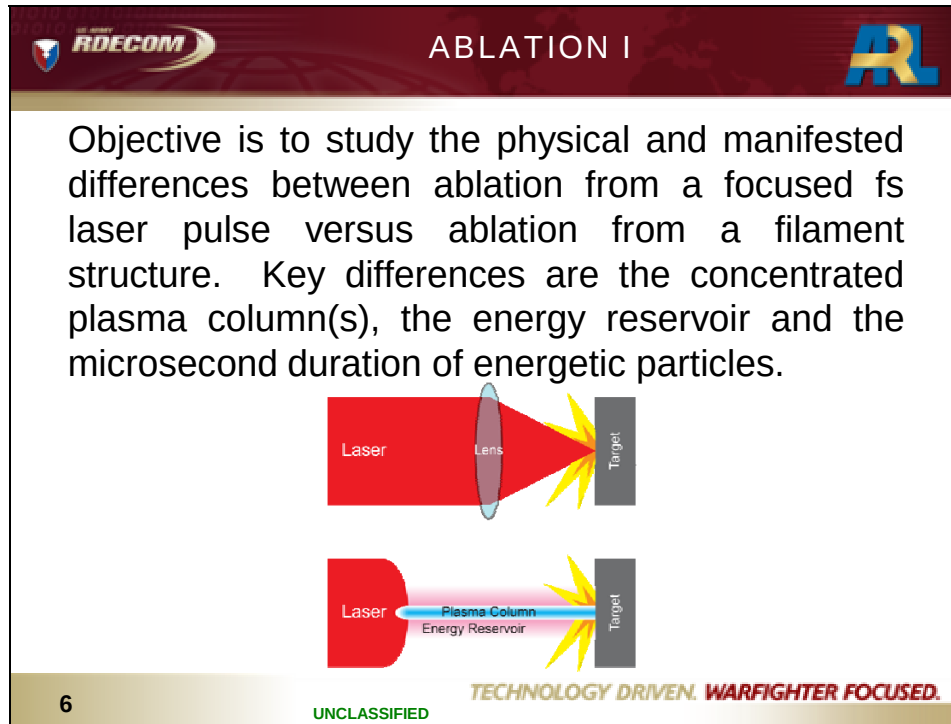


Figure 6. Ablation I.

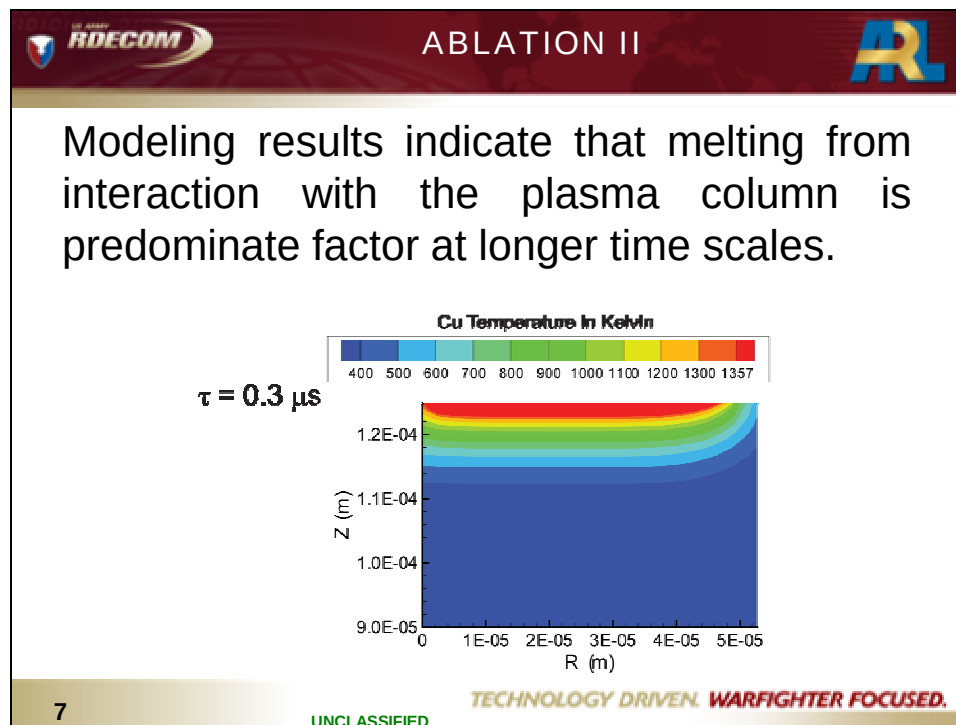
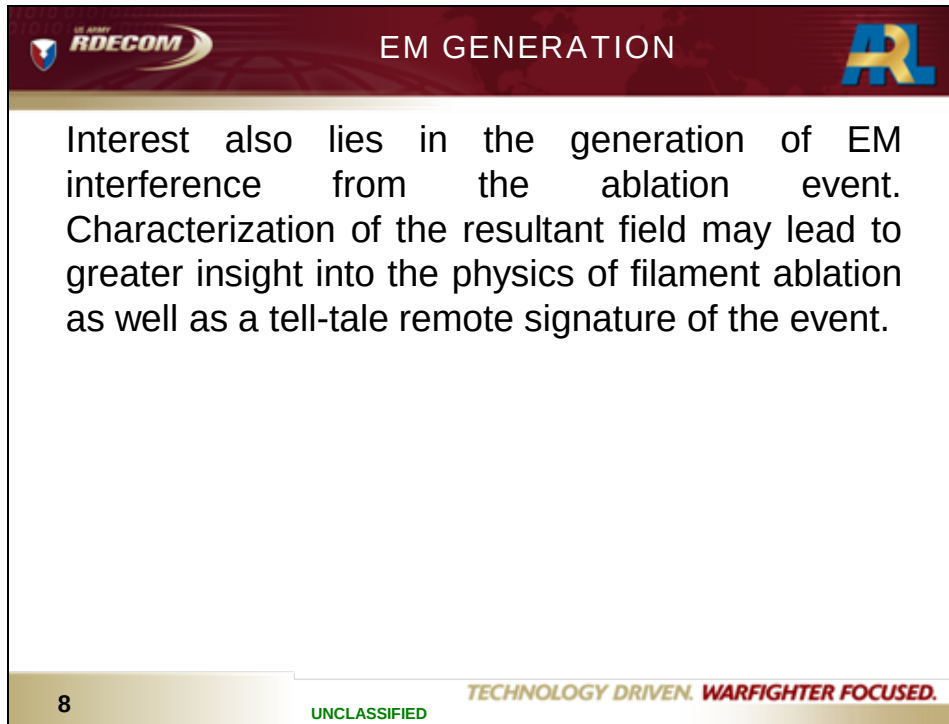


Figure 7. Ablation II.



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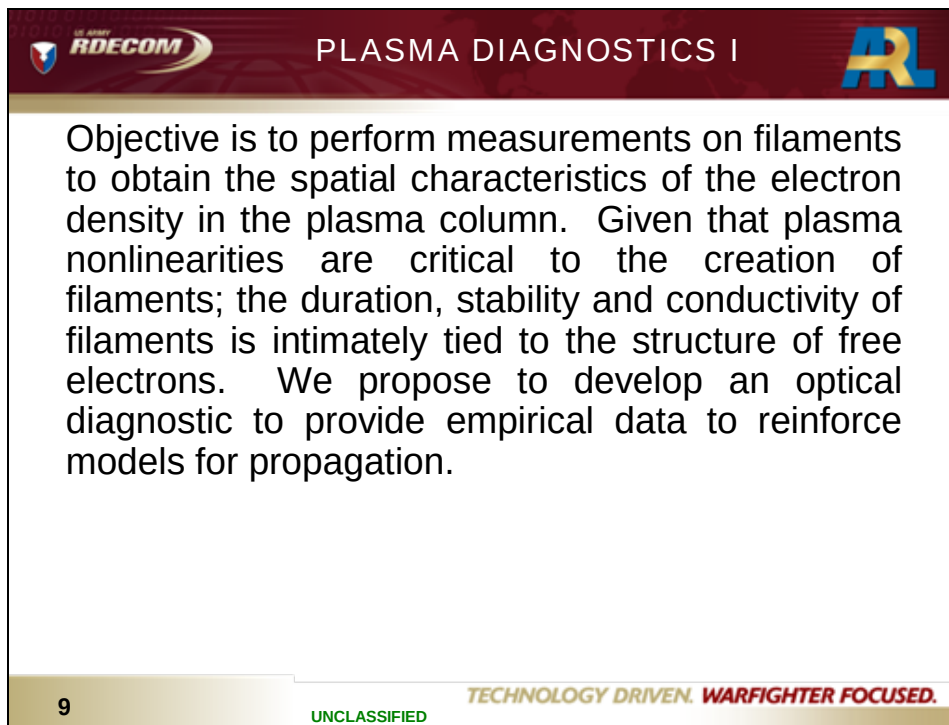
EM GENERATION

AR

Interest also lies in the generation of EM interference from the ablation event. Characterization of the resultant field may lead to greater insight into the physics of filament ablation as well as a tell-tale remote signature of the event.

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Figure 8. EM generation.



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PLASMA DIAGNOSTICS I

AR

Objective is to perform measurements on filaments to obtain the spatial characteristics of the electron density in the plasma column. Given that plasma nonlinearities are critical to the creation of filaments; the duration, stability and conductivity of filaments is intimately tied to the structure of free electrons. We propose to develop an optical diagnostic to provide empirical data to reinforce models for propagation.

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Figure 9. Plasma diagnostics I.

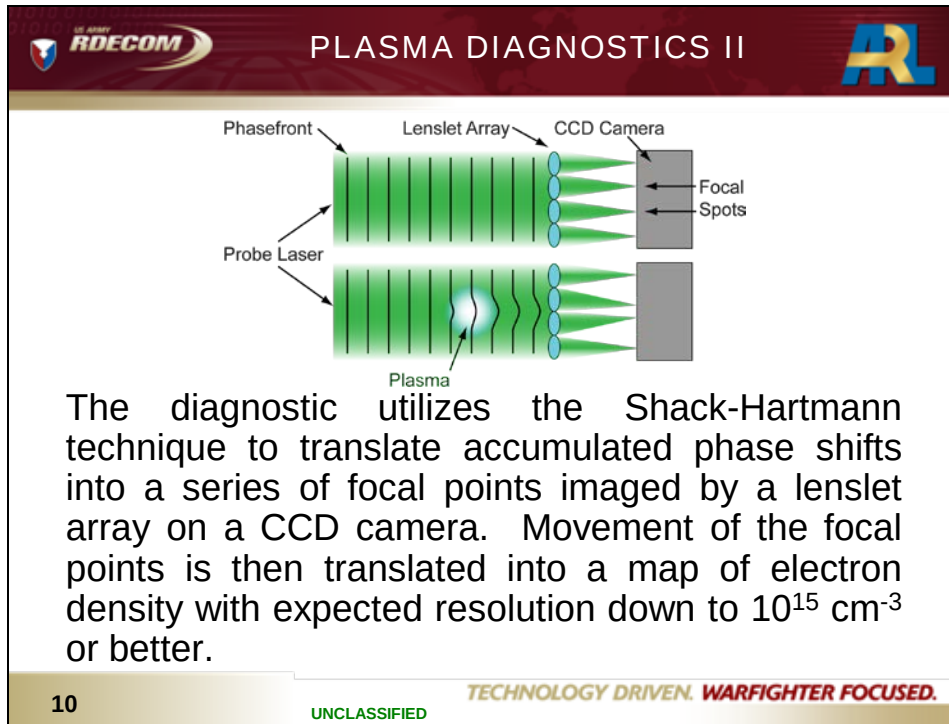


Figure 10. Plasma diagnostics II.

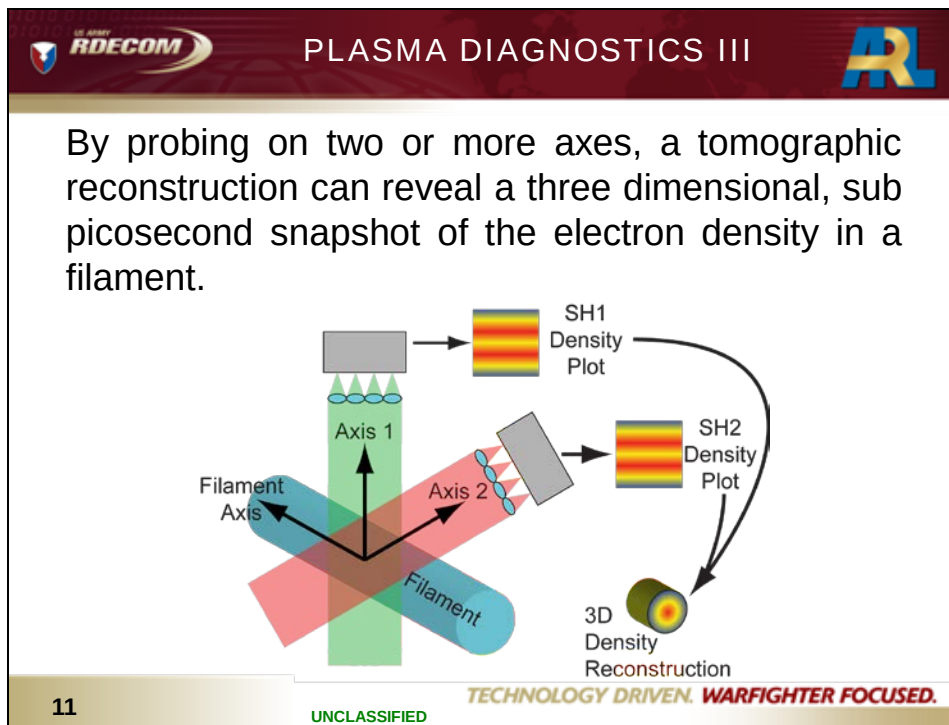
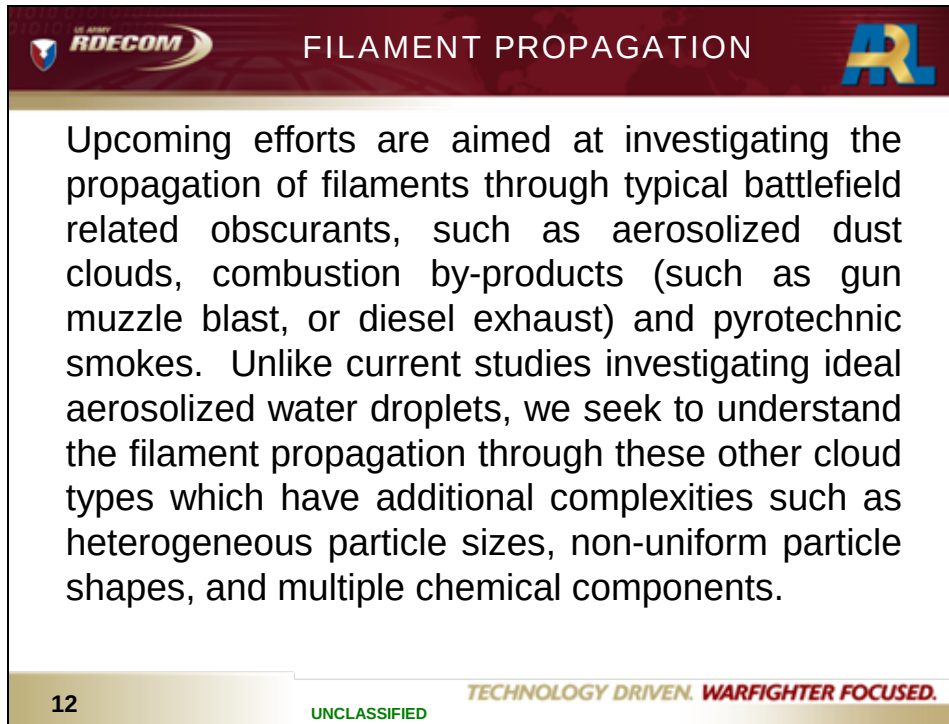


Figure 11. Plasma diagnostics III.

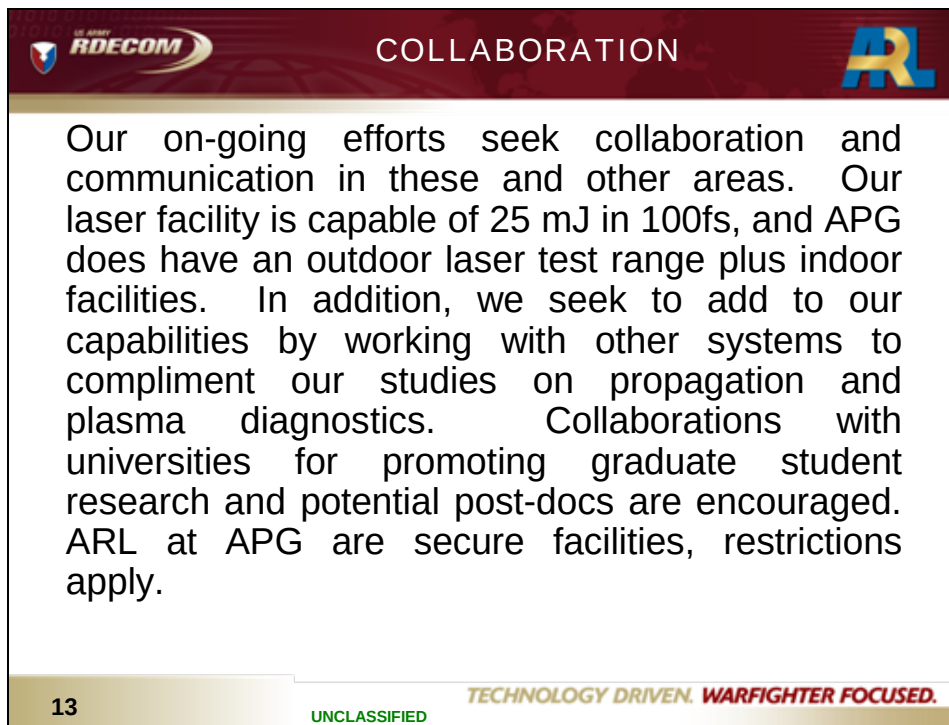


FILAMENT PROPAGATION

Upcoming efforts are aimed at investigating the propagation of filaments through typical battlefield related obscurants, such as aerosolized dust clouds, combustion by-products (such as gun muzzle blast, or diesel exhaust) and pyrotechnic smokes. Unlike current studies investigating ideal aerosolized water droplets, we seek to understand the filament propagation through these other cloud types which have additional complexities such as heterogeneous particle sizes, non-uniform particle shapes, and multiple chemical components.

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Figure 12. Filament propagation.



COLLABORATION

Our on-going efforts seek collaboration and communication in these and other areas. Our laser facility is capable of 25 mJ in 100fs, and APG does have an outdoor laser test range plus indoor facilities. In addition, we seek to add to our capabilities by working with other systems to compliment our studies on propagation and plasma diagnostics. Collaborations with universities for promoting graduate student research and potential post-docs are encouraged. ARL at APG are secure facilities, restrictions apply.

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Figure 13. Collaboration.



CONTACT INFO



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14
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Figure 14. Contact information.



ORIGINAL POSTER





Nonlinear Optics at the US Army Research Laboratory
Weapons & Materials Research Directorate



Anthony Valenzuela, Andrew Poratitzky, Chase Munson

OVERVIEW

WMRD's interest in nonlinear optics has primarily in target effects of filaments impacting on solid surfaces. In addition, we are currently interested in on-going work in the theory and modeling of the basic physical understanding of propagation through atmosphere and particulates. Some of our current and planned efforts include:

- Experimental analysis and modeling of the differences between focused laser ablation and filament ablation on opaque solid targets
- Plasma diagnostics of filament structures for empirical data to support modeling efforts
- EM spectrum generation from filament/target interactions
- Capabilities of filament propagation through individual environments

Beyond our core mission, we are interested in advances in:

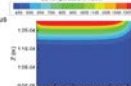
- As laser development
- Propagation modeling
- Non-Gaussian beam dynamics
- Remote laser induced breakdown spectroscopy

ABLATION

Objective is to study the physical and manifested differences between ablation from a focused laser pulse versus ablation from a filament structure. Key differences are the concentrated plasma column(s), the energy reservoir and the microsecond duration of energetic particles.



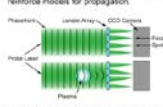
Modeling results indicate that melting from interaction with the plasma column is predominantly faster at longer time scales.



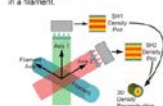
$\tau \approx 0.3 \mu s$

PLASMA DIAGNOSTICS

Objective is to perform measurements on filaments to obtain the spatial characteristics of the electron density in the plasma column. Given that plasma nonlinearities are critical to the creation of filaments, the duration, stability and conductivity of filaments is intimately tied to the structure of free electrons. We propose to develop an optical diagnostic to provide empirical data to reinforce models for propagation.



The diagnostic utilizes the Shack-Hartmann technique to translate accumulated phase shifts into a series of focal points imaged by a sensor array on a CCD camera. Movement of the focal points is then translated into a map of electron density with expected resolution down to 10^{-4} cm^{-3} or better. By probing on two or more axes, a tomographic reconstruction can reveal a three dimensional, sub picosecond snapshot of the electron density in a filament.



FILAMENT PROPAGATION

Ongoing efforts are aimed at investigating the propagation of filaments through typical battlefield related obscuration, such as aerosolized dust clouds, combustion by-products (such as gun muzzle blast or diesel exhaust) and pyrotechnic smokes. Unlike current studies investigating ideal aerosolized water droplets, we seek to understand the filament propagation through these other cloud types which have additional complexities such as heterogeneous particle sizes, non-uniform particle shapes, and multiple chemical components.

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Figure 15. Original poster.

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