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Long Wavelength Electromagnetic Light Bullets Generated by a 10.6 micron CO2 Ultrashort Pulsed Source

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11/29/2016
Final Report

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29/10/2016	Final	01/07/2015 - 31/07/2016

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"Long Wavelength Electromagnetic Light Bullets Generated by a 10.6 micron CO2 Ultrashort Pulsed Source

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5b. GRANT NUMBER
FA9550-15-1-0272

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
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5d. PROJECT NUMBER

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5f. WORK UNIT NUMBER

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This one year of seed funding leveraged new and exciting theory/simulation predictions of a new paradigm for long range USP propagation arising as a key research breakthrough of our AFOSR MURI that ended in November 2015 to extend the study of high power mid-IR filament delivery over kilometer ranges. Our inhouse ultrashort pulse simulation tool was used to provide basic research support for studying atmospheric propagation of a high energy Joule-level few picosecond to sub-picosecond pulsed CO2 laser system being planned within a new DOD joint initiative of AFOSR, AFRL and NRL. Our research focused on understanding the physics of filament creation, propagation at long wavelengths and explored the feasibility sustaining multiple terawatts of power within a single light filament. We demonstrated that shorter wavelength 4μm wavelength high-energy femtosecond pulses could be launched at kilometer range if a

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FINAL REPORT

To: http://afosr.reports.sgizmo.com/s3/>
Subject: Final Report to Dr. Arje Nachman

Contract/Grant Title: Long Wavelength Electromagnetic Light Bullets Generated by a 10.6 micron CO2 Ultrashort Pulsed Source
Contract/Grant #: FA9550-15-1-0272
Reporting Period: July 1 2015 – July 31 2016

Annual accomplishments (200 words max):

This one year of seed funding leveraged new and exciting theory/simulation predictions of a new paradigm for long range USP propagation arising as a key research breakthrough of our AFOSR MURI that ended in November 2015 to extend the study of high power mid-IR filament delivery over kilometer ranges. Our in-house ultrashort pulse simulation tool was used to provide basic research support for studying atmospheric propagation of a high energy Joule-level few picosecond to sub-picosecond pulsed CO_2 laser system being planned within a new DOD joint initiative of AFOSR, AFRL and NRL. Our research focused on understanding the physics of filament creation, propagation at long wavelengths and explored the feasibility sustaining multiple terawatts of power within a single light filament. We demonstrated that shorter wavelength 4μm wavelength high-energy femtosecond pulses could be launched at kilometer range if a suitable negative chirp was applied to the initial pulse. Atmospheric data from the HITRAN database was included in simulating 10 μm ultrashort pulse (100fs and 1 ps) propagation at different humidity levels over hundred meter propagation ranges. Evidence was found that many-body Coulomb interactions of weakly ionized electrons suppresses the Kerr effect and leads to whole beam self-trapping of 10 μm pulses.

Archival publications (published) during reporting period:

1. Paris Panagiotopoulos, Miroslav Kolesik and Jerome Moloney “Exploring the limits to energy scaling and distant-target delivery of high-intensity mid-infrared pulses”, Physical Review A, 94, 033852 (2016)

2. Paris Panagiotopoulos, Kolja Schuh, Miroslav Kolesik and Jerome V. Moloney, “Simulations of 10 μm filaments in a realistically modeled atmosphere”, Journal of the Optical Society of America B, 33, 2154 (2016)

Changes in research objectives, if any: None

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Changes in AFOSR program manager, if any: None

Extensions granted or milestones slipped, if any: None

Include any new discoveries, inventions or patent disclosures during this reporting period (if none, report none):

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Final Report on "Long Wavelength Electromagnetic Light Bullets Generated by a 10 μm CO2 Ultrashort Pulsed Source"

PI: J.V Moloney

Our original request for one year of seed funding was to leverage new and exciting theory/simulation predictions of a new paradigm for long range USP propagation arising as a key research breakthrough of our AFOSR supported MURI that ended in November 2015. The focus of this additional effort was to apply our powerful and sophisticated USP propagation simulation tool to address the specifics of, and provide a basic research support infrastructure for, a high energy Joule-level few picosecond to sub-picosecond pulsed few cycle CO_2 laser system being planned within a new DOD joint initiative of AFOSR, AFRL and NRL. Our research was to provide key feasibility and predictive outcomes at a basic research level in support of this project.

The research project generated two published papers, one in Physical Review A and the other in JOSAB. The first paper "Exploring the limits to energy-scaling and distant-target delivery of high-intensity mid-infrared pulses" confirmed that shorter wavelength 4μm wavelength high energy femtosecond pulses could be launched at kilometer range if a suitable negative chirp was applied to the initial pulse.

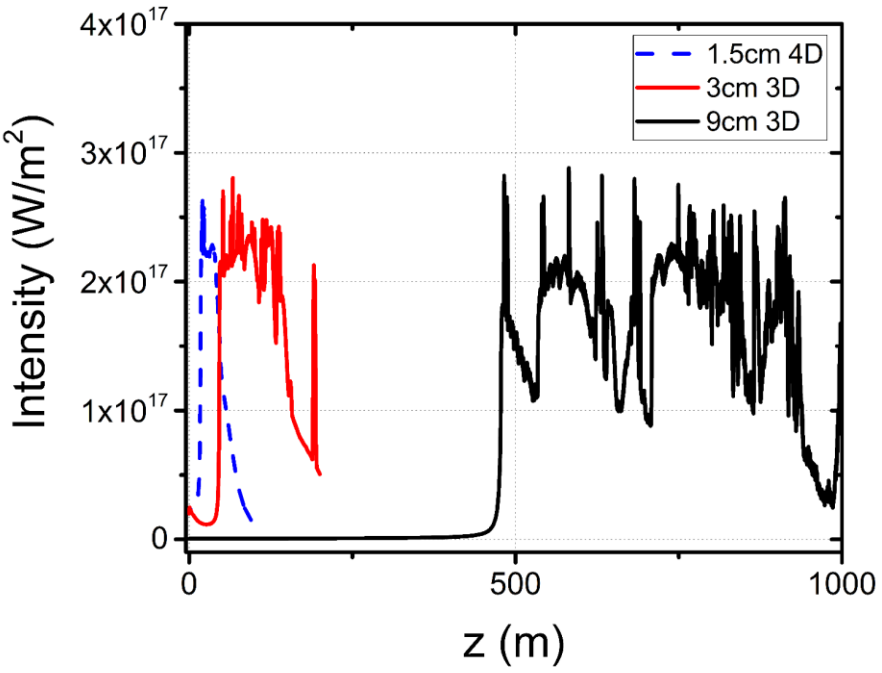

Figure 1. Peak on-axis intensities vs propagation distance in three dfferent pulses. Blue dashed line: 24 fs 1.5 cm input beam, Red continuous line: 24 fs 3 cm beam simulated under assumption of axial symmetry over 200m. Black line: 350 fs chirped pulse with 9 cm beam.

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The second paper in JOSAB “Simulations of 10 *m*m filaments in a realistically modeled atmosphere” included atmospheric data from the HITRAN database to study simulation of 10 µm USPs (100fs and 1 ps) at different humidity levels over hundred meter propagation ranges.

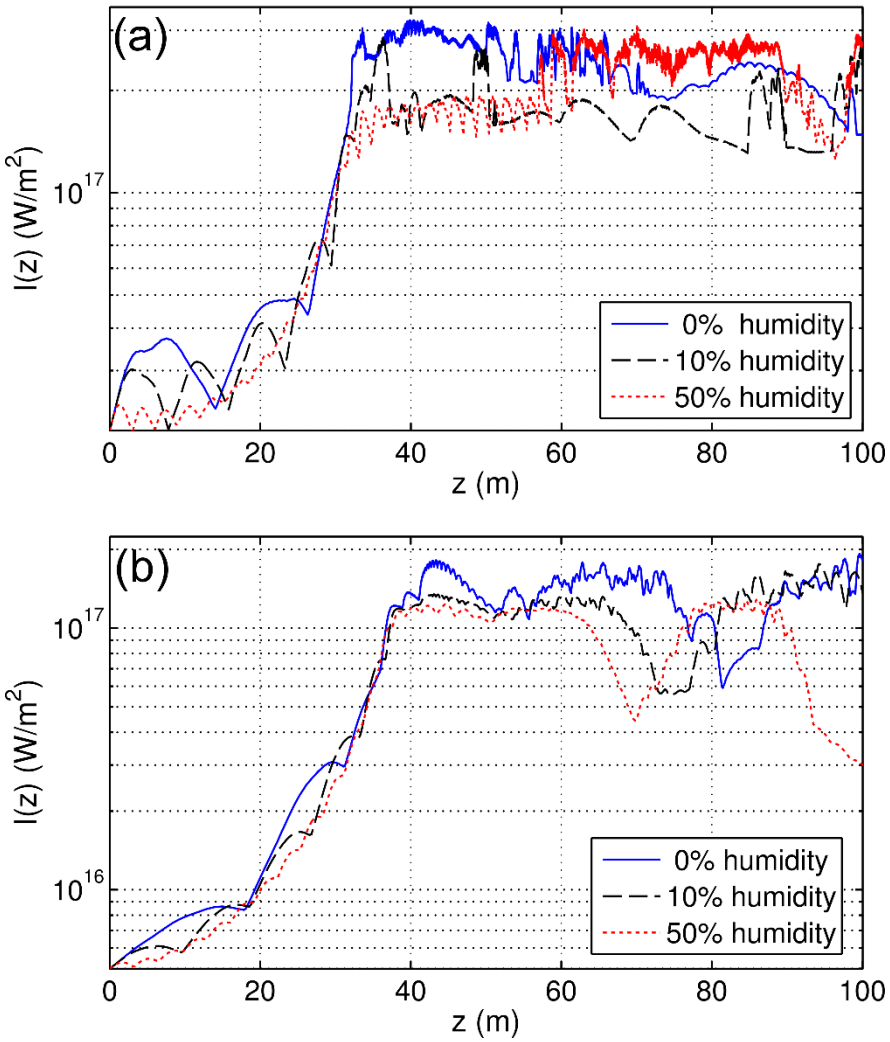

Figure 2 Peak intensity of the 10 *m*m filaments along propagation distance for (a) 100 fs, and (b) 1 ps durations. Blue continuous lines: 0% humidity, black dashed lines: 10 % humidity, and red dotted lines: 50 % humidity.

During the latter phase of this project which overlapped with continuing funding under grant FA9550-16-1-0088 DEF which is currently active, we began to extend our simulation results to include many-body Coulomb interactions between weakly ionized electrons. While these interactions act to weakly suppress the Ker lens self-focusing at 4µm and delay the onset in optical carrier shock regularized filaments, we began to see a profound effect on the propagation of longer wavelength 10 µm pulses. Our preliminary results have led us to prepare

a manuscript for submission to Physical Review Letters which predicts that it should be possible to deliver multiple TWs of power over few kilometer distances. For the first time we predict that such pulses can propagate over multiple Rayleigh ranges of the launched beam waist in stark contrast to all prior filament propagation studies which are constrained to propagate on the order of the Rayleigh range. The physics is now different with the initial launched beam exhibiting whole beam self-trapping followed by weak focusing regularized again by optical carrier shocks. This work is continuing and will be reported on under grant FA9550-16-1-0088 DEF.

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Long Wavelength Electromagnetic Light Bullets Generated by a 10 μm CO2 Ultrashort Pulsed Source

Grant/Contract Number

AFOSR assigned control number. It must begin with "FA9550" or "F49620" or "FA2386".

FA9550-15-1-0272

Principal Investigator Name

The full name of the principal investigator on the grant or contract.

Jerome V. Moloney

Program Officer

The AFOSR Program Officer currently assigned to the award

Arje Nachman

Reporting Period Start Date

07/01/2015

Reporting Period End Date

07/31/2016

Abstract

This one year of seed funding leveraged new and exciting theory/simulation predictions of a new paradigm for long range USP propagation arising as a key research breakthrough of our AFOSR MURI that ended in November 2015 to extend the study of high power mid-IR filament delivery over kilometer ranges. Our in-house ultrashort pulse simulation tool was used to provide basic research support for studying atmospheric propagation of a high energy Joule-level few picosecond to sub-picosecond pulsed CO2 laser system being planned within a new DOD joint initiative of AFOSR, AFRL and NRL. Our research focused on understanding the physics of filament creation, propagation at long wavelengths and explored the feasibility sustaining multiple terawatts of power within a single light filament. We demonstrated that shorter wavelength 4μm wavelength high-energy femtosecond pulses could be launched at kilometer range if a suitable negative chirp was applied to the initial pulse. Atmospheric data from the HITRAN database was included in simulating 10 μm ultrashort pulse (100fs and 1 ps) propagation at different humidity levels over hundred meter propagation ranges. Evidence was found that many-body Coulomb interactions of weakly ionized electrons suppresses the Kerr effect and leads to whole beam self-trapping of 10 μm pulses.

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1. Paris Panagiotopoulos, Miroslav Kolesik and Jerome Moloney "Exploring the limits to energy scaling and distant-target delivery of high-intensity mid-infrared pulses", Physical Review A, 94, 033852 (2016)
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No

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Changes in research objectives (if any):

None

Change in AFOSR Program Officer, if any:

None

Extensions granted or milestones slipped, if any:

None

AFOSR LRIR Number

LRIR Title

Reporting Period

Laboratory Task Manager

Program Officer

Research Objectives

Technical Summary

Funding Summary by Cost Category (by FY, $K)

	Starting FY	FY+1	FY+2
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Equipment/Facilities			
Supplies			
Total			

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