ANNUAL PROGRESS SUMMARY

To: technicalreports@afosr.af.mil
Subject: Annual Progress Statement to Dr. Arje Nachman

Contract/Grant Title: Mathematical Modeling and Experimental Validation of Ultrafast Nonlinear Light-Matter Coupling Associated with Filamentation in Transparent Media
Contract/Grant #: FA9550-10-1-0561
Reporting Period: September 30, 2011 to September 29, 2012

Annual accomplishments (200 words max):

Second year MURI project highlights include: first prediction of THz and optical probe detection of nonequilibrium anisotropic photoionized electron/ion distributions, derivation of a self-consistent quantum photoioization electromagnetic pulse propagator to investigate filamentation; theoretical investigation of means to deliver conical wave beams over kilometer ranges, experimental realization of novel bottle beams initiated by vortex beams in air; spatial, temporal and phase control of ultrashort intense pulses (transverse and temporal profiles) and mid-IR filament enhanced phase matched higher harmonic generation to produce a coherent X-ray source.
At the mathematical level, asymptotic analysis of apodized Bessel beams yields an amplitude equation description on characteristics confined to the surface of a cone and a generalization of the classical ABCD matrix method to create desired pulses at range.
Active collaborative multidisciplinary projects include: an Arizona – Colorado continuing joint work on studying the transition of initially anisotropic photoionized electrons to an isotropic plasma state, an Arizona – Central Florida – Colorado School of Mines collaboration on remote delivery of Bessel and vortex beams, a continuing theory/experiment collaboration on HHG in high pressure gas waveguides involving Colorado, Cornel and Arizona, simulation of nonlinear temporal, phase evolution of femtosecond USPs with Temple. Transitions include a joint long range filamentation experiment between Arizona and the AFRL personnel at the latter's TeraWatt facility.

Archival publications (published) during reporting period:

J. M. Brown, A. Lotti, A. Teleki and M. Kolesik "Exactly Solvable Model for Nonlinear Light-Matter Interaction in an Arbitrary Time-Dependent Field", *Physical Review A*, **84**, 063424 (2011)

C. Ament, P. Polynkin, J. Moloney "Supercontinuum Generation with Femtosecond Self-Healing Airy Pulses", *Physics Review Letters*, **107**, 243901 (2011)

I. Chremmos, N. K. Efremidis, and D. N. Christodoulides, "Pre-engineered abruptly autofocusing beams," *Optics Letters,* **36**, 1890 (2011).

A. Couairon, E. Brambilla, T. Corti and M. Kolesik “Practitioner's guide to laser pulse propagation models and simulation”, *European Physical Journal-Special Topics*, **199**, 5 (2011)

P. R. Hemmer, R. B. Miles, P. Polynkin, T. Siebert, A. V. Sokolov, P. Sprangle, and M. O. Scully, "Standoff spectroscopy via remote generation of a backward-propagating laser beam", *PNAS*, **108**, 3130 (2011).

S. E. Schrauth, B. Shim, A. D. Slepkov, L. T. Vuong, A. L. Gaeta, N. Gavish, and G. Fibich, "Pulse splitting in the anomalous group-velocity dispersion regime," *Optical Express*, **19**, 9157-9171 (2011).

S. E. Schrauth, B. Shim, A. D. Slepkov, L. T. Vuong, A. L. Gaeta, N. Gavish, and G. Fibich, "Pulse splitting in the anomalous group-velocity dispersion regime," *Optical Express*, **19**, 9157-9171 (2011).

Odhner, J.H., Levis, R.J., “Direct Phase and Amplitude Characterization of Femtosecond Laser Pulses Undergoing Filamentation in Air,” *Optics Letters,* **37(10)** 1775-1777 (2011).

Odhner, J.H., McCole, E.T., Levis, R.J., “Filament-Driven Impulsive Raman Spectroscopy,” *Physical Chemistry A,* **115** (**46)**, 13407-13412 (2011).

P. Whalen, J. V. Moloney, M. Kolesik “Self-Focusing Collapse Distance in Ultrashort Pulses and Measurement of Nonlinear Index”, *Optics Letters*, **36**, 13, 2542-2544 (2011)

M. Kolesik, P. Whalen and J. Moloney “Theory and Simulation of Ultrafast Intense Pulse Propagation in Extended Media” *IEEE Journal of Selected Topics in Quantum Electronics*, **18**, 1 (2012)

K. Glasner, M. Kolesik, J. Moloney and A. Newell “Canonical and Singular Propagation of Ultrashort Pulses in a Nonlinear Medium”, *International Journal of Optics*, **2012**, 868274 (2012)

Gombojav O. Ariunbold, Pavel Polynkin, and Jerome V. Moloney, “Third and fifth harmonics generation by tightly focused femtosecond pulses at 2.2 μm wavelength in air,” *Optics Express*, **20**, 2 (2012).

B. Pasenow, J.V. Moloney, S.W. Koch, S.H. Chen, A. Becker and A. Jaron-Becker "Nonequilibrium Evolution of Strong-Field Anisotropic Ionized Electrons Towards a Delayed Plasma-State,” *Physical Review Letters*, **20**, 3 (2012).

B. Shim, S. E. Schrauth, A. L. Gaeta, M. Klein, and G. Fibich, “Loss-of-Phase with Collapsing Beams,” *Physics Review Letters*, **108**, 043902 (2012)

J. M. Brown, E. M. Wright, J. V. Moloney, M. Kolesik, “On the relative roles of higher-order non-linearity and ionization in ultrafast light-matter interactions”, *Optics Letters*, **37**, 10 (2012)

S. Chen, X. Gao, J. Li, A. Becker and A. Jaron-Becker “Application of a numerical-basis-state method to strong-field excitation and ionization of hydrogen atoms”, *Physical Review A*, **86**, 013410 (2012)

M. Kolesik, P. Jakobsen, J. V. Moloney “Quantifying the limits of unidirectional ultrashort optical pulse propagation” *Physical Review A*, **86**, 035801, (2012)

P. Whalen, J. V. Moloney, A. C. Newell and M. Kolesik, “Optical shock and blow-up of ultrashort pulses in transparent media”, *Physical Review A*, **86**, 033806 (2012)

T. Graf, D. N. Christodoulides, M. S. Mills, J. V. Moloney, S. C. Venkataramani and E. M. Wright, “Propagation of Gaussian-apodized paraxial beams through first-order optical systems via complex coordinate transforms and ray transfer matrices”, *Journal in the Optical Society of America A*, **29**, 9 (2012)

Per Jakobsen and J.V Moloney, “The effect of longitudinal electric field components on the propagation of intense ultrashort optical pulses”, *Physica D*, **241**, 1603 (2012)

Durfee, C. G., Greco, M., Block, E., Vitek, D., & Squier, J. A. “Intuitive analysis of space-time focusing with double-ABCD calculation. *Optics Express*, ***20***, 14244 (2012).

Gombojav O. Ariunbold, Vladimir A. Sautenkov, and Marlan O. Scully, “Temporal coherent control of superfluorescent pulses”, Optical Letters, **37**, 2400 (2012).

Tenio Popmintchev, Ming-Chang Chen, Dimitar Popmintchev, Paul Arpin, Skirmantas Ališauskas, Giedrius Andriukaitis, Tadas Balčiunas, Audrius Pugzlys, Andrius Baltuška, Bonggu Shim, Alex Gaeta, Margaret Murnane, Henry Kapteyn, “Bright Coherent Ultrahigh Harmonics in the keV X-Ray Regime from Mid-Infrared Femtosecond Lasers”, *Science 336*, 1287 (2012).

Kolesik M., Wright E. M., Andreasen J. D. Carlson, J.R. Jones, “Space-time resolved simulation of femtosecond nonlinear light-matter interactions using a holistic quantum atomic model: Application to near-threshold harmonics”, Optics Express, **20**, 14 16113-16128 (2012)

Gombojav O. Ariunbold, Wenlong Yang, Alexei V. Sokolov, Vladimir A. Sautenkov, and Marlan O. Scully, “Superradiance in a Three-Photon Resonant Medium”, *Physical Review A*, **85**, 023424, (2012).

Gombojav O. Ariunbold, Vladimir A. Sautenkov, and Marlan O. Scully, Quantum fluctuations of superfluorescence delay observed with ultrashort optical excitations”, *Physical Letters A*, **376**, 335 (2012).

A. Picon, A. Jaron-Becker, and A. Becker “Enhancement of vibrational excitation and dissociation of H2+ in infrared laser pulses” accepted for publication in *Physical Review Letters*

Charles G. Durfee, Michael Greco, Erica Block, Dawn Vitek, and Jeff A. Squier, “Intuitive Analysis Of Ultrafast Pulse Propagation Through Angularly Dispersive Structures,” invited paper to be published in *New Developments in Photon and Materials Research*, ed. J. I. Jang (NOVA Science, 2012).

Changes in research objectives, if any:

None

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):

None