

STTR Topic Number:
AF05-009

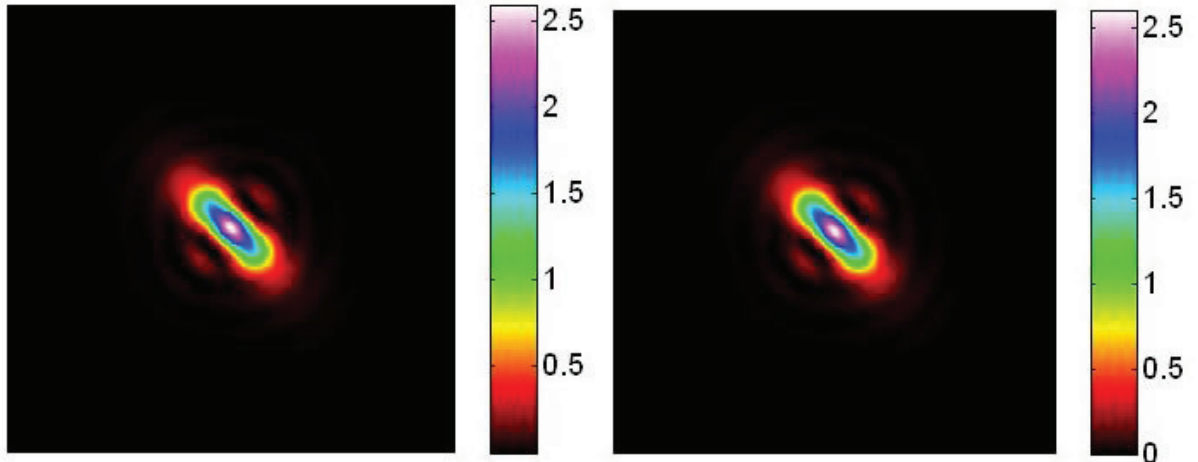
STTR Title:
Simulation of Extended
Scene Imaging through
Turbulence

Contract Number:
FA9451-06-C-0033

STTR Company Name:
LRK Associates
Incorporated,
West Linn, OR

**Technical Project
Office:**
AFRL Directed Energy
Directorate, Kirtland
AFB, NM

This Air Force SBIR/STTR Innovation Story is an example of Air Force supported SBIR/STTR technology that met topic requirements and has outstanding potential for Air Force and DoD.



Comparison of equal accuracy results from Fourier (left, 2048 x 2048 grid) and Finite Difference/PML (right, 342 x 342 grid) propagators. 45 degree astigmatism at 300 Km. Finite Difference/PML is five times faster.

Fast Algorithms for Imaging Simulation through Turbulence

- The Air Force solicited ideas for speeding up light simulation calculations to break the limitations imposed by use of Fourier propagation techniques
- LRK Associates Incorporated has developed such an algorithm, demonstrating comparable accuracy combined with speed-ups that range from 4 to 10, dependent upon problem size
- Although the speed advantage of the new propagator is important on existing problems, the new propagator completely breaks with the boundary condition structure of the Fourier techniques, and this opens the door to investigation of propagation in new scenarios
- A new computational framework for parabolized light propagation has been established by this research with its potential yet to be fully realized

RD09-1605

A

DISTRIBUTION A:
Approved for public
release; distribution
unlimited.

Air Force Requirement

The Air Force requires new processes to improve the water resistance of a large variety of materials including aircraft, ground vehicles and clothing. A novel mechanism to generate water-repelling (hydrophobic) materials was recently identified. A Lotus leaf, shown here, utilizes microstructured hydrophobic coatings to produce ultra-hydrophobic materials that not only repel water but are also self-cleaning to provide protection from dirt and pathogenic organisms. Application of this process could enable the Air Force to enhance corrosion protection of aircraft and ground vehicles as well as provide chemical and biological agent protection and water-proofing for uniforms and other clothing items.

STTR Technology

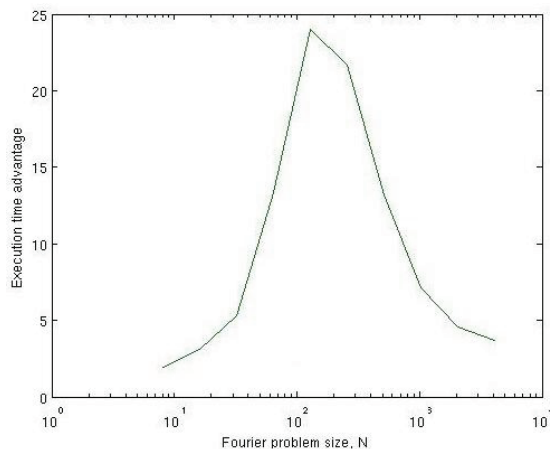
LRK Associates Incorporated has developed such an algorithm, demonstrating comparable accuracy combined with speed-ups that range from 4 to 10, dependent upon problem size. The new algorithm is a combination of three relatively new technologies in numerical simulation: exponential integrators, perfectly matched layer (PML) boundary conditions, and Extended Support finite-differences.

Exponential integrators provide an analytic time- or space-advance in systems where they are applicable. This effectively gives them infinite-order accuracy, a quality that the Fourier methods also possess. In this case, their stability properties allow arbitrary step sizes, enabling vacuum propagation of light hundreds of kilometers in one step. PML boundary conditions permit strong domain truncations with respect to Fourier problem sizes, because wrap-around errors that have required artificial domain inflation are no longer necessary. Extended Support finite-differences yield high-accuracy derivatives on a given screen grid, with resolving power superior to traditional finite differences. As a result, the speed and direction of calculated waves match the analytic dispersion relation for greater than 80% of the grid wave number range.

For simulations of nanometer-wavelength light over tens of kilometers, where loss of phase information would be disastrous, the combination of exponential integrator and Extended Support finite-differences yields an algorithm that gives accuracy comparable to the Fourier methods it was developed to replace.

Potential Air Force Application

Although the speed advantage of the new propagator is important on existing problems, the new propagator completely breaks with the boundary condition structure of the Fourier techniques, and this opens the door to investigation of propagation scenarios which are completely beyond the capabilities of the Fourier methods. One can, for example, use the new methods for electromagnetic wave propagation parallel to the ground or water in which the lower boundaries have impedance-type boundary conditions appropriate to the partially reflective surface underneath, but the remaining boundaries have absorbing conditions that mimic the loss of wave energy to free space. Such a situation would be impossible to simulate with legacy Fourier methods.



Execution time advantage of new propagator over Fourier methods for equal accuracy

A new computational framework for parabolized light propagation has been established by this research. Its full potential has yet to be reached, and other researchers will undoubtedly advance its capabilities still more in coming years.

Company Impact

LRK Associates' marketing strategy is to develop the algorithms for inclusion in MZA Associates' WaveTrain software and, by so doing, reach the broader user community in the directed energy field. In January 2009, the final algorithm was incorporated in the development repository of WaveTrain, and is available to users for application to their particular problems. LRK Associates also expects to publish a generic description of the algorithm in the open literature on computational physics and light propagation.



SBIR/STTR

Air Force SBIR Program
AFRL/XP
1864 4th Street
Wright-Patterson AFB OH
45433

AF SBIR/STTR Program Manager: Augustine Vu
Website: www.sbirsttrmall.com
Comm: (800) 222-0336
Fax: (937) 255-2219
e-mail: afrl.xppn.dl.sbir.hq@wpafb.af.mil

