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			5c. PROGRAM ELEMENT NUMBER 611102		
6. AUTHORS Hareesh Tippur			5d. PROJECT NUMBER		
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14. ABSTRACT This grant was to acquire instrumentation for investigating failure behavior of novel transparent materials. Specifically, a high energy LED-based pulsed laser light source suitable for capturing blur-free digital images of stress and deformation fields in the vicinity of a rapidly evolving damage or a growing crack, and a low-capacity load-cell to study deformation of polymer tissue simulants had been proposed.					
15. SUBJECT TERMS Instrumentation, High speed photography, illumination, incoherent light, load-cell					
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				19b. TELEPHONE NUMBER 334-844-3327	

Report Title

Final Report: Incoherent LED Pulse Laser for High-Speed Imaging and Optical Metrology

ABSTRACT

This grant was to acquire instrumentation for investigating failure behavior of novel transparent materials. Specifically, a high energy LED-based pulsed laser light source suitable for capturing blur-free digital images of stress and deformation fields in the vicinity of a rapidly evolving damage or a growing crack, and a low-capacity load-cell to study deformation of polymer tissue simulants had been proposed.

Enter List of papers submitted or published that acknowledge ARO support from the start of the project to the date of this printing. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in peer-reviewed journals:

(b) Papers published in non-peer-reviewed journals (N/A for none)

Received Paper

TOTAL:

Number of Papers published in non peer-reviewed journals:

(c) Presentations

Optical and Mechanical Characterization of a Tissue Phantom Polymer Gel, R.K.A. Pasumarthy, H.V. Tippur, SEM XIII International Conference, Orlando, FL, June 2016.

Mechanical and Optical Characterization of a Polymer Gel Tissue Simulant, R.K.A. Pasumarthy, H.V. Tippur, ASME-IMECE, Houston, TX, November 2015.

Number of Presentations: 2.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Received Paper

TOTAL:

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):

(d) Manuscripts

Received Paper

TOTAL:

Number of Manuscripts:

Books

Received Book

TOTAL:

Received

Book Chapter

TOTAL:

Patents Submitted

Patents Awarded

Awards

Graduate Students

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Faculty Supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Names of Under Graduate students supported

<u>NAME</u>	<u>PERCENT SUPPORTED</u>
FTE Equivalent:	
Total Number:	

Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:..... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):..... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:..... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:..... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME
Total Number:

Names of other research staff

NAME PERCENT SUPPORTED
FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Scientific Progress

See attachment.

Technology Transfer

Project Summary - Grant # 67816-EG-RI (W911NF-15-1-0295)
(Reporting Period: July 1, 2015 – June 30, 2016)

Incoherent LED Pulse Laser for High-Speed Imaging and Optical Metrology

Hareesh Tippur
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Auburn University, Alabama 36849

Objective

This grant was to acquire instrumentation for investigating failure behavior of novel transparent materials. Specifically, a high energy LED-based pulsed laser light source suitable for capturing blur-free digital images of stress and deformation fields in the vicinity of a rapidly evolving damage or a growing crack, and a low-capacity load-cell to study deformation of polymer tissue simulants had been proposed.

Approach

The proposed light source generates electronically synchronized nanosecond light pulses to mitigate problems associated with traditional high-intensity single long-duration flash illumination used for digital ultrahigh-speed photography. The proposed instrumentation (a) produces incoherent light devoid of speckle noise associated with traditional lasers, (b) can be programmed to produce light pulses of different duration and inter-pulse time, and (c) can be easily synchronized with digital high-speed cameras. The low-capacity load-cell is to measure small loads associated with mechanical characterization of polymer ballistic gel tissue simulants.

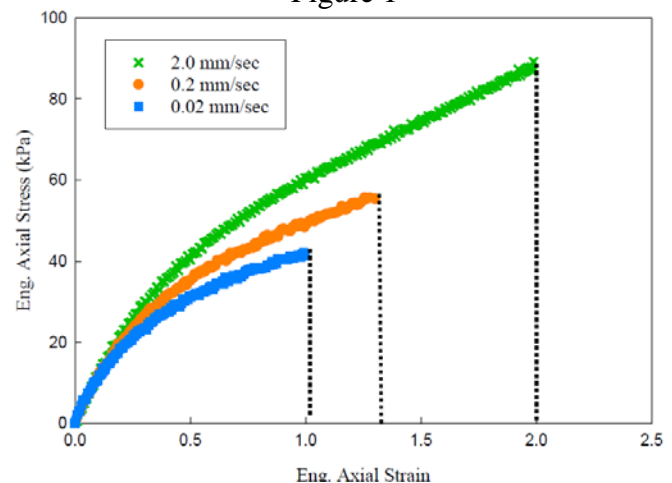
Relevance to Army

Optically transparent engineered materials are important in both the military and civilian applications. Blast resistant windows, impact resistant aircraft canopies, and protective visors for personnel, are some of the examples of their use in the military. Some soft tissue simulants such as ballistic polymer gels are also transparent. Many such materials offer unusual technological challenges due to the requirements placed on them namely stiffness, strength, toughness, and/or thermal stability all the while being optically transparent.

Accomplishments for Reporting Period

- Following the approval of the grant, a low-load capacity (0-50 N) load-cell was purchased from Instron, Inc. to perform mechanical characterization of a transparent polymeric ballistic gel. The choice of the vendor was dictated by the instrument's compatibility with an existing loading frame from the same vendor (Instron 4465) in PI's laboratory.

Figure 1



Using this load-cell, the mechanical properties as well as the elasto-optical characteristics of a tissue surrogate polymer gel was evaluated. The former involved carrying out tension, compression, and shear tests on the gel material using specially designed gripping and specimen sizing methods. Traditional digital image correlation methods were also implemented for measuring biaxial in-plane strains along with loads measured from the load-cell. The resulting tensile stress-strain responses of the gel (Figure 1) were modeled as Money-Rivlin hyperelastic material at strain rates ranging from 0.0004/sec to 0.04/sec. The resulting measurements are tabulated in Figure 2. Interestingly, the gel material showed increase in strain at failure with crosshead speed besides a similar behavior expected of the ultimate stress.

Figure 2

Crosshead Speed (mm/sec)	Elastic Modulus, E (kPa)	Poisson's Ratio, ν	Ultimate Stress, kPa	Failure Strain	Strain Rate, $\dot{\epsilon}$ (sec ⁻¹)
2.0	125.4±4.08	0.46±0.011	87.16±1.63	1.97±0.05	0.04
0.2	118.4±2.80	0.47±0.006	54.48±1.01	1.25±0.11	0.004
0.02	111.4±3.17	0.46±0.013	42.69±2.81	0.99±0.01	0.0004

- The effectiveness of the LED pulse light source with the existing ultrahigh-speed digital cameras in PI's laboratory was evaluated following the approval of the grant. Although the efficacy of the light source was demonstrated the electronic interconnectivity between the existing cameras in PI's lab and the light source was found highly restrictive. Recording rates of only 100K frames per second (or inter-frame rate of 10 microseconds) could be achieved. This was found insufficient for dynamic crack growth studies requiring higher temporal resolution. In light this difficulty, the funds allocated for the purchase of LED light source were used for the purchase of an ultrahigh speed camera by leveraging a DURIP (Grant W911NF-15-1-0357) grant after communicating with ARO and securing necessary approvals.

Collaborations and Technology Transfer

- Nothing to report yet.

Resulting Journal Publications during Reporting Period

- Nothing to report yet.

Graduate Students Involved During Reporting Period

- N/A (Instrumentation Grant)

Awards, Honors and Appointments

- F. G. Tatnall Award, June 2016, Society for Experimental Mechanics