

Ordinance, Munitions & Explosives (Degree Apprenticeship)

Investigation into Potential Light Sources for Shadowgraph Imaging Technique

ACDA5012, L5 Research Methods

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[Date]

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Introduction

Dstl has recently begun the development of shadowgraph techniques in order to provide more accurate and revealing imagery of energetic events. Shadowgraph allows the user to observe shock wave structures in a wide field of view allowing for the imaging of large-scale energetic events such as cylinder expansion studies, fragmentation studies and device exploitation. The ability to view structures that are otherwise only inferable from blast gauges and data recording scopes allows the user to rapidly understand and analyse the impact these structures have on any given experiment. [1] For example, shockwave interactions, reflective wave effect and Mach Stem events.

This is a field of study being undertaken by several large S&T organisations such as the University of New Mexico Mining institute, Lawrence Livermore Laboratories and several defence agencies within the United States. In order to keep Dstl, and UK capability, on par with our allies this field of study must be researched and developed.

Aims & Objectives.

The aim of this proposed research is to identify an ideal light source to be used with Dstl's newly designed shadowgraph system. Sources will be investigated and assessed against one another in the following criteria: cost effectiveness, performance, and safety considerations.

The former and latter points will be resolved and compared through cost benefits analysis and research into product design, reviews, and company policy. Performance will be assessed through comparative experimentation.

In order to meet the aim, the following objectives have been selected:

- Establish effect criteria to judge light sources against.
- Investigate potential light sources.
- Narrow test field.
- Design and develop a test series to evaluate test subjects.
- Evaluate sources against criteria.

Expected Outcomes.

The outcomes of this research will be a recommendation of light source for use with Dstl's shadowgraph system along with empirical evidence that informed this decision. An experimental design will have also been developed as a result of this proposal which can be applied to other light sources used within the wider company, and therefore better inform future purchases. Resulting of a potential cost and time saving for the company.

Background Research

Shadowgraph systems provide the capability to visualise and record changes in density of a transparent medium over time. The technique is achieved by exploiting the way that a medium (air) with varying densities will refract light at different angles.

The sensitivity of any given Shadowgraph or Schlieren system is directly related to light intensity. More light allows any camera being used to film an event, in Dstl's case a Phantom v2512, to run at a lower exposure time. i.e., the time with which the camera's detector is exposed to the event. This is directly proportional to the amount of "smearing" seen within dynamic footage. The lower the exposure time of the camera, the less movement any given object is detected. Resulting in sharp edges to the test subject. This is explored in depth by M.J Hargather in "Retroreflective shadowgraph technique for large-scale flow visualisation" [1] and becomes relevant when filming energetic shock structures as these events are typically traveling upwards of 500m/s.

Due to this requirement of high light output most shadowgraph system designs use high power arc lamps, flash guns/strobes or lasers. The Edgerton technique, designed in the 1950's, used a strobing light source to synchronise light bursts with camera frames [2] however, due to technology advancements this is now no longer required, and for ease-of-use, permanent sources are preferred. Pen State university for example use a 1kW arc lamp to produce enough light for shock structure work [3]

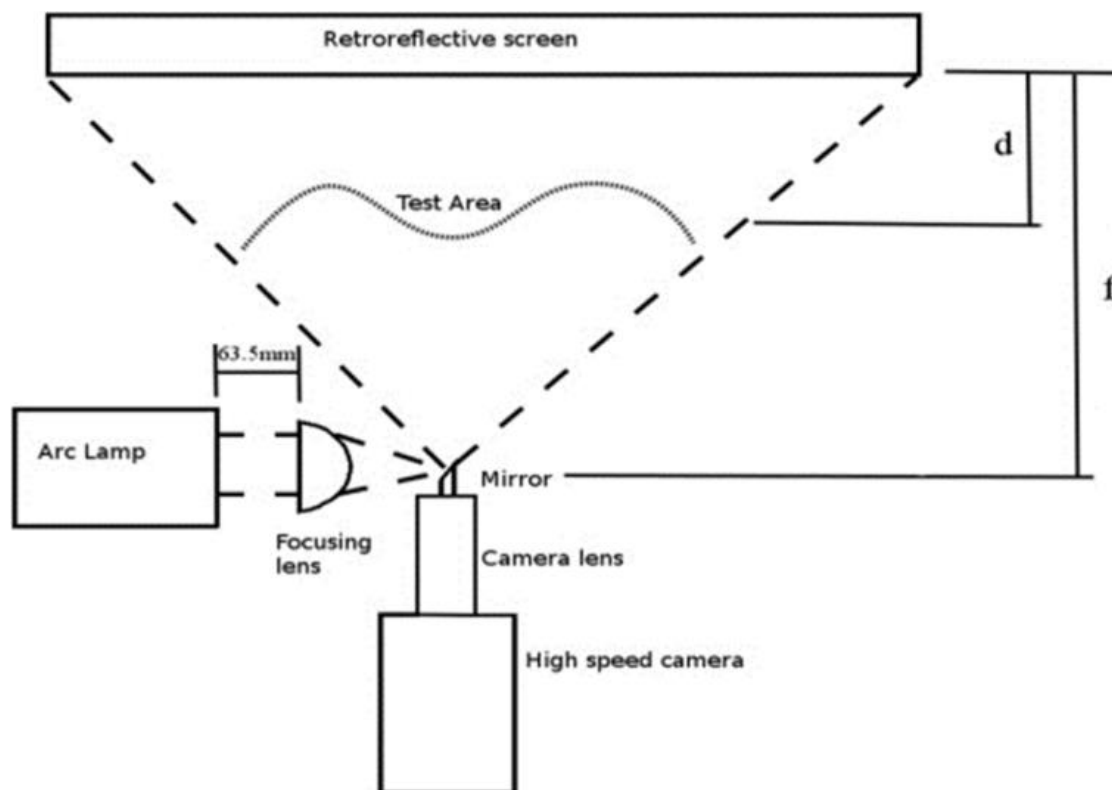


Figure 1 - Schematic diagram of a shadowgraph system [4]

Currently held within the investigators teams assets is a Newport Instruments, 1kW xenon arc lamp. This system has a built-in collimation system and replaceable bulbs. However, this system emits in the ultraviolet region and so filters will require installation to ensure safety concerns are addressed. [5] this is also the most expensive of the three systems.

The investigators team also owns a suite of flash guns predominantly used for photography, these have an 1kW output and can be synchronized with high-speed cameras for multi-flash/strobe uses. The strobing feature of this system however requires the highspeed camera to run at a lower frame rate when compared to the other systems being investigated. [6]

A 100,000-lumen handheld torch was identified as a potential test source due to its high output, portability, and re-chargeable battery. This system does however produce intermittent flicker after several seconds on full power, this is due to the internal safety feature protecting the bulbs from overheating and subsequent damage. [7]

The forefront of shadowgraph design and use is stepping away from high output sources such as arc lamps or strobing systems and instead investigating the use of laser illumination. This allows for the imaging of events through specific light wave lengths allowing the use to mitigate features such as over flash or light bleed from the energetic event under test. The use of specific wave bands further allows the user to operate within the spectral sensitivity of the camera in use. [8] [9]

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Table 1: Experimental Test Programme

Each test will be carried out a minimum of 5 times to ensure a sufficient number of data points are collected at each power intensity and back board distance.

4.2 Data Collection

A control measurement will be taken at the beginning of the experiment to allow for ambient light conditions to be measured. This measurement, combined with a black reference measurement (collected with camera's internal shutter closed), will serve as the base line of the experiment.

Data will be collected by logging pixel values and spot size area on the back board, the high-speed camera software will be used to collect both data sets. Each measurement will be collected 5 times and averaged to give the mean value.

Pixel values will be collected using the circle area function with the high-speed camera software. This tool allows for the area of interest to be selected and values of the pixels within automatically averaged to give a single output. This area function will be cleared from the image after each measurement and redrawn before the next data point is collected. This is to ensure each measurement is separate and user bias is minimised.

4.3 Data Evaluation

All data points will be compiled into a spread sheet where mean values and standard deviation are taken. These output values will then be graphed according to back board distance, source power level, mean spot size and mean pixel intensity.

A Cost Benefits Analysis will be carried out to highlight features of each source. These features will be, health and safety considerations (UV intensity, high voltages, heat), availability, survivability, duration, and cost. Weightings will be assigned to categories to reflect importance and company policy. For example, health and safety considerations will be weighted more heavily than product survivability as staff safety and welfare is clearly a more important trait than how hardy the equipment may or may not be.

4.4 Risks & Limitations

High power light sources typically emit in the ultraviolet region and so pose a visual and dermatological hazard. Additionally these sources produce large quantities of thermal energy and so source housings/enclosures can cause burning. High power sources also require significant energy, resulting in high current draw and an increased risk of electrical hazards such as fire and shock.

The experiments outlined only compare sources when in use within a shadowgraph system and therefore cannot be used to quantify the sources for other uses, additionally the optical arrangement developed to co-align the light source to camera lens may lead to losses through misalignment. Collimation of each light source cannot be standardized due to the design and features of each source; therefore, each source will use bespoke collimation designs in order to allow the focusing lens to perform correctly.

4.5 Ethical Issues

This proposal does not require the use of participants in any capacity, nor does it contain any element of animal or human testing.

All electronic data collected will be stored on the device it is collected on until the end of the project's completion and subsequent report at which point it will be deleted. Said device will be stored in the investigators local strong room and accessible to the investigator through sign out procedures whereby they must produce identification. All written logs will be managed in line with electronic devices and destroyed once a final report is presented.

See Ethical document attached.

Resources and planning

6.1 Resources Required.

An itemised list of all resources required to complete the proposed experiment. It is noteworthy that all equipment is already held within the company and so no additional purchasing is required for the experiment to be carried out.

6.1.1 Physical Resources

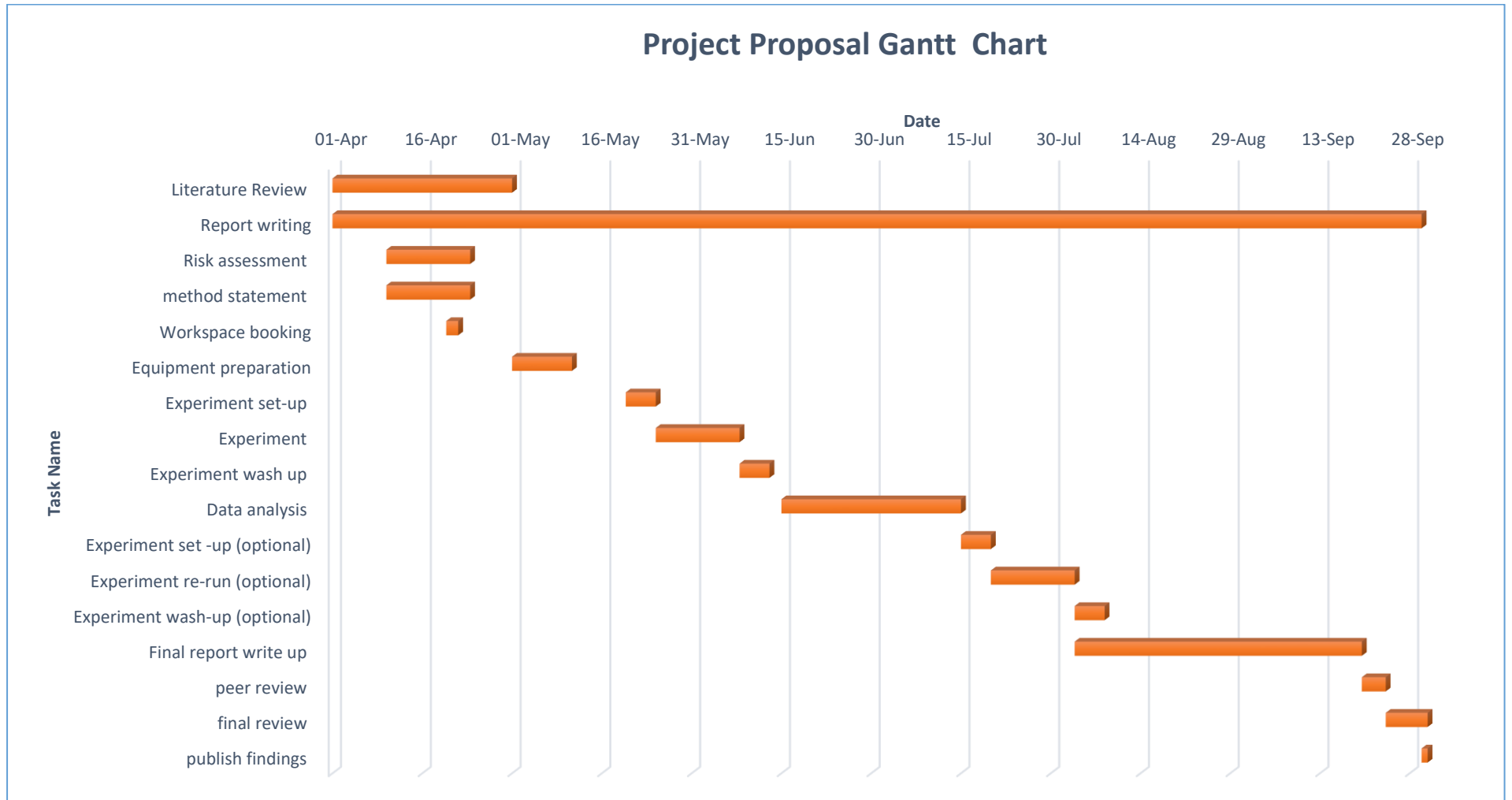
- Optics laboratory
- Work laptop, 1TB HDD, 16GB RAM. Signed out to investigator only.
- Office 365.
- Logbook's. signed out to investigator only.
- Plywood backing board, 2m square.
- Scaffolding base plates.
- Scaffolding straight sections, two 1m lengths.
- Board clamps.
- Phantom High-speed camera v2512.
- PCC3.3 - Phantom high-speed camera software.
- Nikon 50mm lens.
- 50.8mm diameter, 100mm focal lens plano-convex lens.
- Edmund optics 90 degree, 10mm diameter rod mirror
- 52mm clear glass lens filter. To locate the rod mirror on
- 1m square optical breadboard. To position the lens holder
- Central locating lens holder to hold the focusing lens.
- 12.7mm optical post. To mount the lens holder to the bread board.
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6.1.2 Human Resources

- The investigator.
- Peer reviewer. To review documentation, data, and conclusion to ensure best practice and accuracy is maintained throughout the experiment.

- Report Reviewer. To technically review finding and final report.
- H&S Representative. To allow for sign off and approval of all relevant risk assessments and method statements.
- Local area Management. To sign off on use of facilities and equipment procedures.

6.2 Gantt Chart



References

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