Laser Technology Update: Pulsed Impulsive Kill Laser (PIKL)

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Presentation Topics

• Introduction
• PIKL program
  – Overview
  – LANL prototype development
  – Armstrong labs bio-effects analysis
• Solid state lasers
  – Overview
  – Technology advancements
• PIKL Technology
  – Operational benefits
• Summary
Introduction

- Strong interest in ability to vary target effects
  - Lethal to less than lethal
  - Military, DOJ, other law enforcement agencies
  - Area denial, MOUT, MOOT, MOBA, facility protection

- Laser technology pursued over last 15 years
  - PIKL technology sponsored
  - Subject target to mechanical loading and ablation
  - Chemical lasers present problems

- Solid state laser technology promising
  - Size, weight, performance advantages
  - Peak and average powers
  - Performance parameters can be achieved
PIKL Program

Overview

• Program began in 1992 under auspices of JSSAP
  – ARDEC program lead
  – Effort split into 2 concurrent research projects:
    • Los Alamos National Lab (LANL): development of operational prototype of a surface discharge initiated DF laser
    • Armstrong Laboratory/Optical Radiation Division: analysis of biological effects of exposure to moderate energy (<1 kJ) infrared laser pulses
PIKL Program

Overview

1. Laser heating causes plasma to form on target surface

2. Electrons in the plasma absorb laser light through inverse Brehmstrahlung and heat the air

3. Plasma is heated strongly, shock wave forms and moves away from surface. Electron density high enough to absorb all laser light in the shock front

4. High pressure air plasma exerts a very large mechanical force on target
PIKL Program

Overview

• Pulsed impulsive kill laser (PIKL)
  – Target interaction: ablation and mechanical impulse
  – Pulse ‘trains’ can literally chew through target material
    • No burning
  – Effect is independent of:
    • Laser type
    • Target type
PIKL Program

LANL Prototype Development

• Chemical laser chosen to meet energy per pulse and system portability goals
• DF laser chosen for excellent transmissivity especially over longer distances desired (1-2km)
• UV initiation chosen to improve efficiency and reliability
PIKLN Program

LANL Prototype Development

- 1992: pre-prototype proof-of-principle laser built using parts from LANL’s meteor chemical laser program
  - Surface discharged DF laser
  - Produced over 100 joules in a 10 microsecond wide pulse
  - Suffered from flaws such as gas leakage
PIKL Program

LANL Prototype Development

• May 1993: compact prototype DF laser put into service
  – Redesign of pre-prototype laser
  – Improvement in UV illumination
    reduced pulse width to 3-5 ms
  – Produced energies up to 126 joules
  – Arcing problems necessitated redesign
PIKL Program

LANL Prototype Development

• December 1993: high-energy DF prototype laser built
  – Incorporated best aspects of pre-prototype and compact prototype
  – Arcing problem eliminated
  – Energies over 300 joules per shot
  – Pulse widths of 3-5 microseconds
  – Design provided proof of pulsed DF laser concept with high pulse energies and good reliability
PIKL Program

LANL Prototype Development

• High energy prototype used to study laser pulse effects
  – Photographic paper, wet chamois (skin simulant), BDU material, Kevlar vest material
  – Quantifying target effect required measuring impulse delivered to target
  – Impulse transducer system designed to measure effects
PIKL Program

LANL Prototype Development

• Impulse tests performed using both high-energy prototype DF laser and WSMR CO$_2$ laser
  – DF laser tested at pulse energies up to 200 joules
  – CO$_2$ laser tested at pulse energies up to 900 joules
  – Measured impulses were 7-10 dyne-seconds per joule for chamois, Kevlar and BDU targets
PIKLL Program

Armstrong Labs Bio-effects Analysis

- Goal: assess technical viability of the PIKLL concept
  - Estimate the injury/lethality potential of PIKLL
  - Use a combination of theoretical modeling, experiments on biosimulant targets, and previously published data on impulse injuries
- Experiments: high energy microsecond length infrared pulses on targets
  - Ballistic pendulum-mounted planar targets: total impulse coupling and coupling efficiency
  - Gel-block targets: embedded with pressure sensors to measure surface and internal pressures generated
  - Target materials included chamois, BDU cloth, and Kevlar
  - Data obtained both with LANL prototype laser and PLVTS device at HELSTF/WSMR
PIKL Program

Armstrong Labs Bio-effects Analysis

• PLVTS details
  – Pulsed CO$_2$ laser
  – Wavelength: 10.6 microns
  – Pulse duration: 32 – 34 microseconds
  – Single pulse or multi-pulse mode (10 Hz)
  – Pulse energies: 100 – 1200 j/pulse
  – Spot size used for testing: 2 x 3 cm
PIKL Program

Armstrong Labs Bio-effects Analysis

• Test results
  – Detonative coupling occurred at pulse energies of ~ 400 J
  – Breakdown threshold: ~ 2 x 10^6 w/cm^2
  – Average coupling coefficients
    • Chamois: 8 dyne-sec/j
    • BDU over chamois: 9 dyne-sec/j
  – Maximum impulse and pressure: 10,000 dyne-sec and 25 atmospheres
PIKL Program

Armstrong Labs Bio-effects Analysis

• Conclusions
  – Impulses and pressures developed were two orders of magnitude below those needed to produce serious injuries with single pulses
  – Detonative coupling does not appear to produce greater probability of damage than ablative coupling
  – Surface damage can be significant with ablative coupling
  • Multiple pulse trains produced moderate to severe damage
PIKSL Program

Armstrong Labs Bio-effects Analysis
Solid State Lasers
Overview

• Solid state (SS) laser technology is advancing rapidly
• SS lasers offer many advantages to future weaponization concepts:
  – Smaller size
  – Lower weight
  – Ease of use/handling (no hazardous chemicals)
  – Frequency agility through dye doping
Solid State Lasers
Technology Advancements

• Diode-pumping
  – Higher electrical efficiency than flash pumping
  – Higher reliability and lifetimes
  – Smaller weight/volume
  – More rugged
  – Less waste heat
Solid State Lasers
Technology Advancements

• Slab lasers
  – High optical performance
  – Minimal performance degradation due to thermal effects
    • Reduced optical distortions
    • Easier removal of waste heat
Solid State Lasers
Technology Advancements

• Dye-doped solid state laser rods
  – Frequency agility without dangerous liquid solvents
  – Ease of use with solid state host
  – Operation in three pump modes: CW, mode-locked, and pulsed
    • Outputs can be varied
PIKL Technology
Operational Benefits

• PIKL is a “feeder” technology into the Agile Target Effects (ATE) STO and Future Combat System (FCS)
  – ATE STO addresses AAN short list for Future Fighting Ground Vehicle
  – Developing brassboard weapons capable of lethal tunable target effects
  – Demonstrate utility of Directed Energy Weapons (DEW) against personnel and materiel targets
• Leveraging with SMDC and LLNL and their SS laser technology
PIKL Technology
Operational Benefits

• Applying PIKL technology for FCS:
  – Anti-materiel effects:
    • Disrobing explosive armor
    • “Blunt Trauma”
    • Anti-UAV
  – Anti-personnel effects:
    • “Blunt Trauma”
    • Suppression

• Rapidly project Tunable Target Effects to ranges of 2 km
PIKLM Technology
Operational Benefits

• Application of PIKLM technology
  – Area Denial
  – Crowd Control
  – Facility Protection
  – Suppression
  – Military Operation Other than War
  – Military Operation on Urban Terrain
  – Law Enforcement
Summary

• Technologies such as PIKL that can provide varying target effects (lethal and less than lethal) have a broad area of interest
• PIKL technology has made significant progress over the past 15 years
• Solid state lasers have also made significant strides
• Combining SS laser technology and the PIKL concept can produce systems with the necessary parameters required for military utility