**Title and Subtitle:** Development and Characterization of a Bidirectional Optical Multipass Cavity for Counter-propagating High Energy Pulsed Laser Applications

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**Abstract:**
Briefing Charts for the American Institute of Aeronautics and Astronautics Rocky Mountain Section Technical Symposium, Denver, Colorado in 26 October 2012.
Development and Characterization of a Bidirectional Optical Multipass Cavity for Counter-propagating High Energy Pulsed Laser Applications

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Overview

- Multipass cavity was developed for counter-propagating high energy pulsed laser applications
- Cavity was designed to potentially allow for repeated temporal and spatial superposition of counter-propagating pulses
  - Trap: One-time change in pulse polarization state
  - Maintain: Optical focusing system employed
  - Optimized: by simulation
  - Experimentally characterized
Optical Cavities

• **Cavities**
  - provide a closed path for circulation of light
  - Function follows form:
    1.) Active & resonant
    2.) Passive & resonant /nonresonant

• **What can they do for me?**
  - Increased laser pulse repetition rates
  - Increased laser-gas energy deposition efficiency
  - Increased absorption path length
  - Increased sensitivity in spectroscopy studies
  - Variety of energy storage & amplification schemes
Prior Multipass Cavity Applications

1. Potential non-resonant laser gas heating
2. X- and γ-ray production using Inverse Compton scattering
3. Chemical Kinetics using Infrared Multiple Photon Dissociation (IRMD)
4. Raman scattering for molecular structure studies
5. Cavity ring-down laser absorption spectroscopy (CRDS)
6. Laser absorption spectroscopy

Experimental Cavity Requirements

Experimental

• For the requirement of this study, any potential cavity design must:
  – Efficiently trap/contain pulsed laser light at 532 nm
  – Simultaneous injection pulses
  – Exhibit high damage thresholds
  – Spatial/temporal superposition
  – Reduce beam diameters down to ~50 μm

Implementation

• Problem: Time reversibility
• Possible solutions
  1. Laser Resonant Cavity
  2. Long path length
  3. Modification and Trap
     a. Color Change Cavity
     b. One-time Polarization Change
• Selected Approach: Pockels Cell
  – Linear electro optic Pockels effect
  – Introduces net relative phase shift between orthogonal components
  – Can act as a dynamic $\lambda/2$ or $\lambda/4$ wave plate/dynamic phase retarder/frequency shifter

\[ T_0 = T_1 \]

Mirror

0°
Single Pockels Cell Cavity Design

Mohamed et al.

- Pockels effect is a linear electrooptic effect
- Birefringence
  - Index of refraction
    \[ n = \frac{c}{v} \]
- Pockels cell used for dynamic phase retardation
- 2 important voltages

\[ V_{\lambda/2} = \frac{\lambda}{2n_3^3 r_{63}} \]

\[ V_{\lambda/2} \text{ for KD*P at 532 nm } \approx 3.6 \text{ kV} \]
Single Pockels Cell Cavity Design

- **Conditioning wave plates**
- **Faraday Isolator**
  - Faraday effect
  - Faraday rotator & 2 Glan polarizers
  - Non-reciprocal rotation
  - One-way valve
- **Galilean Telescopes**
- **PBCs**
  - p/s polarization
  - Differential response
- **Pockels Cell/Driver**
  - @ $V_{A/2}$ on 1st pass
  - V=0 on subsequent passes
  - One-way valve
- **Keplerian**
Implementation

Experimental Setup

Equipment

- Laser(s)
  - Nd:YAG 532 nm, 5 ns FWHM, Continuum Minilite/Powerlite
- Cavity length 2.4284 m (96 in); rt pulse time 8.09 ns
- Timing Control
  - SRS DG535 x3
- Pockels cell/driver
  - Leysop Ltd. UPC 6 mm aperture; 250 ps rise, 6 ns width; KD*P 650MW/cm2
- Intra- and extra-cavity focusing system
- Knife Edge System
Results: Spatial Superposition

Vertical Knife Beam Centers

R² = 0.9713

R² = 0.9974

Vertical Knife Beam Diameters

Div Centers

Conv Centers

Linear (Div Centers)

Horizontal Knife Beam Centers

R² = 0.9982

R² = 0.991

Horizontal Knife Beam Diameters

Div Centers

Conv Centers

Linear (Div Centers)

Vertical Knife Data: Beam Superposition

Horizontal Knife Data: Beam Superposition

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Results: Temporal Superposition

- **Temporal pulse superposition**
- Greater than 40 rt
  - 532 nm, 5 ns FWHM, Continuum Minilite, 4 mJ
- Cavity length 2.4284 m (96 in); period 8.09 ns
- Pockels cell/driver
  - Leysop Ltd. UPC 6 mm aperture; 250 ps rise, 6 ns width
- Periodicity matches cavity
- PD
  - Active area .006 mm²
Results (continued)

3-D Plot of Roundtrip Amplitude as a function of Horizontal Translational Position and Time

PD Amplitude [V]

Position [mm]

Time [nanoseconds]
Results (continued)
Summary

• First bidirectional cavity for counter-propagating high energy laser pulses
  – Temporal superposition confirmed within cavity on every round trip
  – Spatial superposition confirmed on 1st R.T.
  – 40+ R.T. observed for 4 mJ initial pulse energy
  – Cavity indicates a dual-stability condition
  – 8.3 fold increase in energy deposition ‘opportunity’ over the single pulse/single pass case