Spectroscopic and Kinetic Measurements of Alkali Atom-Rare Gas Excimers

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Distribution Statement A: Approved for Public Release; Distribution is Unlimited
Goals

- Novel use of alkali/rare-gas molecules to efficiently couple high power diode arrays into alkali vapors
  - Exciplex molecules absorb over much greater bandwidth
- Control of inherent high optical gain to minimize ASE and optimize laser oscillation
- Development of large volume resonators that allow efficient power extraction
- Demonstration of high electrical-to-optical efficiency/power Exciplex assisted diode Pumped Alkali Laser (XPAL)
- Education of a future generation of laser scientists
Novel Approach

- This new laser exploits the optical properties of weakly-bound alkali/rare-gas exciplexes for pumping the $^2P_{1/2, 3/2}$ alkali atomic excited states.
Cs-Ar Energy Level Diagram

Energy (cm$^{-1}$)

Interatomic Distance (Å)

- $X^2\Sigma_{1/2}^+$
- $A^2\Pi_{3/2}$
- $A^2\Pi_{1/2}$
- $B^2\Sigma_{1/2}^+$
- $6^2P_{3/2}$
- $6^2P_{1/2}$
- $6^2S_{1/2}$

Electromagnetic transitions:
- 837 nm
- 894.3 nm
- 852.1 nm
Alkali Cell Oven Design

- Cartridge heater (x 4)
  Stainless steel
  75 W

- Heater block (top half)
  6061 Aluminum

- Window heater insert (x 2)
  6061 Aluminum

- Ceramic insulation

- Triad Technologies sealed Rb vapor cell
  Pyrex

- Heater block (bottom half)
  6061 Aluminum
Assembled Alkali Cell Oven: Exterior

- End View
  - Optical Access Through Heated Inserts
- Cartridge Heater Ports (x 4)
- Temperature Controller
- Side Port for OMA Spectrometer Diagnostic Access and Side Pumping
Photograph of Rb Atom Fluorescence Viewed Through the Alkali Atom Oven Side Port: $\lambda_{\text{excitation}}$: 780 nm
Absorption Spectra of Cs Buffered with 500 Torr of Ar
Absorption Spectra of Cs Buffered with 500 Torr of Ar and 75 Torr of Ethane
Absorption Spectra of Cs Buffered with 500 Torr of Xe
Temperature Dependant Absorption of Rb (Rb-He-Ethane Cell)

Rb cell buffered with 500 Torr Helium and 75 Torr Ethane

- 150 °C
- 200 °C
Temperature Dependent Rb–Kr and Cs–Kr Absorption Spectra

Cs/Rb cell buffered with 500 Torr Krypton

- 101 °C
- 150 °C
- 200 °C

Wavelength (nm)

Transmission
Cs Atom Fluorescence Spectra as a Function of Excitation Wavelength

Casium cell buffered with 560 Torr Krypton
Cell temperature = 200 °C

- $\lambda_{\text{pump}} = 870.1 \text{ nm}$
- $\lambda_{\text{pump}} = 852.0 \text{ nm}$
- $\lambda_{\text{pump}} = 841.1 \text{ nm}$
- $\lambda_{\text{pump}} = 833.9 \text{ nm}$

Cs emission at 852 nm and 865 nm
Experiments to Develop Kinetics Data for XPAL Based on Optical Gain

- Measurements will provide a key parameter concerning efficiency of XPAL process
  - Probe gain medium directly in absence of optical resonator
    - Provides information on population inversion and its sensitivity to pump laser intensity and wavelength, cell temperature, bath gas type and pressure

- Will enable design of optical resonators for optimal output coupling

- Portable system will be transportable to MRI partners’ facilities for collaborative experiments

- Applicable to both CW and pulsed laser excitation configurations
Experimental Setup for Gain Measurements in Optically Pumped Lasers

- For XPAL studies
  - Pump: Ti:S laser
  - Probe: 794 nm and 895 nm diode lasers
  - Portable systems; will be used at PSI and UIUC
Strategy for XPAL Gain Measurements

- Rb
- Cs
- Probe D1 Line
- \( ^2P_{\frac{1}{2}} \leftarrow ^2S_{\frac{1}{2}} \)

Vary Pump Wavelength

Transmission vs. Wavelength (nm)
Experimental Setup for Initial Gain Probe Measurements

Cesium cell mounted inside temperature controlled heater block

½ wave plate

Ti: Sapphire laser output

Polarization Beam combining cube

Diode laser launch fiber optic collimator
Absorption Spectrum of Cs $D_1$ line in CsKr Cell
(no optical excitation by Ti:S laser)
Absorption and Gain Spectra for CsKr Cell

- Black Trace: Ti:S tuned to Cs D$_2$ line
- Red Trace: Ti:S laser tuned off the D$_2$ resonance

- These data confirm the approach
- Will develop key data base for both DPAL and XPAL pumping schemes
“Blue” Cs Doublet Emission at $\lambda_{\text{excitation}}$: 852 nm

Cesium cell buffered with 500 Torr Krypton
Cell temperature = 200 °C

Cs emission
455.5 nm and 459.3 nm

$\lambda_{\text{pump}} = 852.0$ nm
Energy Level Diagrams for Cs and Rb Showing the Ground $^2S_{1/2}$ State and Several Excited States Relevant to Alkali Atom Lasers

Cs Near-IR Emission Line \((7\,S_{1/2} \rightarrow 6\,P_{3/2})\)
\((\lambda_{\text{pump}} \sim 780\,\text{nm})\)
Summary and Future Work

- Demonstrated fluorescence at 852 and 894 nm when pumping in blue-wing of exciplex in Cs-Kr cell
- Measured absorption spectra in Cs-Kr and Rb-Kr cells
  - Blue wings significant
- Have observed blue fluorescence and IR fluorescence from higher lying states in both Rb and Cs excited at or near $D_2$ lines
- Developed gain diagnostic for alkali systems
- Continue work on side pumping and unstable resonator configurations
- Utilize high power Q-Peak diode laser system for Rb XPAL experiments
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