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TP-2018-0021

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DIODE PUMPED ALKALI LASERS (DPAL) AND OTHER GAS LASERS

Matthew Cooper

29 November 2018

Technical Paper

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REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
29 11 2018	Technical Paper	Oct 2016-Oct 2018

4. TITLE AND SUBTITLE
DIODE PUMPED ALKALI LASERS (DPAL) AND OTHER GAS LASERS

5a. CONTRACT NUMBER
In-House

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Matthew Cooper
Greg A. Pitz

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
D058

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
3550 Aberdeen Ave, SE
Kirtland AFB, NM 87117-5776

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/RDLT

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RD-PS- TP-2018-0021

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release: distribution unlimited.
OPS-18-22110. AFMC-2019-0391

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The Next generation program has achieved the highest power level for a potassium DPAL. This was achieved through a vigorous experimental and modeling effort. They have also looked into alternate lasing schemes such as the first pulsed DPAL. Additionally, the program studied a new concept for pumping an alkali laser using an erbium doped ZBLAN fiber.

15. SUBJECT TERMS
Gas Lasers, Diode Pumped Alkali Lasers, Cavity Dumped DPAL, Fiber Pumped Alkali Laser, Alkali Laser Modeling, CFD Modeling

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Matthew Cooper
Unclassified	Unclassified	Unclassified	SAR	20	**19b. TELEPHONE NUMBER** *(Include area code)* 505-846-0202

Reset

2018 Interim Report for Case File D058 (Diode Pumped Alkali Lasers)

PM: Capt Matthew A Cooper

PI: Dr. Greg A. Pitz,

Outline

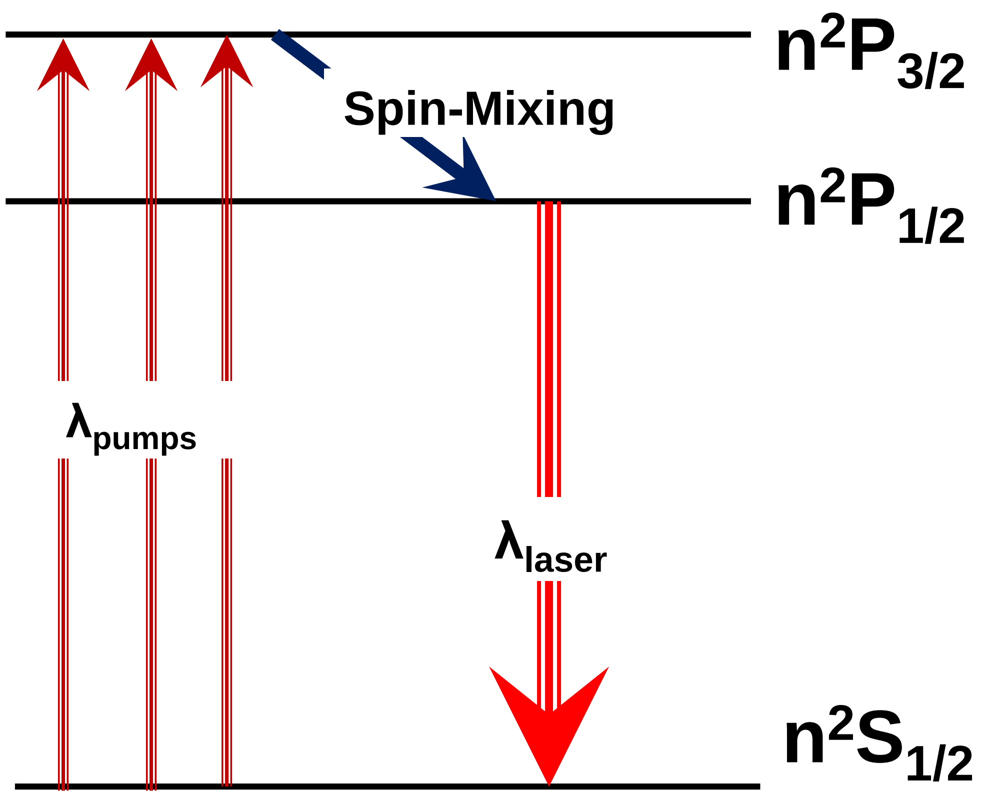
I. DPAL Refresher

II. Scaling of flowing DPAL system at AFRL

III. Cavity dumped DPAL

IV. Fiber Pumped Alkali Laser

Diode Pumped Alkali Lasers (DPAL)



Alkali Atom	Pump D_2 wavelength (nm)	Lasing D_1 wavelength (nm)	Spin-Orbit Splitting (cm^{-1})
K	766.70	770.11	57.7
Rb	780.25	794.98	237
Cs	852.35	894.59	554

Positive Attributes of DPALs

- Excitation wavelength accessible by diode laser
- Small quantum defect (~0.5 – 5%)
- Gas phase lasing media

Lots of low power, poor BQ diodes in…bright intense beam out

Current FDPAL Setup

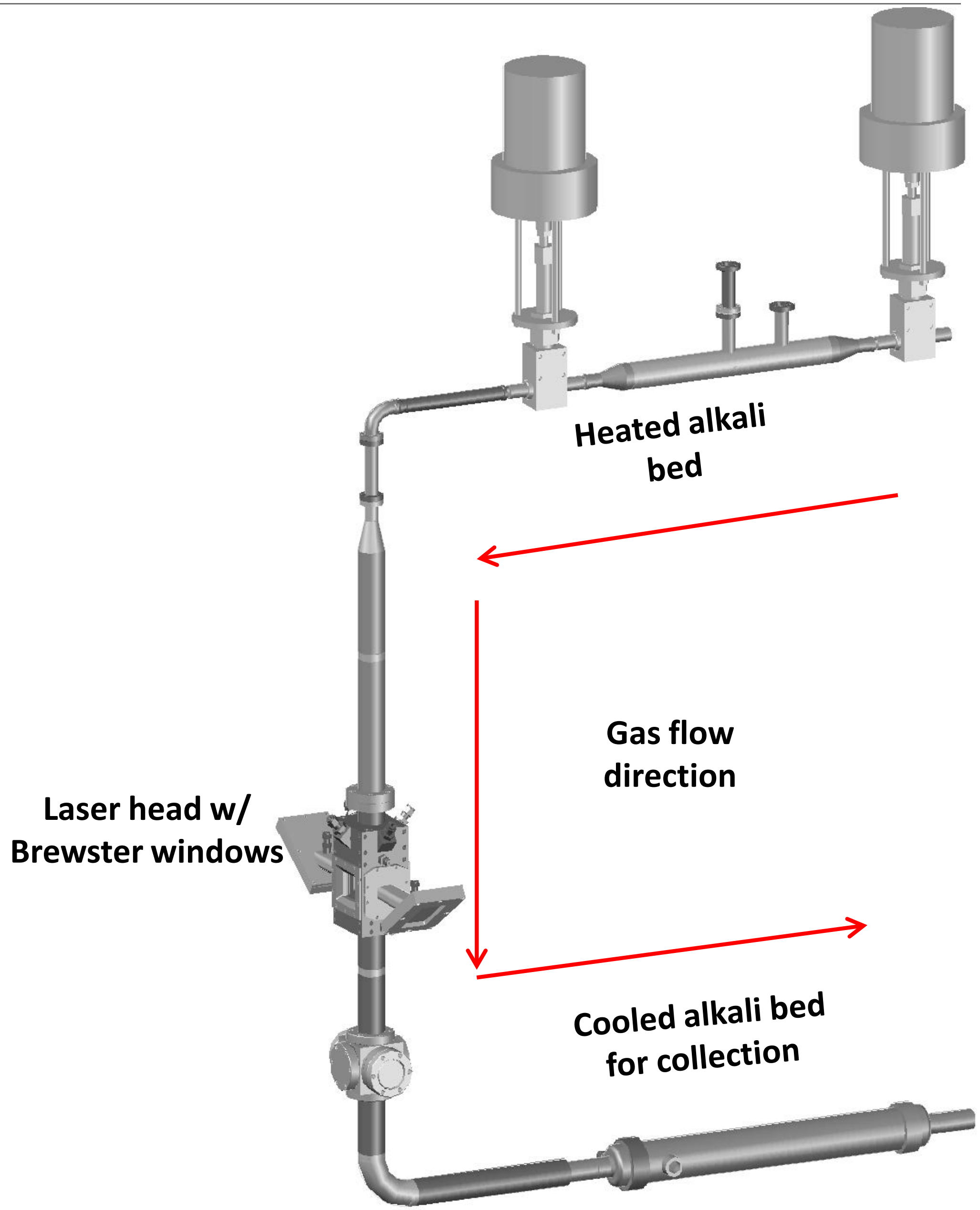
Same simple flow design from 2009

- Decouples the thermal management system from the lasing head
- Reduce thermal gradients in the lasing region
  - •Improved BQ

•Added mixing nozzle to add in hydrocarbon post alkali bed to avoid breakdown

Continued exploration of Open Loop

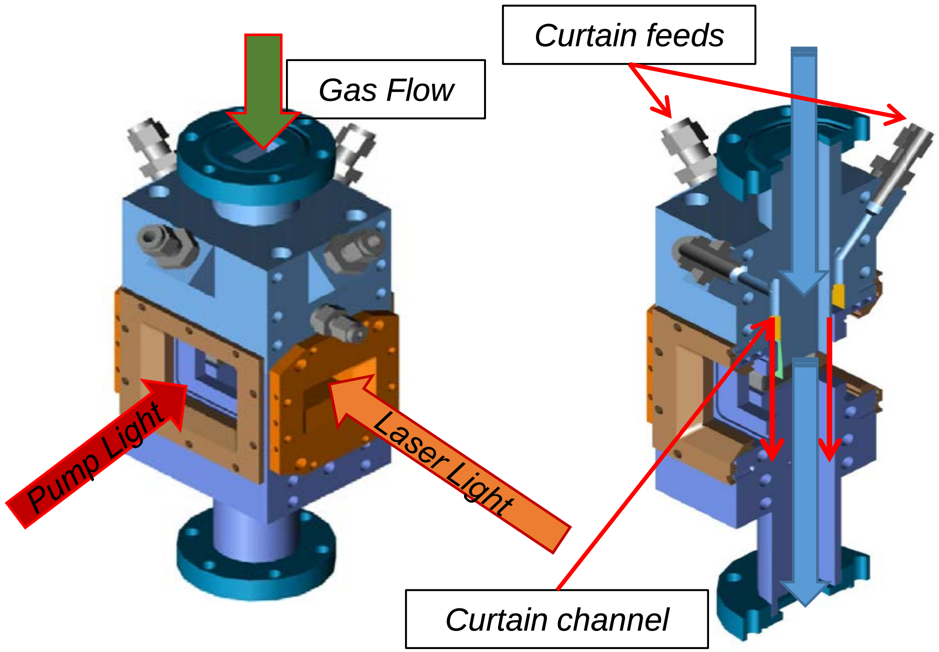
- Moving through open loop trade space for expanded model validation
  - Pressures, flow rates, gas mixtures, alkali concentrations, etc.



Flowing DPAL at AFRL

Current Laser head Design:

- Triply Transverse Design
  - Reduce intensity on windows
  - Added Brewster windows on laser side
- Curtain flows:
  - Helium gas flow
  - Both pump, lasing windows



AFRL

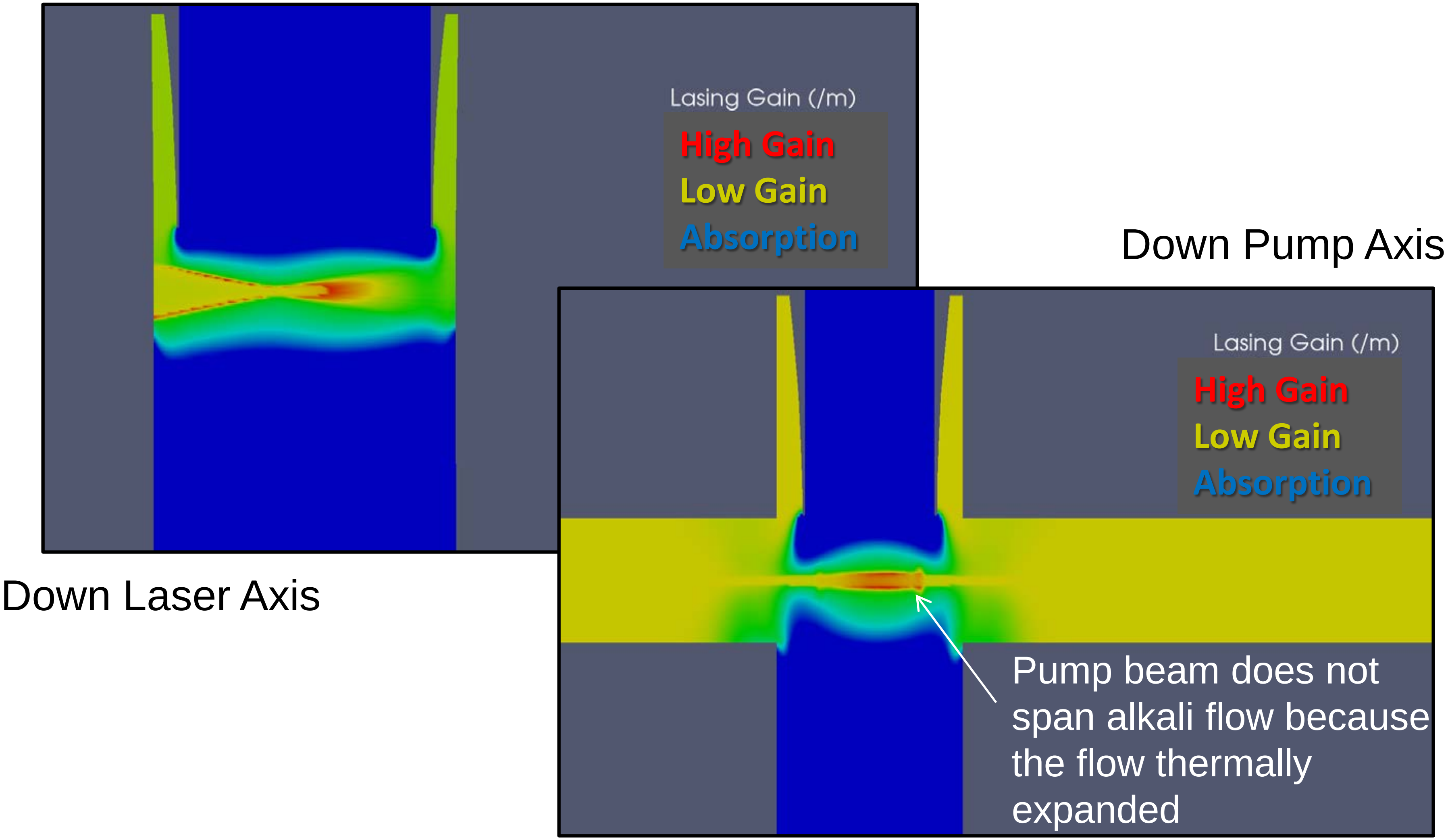
DPAL 8 Level Model

- Finite volume CFD with thermal transport
- Laser kinetics
- Radiation transport
- Spectral Resolved Ray-Optic Pumping
- Ray Optic or Wave Optic Laser Model

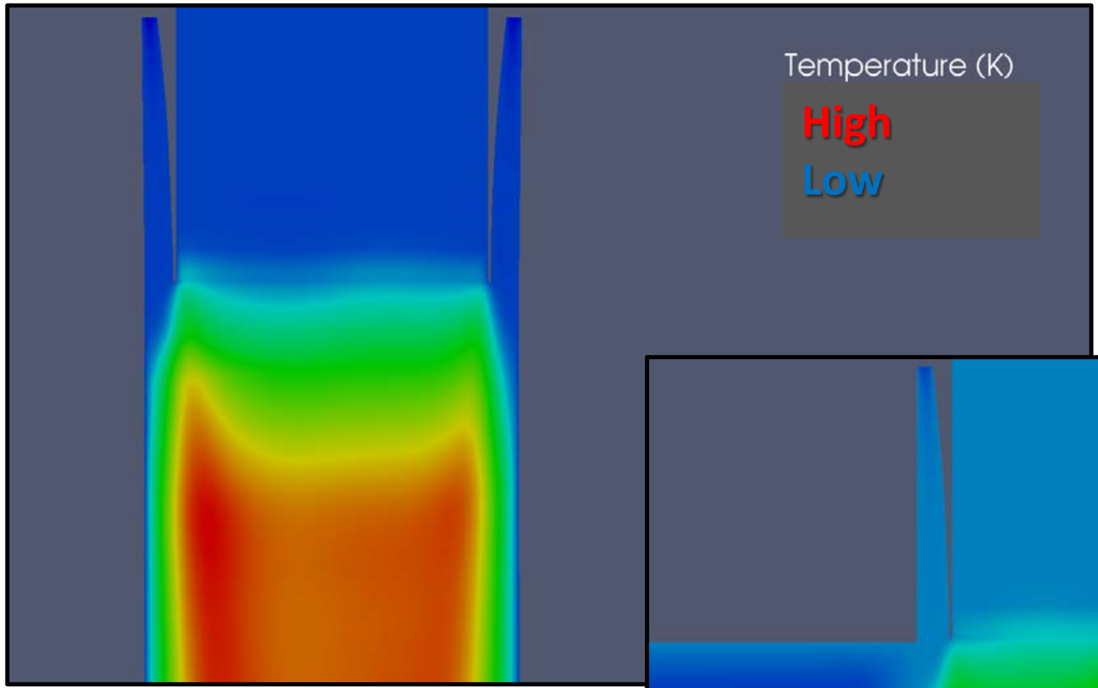
- *Numerous rates missing, using analogous rates from other alkali as basis for assumptions.*

Process	Formula Description
Alkali number density decrease in high temperature regions	Results from fluid dynamics
Convective flow	Results from inclusion of buoyancy in fluid dynamics
Pressure broadening and shifting of the absorption lineshape including hyperfine structure	Pressure dependent variations in absorption lineshape
Radiative decay	$A^* \rightarrow A + h\nu$
Quenching	$A^* + M \rightarrow A + M$
*Off-resonant absorption**	$A^* + h\nu \rightarrow A^{**}$
Penning ionization	$A^{**} + A^* \rightarrow A^+ + e^- + A$
Radiative recombination**	$A^+ + e^- \rightarrow A^{**} + h\nu$
Three-body recombination**	$A^+ + 2e^- \rightarrow A^{**} + e^-$ $A^+ + e^- + M \rightarrow A^{**} + M$
Thermal aberration	Change to resonant mode structure
Dissociative recombination**	$A^+ + A + M \rightarrow A_2^+ + M$, then $A_2^+ + e^- \rightarrow A^{**} + A$
*Multi-photon ionization**	$A^* + 2h\nu \rightarrow A^+$
Alkali-hydrocarbon reaction	$A^{**} + HC \rightarrow AH$ + products
*Electron impact ionization**	$e^- + A^* \rightarrow (e^-)^*$, then $(e^-)^* + A^{**} \rightarrow A^+ + 2e^-$

Gain (During Steady-State Lasing)

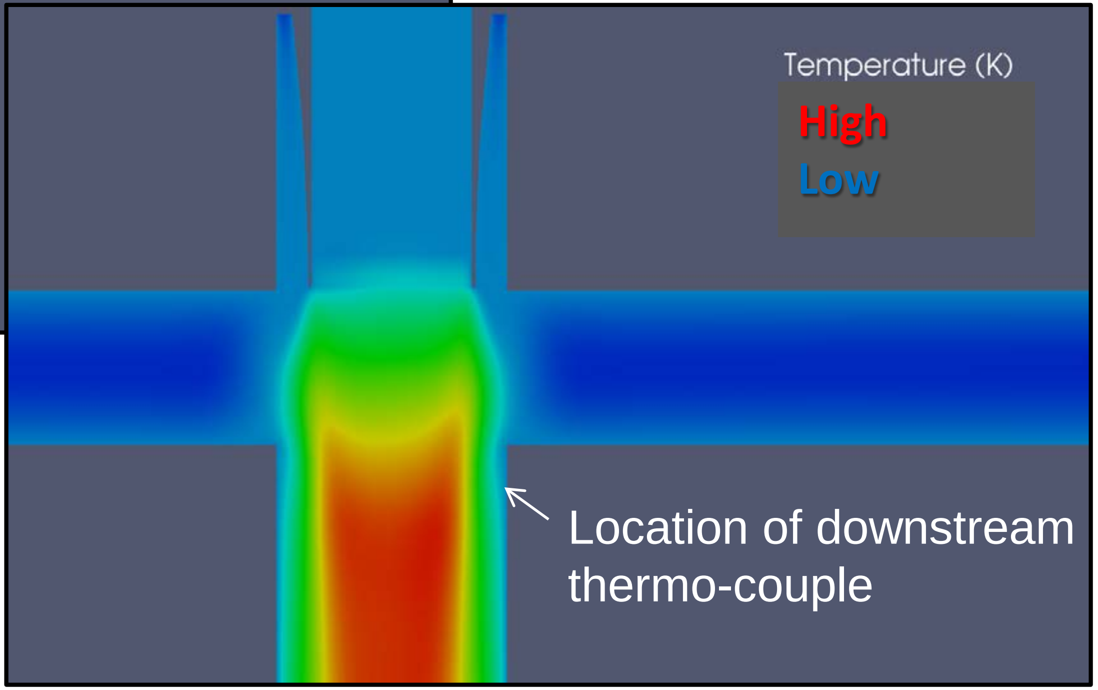


Temperature

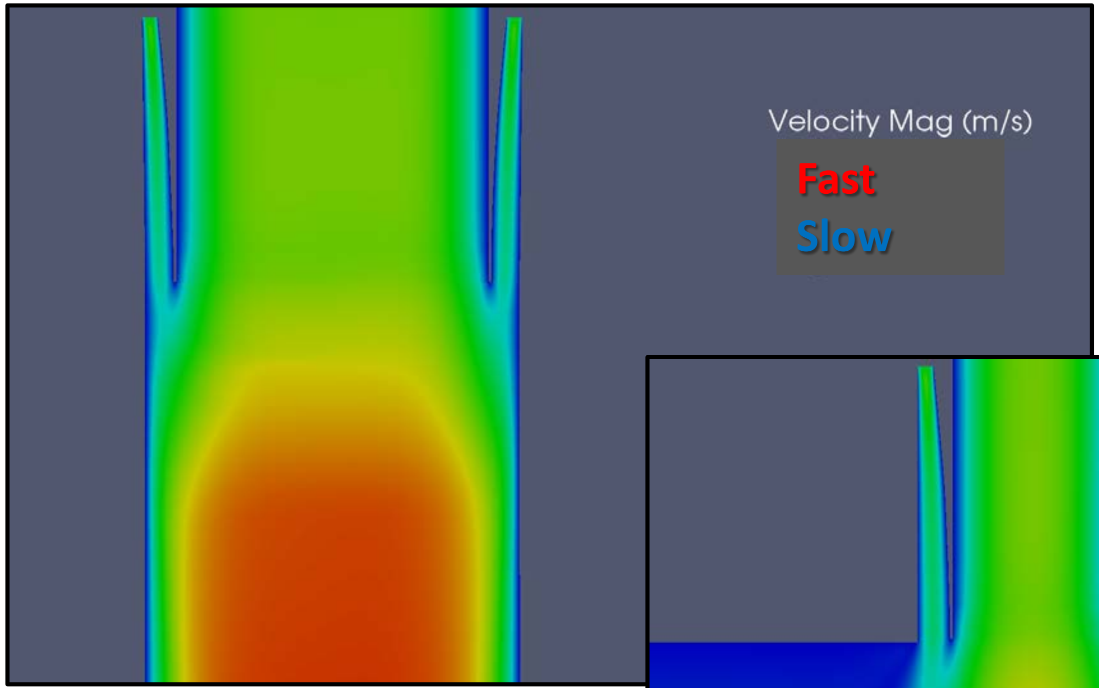


Down Laser Axis

Down Pump Axis



Velocity



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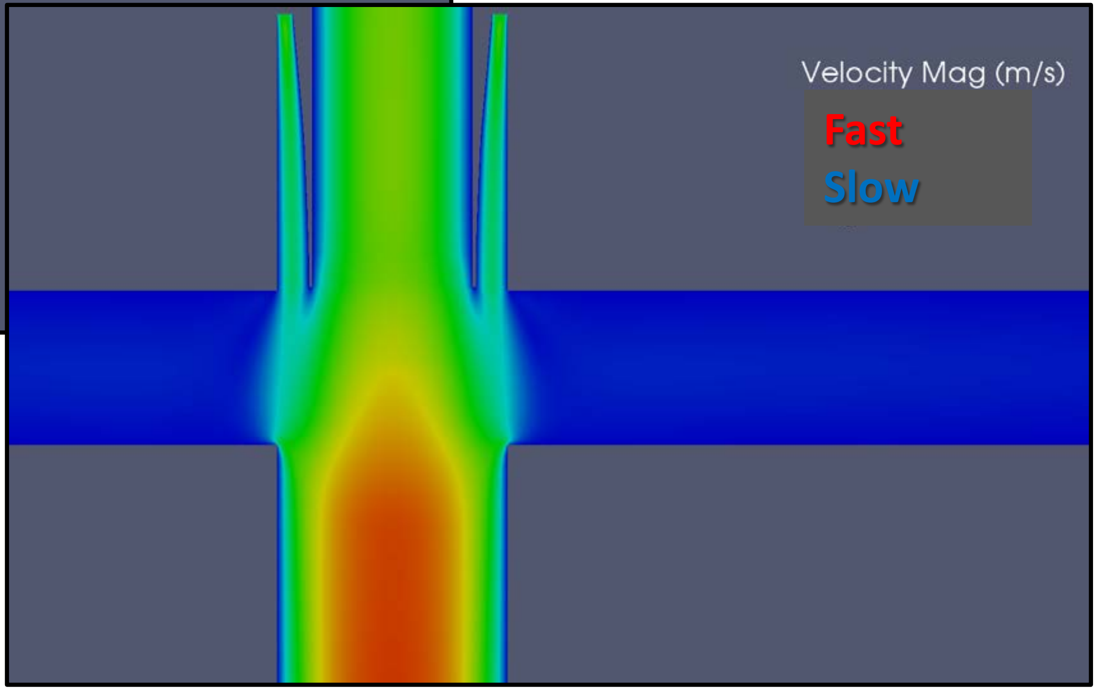
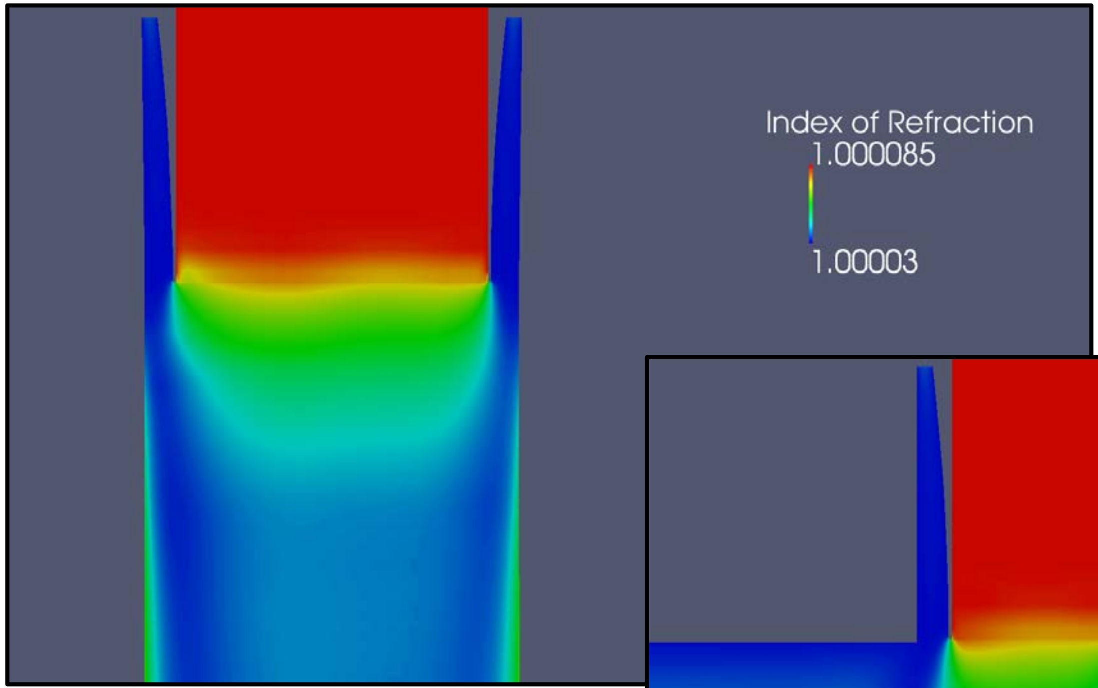
Down Pump Axis

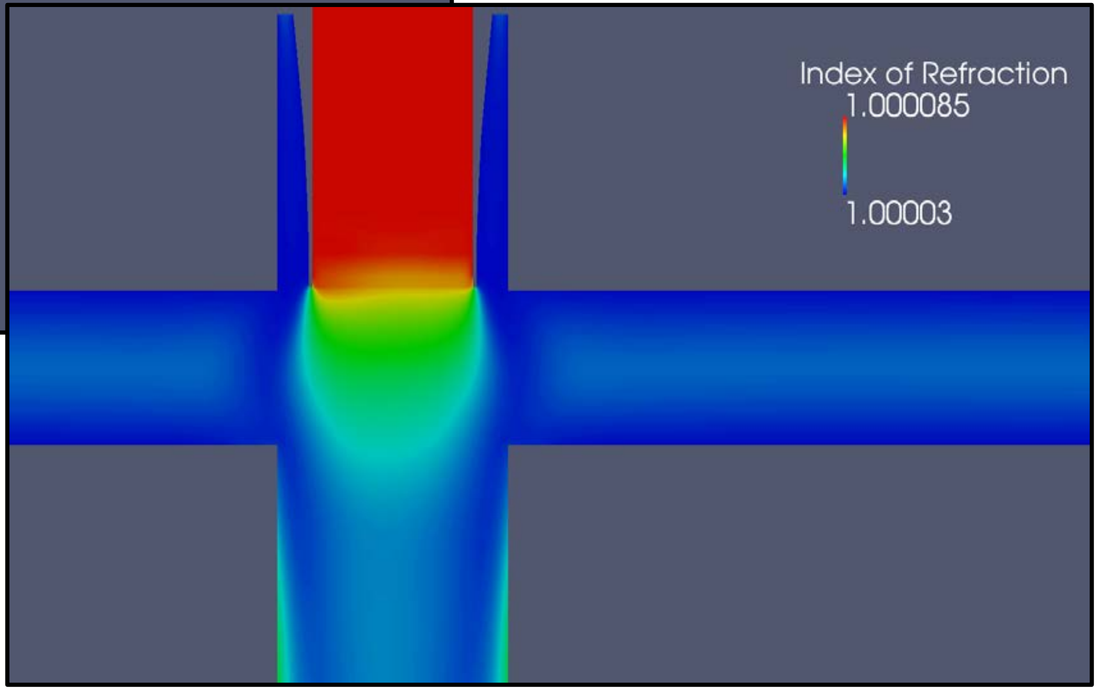


Index of Refraction



Down Laser Axis

Down Pump Axis



Optimized Simulation
Power and Efficiency Results

	Power (W)	Percent of Pump
Pump Power	5525	N/A
Laser Power	4395	79.5%
Unabsorbed Pump Power	23	0.4%
Optical Loss (at windows & mirrors)	160	2.9%
Fluorescence	448	8.1%
Heat	499	9.0%

Peak Temperature Rise: 333 ^{o}C

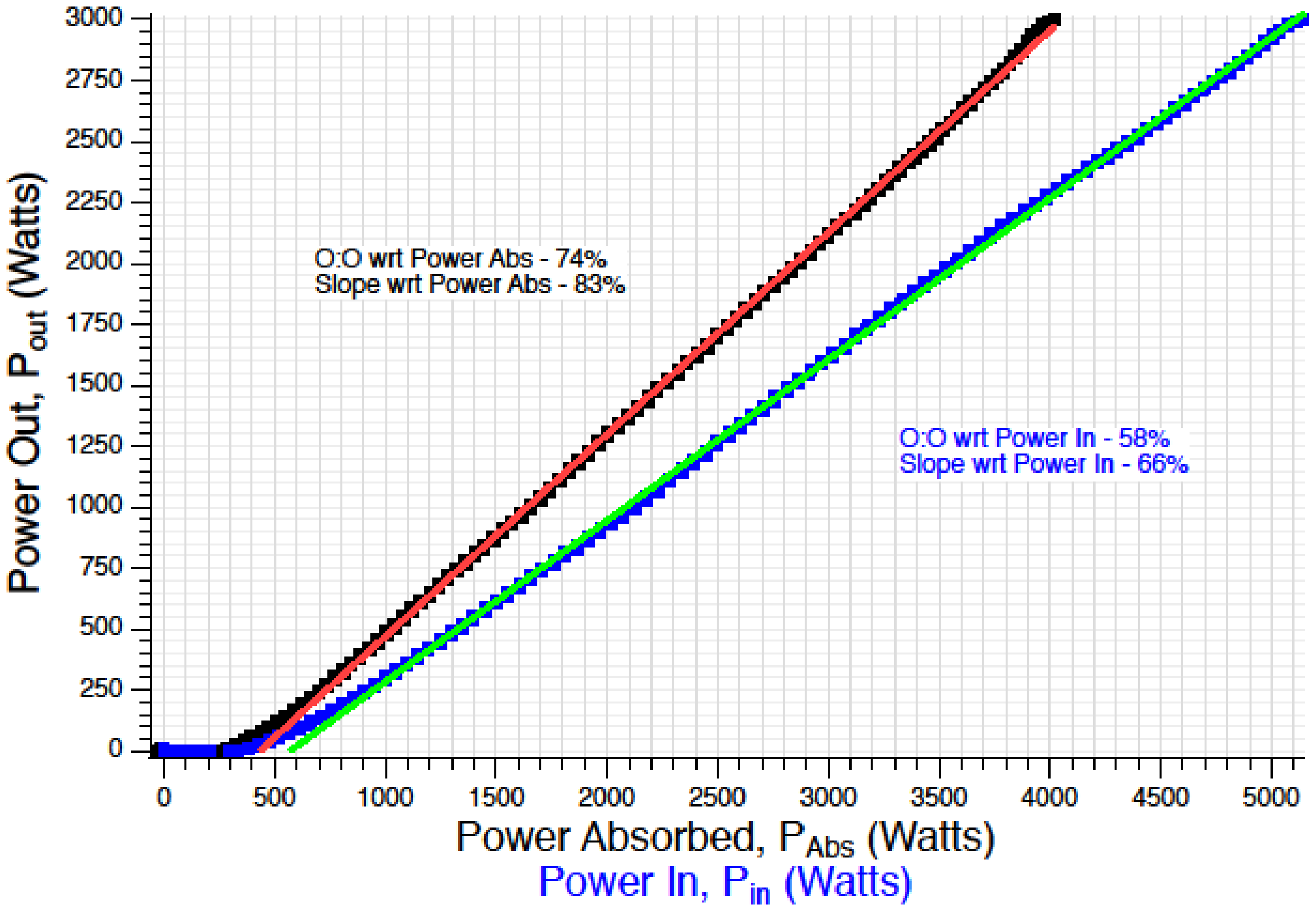
Results

- 13 Modules
  - 11 with 425W of max power
  - 2 with 360W of max power

- Slope efficiency of *66%*
  - *Predicted 72%*
  - *wrt absorbed power 83%*

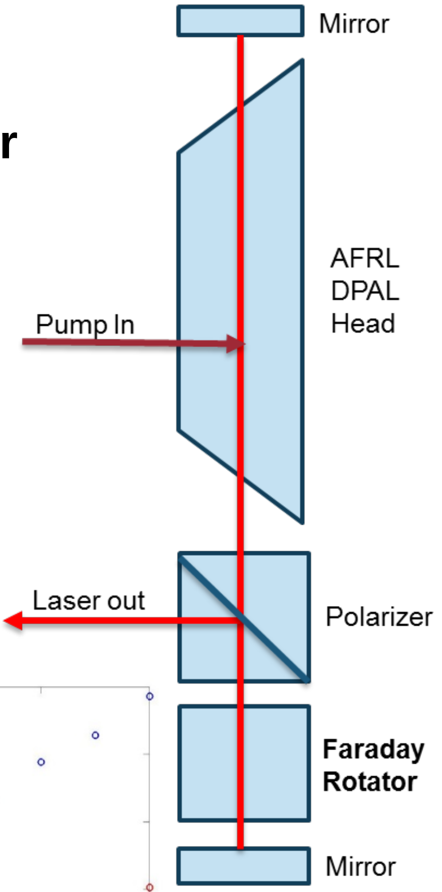
- O:O efficiency of *58%*
  - *Predicted 68%*
  - *wrt absorbed power 74%*

- 3kW Out - Highest published power to our knowledge for a diode pumped alkali laser

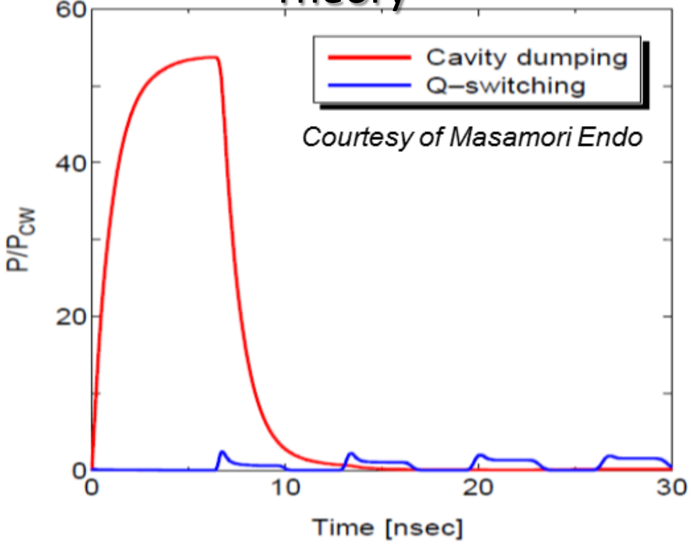


Cavity Dumped DPAL

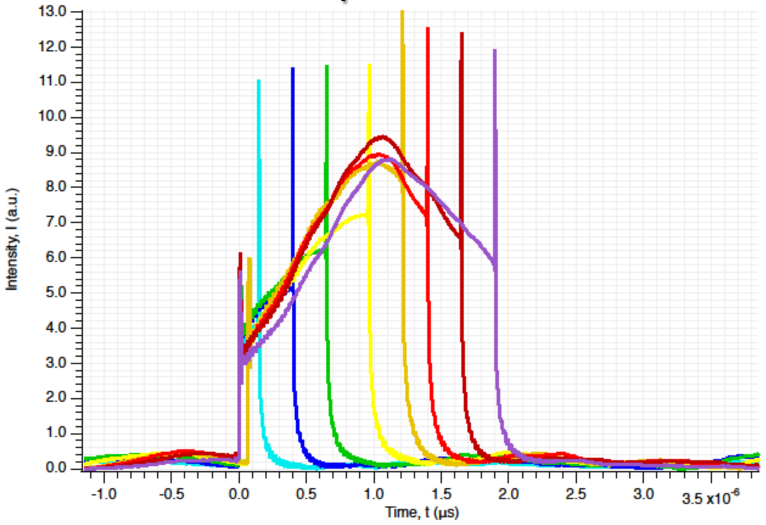
- **Dr. Masamori Endo suggested Cavity dumping is a viable energy storage method for alkali lasers**
  - Alkali lifetimes too short for Q-switching
- **AFRL produced [World's First Cavity Dumped Alkali Laser]()**
  - Characterizing to assess potential at small-scale (10's mW)
  - Characterizing a gas phase rotator to be employed with FDPAL
    - Initial concept review being perform mid-December

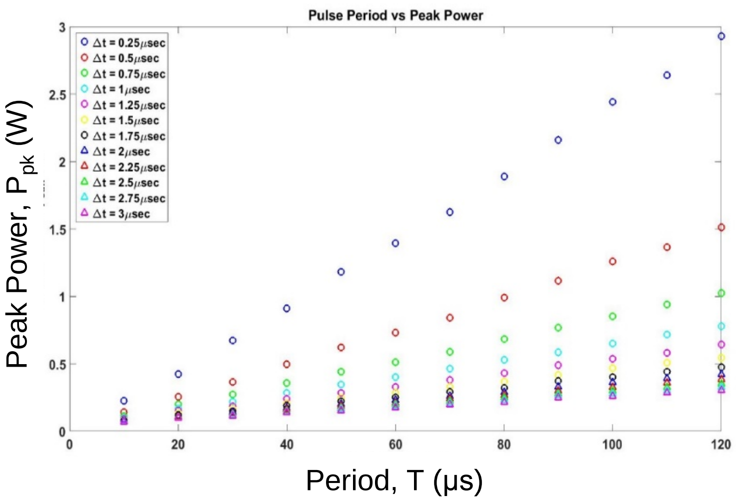


Theory



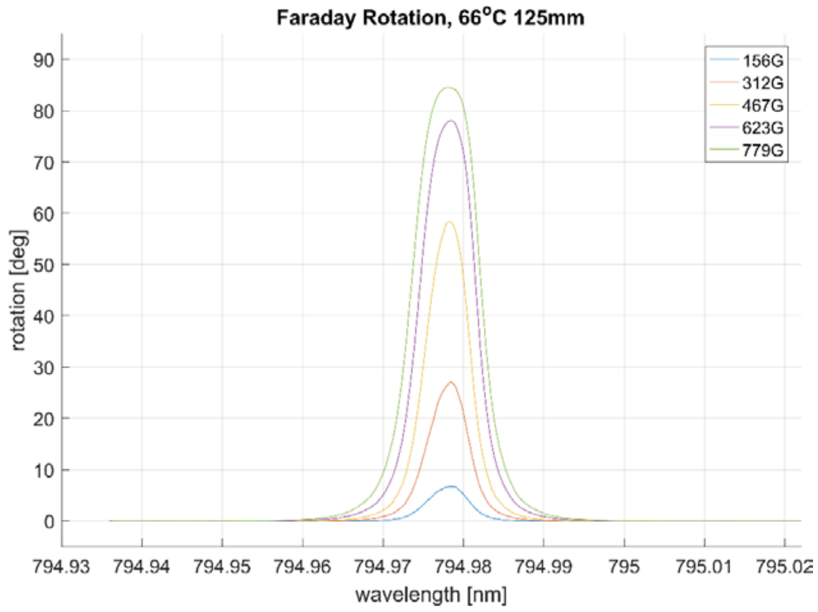
Experiment

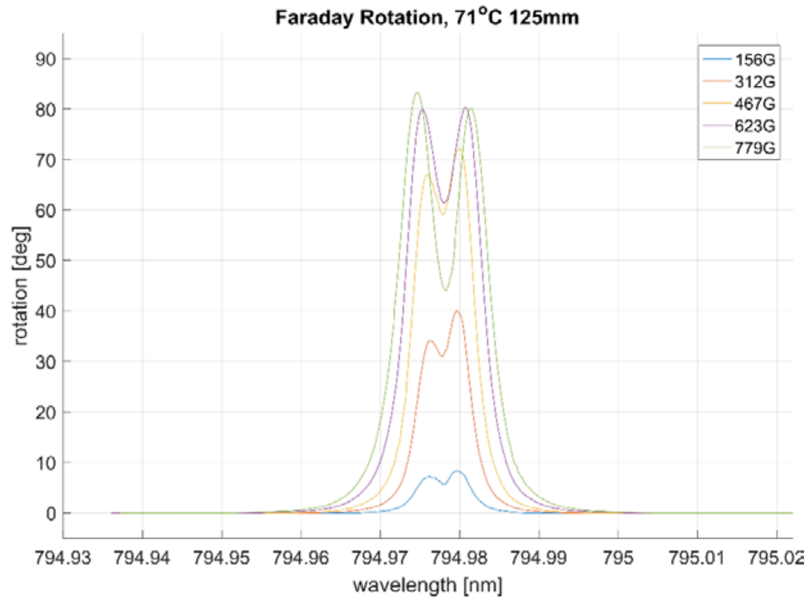




Gas Phase Faraday Rotator Characterization

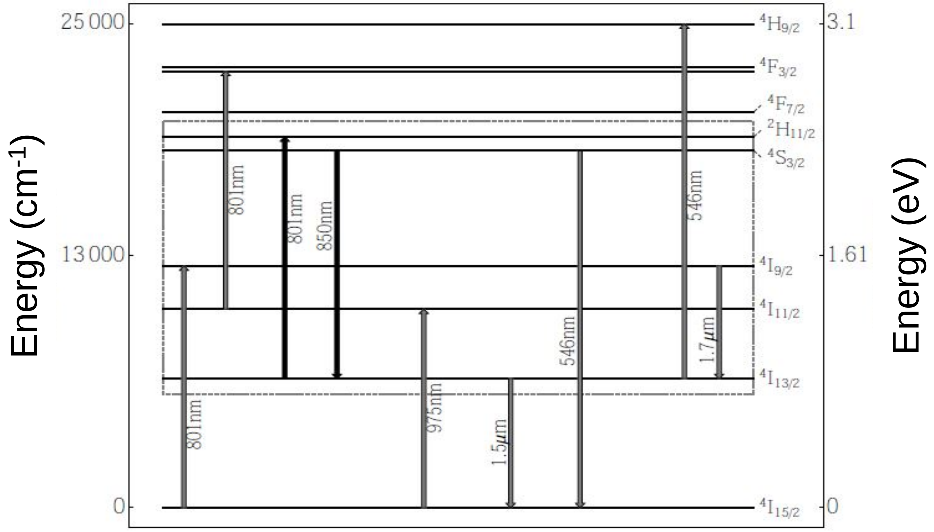
- Solid-state rotation, limits scalability
- Able to map spectral-dependency of FR using alkali metal vapor lasing cell
- Identified coil temperature issues for high current required for polarization rotation
- Completed design of new cooled coil to allow pulsed operation of high current to drive magnetic field
- Planned cavity dump demonstration using new coil later this month

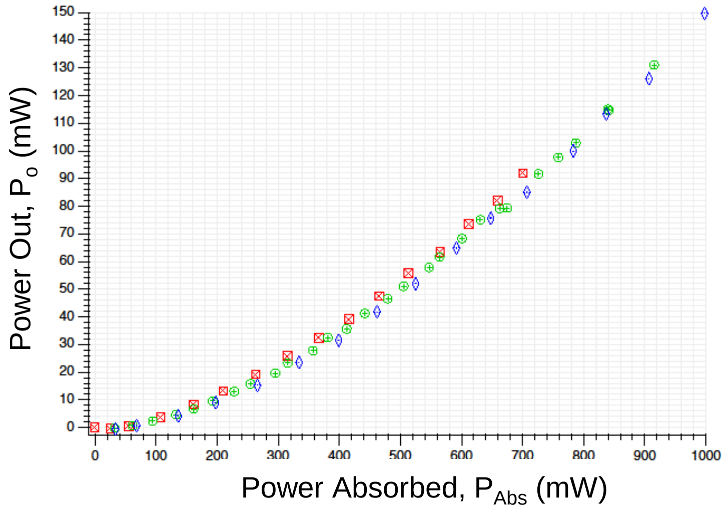


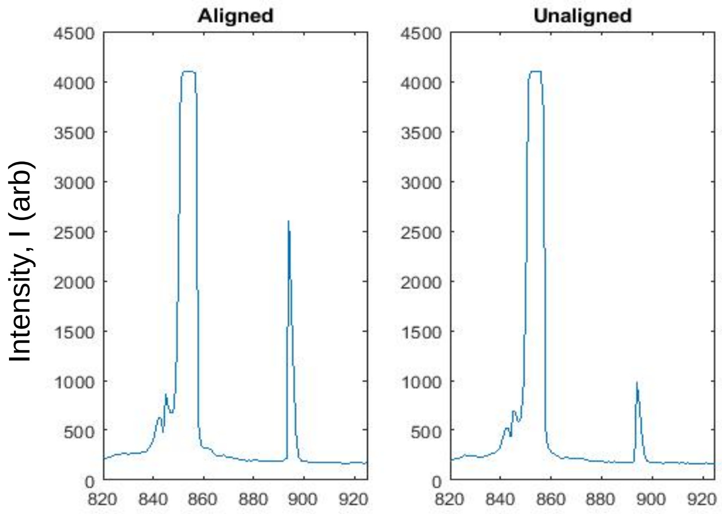


Fiber Pumped Alkali Laser

- **Goal: create a fiber capable of pumping an alkali**
- **Purpose: provides a narrow band source for atomic transition while providing a brightness converter in lieu of beam combination**







Results

- Max power out 172mW
- Efficiency of 27% wrt power absorbed
- Demonstrated first Fiber-Pumped Alkali Laser

Possible Future Work:

- Hyperfine Lasing within alkali
- Fiber study to improve efficiency of Er-ZBLAN

Summary

- Demonstrated high power DPAL approaching 5kW
- Developed high power validated numeric DPAL Model
- Demonstrated first cavity dumped alkali laser
- Demonstrated first fiber pumped alkali laser

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