Status of Advanced Lidar Technology Project at NASA/LaRC

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Meeting of the Working Group on Space-Based Lidar Winds

North Conway, New Hampshire

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Advanced Lidar Technology Project

ALTP was formed at LaRC in support of NASA's Lidar Risk Reduction program

Lidar Risk Reduction plan developed jointly by LaRC/GSFC (Upendra Singh and Bill Heaps) per ESE's direction.

Lidar Risk Reduction Program is funded by NASA Codes Y and R.

Major Lidar Risk Reduction Tasks:

- 1-micron Laser Testbed
- 2-micron Laser Testbed
- Laser Diode Arrays for pumping solid state lidar transmitters
- Wavelength Conversion for converting energy from pump lasers to wavelengths of interest in UV and IR regions.

Advanced Lidar Technology Project

ALTP consolidated other existing Laser/Lidar programs at LaRC to efficiently achieve all technical milestones.

PI: Upendra Singh
PM: Michael Kavaya
Sys. Eng.: Farzin Amzajerdian

ALTP Charter

- Develop lidar technology for NASA's future measurements
- Assemble team with end-to-end lidar expertise (theory to hardware to field deployment)
- Collaborate with industry, academia, and government
- Validate technology to reduce risk of space lidar missions
- Transfer technology to industry

Lidar Technology Applications

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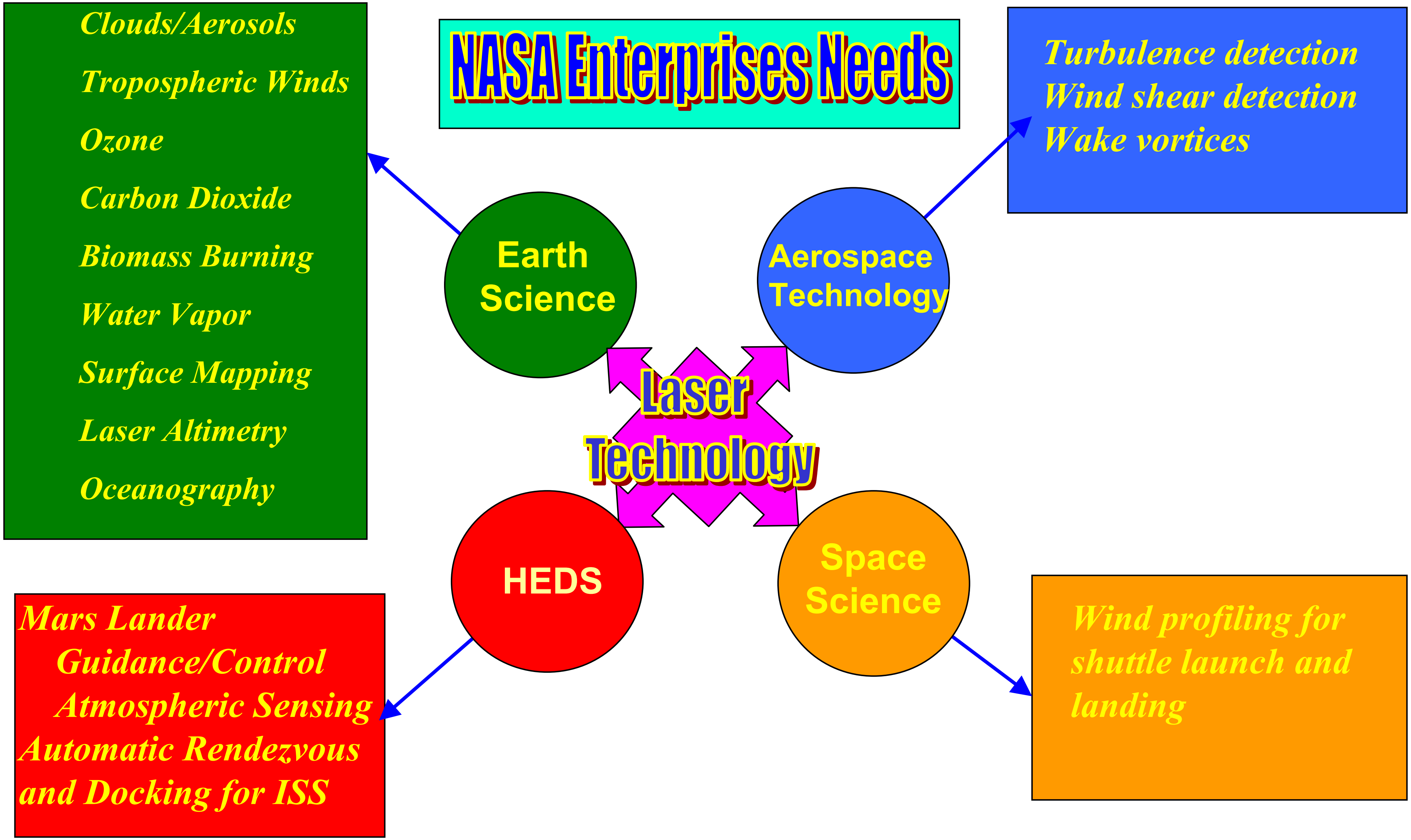
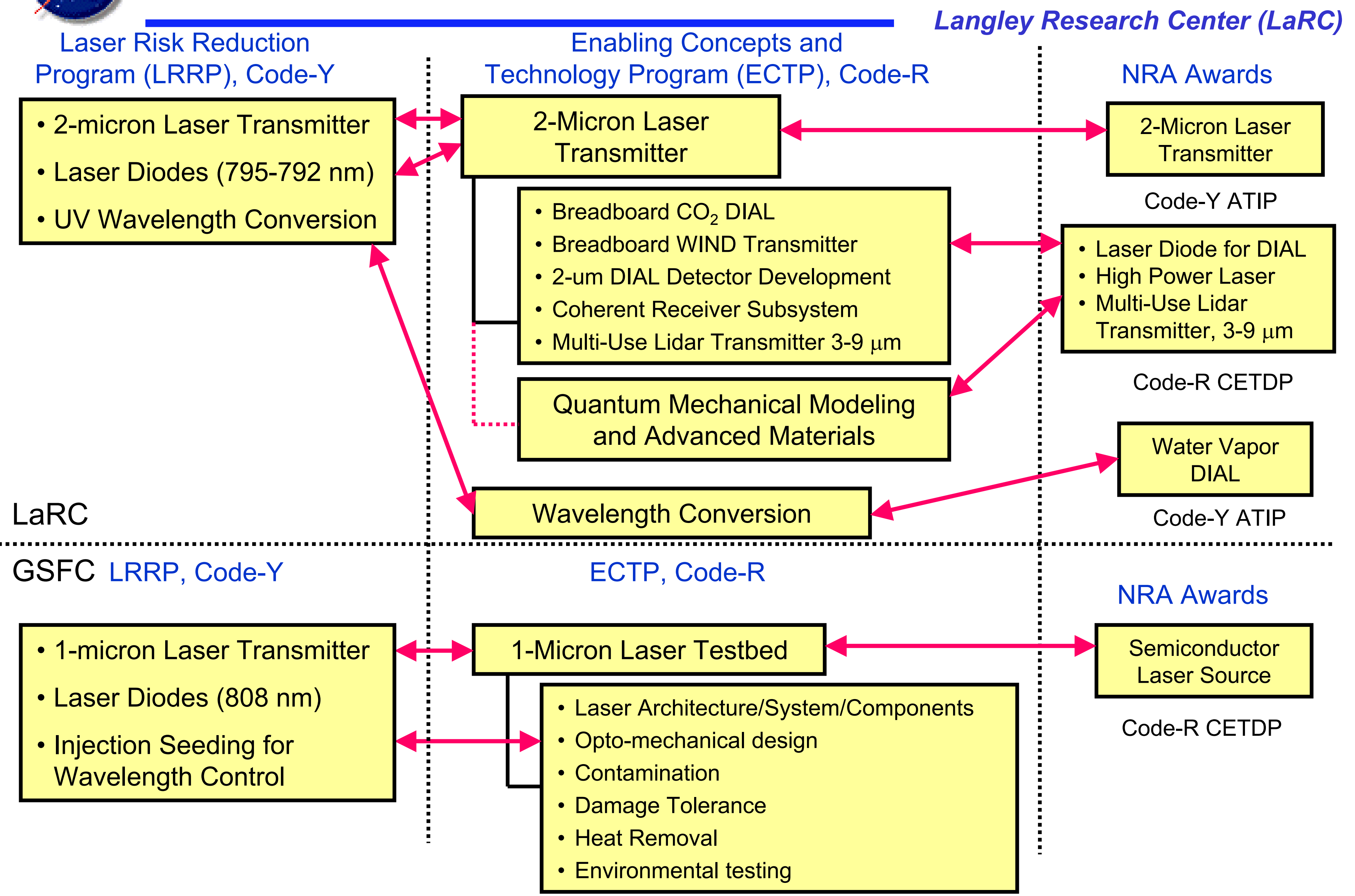


FY02 Joint Laser Technology Program Task Synergies



End-to-End Lidar Capabilities

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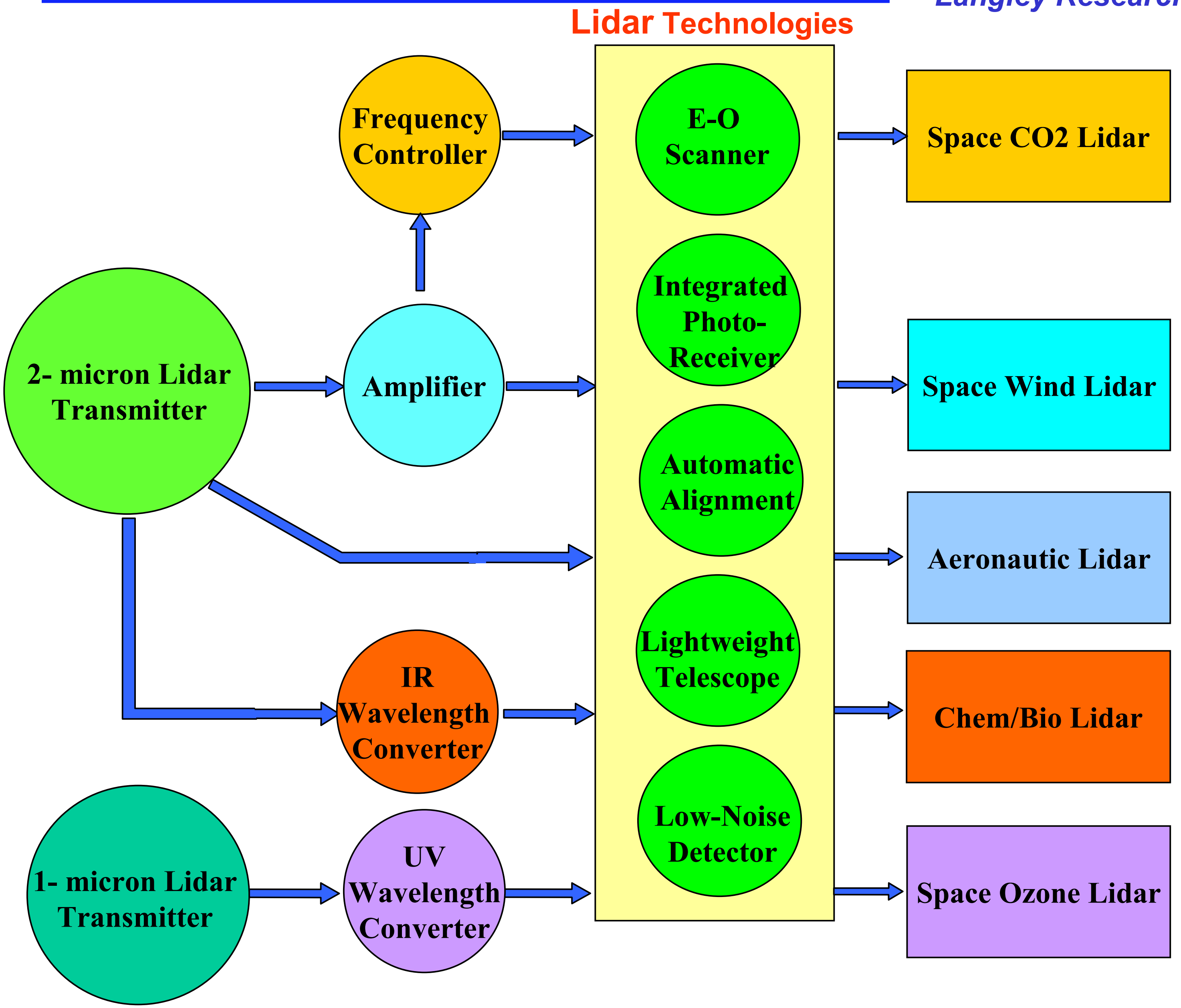


UV Laser Wavelength Conversion

Objectives

Develop wavelength conversion technology to convert a Nd:YAG laser into an efficient, high-energy, tunable, pulsed UV laser in the 250-320 nm range capable of space-based operation in future NASA missions including Differential Absorption Lidar (DIAL) measurement of O_3.

UV Laser Wavelength Conversion

Technical Goals/Requirements

- Wavelengths from 305-308 and 315-320 nm
- Energy – 500 mJ pulse energy
  - 200 mJ / Laser unit (3 units per mission)
- 10 Hz pulse repetition freq., double pulsed [10 Hz]
- Double pulse separation > 250 μs
- Pulse spectral width FWHM < 50 pm
- > 2% wall-plug efficiency
  - Nd:YAG (1 micron) wall –plug efficiency 10% - 20%
  - 1 micron to UV – conversion efficiency 10% - 20%

UV Laser Wavelength Conversion

FY02 Accomplishment

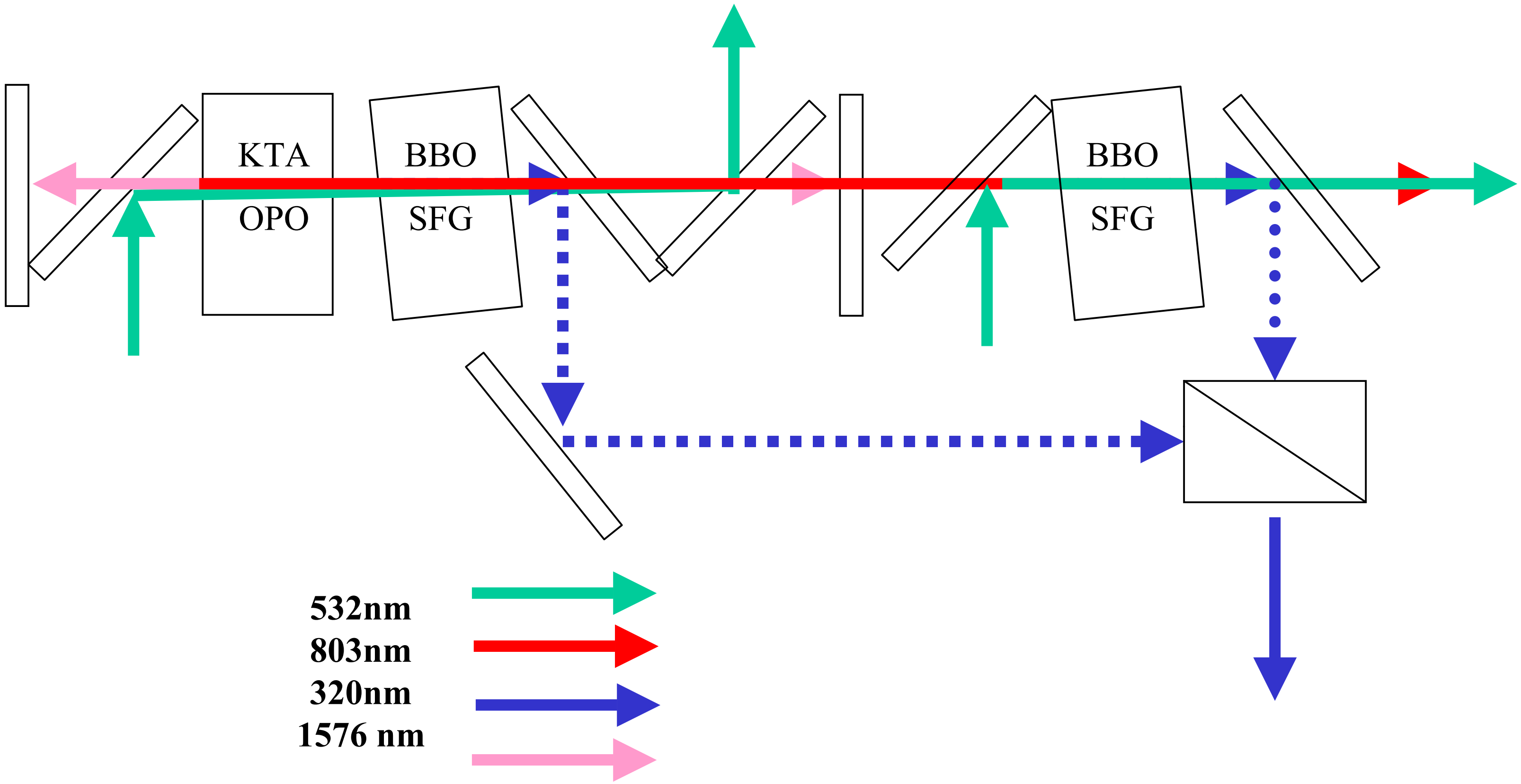
- Obtained 150 mJ @ 320 nm / 1 micron to UV conversion efficiency of 10%. (highest energy at this wavelength)
- Established collaboration with Sandia National Laboratory.
- Developed two designs for boosting the UV output to 200 mJ with a 20 % efficiency.

UV Laser Wavelength Conversion

Langley Research Center (LaRC)

Optical Parametric Oscillator / Sum Frequency Mixing

(*configuration used to obtain 10% from 1 micron to UV*)



2-Micron Detector Development

Technology Applications

Advanced 2 µm Avalanche Photodiodes (APDs) development technology will enhance the measurement capabilities for

- **CO_2 profiling and global winds**
- **wind Lidar**
- **aerosol and cloud profiling**
- **water vapor profiling**

2-Micron Detector Development

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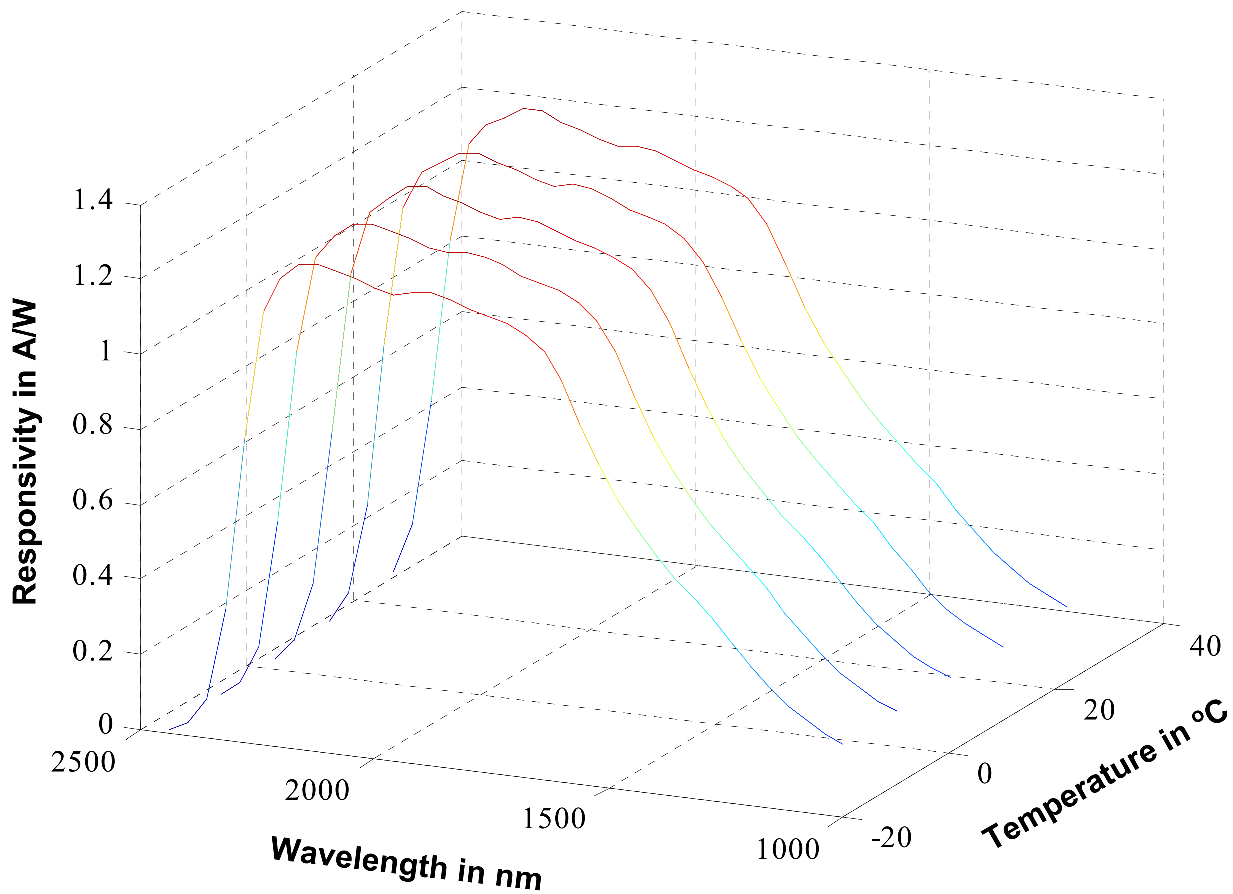
Responsivity Variation of InGaAs diode with Temperature



2-micron Transmitter Laser

Objective

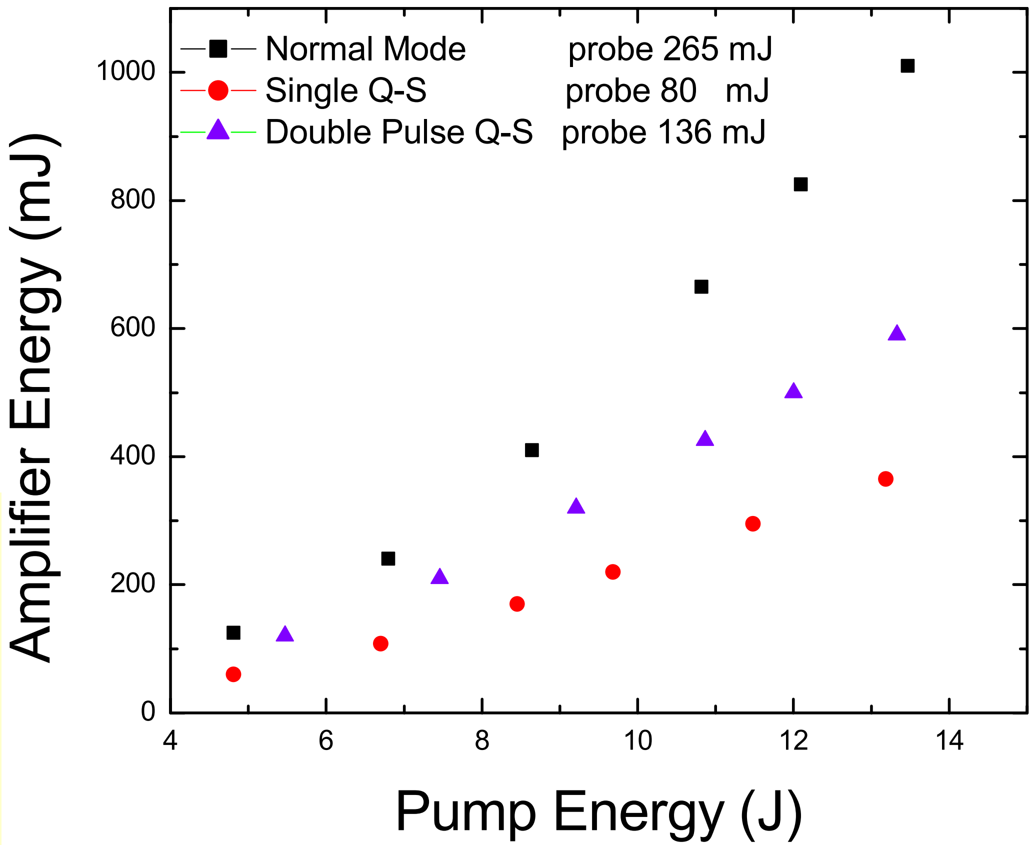
- Develop a conductive-cooled, diode-pumped 2-micron laser transmitter capable of generating J level energy at 10 Hz and 5% Wall Plug Efficiency

- Approach
  - ➢ Fully conductive-cooled laser head
  - ➢ Double pulse operation
  - ➢ New laser host materials

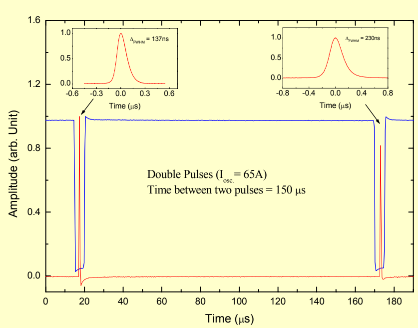
2-micron Transmitter Laser

Langley Research Center (LaRC)

600 mJ, double pulsed 2-micron laser



Ho:Tm laser double pulse operation



2-micron Transmitter Laser

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Partially conductively cooled laser

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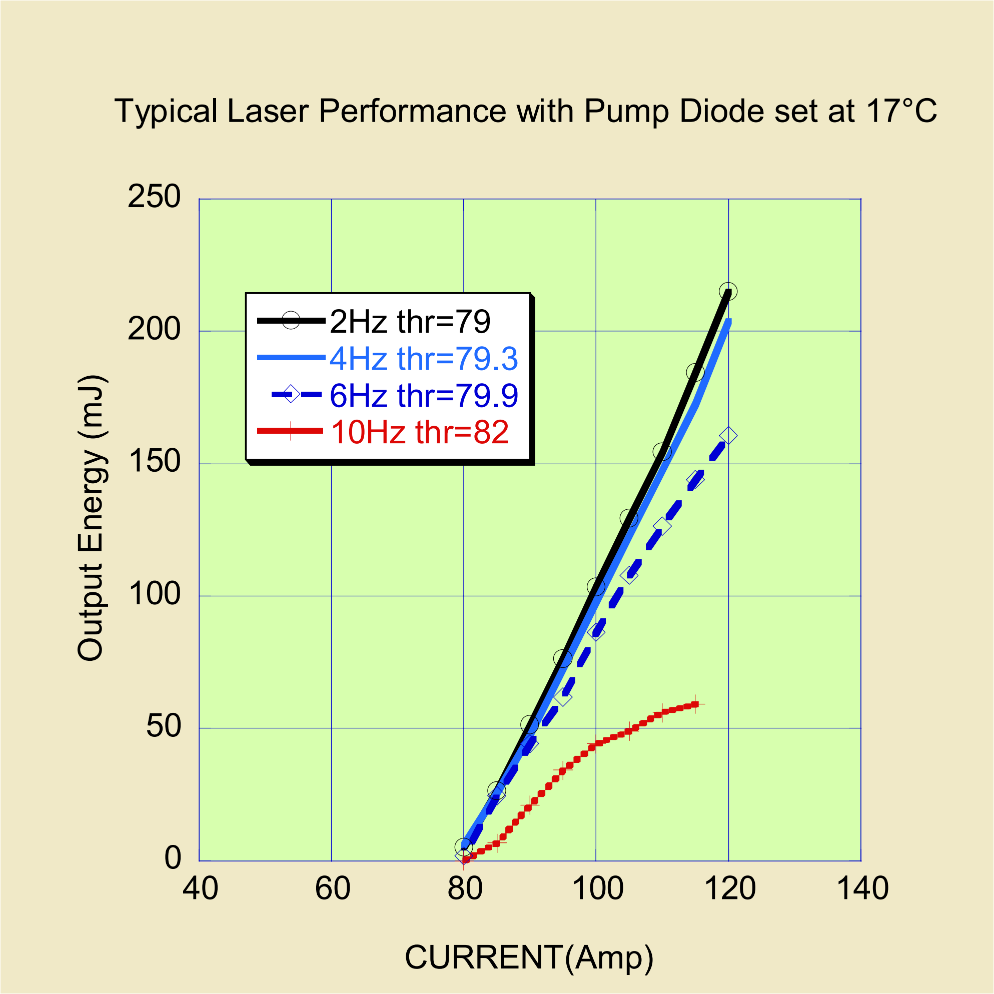
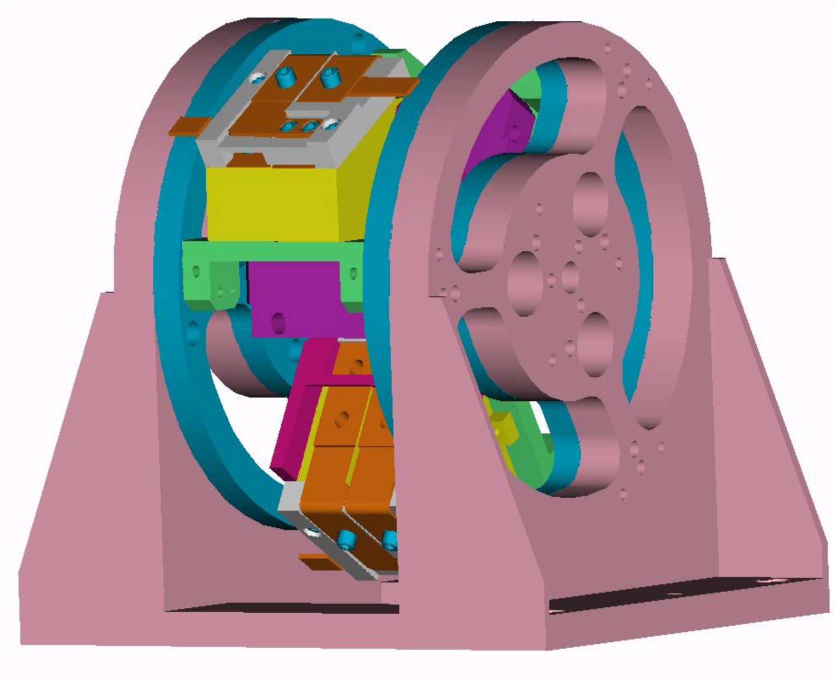
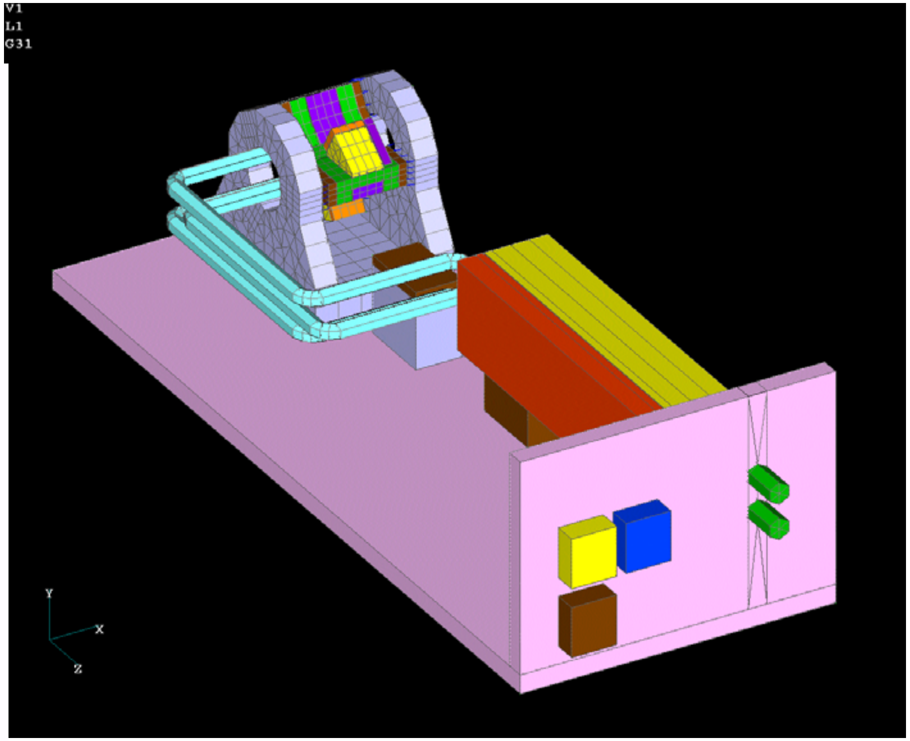


2-micron Transmitter Laser

Fully conductively cooled laser design





LASER DIODE TASK DESCRIPTION

Laser Diode Risk Reduction work is one of the three major tasks under the Lidar Risk Reduction Program established by NASA in FY'02.

(1. 1μm and 2μm Transmitter Lasers   2. Laser Diode   3. Wavelength Conversion)

Joint LaRC/GSFC Effort

- LaRC responsible for 792 nm wavelength Laser Diodes used for pumping 2-micron lasers
- GSFC responsible for 808 nm wavelength Laser Diodes used for pumping 1-micron lasers

Diode Laser

MOTIVATION

Laser Diode has been identified as a major risk area in deployment of Lidar instruments in space.

Laser Diode is a critical component of lidar transmitter required for pumping the laser crystals.

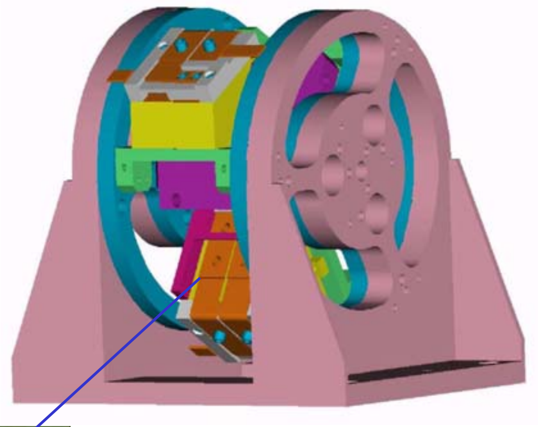
Laser Diodes Establish Instrument Lifetime

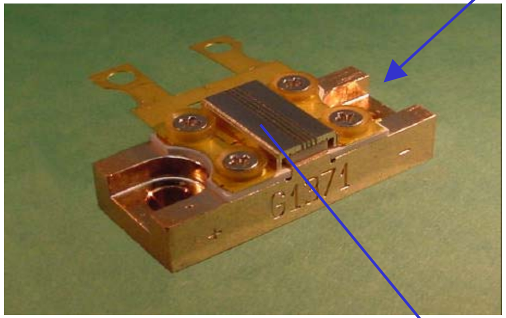
Major Issues:

- Limited reliability and lifetime
- Lack of statistical and analytical bases for performance and lifetime prediction
- Limited commercial availability

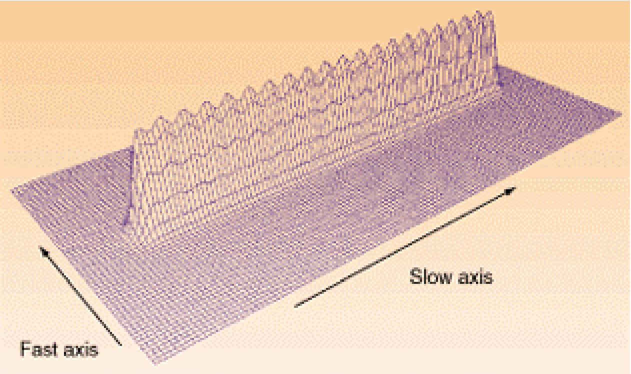
Diode Laser

Conductively-Cooled Laser Head

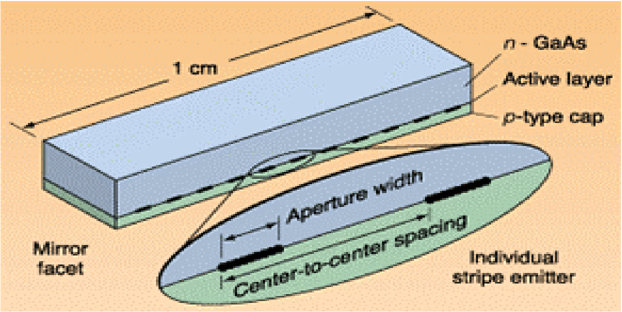




Laser Diode Array
(6-10 Bars)



Laser Diode Bar



Integrated Lens Array

Diode Laser

OBJECTIVES

- Develop a state-of-the-art characterization facility capable of:
  - Measuring Performance and Characteristic Parameters
  - Lifetime Testing
  - Environmental Testing
- Establish working relationships with laser diode manufacturers, researchers, and DOD users.
- Advance packaging, beam delivery, and fabrication technologies for improved efficiency and reliability.
- Advance LD theories and develop analytical models for predicting lifetime and allowing for a end-to-end lidar system design trade analyses.
- Establish a lifetime database to allow for formulating future lidar missions and performing meaningful cost and risk assessment analyses.

Diode Laser

792nm versus 808nm

792 nm Diode Lasers for Pumping 2μm Solid State Lasers

Accelerated test not possible

– Pulse width: > 1ms

– Activation Energy Statistical Data Unavailable

808 nm Diode Lasers for Pumping 1μm Solid State Lasers

Accelerated test possible

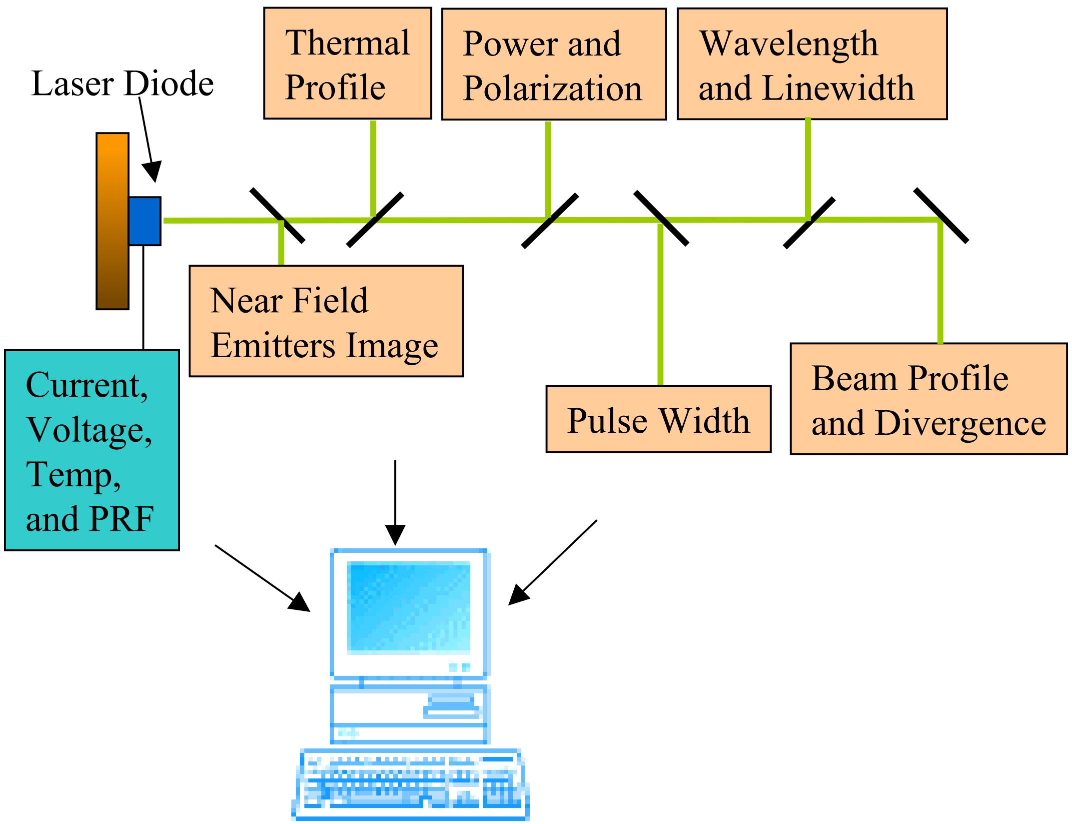
– Pulse width: ~ 200 μs

– Some Activation Energy Data May Be Available

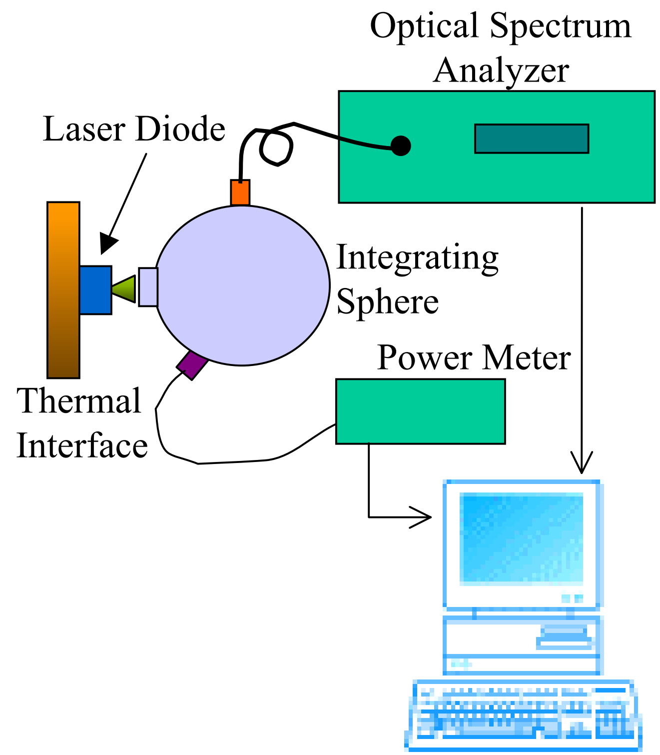
Diode Laser

Laser Diode Characterization Facility

LD Characterization



LD Lifetime Test



Coherent 2-μm Receiver Subsystem

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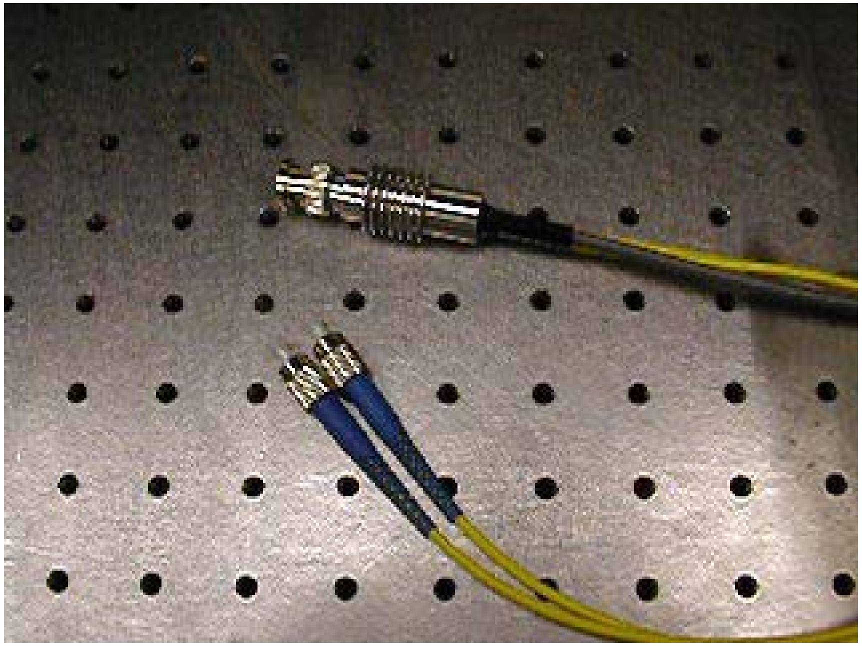
Technology Areas

- **Integrated Photoreceiver**
  - Integrating **detectors**, **processing electronic**, and **Tunable Semiconductor Local Oscillator Laser**, on a single chip for improved the lidar sensitivity and robustness.
- **Lightweight Lidar Telescope**
  - Advanced telescope technology addressing accommodation and cost issues associated with lidar instruments and **enables scanning** the laser beam by rotating the telescope.
- **Scanner**
  - **Non-mechanical electro-optical devices** to mitigate many technical issues associated with the scanning lidar instruments.
- **Automatic Optical Alignment**
  - **Active pixel array** technologies combined with **intelligent autonomous controller** to maintain instrument optical alignment and correct for distortions

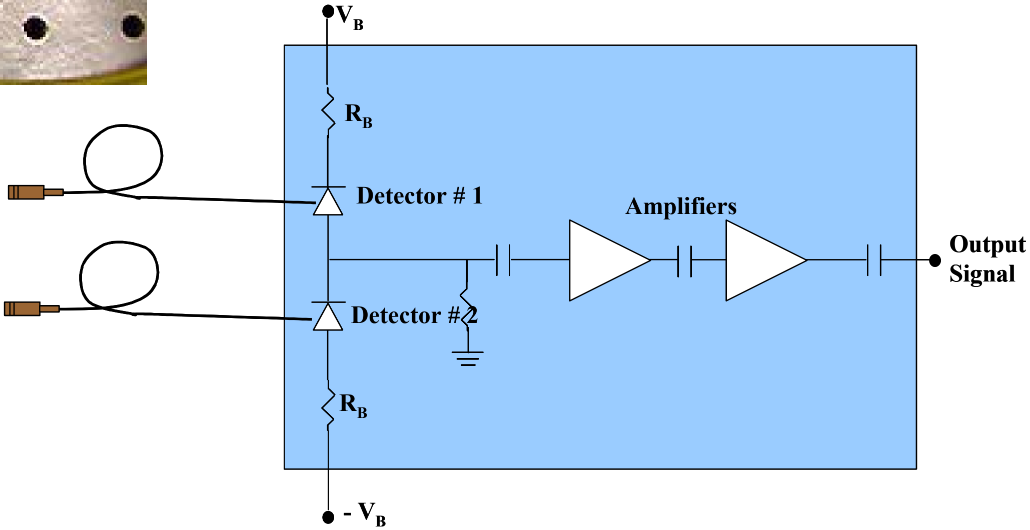
Current Activities

- **Multi-Chip Module (MCM) Integrated Detector/Preamplifier**
- **Coherent Lidar Receiver Characterization Setup**
- **Lightweight lidar telescope**
  - **Lightweight Optics using Metal Alloy Shells and Surfaces (LOMASS)**
  - **Experimenting with a novel "Plasma Spraying" Process for producing mirror shells**

MCM Integrated Detector/Preamplifier



Bandwidth >> 1GHz Bandwidth



Coherent Lidar Receiver Characterization Facility

Langley Research Center (LaRC)