Status of 2 Micron Laser Technology Program
Mark Storm, NASA Langley
October 17, 1990

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This paper describes the status of 2 micron lasers for windshear detection. Theoretical atmospheric and instrument system studies by Russell Tang and Rowland Bowles have demonstrated that the 2.1 micron Ho:YAG lasers can effectively measure windspeeds in both wet and dry conditions with accuracies of 1 m/sec. Two microns laser transmitter technology looks very promising in the near future but several technical questions remain. Ho:YAG laser would be small, compact and efficient requiring little or no maintenance. Since the Ho:YAG laser is diode laser pumped and has no moving part, the lifetime of this laser should be directly related to the diode laser lifetimes which can perform in excess of 10,000 hours. Ho:YAG efficiencies of 3-12% are expected but laser demonstrations confirming the ability to Q-switch this laser are required. Coherent laser operation has been demonstrated for both CW and Q-switched lasers.
Status of 2-Micron Laser Technology Program

Presented to the:


October 17, 1990

Mark E. Storm
STX/NASA Langley
OUTLINE

1.0 Introduction
   - Requirements for Coherent Lidar
   - Laser approach

2.0 Single-Frequency Ho:Tm:YAG
   - Laser performance
   - Frequency Tuning
   - Heterodyne detection

3.0 2-micron laser issues:
   - Efficiency Considerations
   - Crystal Spectroscopy

4.0 Injection Seeding Experiment
   - Coherent Technology Results

5.0 Summary and Prospects for a Windshear Transmitter.
Laser Requirements for a Windshear Transmitter

Single-Frequency, Q-switched

Laser energy: 5-10 mJ

Repetition rate: 150-300 Hz

Laser Bandwidth: 1.0 MHz

Compact, Efficient, Reliable- 200+ hours of maintenance free operation.
GaAlAs diode laser 785 nm

GaAlAs diode laser 785 nm

2.1 micron slave oscillator (pulsed)

2.1 micron amplifier (pulsed)

WINDSHEAR TRANSMITTER
RESEARCH GOAL:
SINGLE-MODE LASER FOR INJECTION LOCKING OF Q-SWITCHED, 2-MICRON LASER.

APPROACH:
FABRY-PEROT
PLANO-PLANO
DIODE-LASER PUMPED

ACHIEVEMENTS:
• SINGLE-MODE LASING OF HO:TM:YAG
• 10 mW optical power at 2.091 microns
• 68% slope efficiency, QE. = 1.8, 4% optical-optical
• 31 GHz [4.5 Angstroms] Temperature Tuning
• Demonstrated Heterodyne Detection
785 NM
INPUT SPECTRUM OF LASER DIODE

2.1 MICRONS
OUTPUT LASING SPECTRUM

INPUT ELECTRICAL POWER

2.1 MICRON LASER POWER

SINGLE-FREQUENCY HO:TM:YAG LASER
SINGLE FREQUENCY Ho:TM:YAG

Fig. 1. Multimode lasing spectra of 2.5-mm thick Planoconvex Ho:TM:YAG at two different laser output powers.

Fig. 2. Fluorescence spectra and single-longitudinal-mode lasing spectrum of a 1-mm thick Ho:TM:YAG.

MULTIMODE LASING

SINGLE MODE LASING
SINGLE FREQUENCY Ho:TM:YAG

FREQUENCY VS. TEMPERATURE
Ho:TM:YAG

CRYSTAL TEMPERATURE [CELSIUS]

TEMPERATURE TUNING

SELF-HETERODYNE
BEAT FREQUENCY

HETERODYNE SIGNAL
Single-Frequency Laser Power

![Graph showing absorption power vs. absorbed laser power with various temperature conditions and absorber characteristics.]

Ho:YAG 750 microns thick [ilat/flat, HR/99.0]

-31 C: 68% slope
-22 C: 38% slope
-1.65 C: 35% slope
### Gaussian Fit Data

<table>
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<tr>
<th>Vert</th>
<th>Horiz</th>
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<tr>
<td>Correlation Coeff.</td>
<td>0.939</td>
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<td>Peak Position</td>
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<td>Mean Dia. 0 l/e² (nm)</td>
<td>5.234</td>
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<tr>
<td>Percent of Peak</td>
<td>75.582</td>
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### Profile Location

- Profile Location:
  - X (Vert) = 215
  - Y (Horiz) = 125

![Graph](image)

**LEFT MOUSE BUTTON draws profile.**

**SINGLE-MODE SPACIAL PROFILE: TEM₀₀**
2 MICRON LASER EFFICIENCY

\[ \eta_{\text{laser}} = \eta_{\text{diode laser}} \times \eta_{\text{absorption}} \times \eta_{\text{energy transfer}} \times \eta_{Q\text{-switch optical extraction}} \]

DIODE LASER \rightarrow Ho:YAG \rightarrow \text{TO TELESCOPE}

40\% \rightarrow ? - 70\%
<table>
<thead>
<tr>
<th></th>
<th>Present</th>
<th>Projected</th>
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<tr>
<td>Diode Laser</td>
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<td>.50</td>
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<tr>
<td>Optical Coupling Effic.</td>
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<td>.90</td>
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<tr>
<td>Absorption Effic.</td>
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<tr>
<td>Energy Transfer</td>
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<tr>
<td>Optical Extraction</td>
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<td>.60</td>
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<td>Q-switching</td>
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<td>.80</td>
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<tr>
<td>Total Efficiency</td>
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</tbody>
</table>
Multi-mode Lasing Spectrum

295 K Fluorescence

Q-switched Lasing Spectrum
Ho:Tm:YAG

Intensity

Wavelength [Angstroms]
2-Micron Accomplishments for Coherent Transmitter

-CW, single-frequency demonstrated.  
Storm, Kane

-Pulsed, single frequency demonstrated in flashlamp-pumped, injection control experiment.  
Henderson

-Heterodyne detection demonstrated in self-heterodyne experiment.  
Storm

Future Demonstrations Necessary for Windshear Laser

-Efficient energy scaling to 10 mJ level for Q-switched operation.  
-Diode laser pumped  
-100 Hz min. rep. rate
LASER DIODE PUMPED REMOTE SENSING DEVELOPMENT

Tm:Ho laser

Rare earth eye-safe laser

Fiber optic transmission line

Cr doped flashlamp pumped laser

Laser diode array bank
OUTPUT VS. ABSORBED ENERGY FOR ROOM TEMPERATURE 
Cr:GSAG (Gd3 Sc2 Al3 O12) PUMPED RARE EARTH LASER

w/98% Reflective Mirror
\[ y = 0.336(x-5.271) \]

w/95% Reflective Mirror
\[ y = 0.263(x-14.116) \]