Lidar at Adelaide

CTA Workshop, 30 Sept 2013

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SUB CRUCE LUMEN

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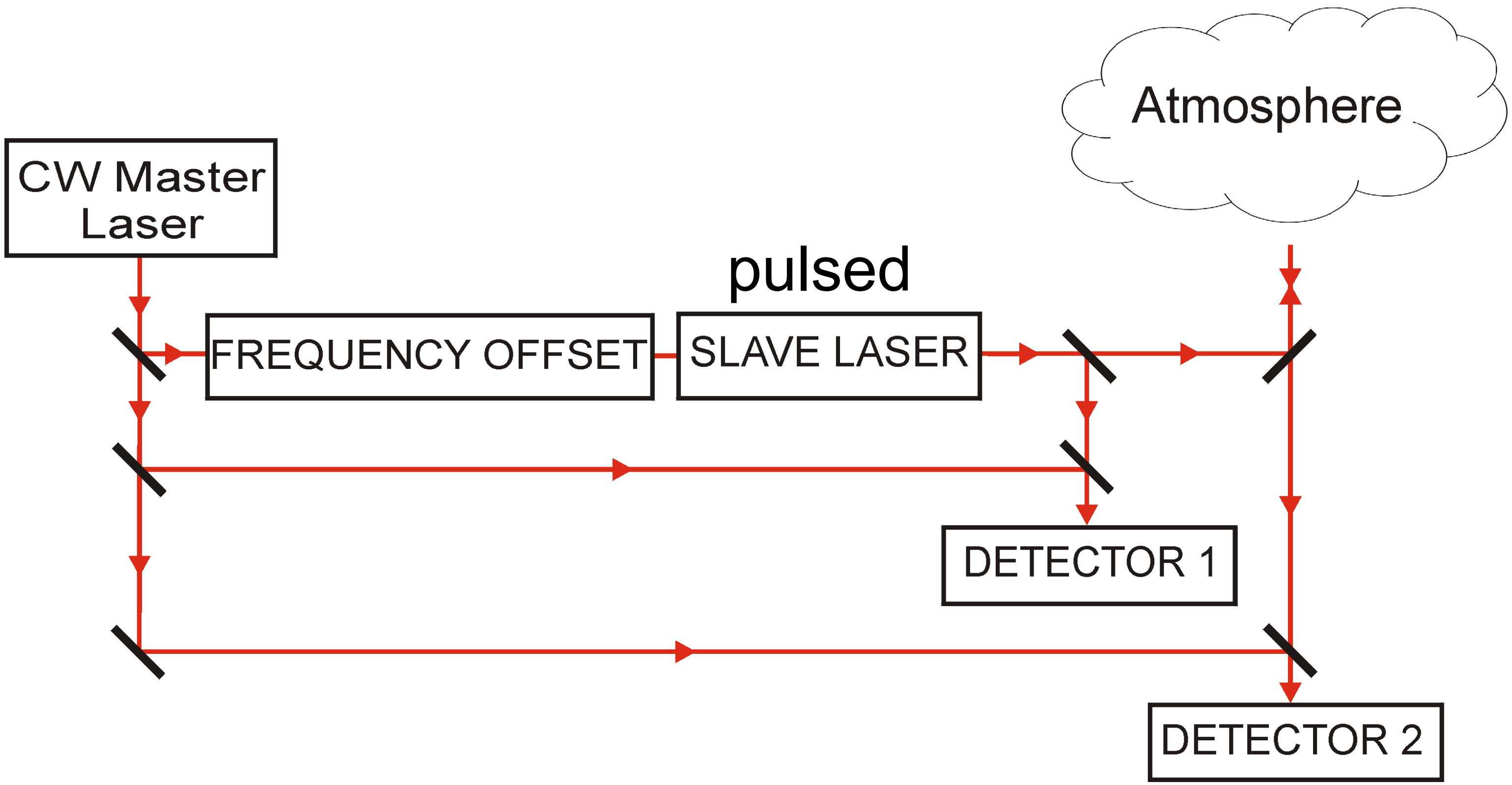
People

Nick Chang, Myles Clark, Alex Dinovitser, Murray Hamilton, Lachlan Harris, Matthew Heintze, David Hosken, Andrew MacKinnon, Jesper Munch, David Ottaway, Iain Reid, Tom Rutten, Nikita Simakov, Liam Twigger, Peter Veitch, Bob Vincent, …

Coherent Laser Radar System



Initally: diode-pumped Er:Yb:glass (0.5 mJ, 2 Hz, 1535 nm)

Now: diode-pumped Er:YAG (10-20 mJ, 1 kHz, 1645 nm)

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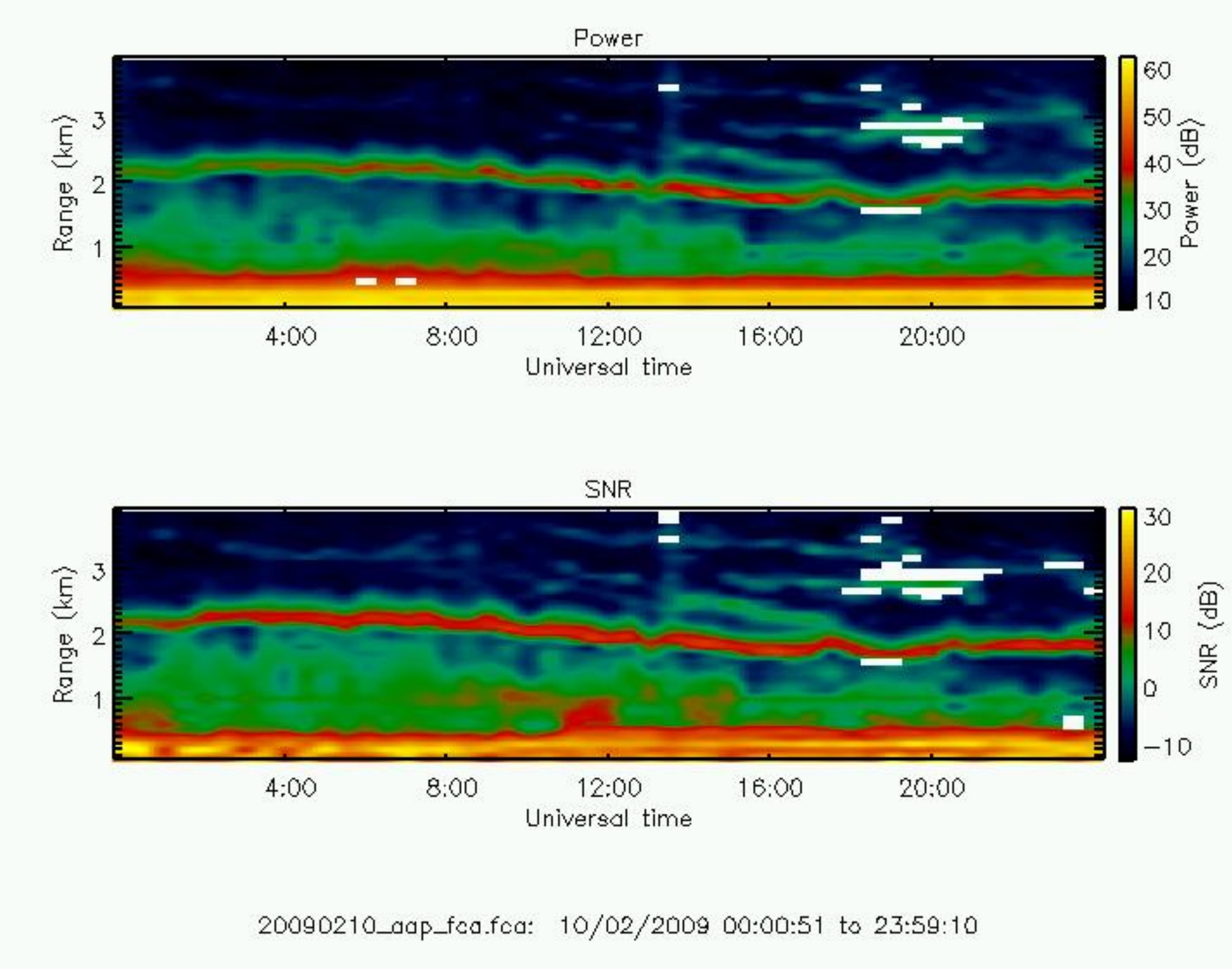
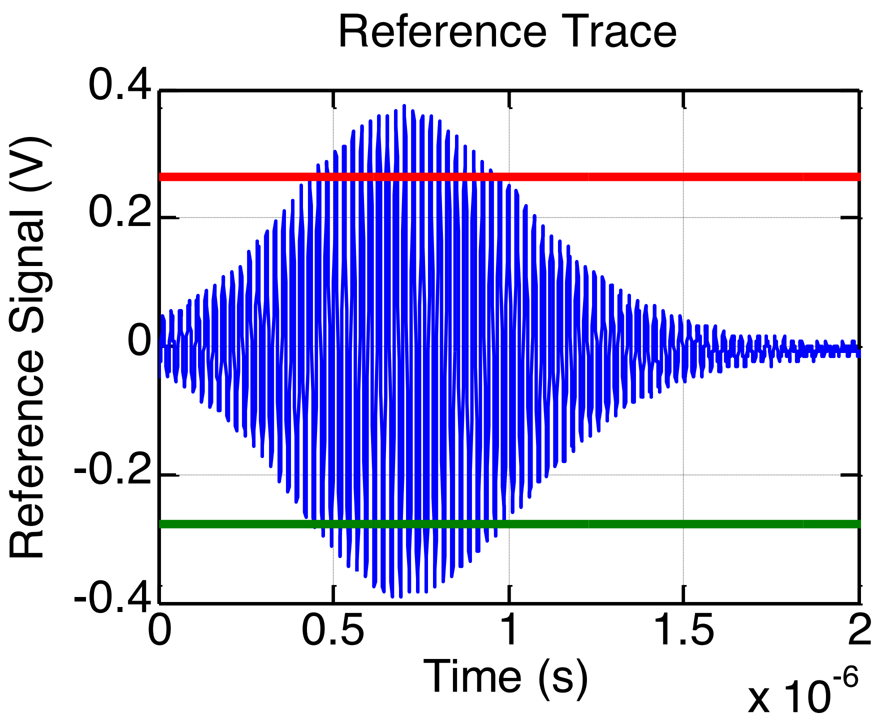
An example of a wind-speed measurement

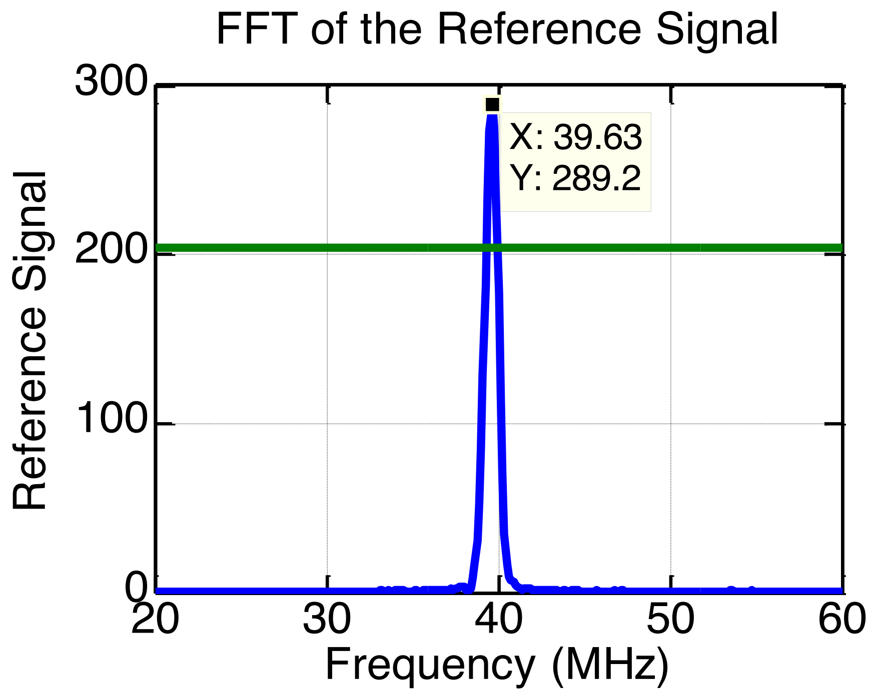
- Er:Yb:glass slave laser
- Pulse energy: 0.5 mJ
- Direction: 12º from zenith
- 500-sample range gates (500 ns duration, 75% overlap)
- 3500 sample zero padding → 0.25 MHz bins
- Single shot (no averaging)
- Spectra for range gates in which no signal usually not shown
- Statistically significant peaks in spectra are labeled

Adelaide Airport Boundary Layer Radar



Reference pulse





Pulse duration ~ 500 ns → range resolution ~ 75 m

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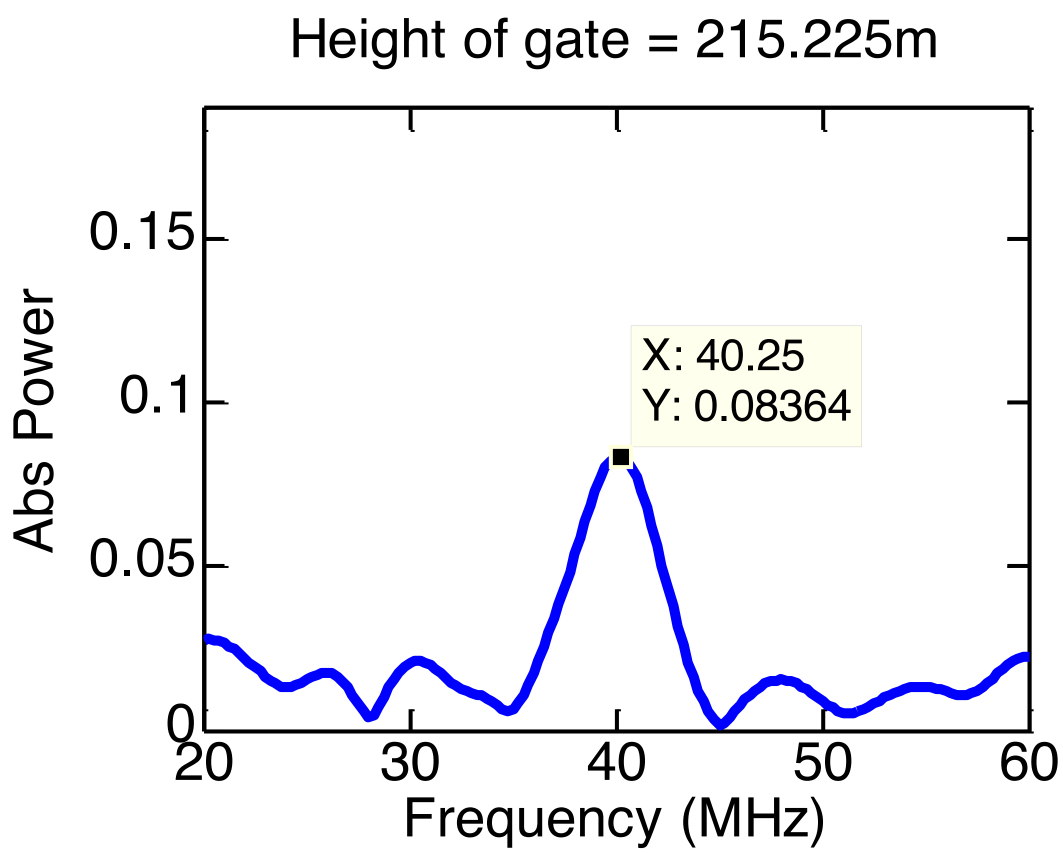
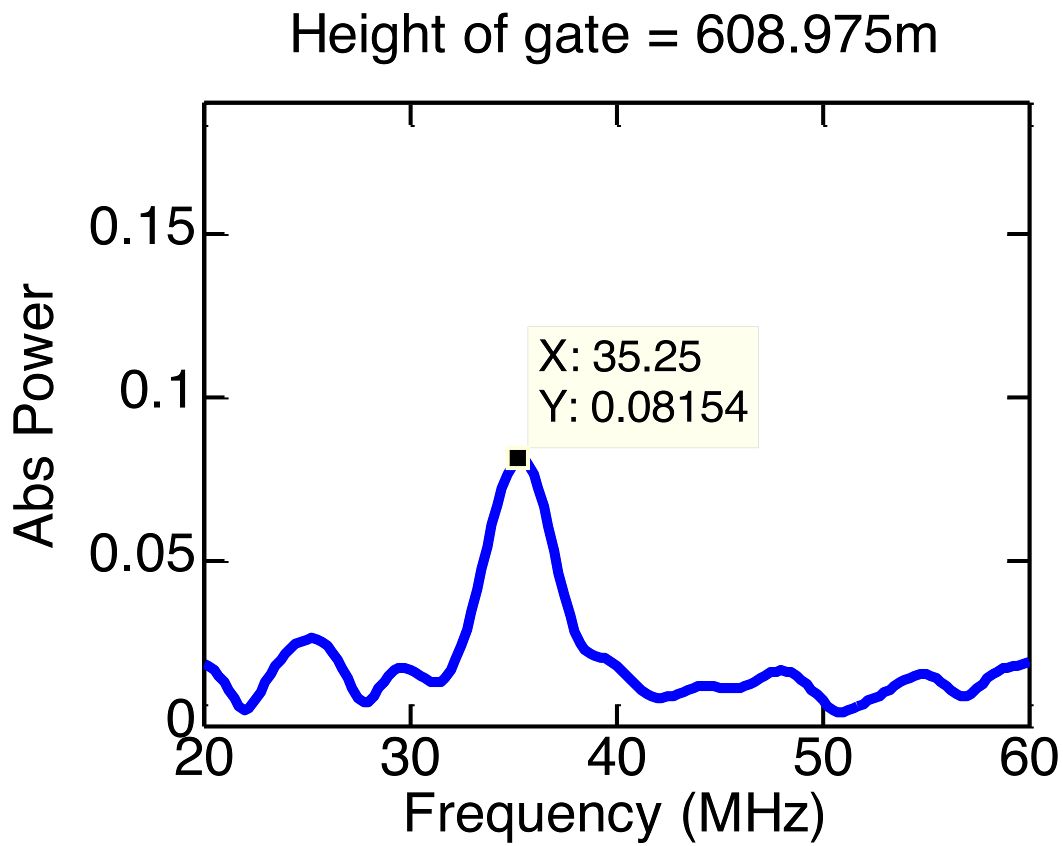
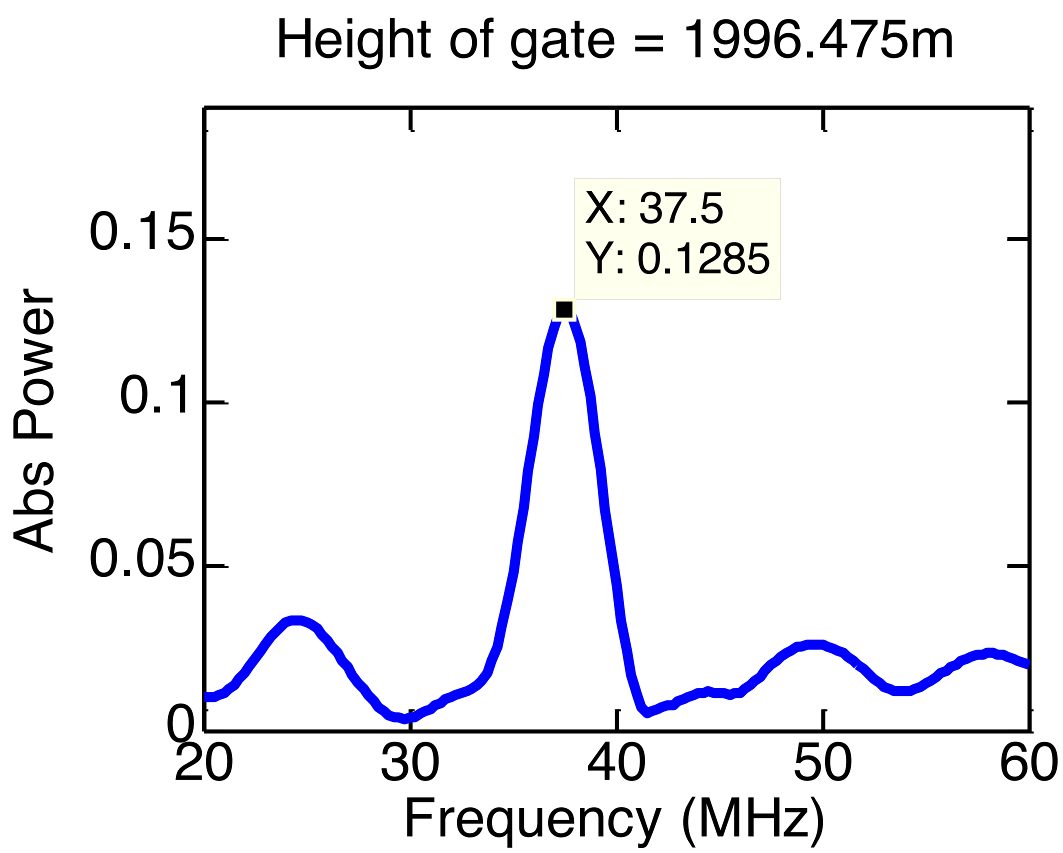
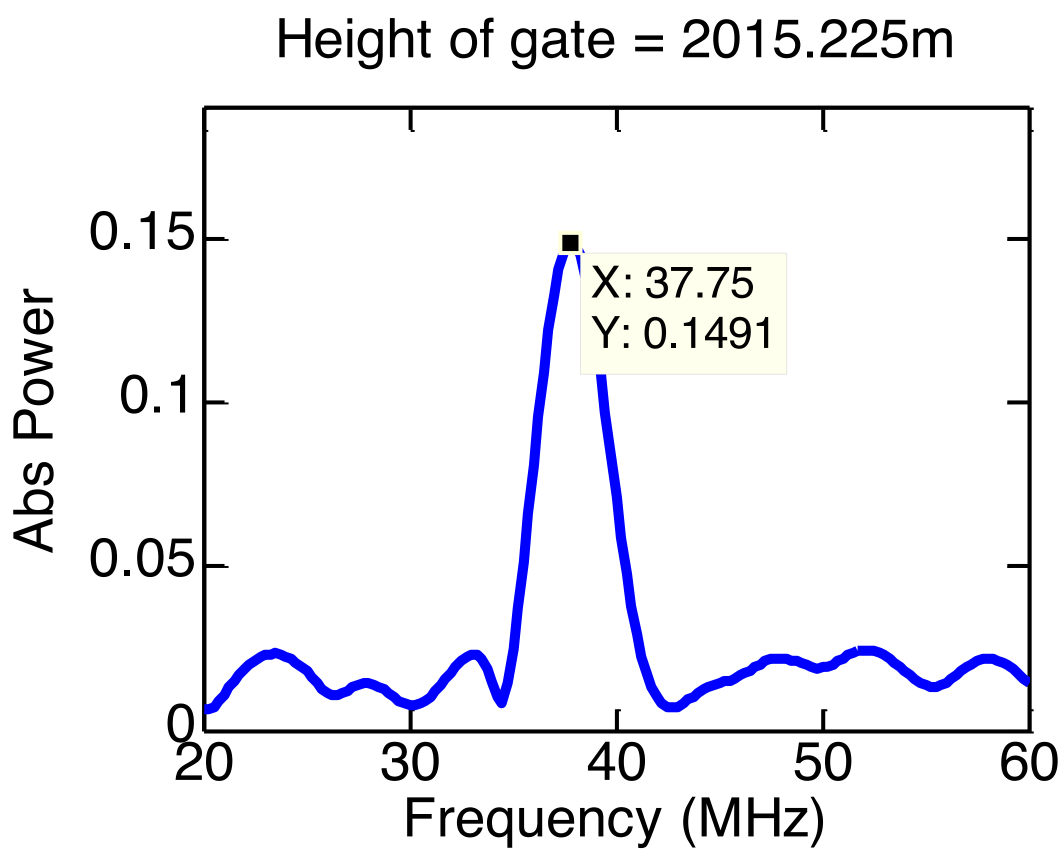

Height of gate = 215.225m
X: 40.25
Y: 0.08364
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

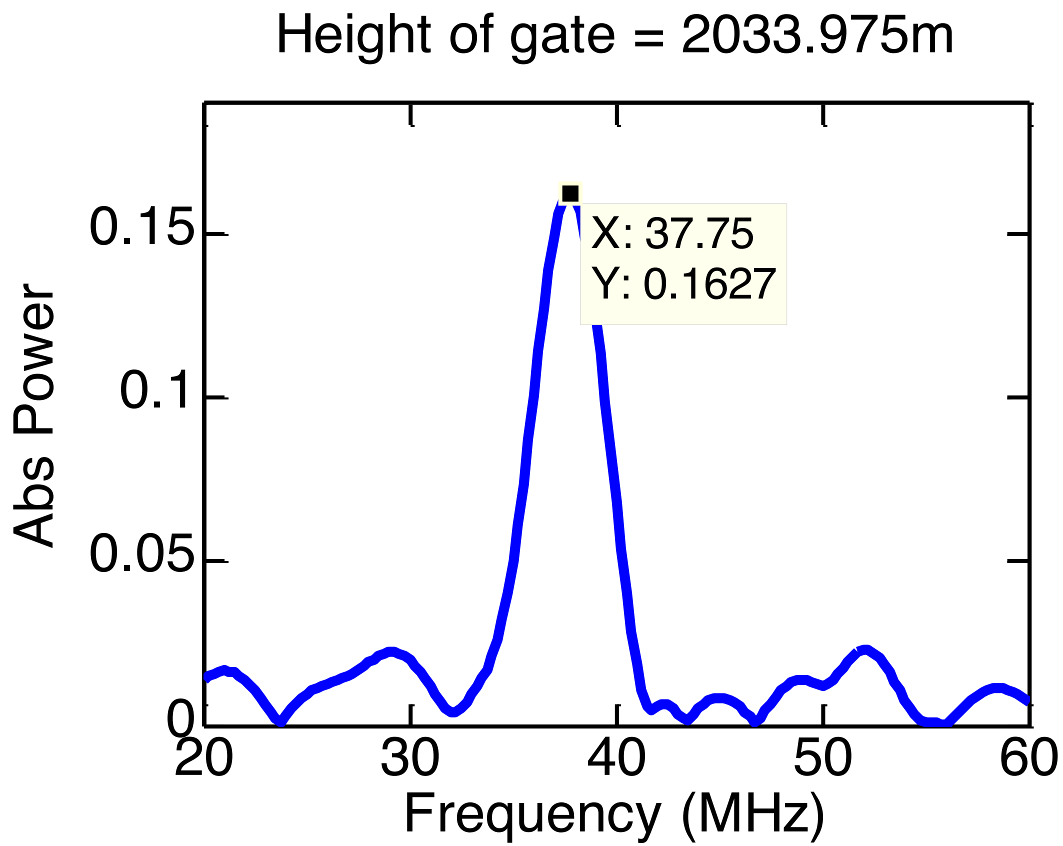


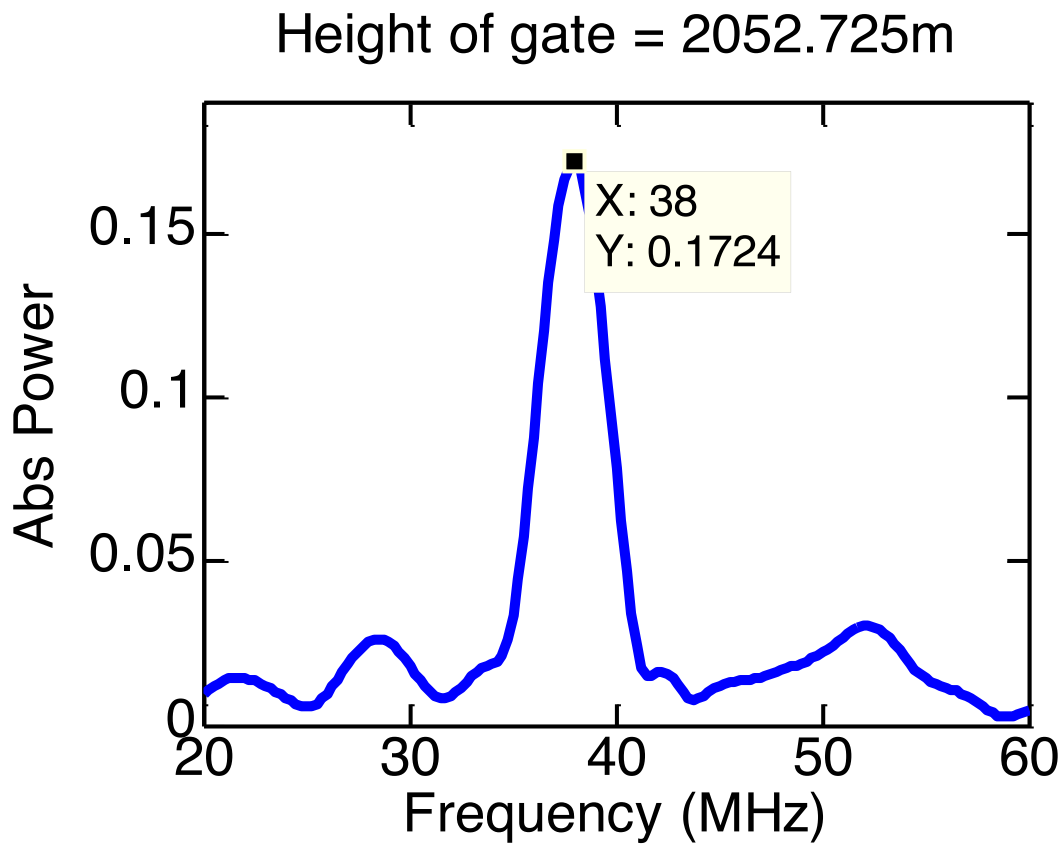
Height of gate = 608.975m
X: 35.25
Y: 0.08154
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

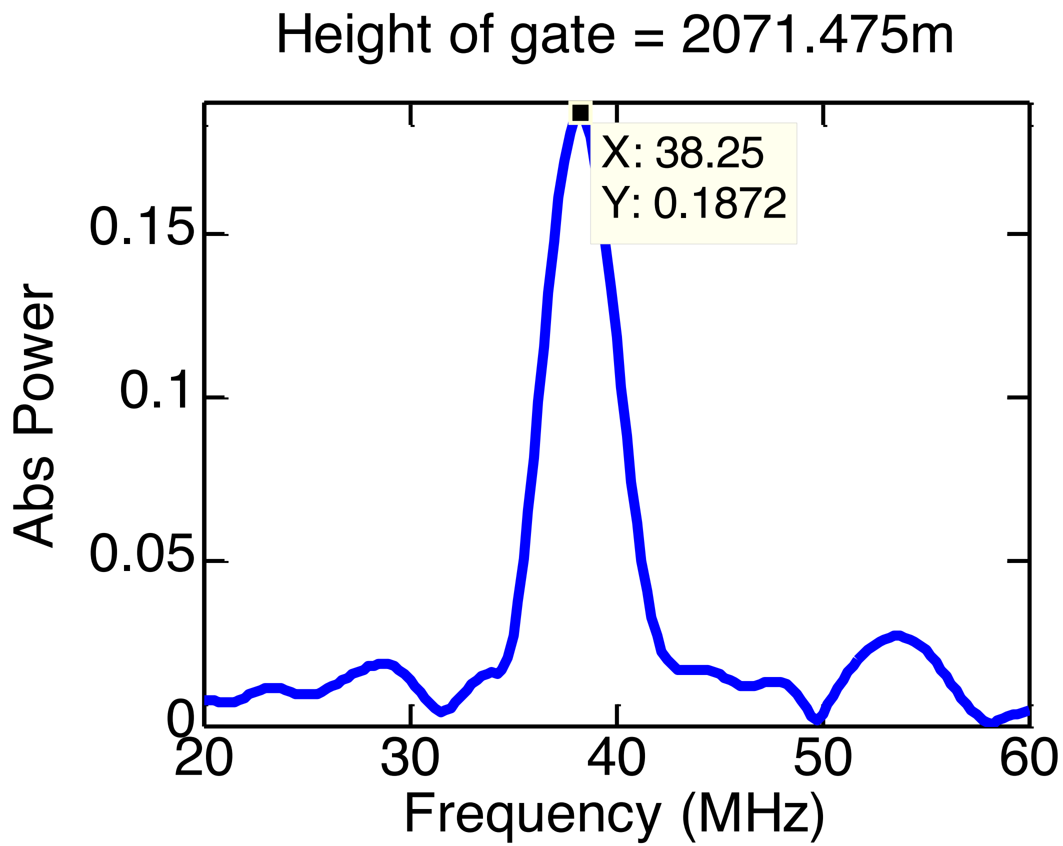

Height of gate = 1996.475m
X: 37.5
Y: 0.1285
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

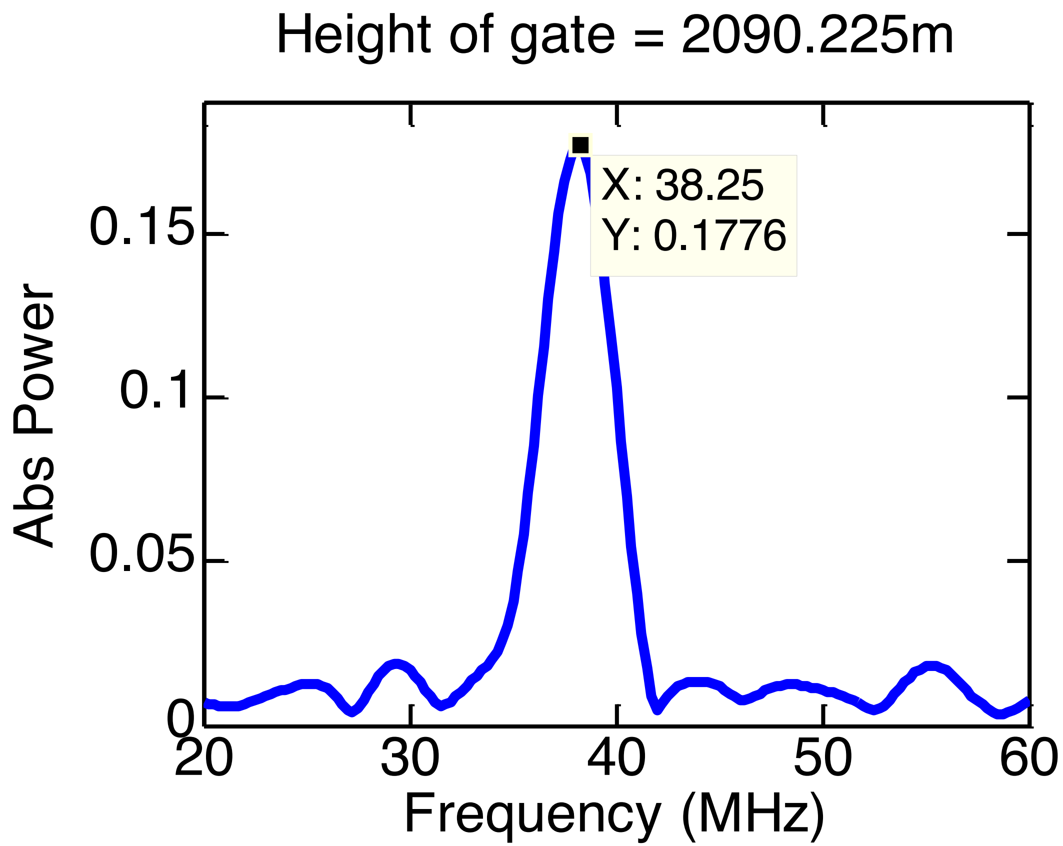


Height of gate = 2015.225m
X: 37.75
Y: 0.1491
0.15
0.1
0.05
0
20
30
40
50
60
Abs Power
Frequency (MHz)

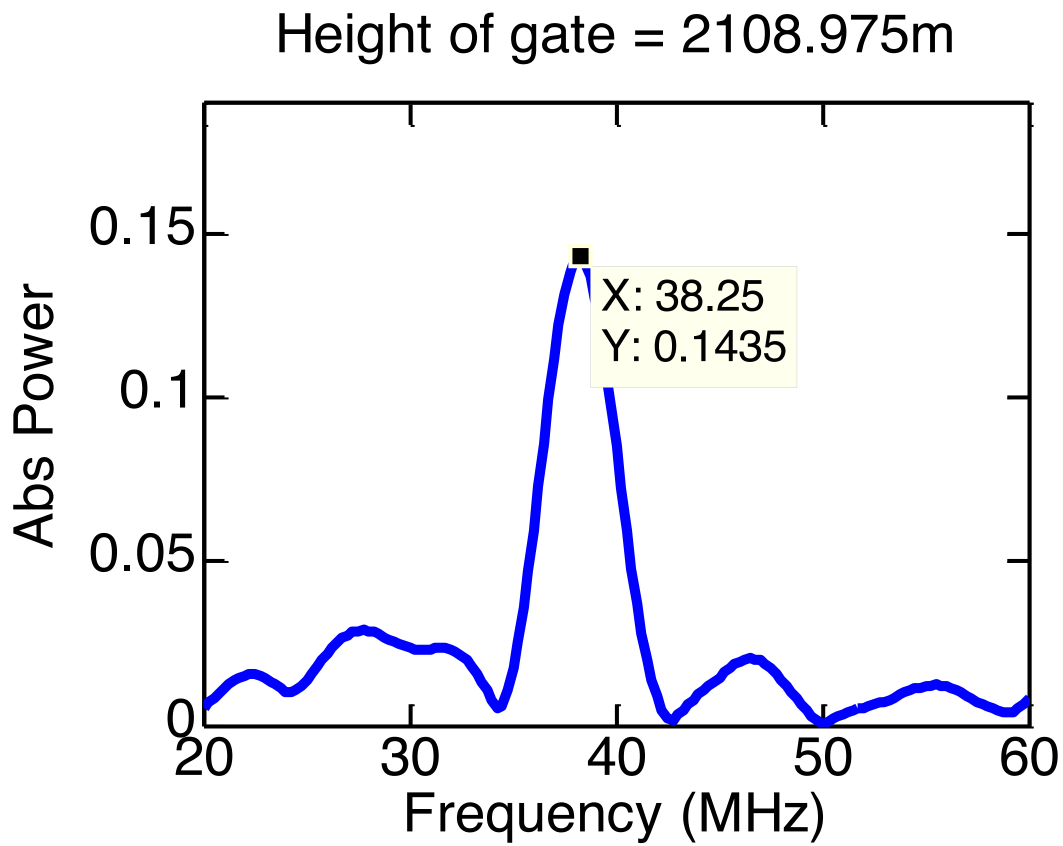

Height of gate = 2033.975m
X: 37.75
Y: 0.1627
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

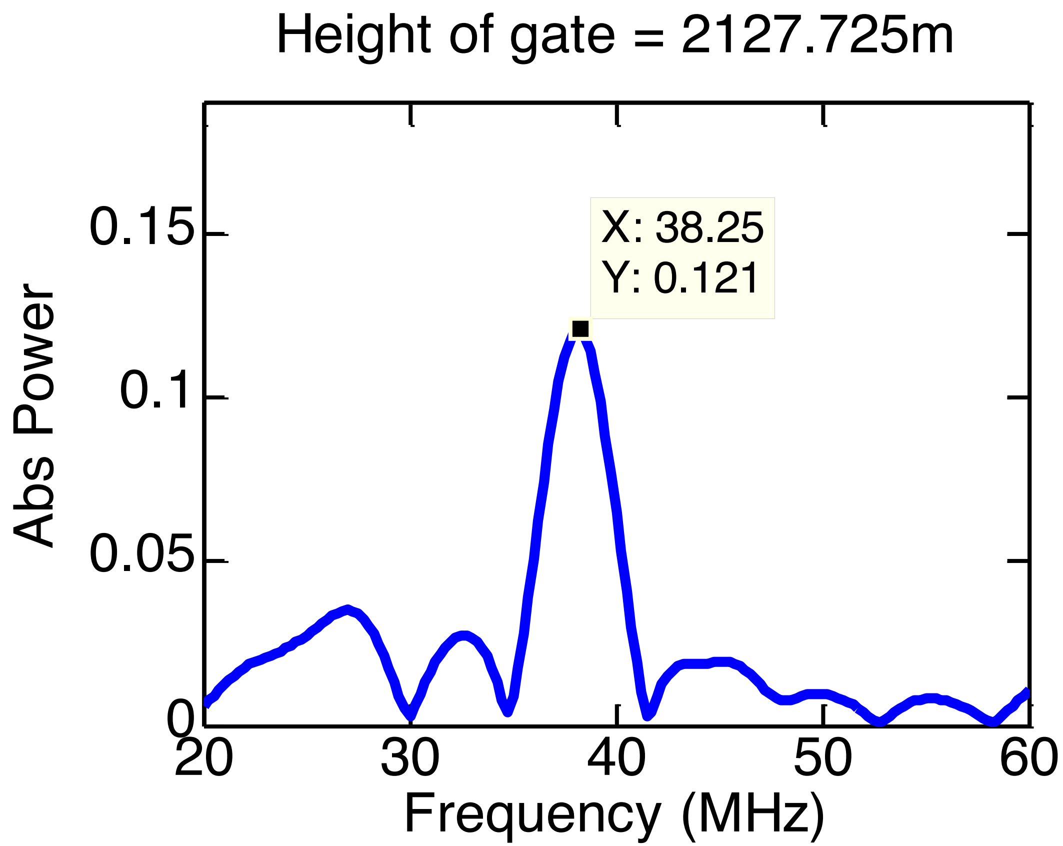

Height of gate = 2052.725m
X: 38
Y: 0.1724
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

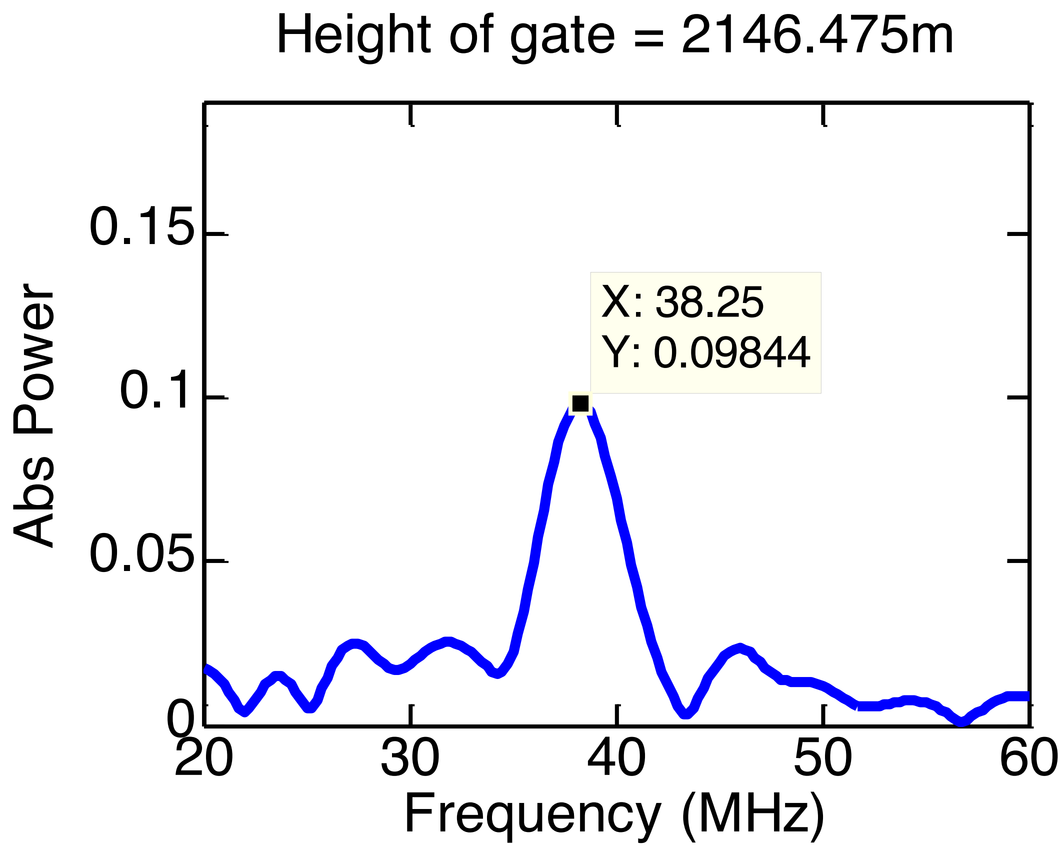

Height of gate = 2071.475m
X: 38.25
Y: 0.1872
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

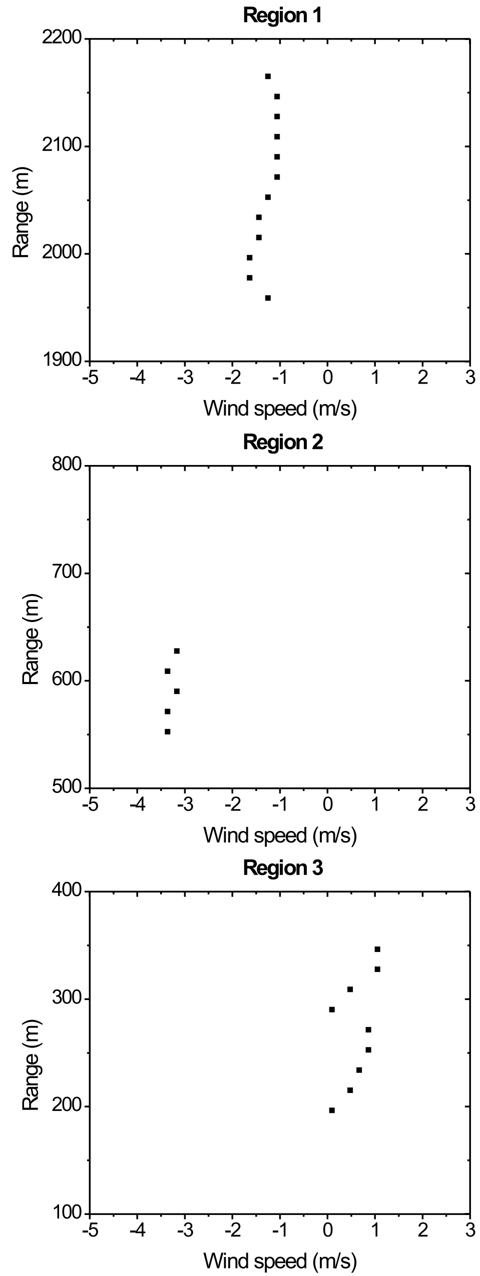


Height of gate = 2090.225m
X: 38.25
Y: 0.1776
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)


Height of gate = 2108.975m
X: 38.25
Y: 0.1435
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)

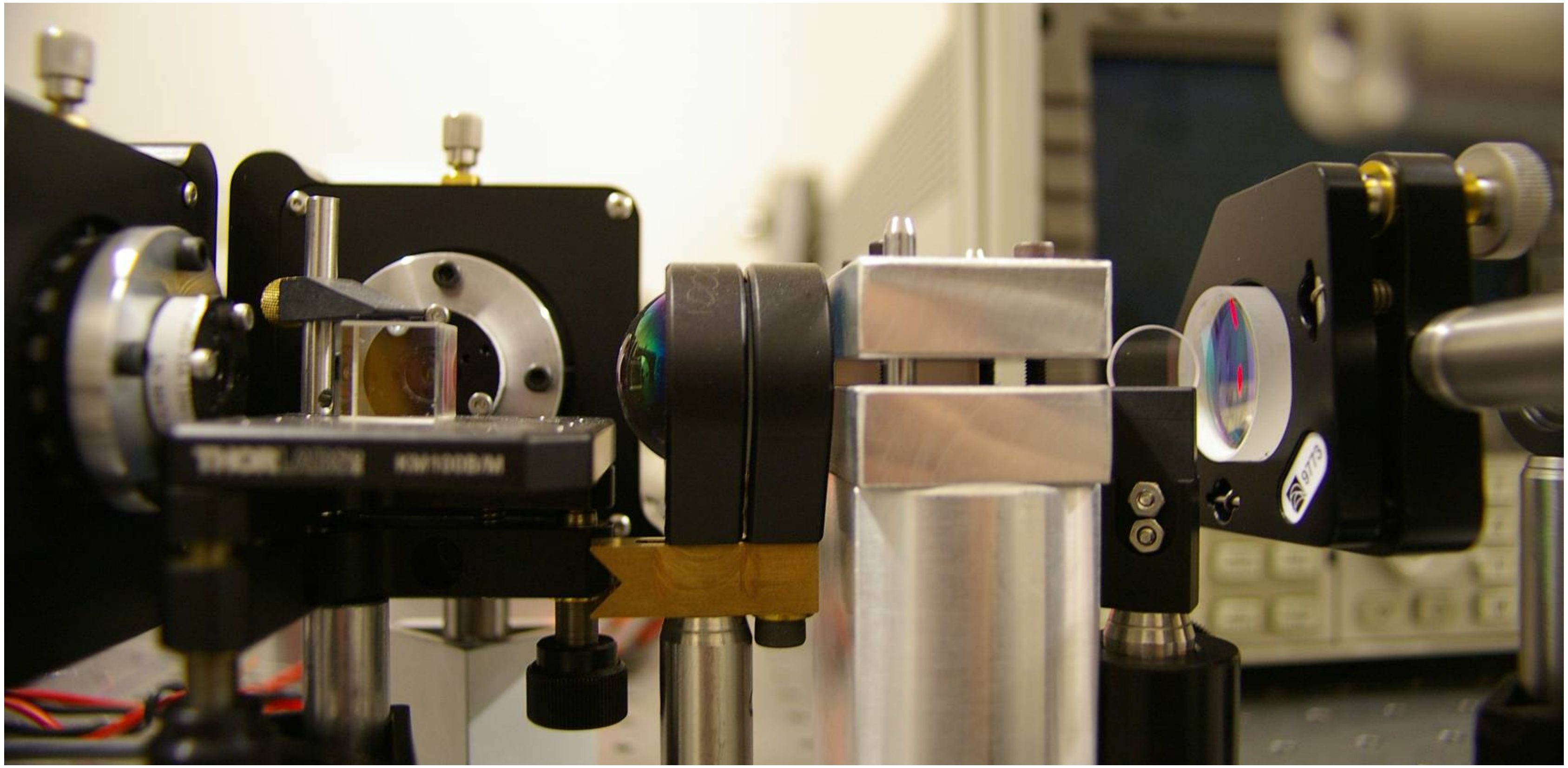

Height of gate = 2127.725m
X: 38.25
Y: 0.121
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)


Height of gate = 2146.475m
X: 38.25
Y: 0.09844
Abs Power
0.15
0.1
0.05
0
20
30
40
50
60
Frequency (MHz)



Upper limit for instrument-limited shot-to-shot reproducibility: 0.4 ms^{-1}

Er:YAG master laser



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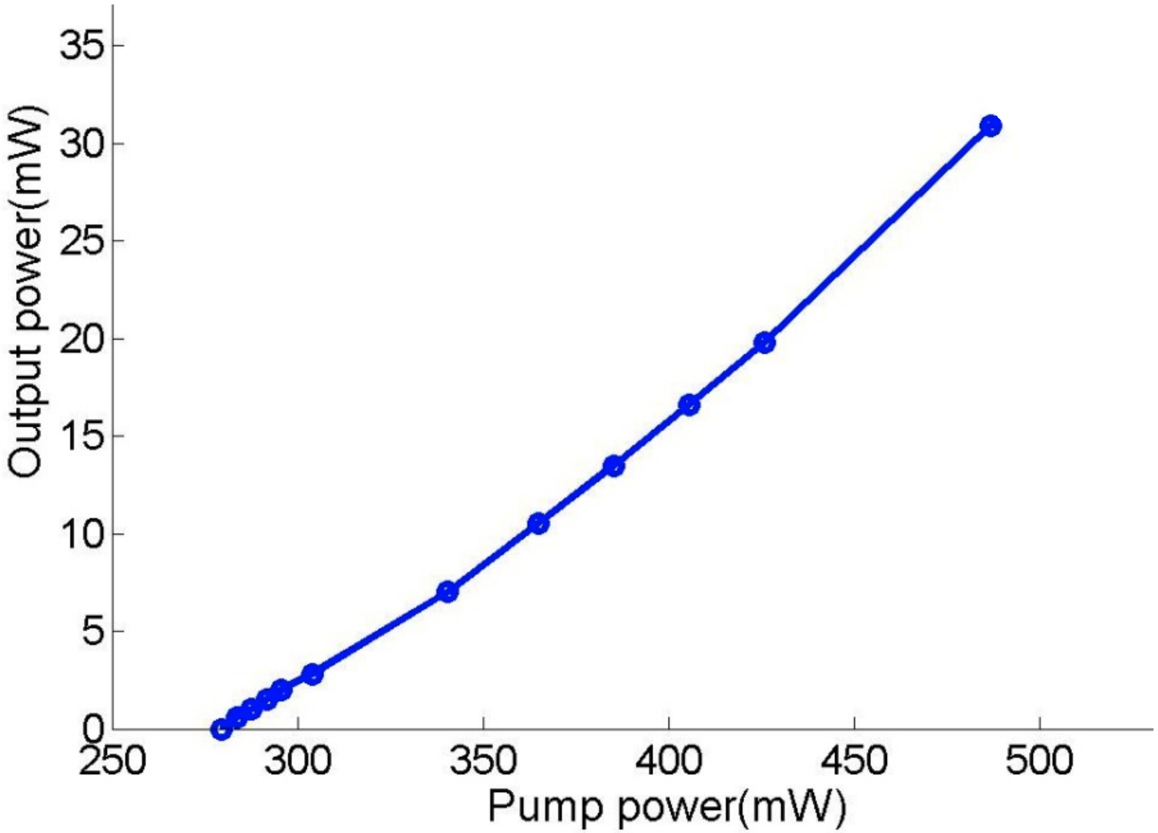
Single frequency, polarized output at 1645nm



line-width < 12 kHz

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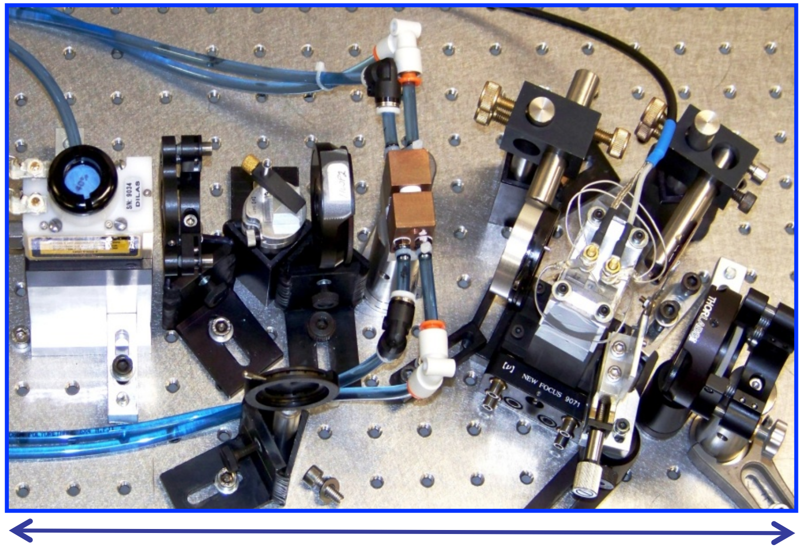
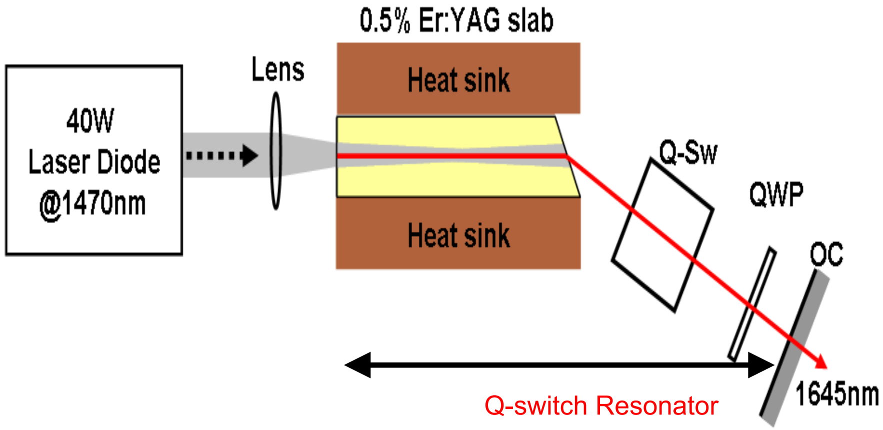
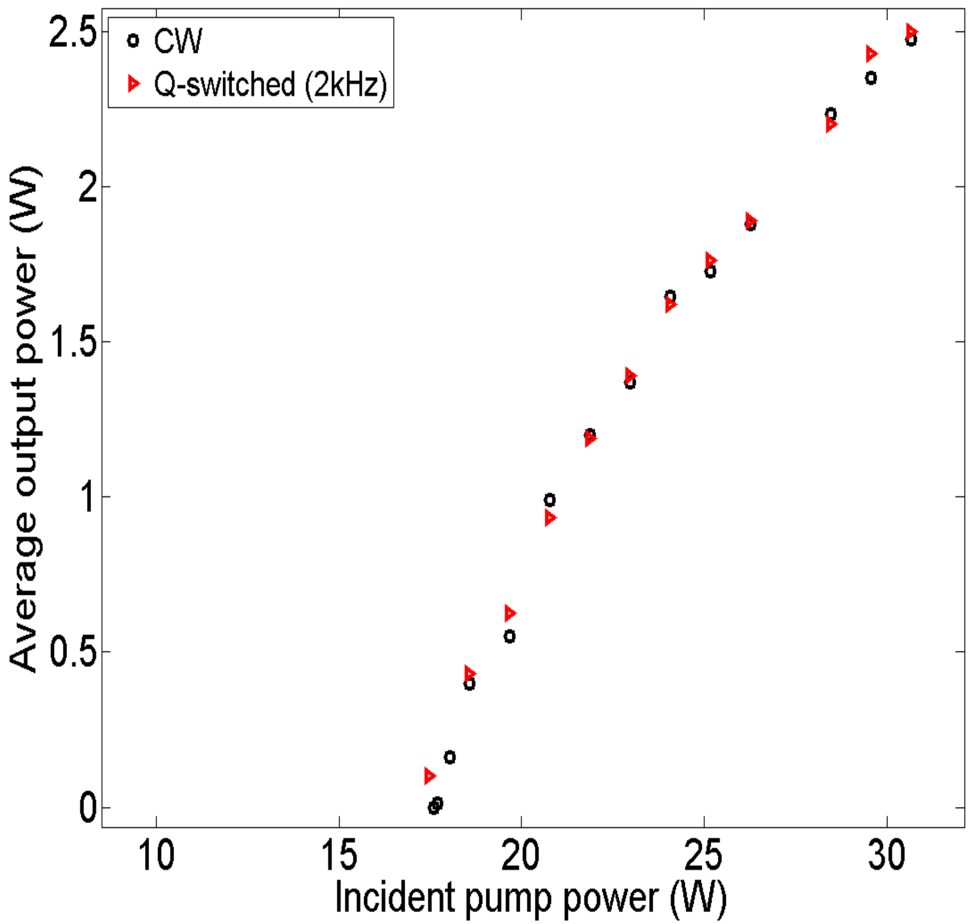
Initial pulsed Er:YAG laser

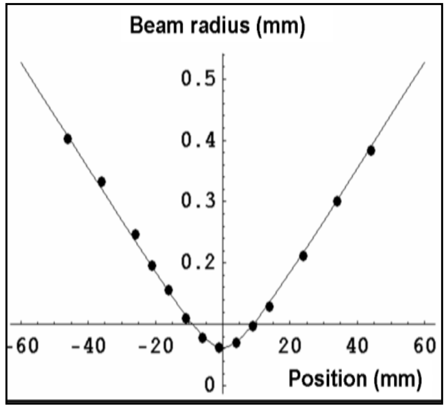


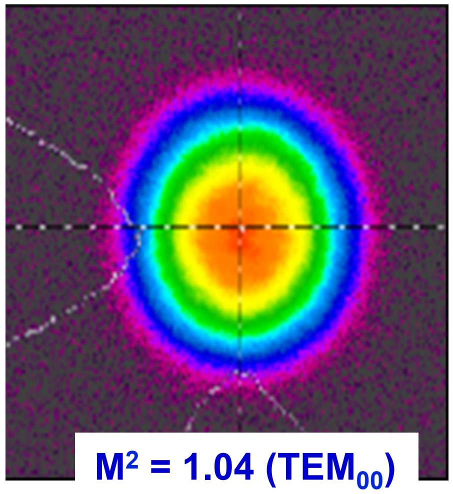
Length = ~30cm



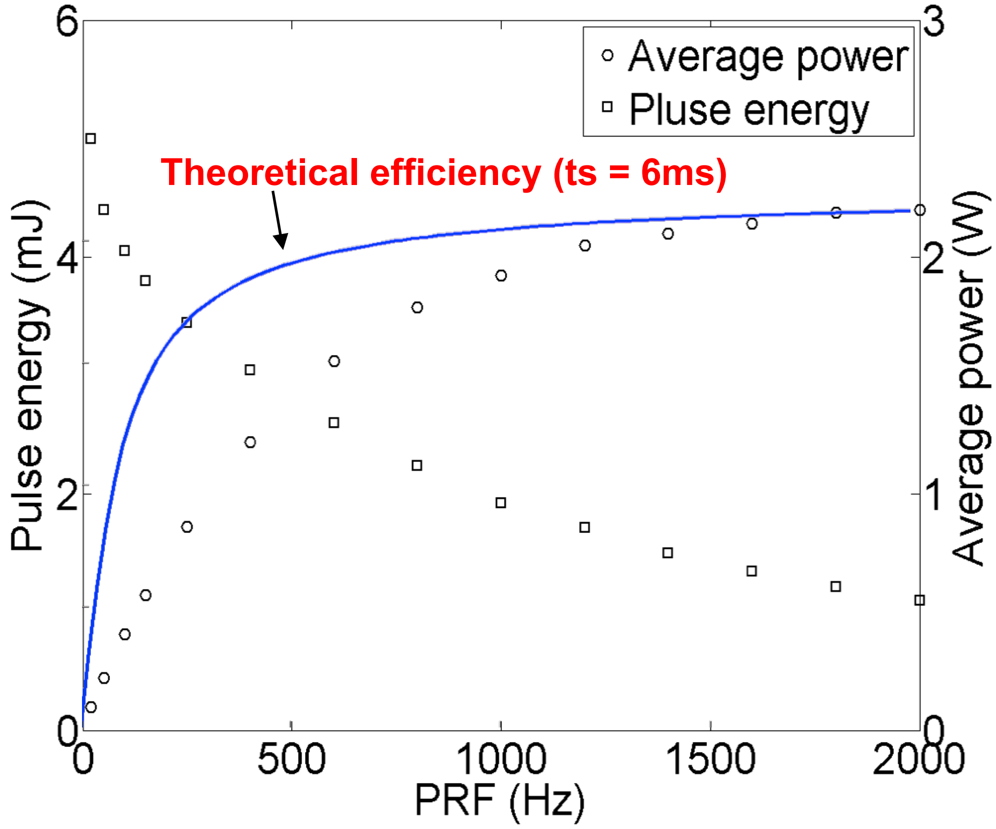
Output of pulsed Er:YAG laser







Output v's PRF



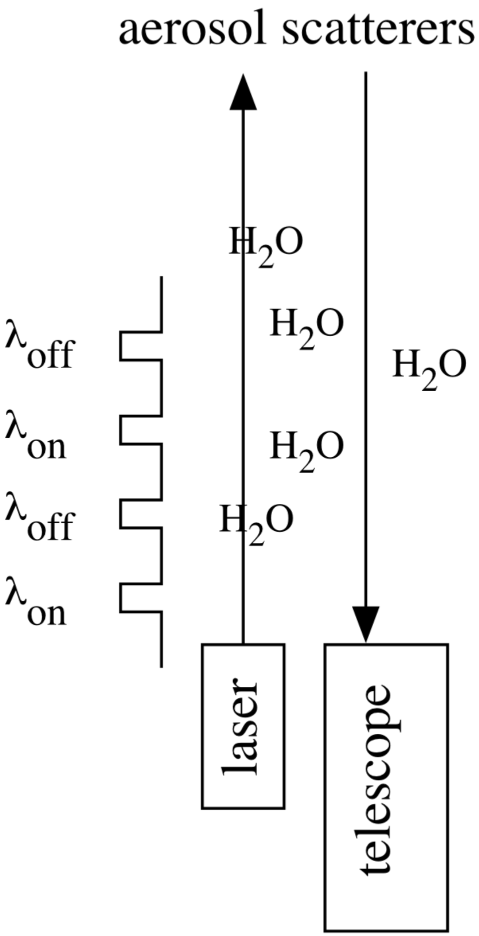
Output coupler, R = 85%

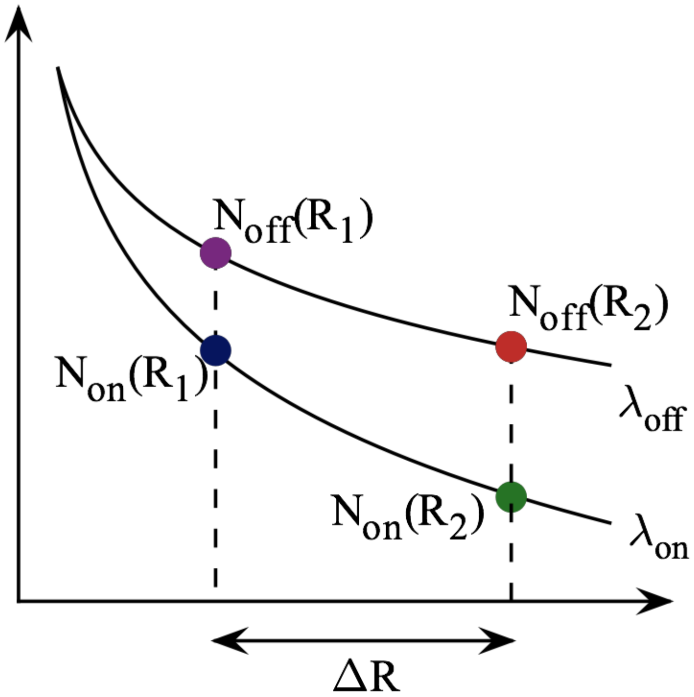
Next for Coherent Lidar?

- Change gain medium to end-pumped CPFS gain
- Use cheaper FAC 1470 nm pump diodes
- Increase output to 10-20 mJ @ 1 kHz PRF
- Incorporate in static (then scanning) coherent lidar system

Low-cost water-vapour DIAL

DIAL principle





Water vapour concentration between R1 and R2:

$$n_{H_2O} = \frac{1}{2\Delta R(\sigma_{on} - \sigma_{off})} \ln\left[\frac{N_{on}(R_1)N_{off}(R_2)}{N_{on}(R_2)N_{off}(R_1)}\right]$$

Low cost DIAL - laser considerations

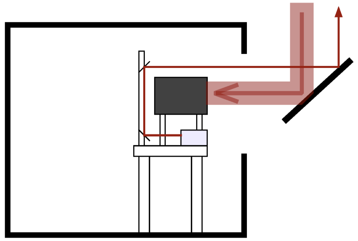
Diode laser is only really low cost laser available, but need a semiconductor optical amplifier!

Choice of wavelength

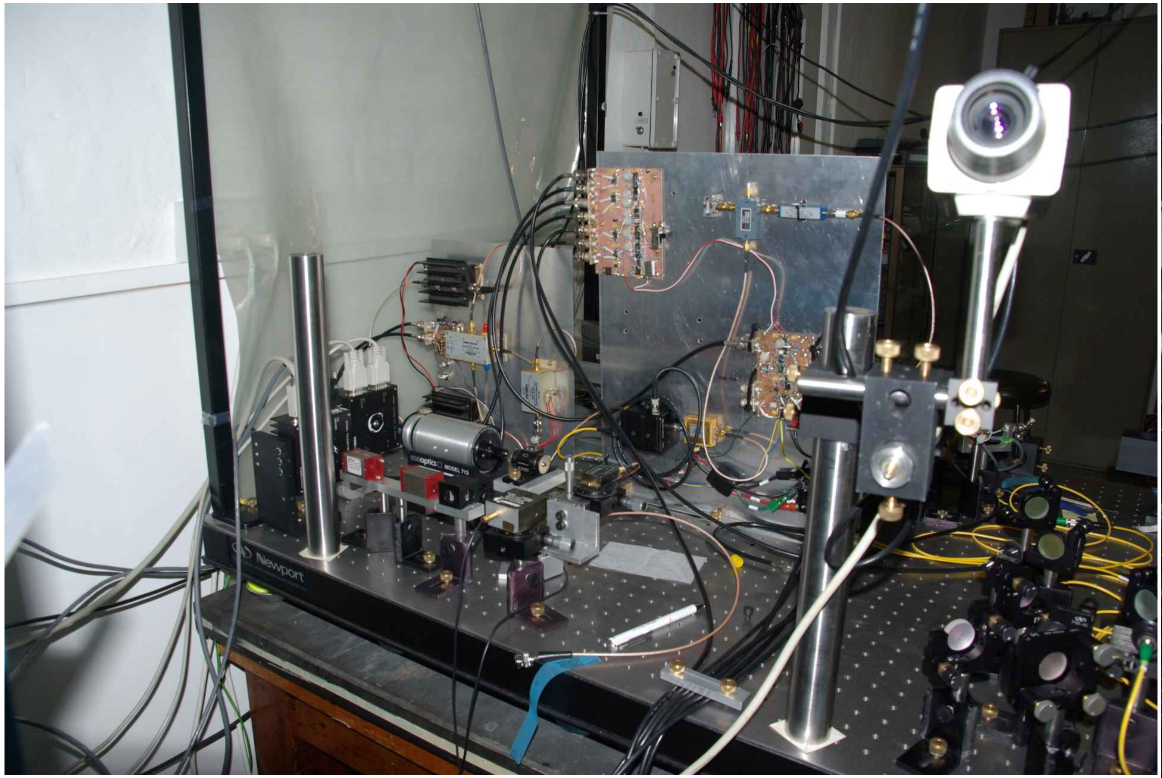
- 830 nm GaAs (mature technology)
- Single mode limited to ~ 0.5 W (high power diode or optical amplifier)
  - Implies single photon counting
- Detector technology well developed (PMT or Si PIN/APD)

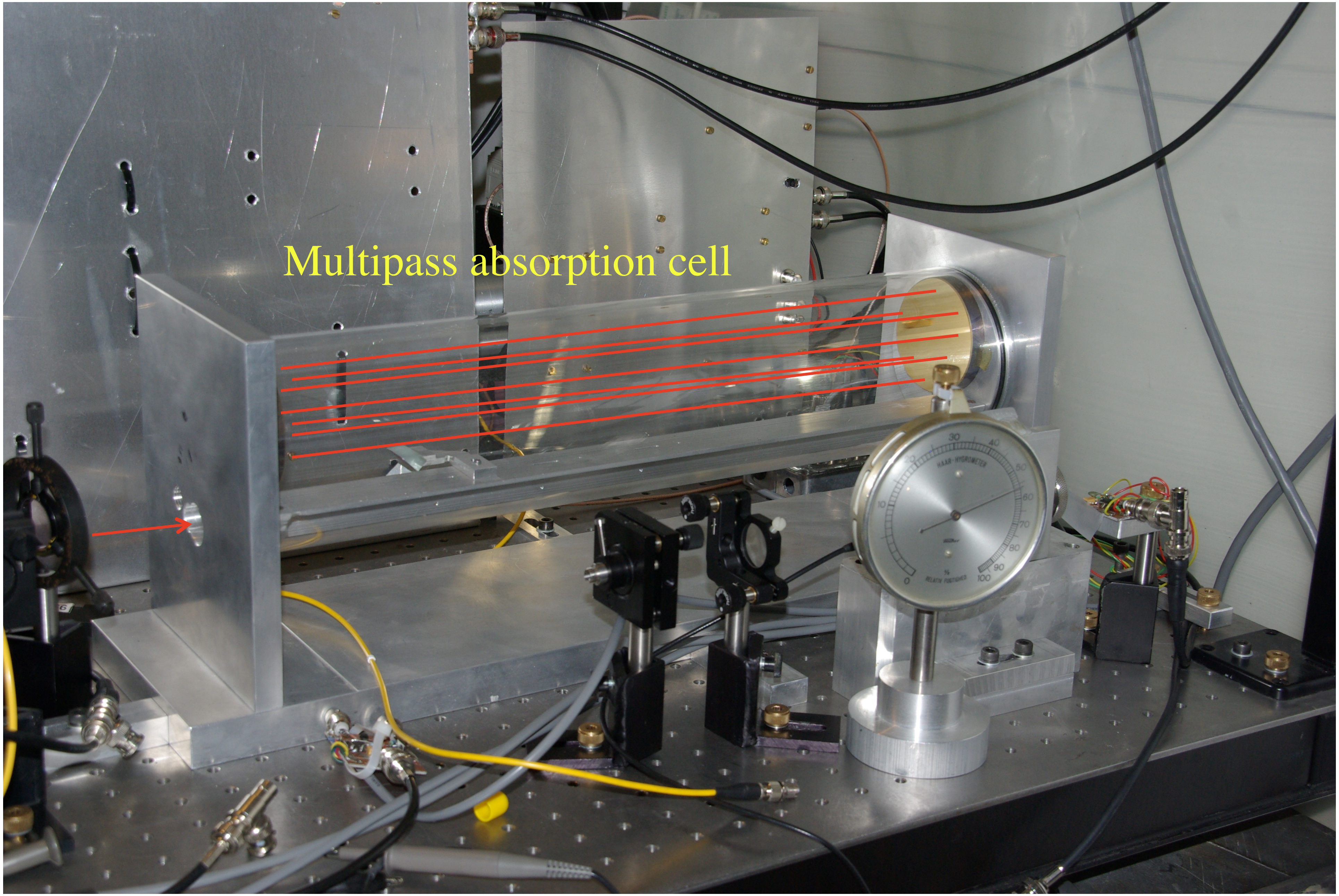
Type of diode?

- Use FP diode (for better or for worse)
- DFB diode (NOAA, Machol et al.)
- External cavity (MSU, see Nehrir et al. ISTP8 S13-P08)

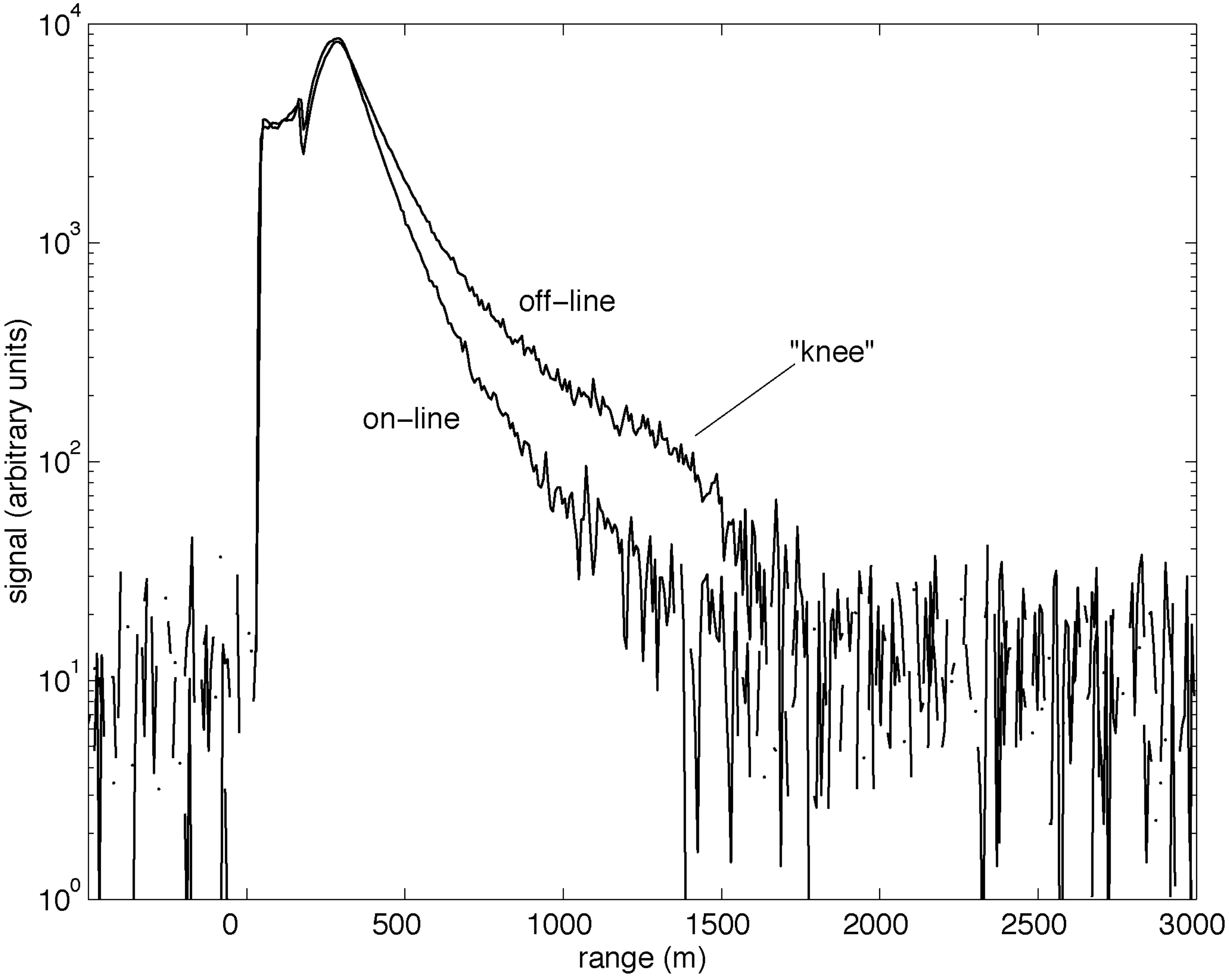


DIAL Hardware



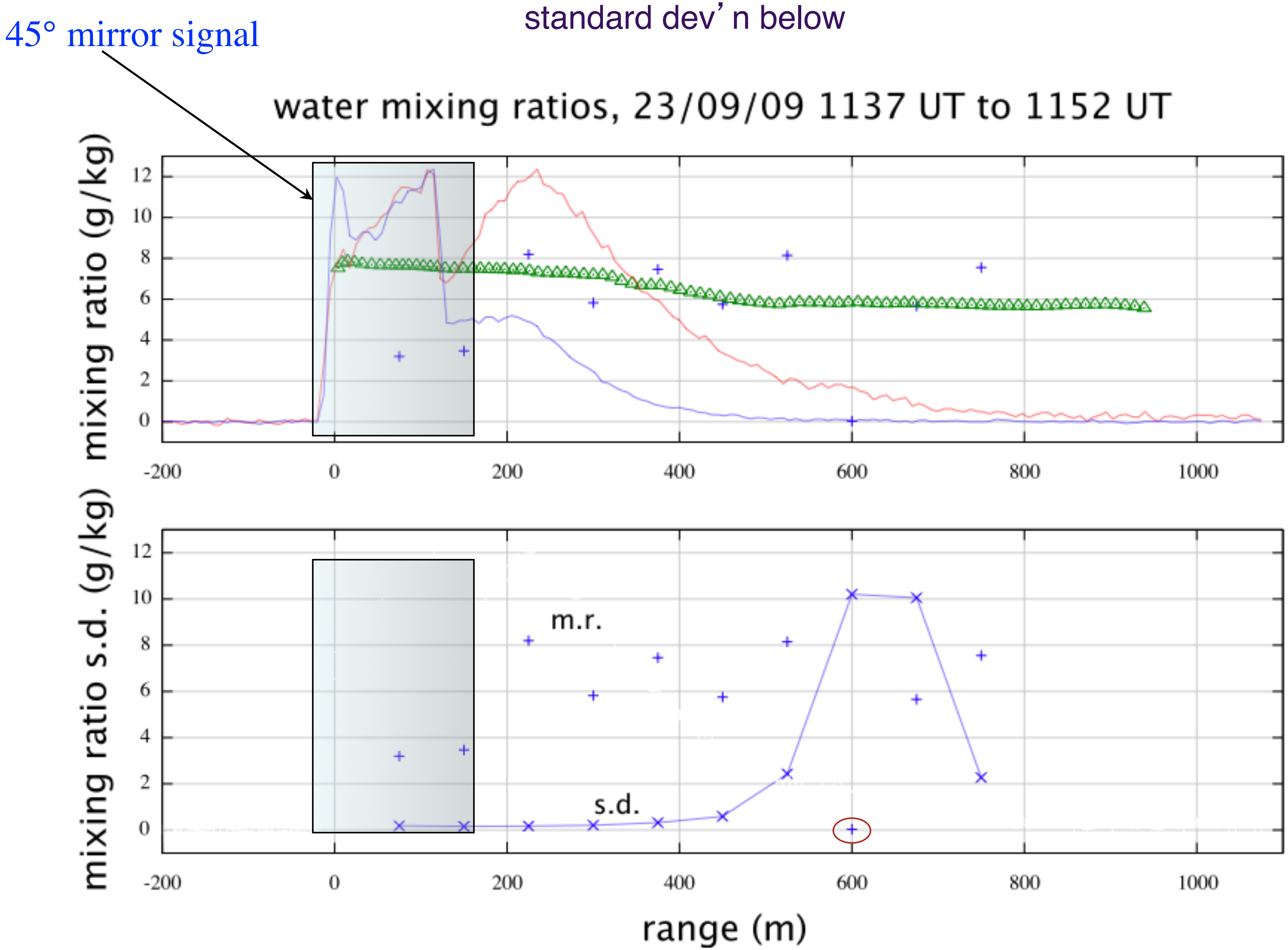

Multipass absorption cell

Raw DIAL Return Signals



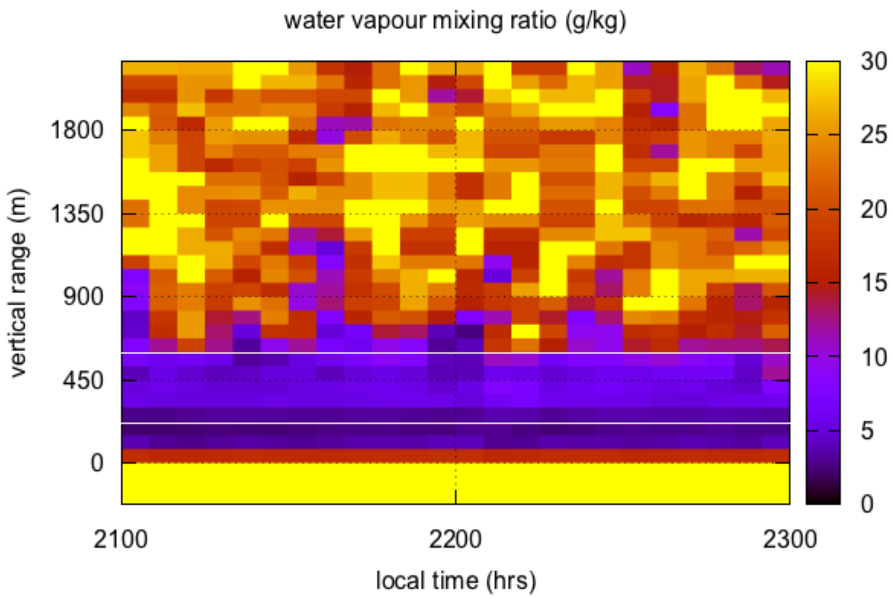
822.922 nm absorption line used is better suited to very dry environments.

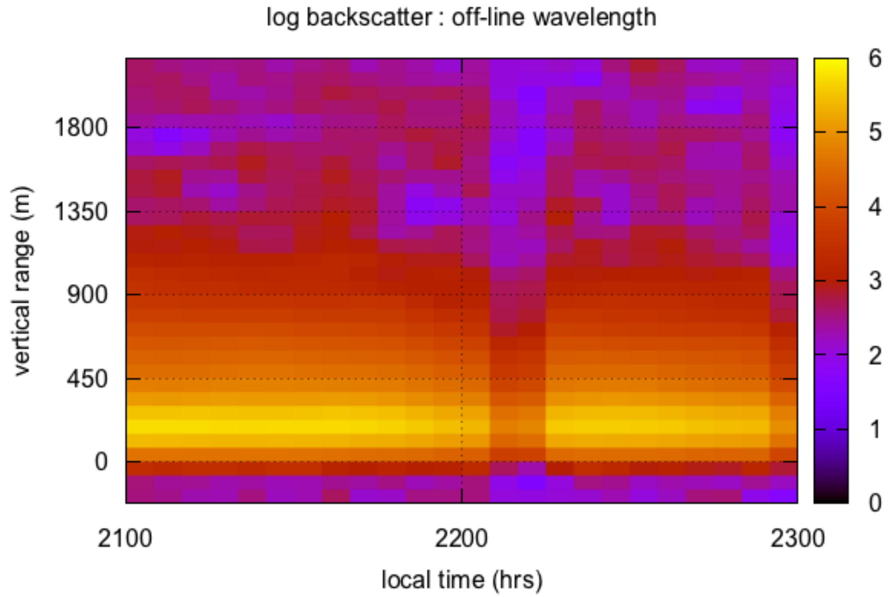
Inversion of raw DIAL data 23/9/09 - blue plus signs
BoM sonde data - green triangles
standard dev' n below



DIAL RESULTS

- Adelaide 22 03 2010





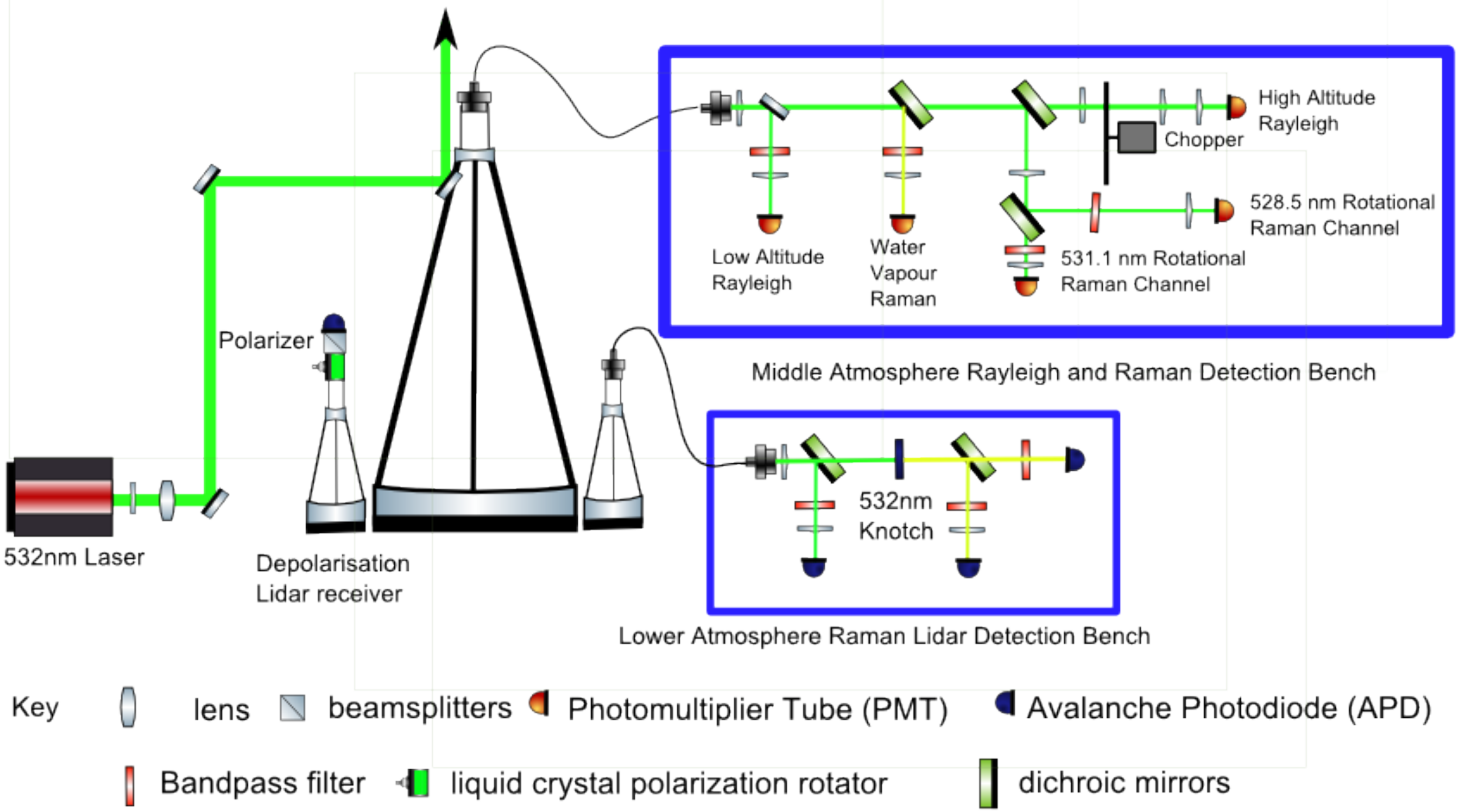
Next?

- Use weaker absorption line
  - 822.922 nm better suited to very dry environments
- Receiver efficiency needs work
- Better control of ASE to improve spectral purity
- Background city light is a major limitation to range
  - reduce receiver FoV?

- And after that
  - DFB diode technology?
  - Engineer for the field?
  - Try operation further inland?
  - Long-range system using higher power lasers?

Rayleigh/Raman Lidar

System schematic



Profiling the Atmosphere

- Rayleigh lidar allows investigation of middle atmosphere (30-80 km)
  - temperature, pressure, density, gravity waves, tidal effects …
  - with high spatial and temporal resolution
- Raman (+ Rayleigh) lidar used for < 30 km
- Being assembled at Buckland Park Lidar Facility
- Status:
  – laser (Powerlite DS9000: 532nm, 0.5 J, 5 ns, 50 Hz PRF) installed,
  – objective (area = 0.7 m^2) in place,
  – receiver electronics currently being developed

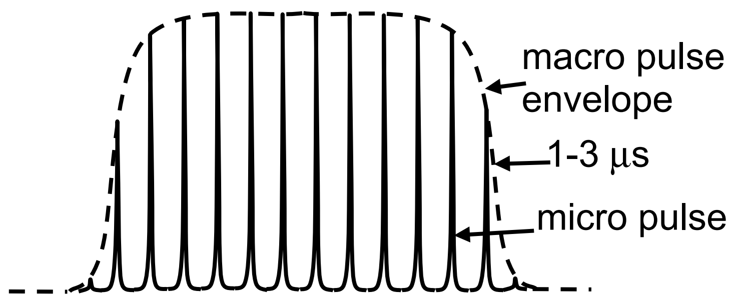
- Also, we have started developing an all-solid-state Alexandrite laser for Fe Boltzmann lidar profiling of the MLT (80-100 km)

Na Guide-Star Laser

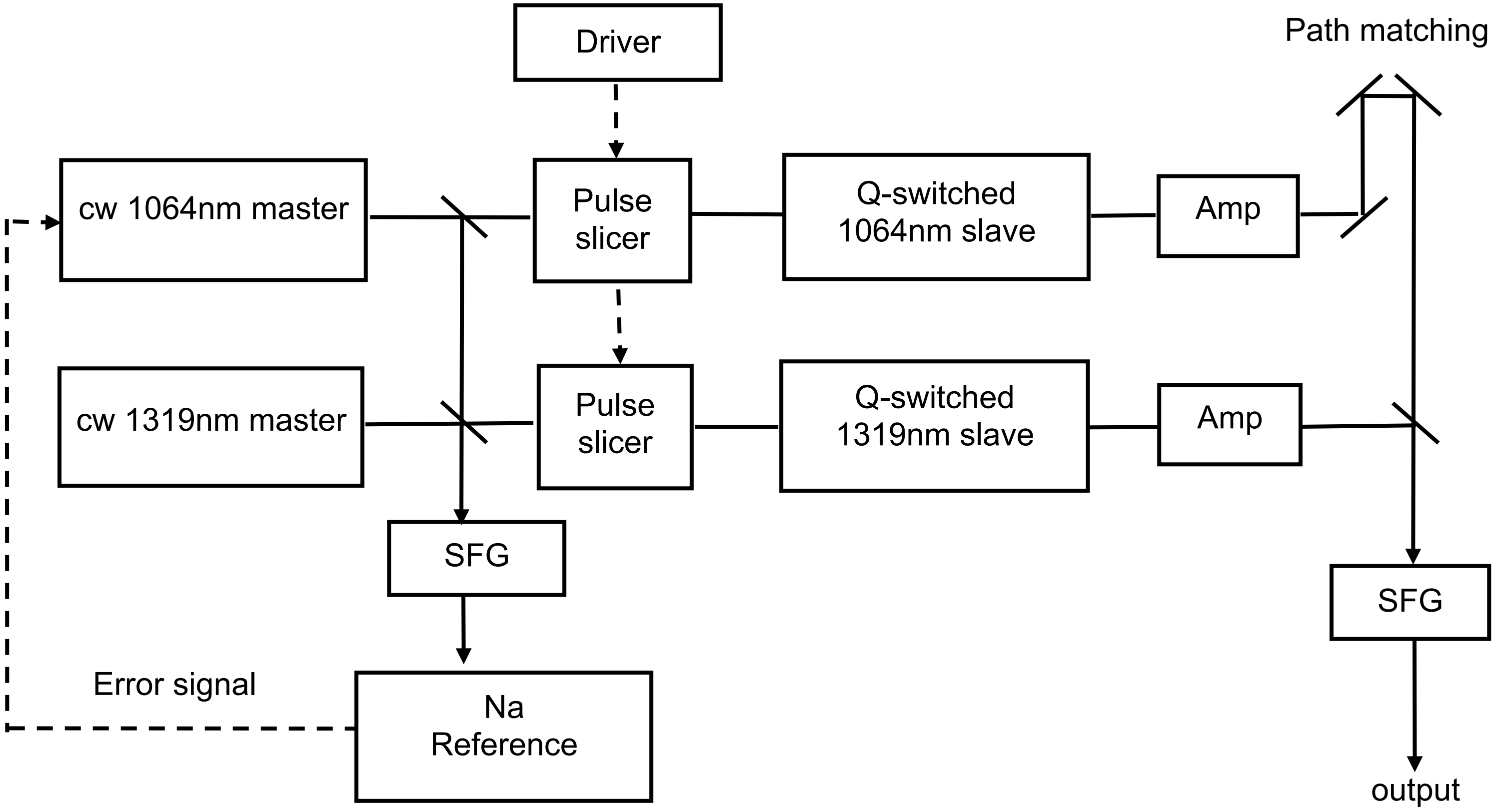
ELT laser guide-star requirements

- Wavelength: 589 nm (sodium D2a resonant)
- Pulse width: 1-3 μs - avoid elongation
- PRF: 800 Hz - range gate
- Bandwidth: 1-3 GHz - excite all Na – but it is easy to saturate!
- Beam quality: <1.2 - small, bright LGS
- Output power: ≥ 50 W
- Robust, all solid state, efficient, reliable

- Potential pulse shape:

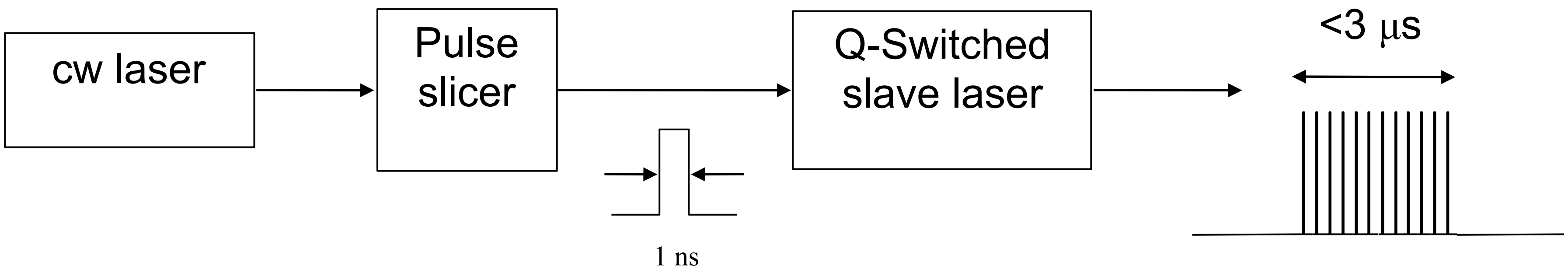


Na-resonant laser approach



SFG (1064 nm + 1319 nm → 589 nm) uses single-pass LBO

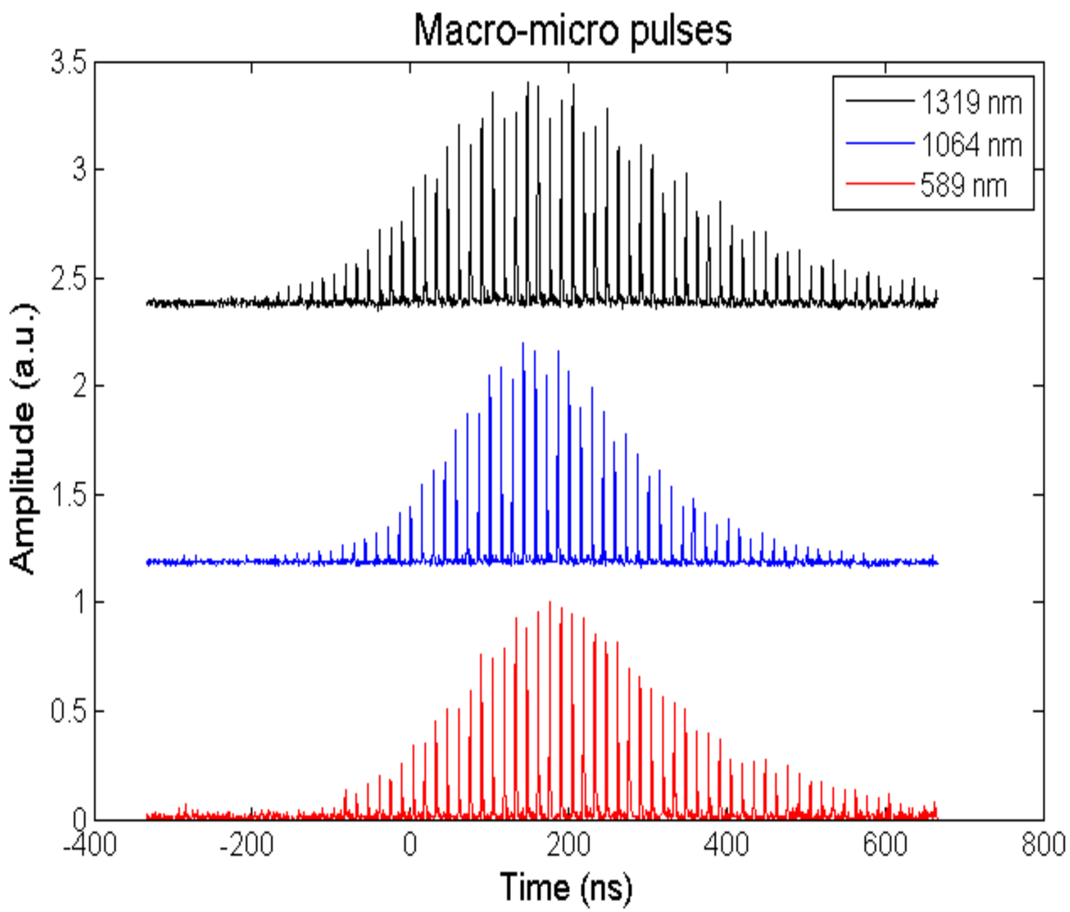
Injection mode-locking



- Slice narrow pulse from output of narrow line-width cw master laser
- Inject pulse into slave laser
- Pulse seeds multiple longitudinal modes
- Q-switch laser
- Output: train of mode-locked pulses under Q-switched envelope

- a “macro-micro” pulse burst

SFG of macro-micro pulse at 589 nm



Input: 11 mJ at 1319 nm
9 mJ at 1064 nm

Output: 6 mJ at 589 nm
(~10 mJ if correct for Fresnel losses)

$M^2 < 1.1$ at 7 W average power

Conversion efficiency ~ 30%