Hyperdog. Trace gas sniffer.

Robert E. Peale

Andrei Muraviev, Doug Maukonen,
Chris Fredricksen, Gautam Medhi

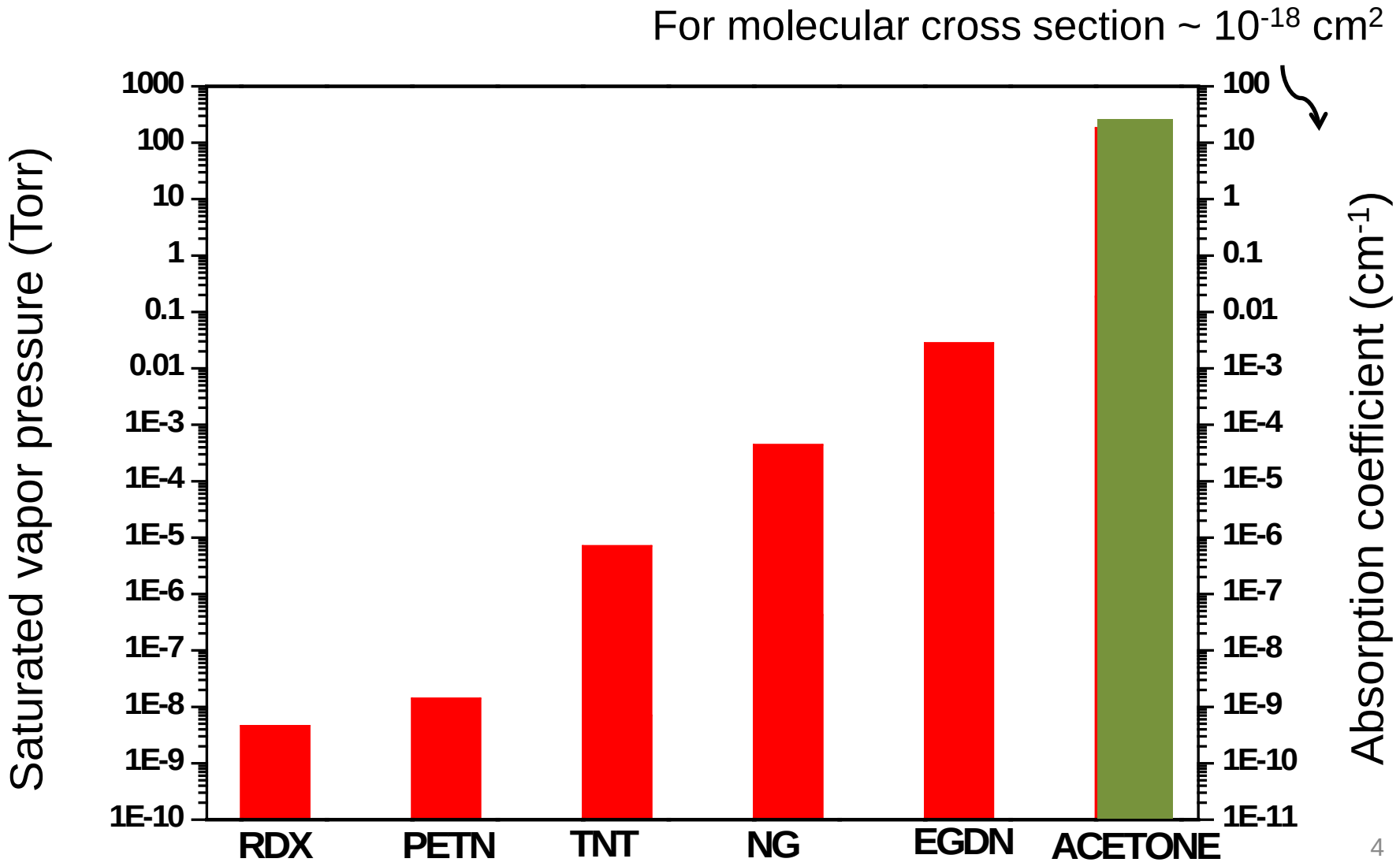
Can an instrument compete with a dog in speed, sensitivity, and accuracy of trace gas detection?

- Explosives
- Drugs
- Medical diagnostics
- Forensics
- Land mines
- Process monitoring
- Rescue
- Atmospheric science
- Planetary probes

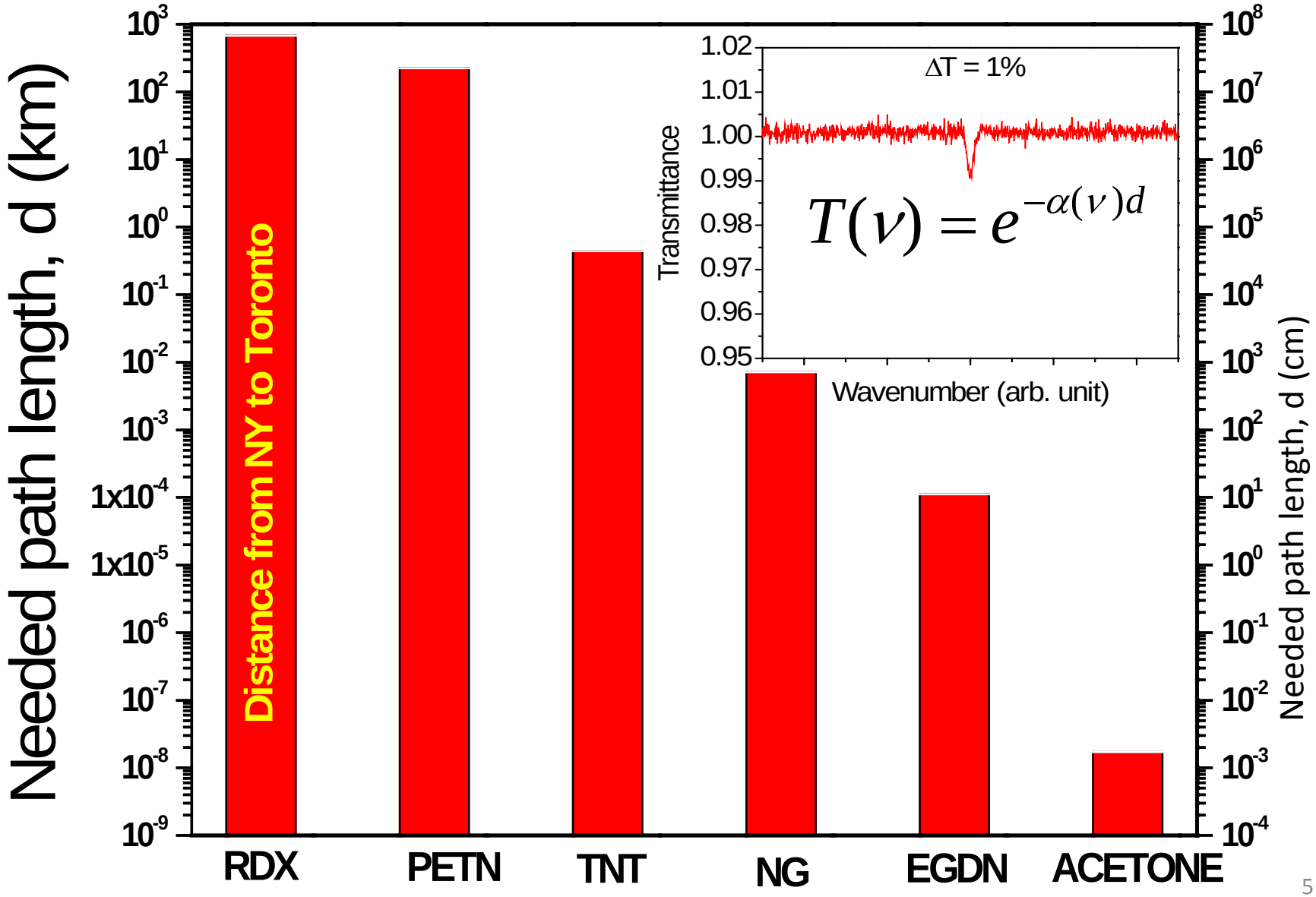
For speed and chemical specificity, we focus on infrared spectral sensing

What about sensitivity?

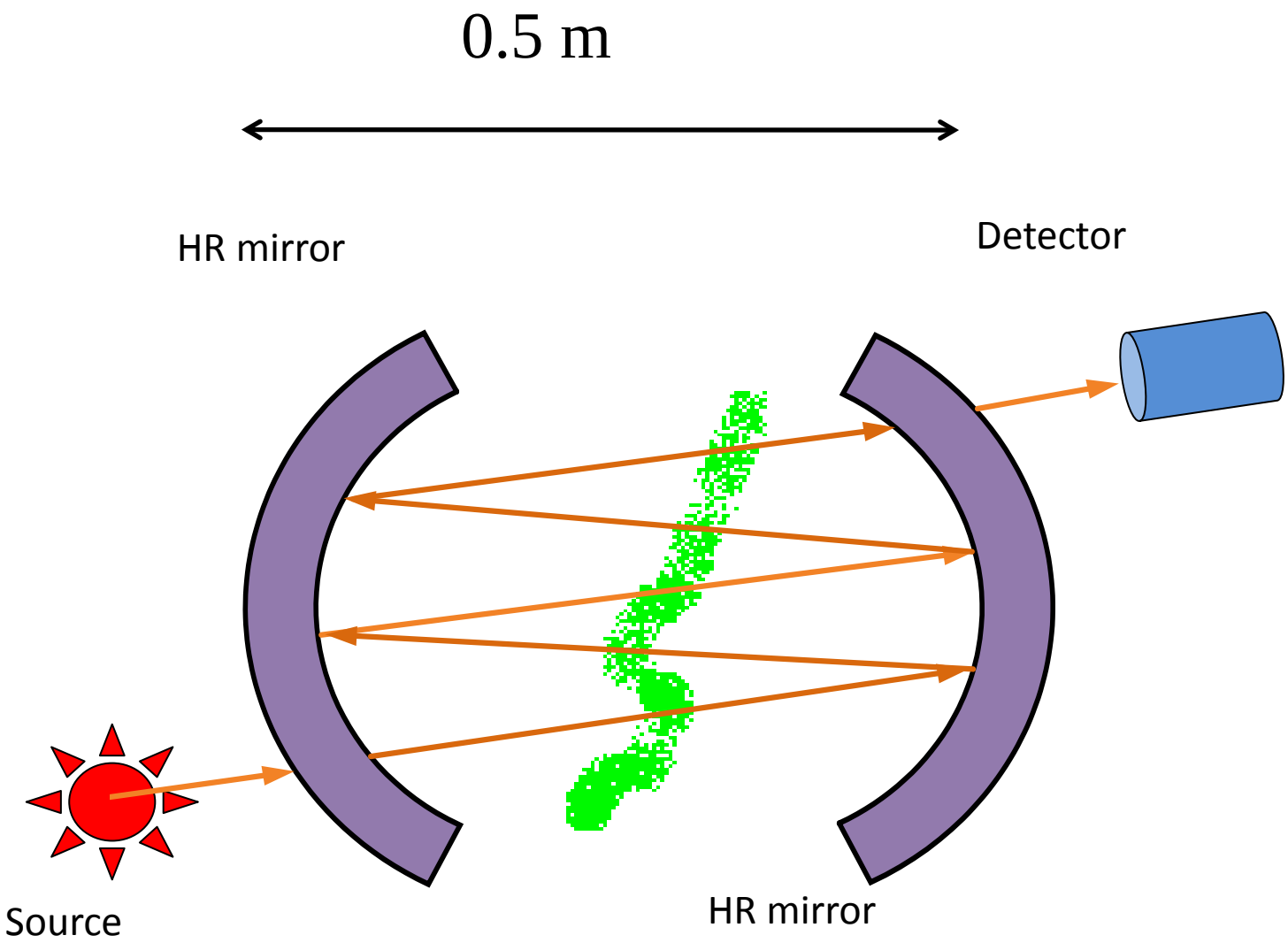
Example: Explosives have very low vapor pressures and absorption coefficients



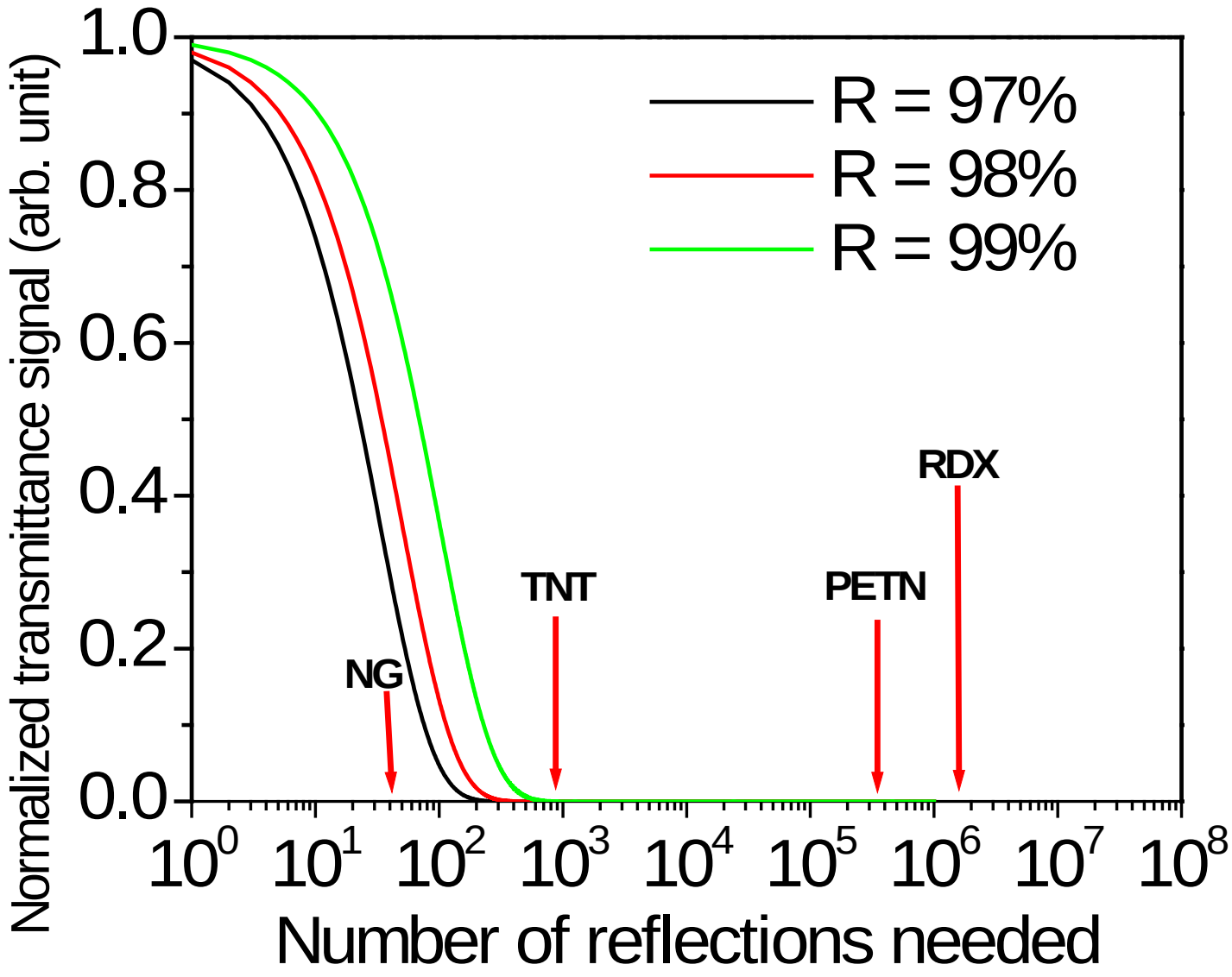
Long optical path lengths needed to detect explosives



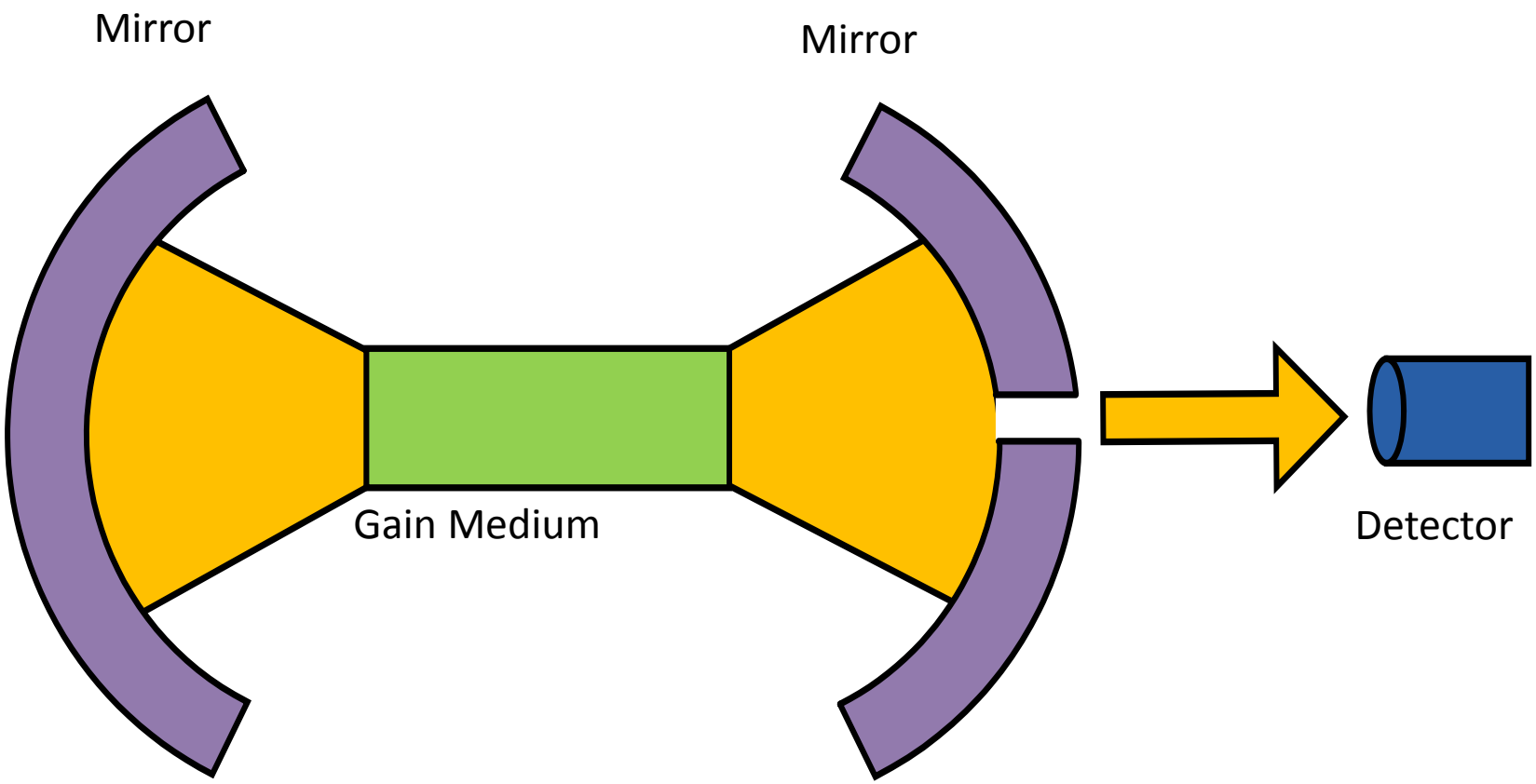
Long paths need to be folded, e.g. White cell



Passive cavities provide insufficient path length for detecting explosives

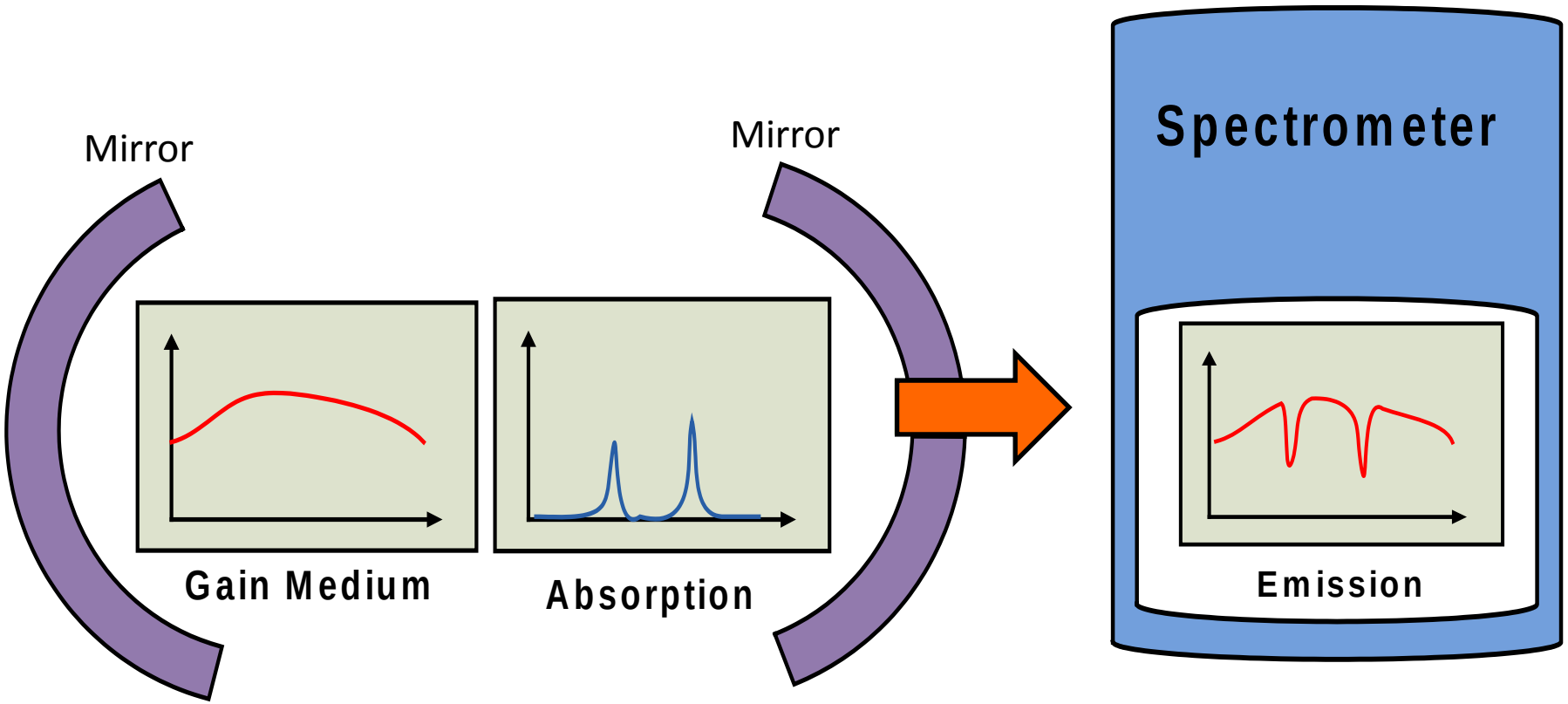


Opportunity: Active cavity can give sufficient path length



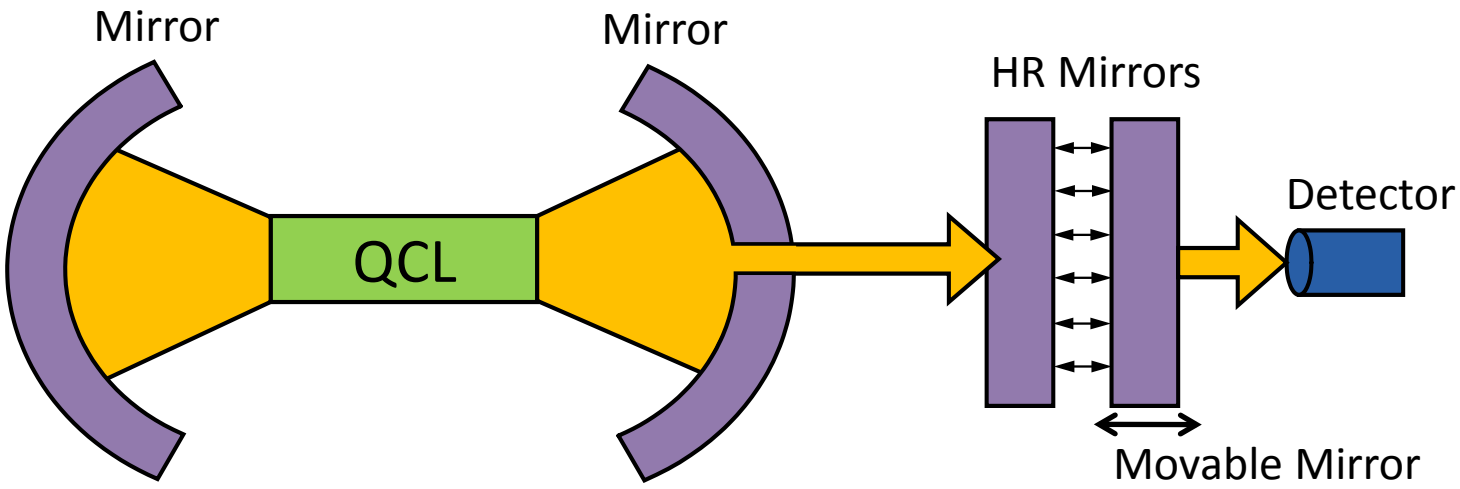
Effective path length for physical 35 cm path
can exceed 1 kilometer

Basis of Hyperdog:
Intracavity Laser Absorption Spectroscopy

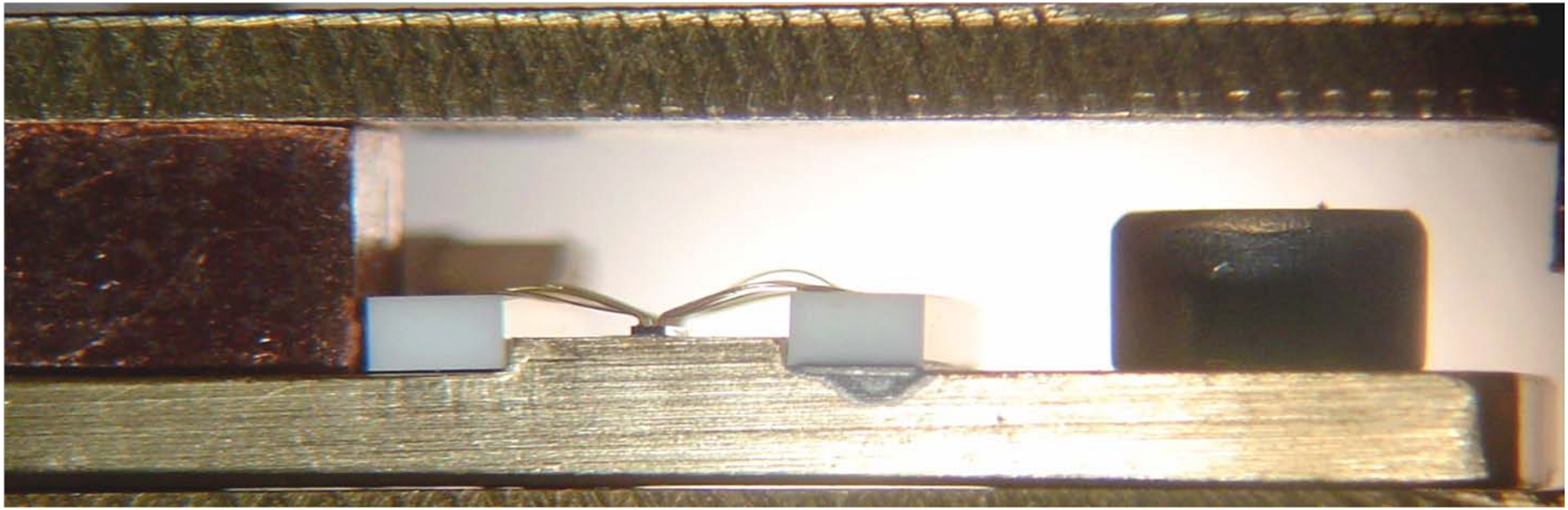


Key Enablers are…

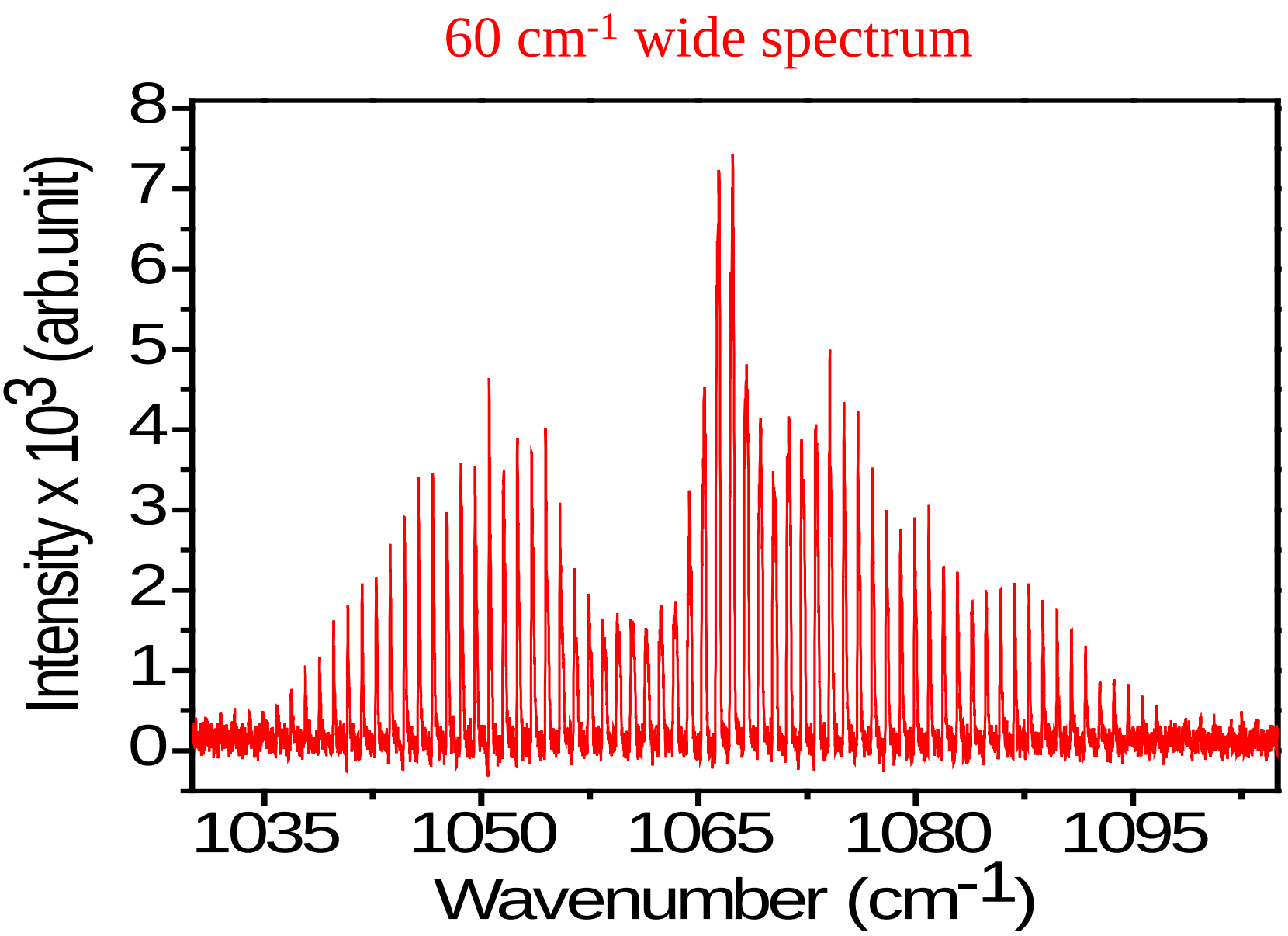
1. External Cavity Mid-IR Quantum Cascade Laser
2. Scanning Fabry-Perot Spectrometer
3. Control and acquisition electronics



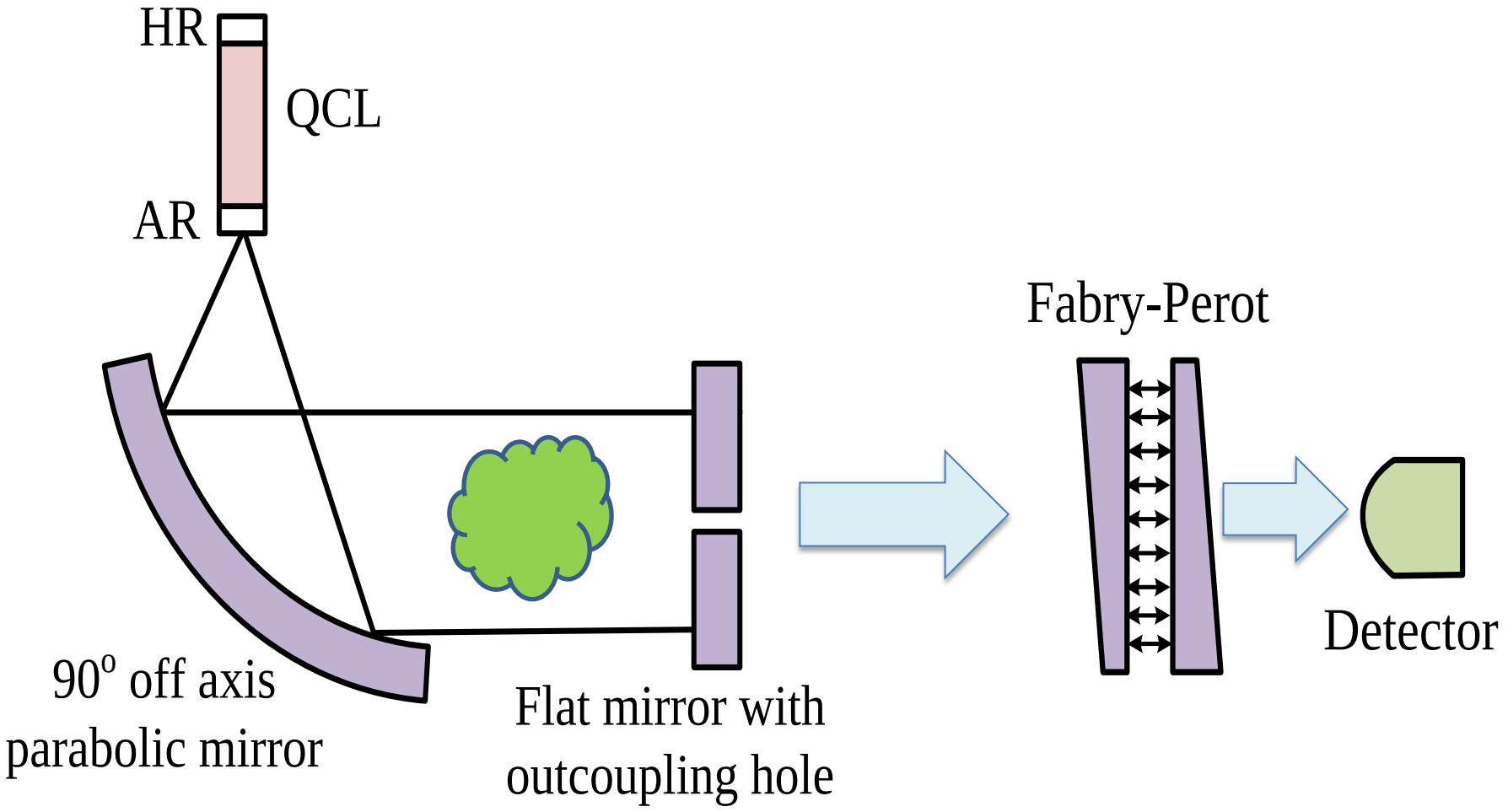
QCL

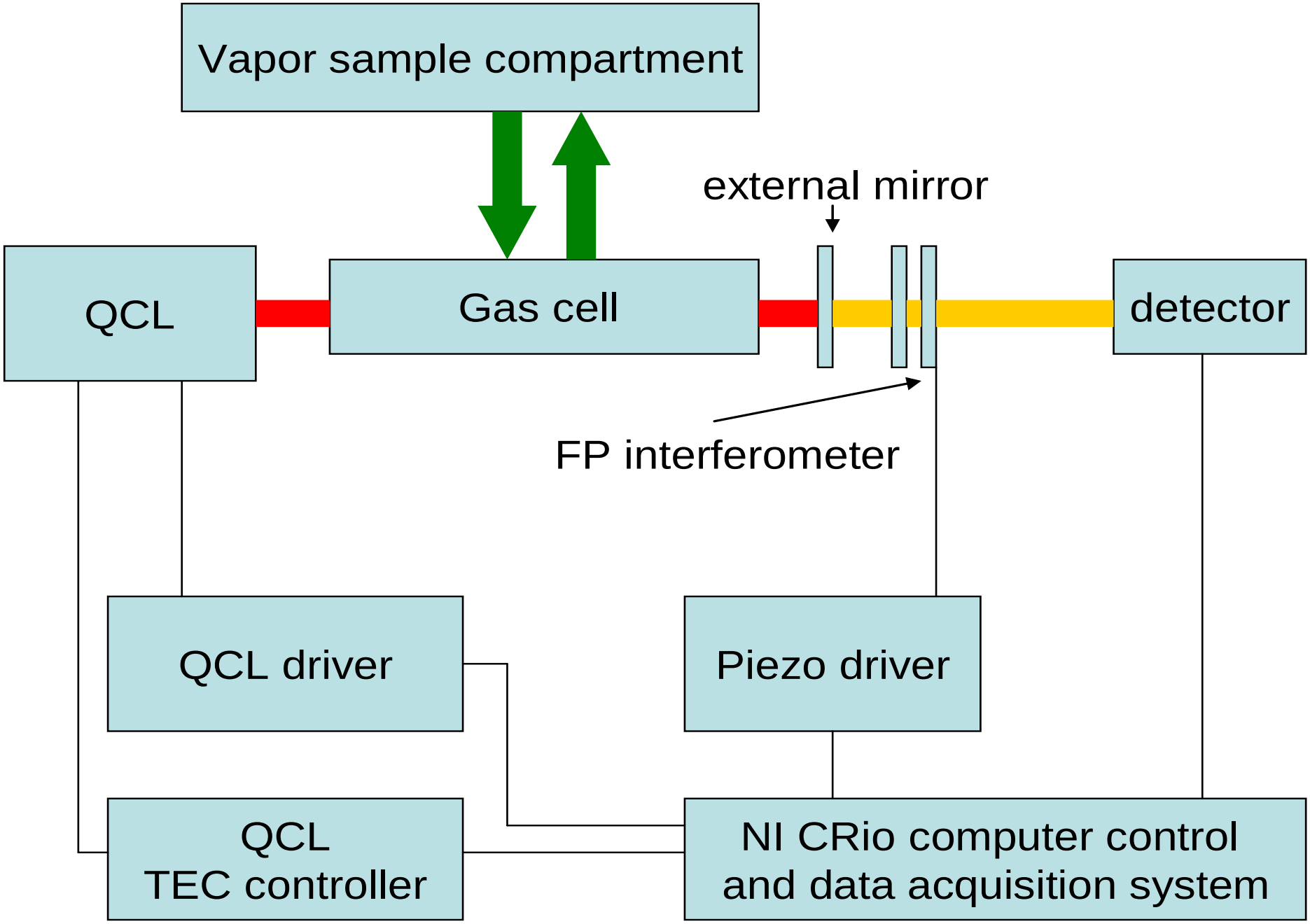


Emission spectrum of multimode QCL

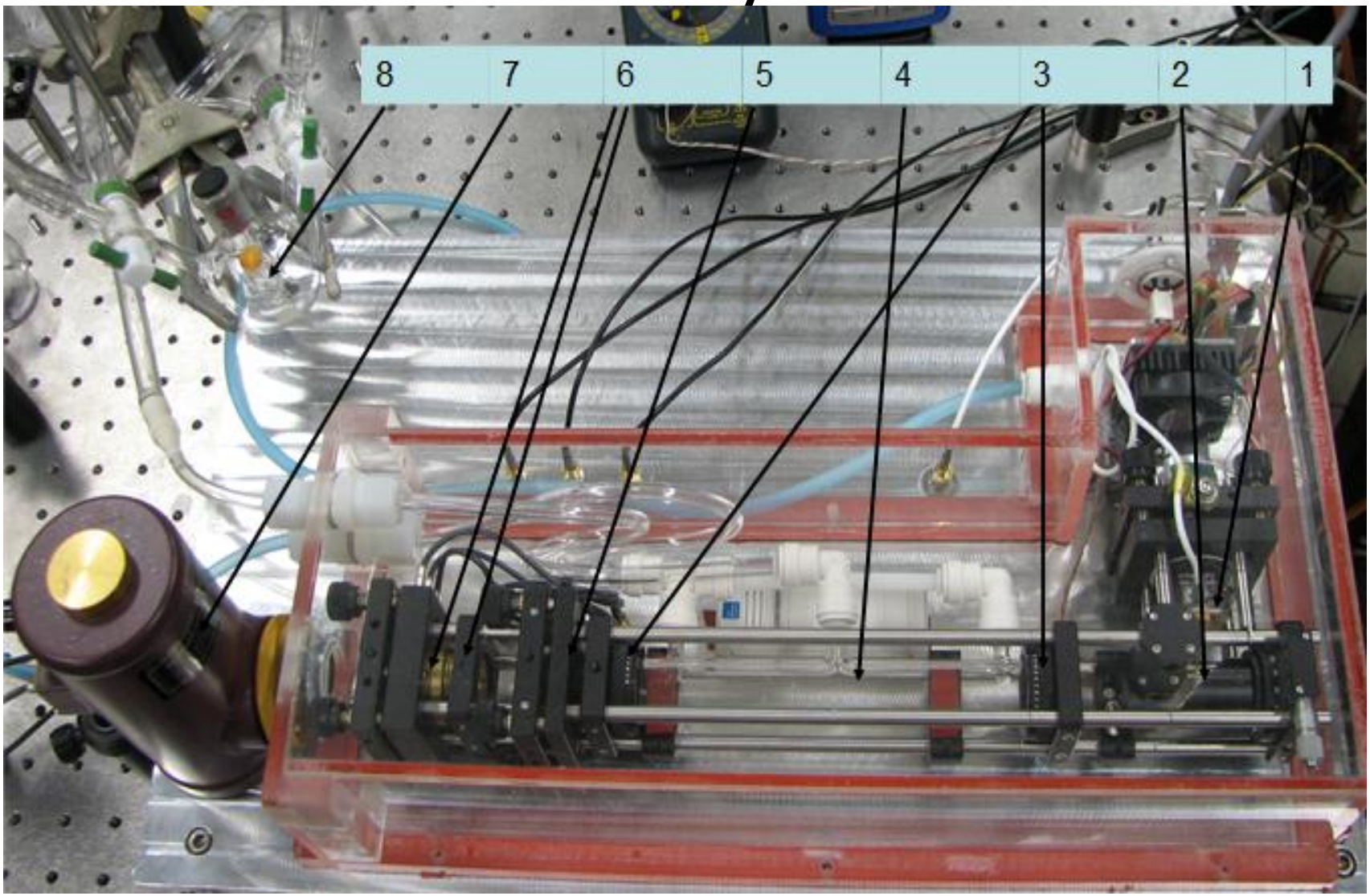


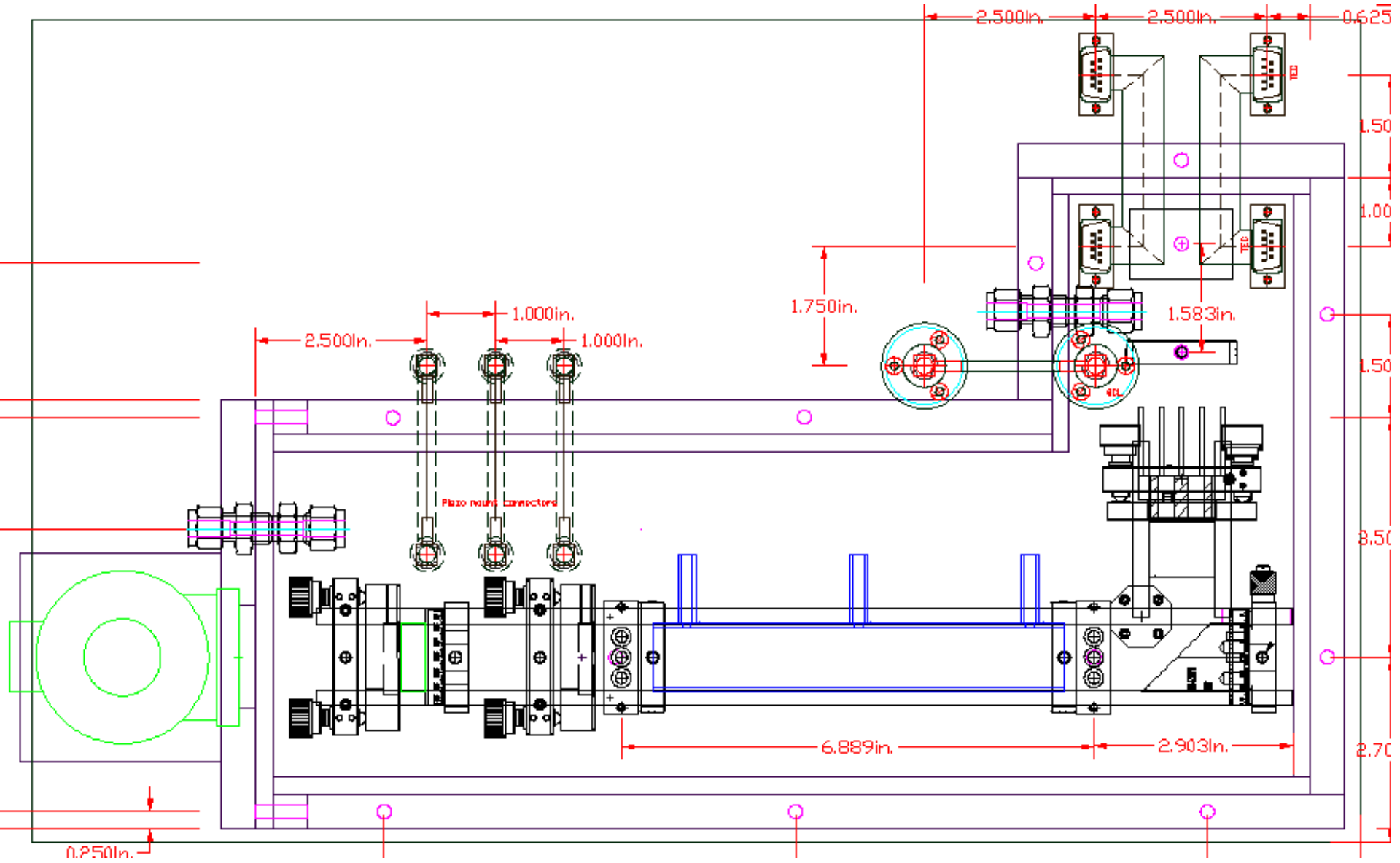
Hyperdog is an intracavity laser absorption spectrometer

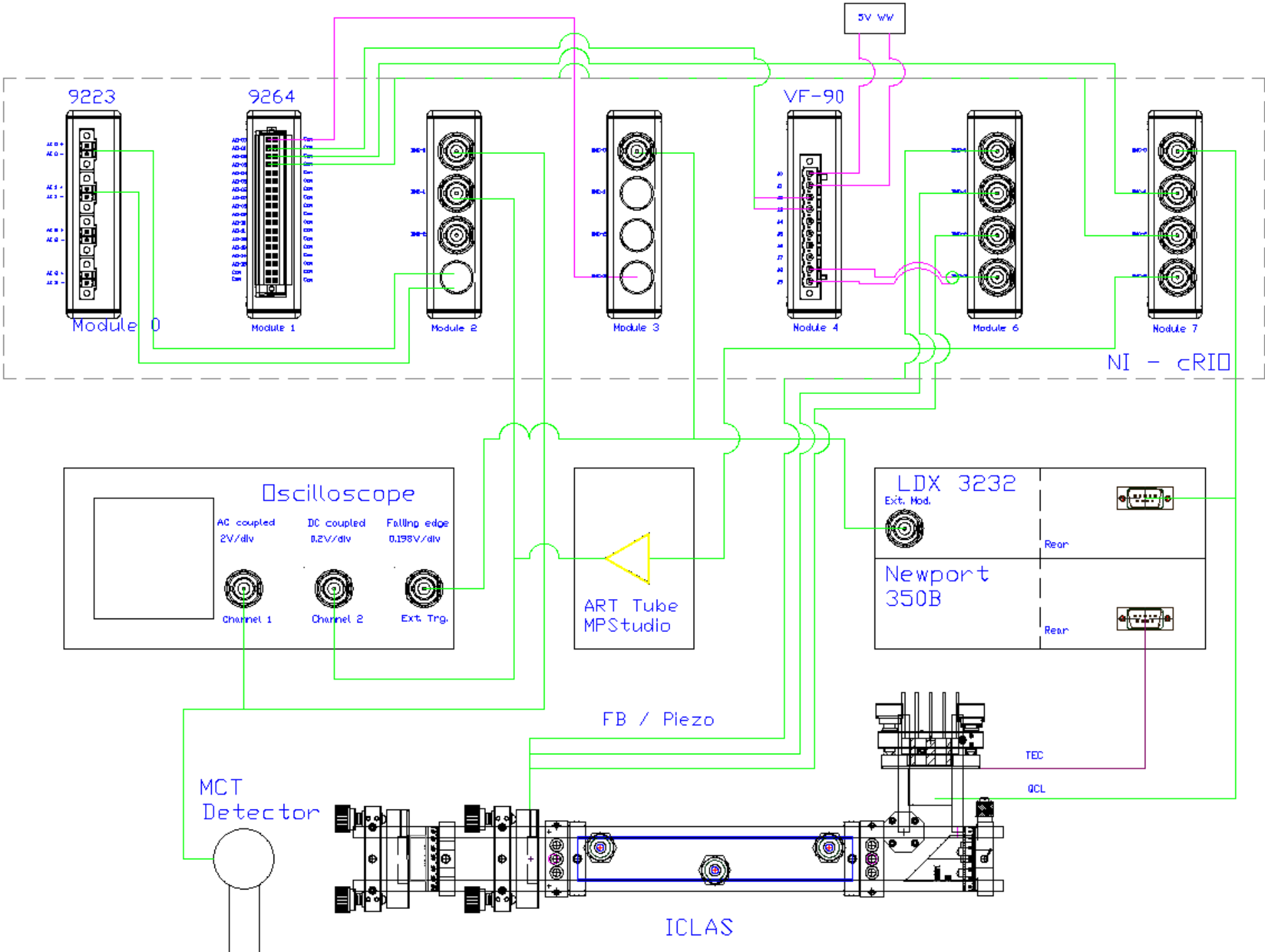


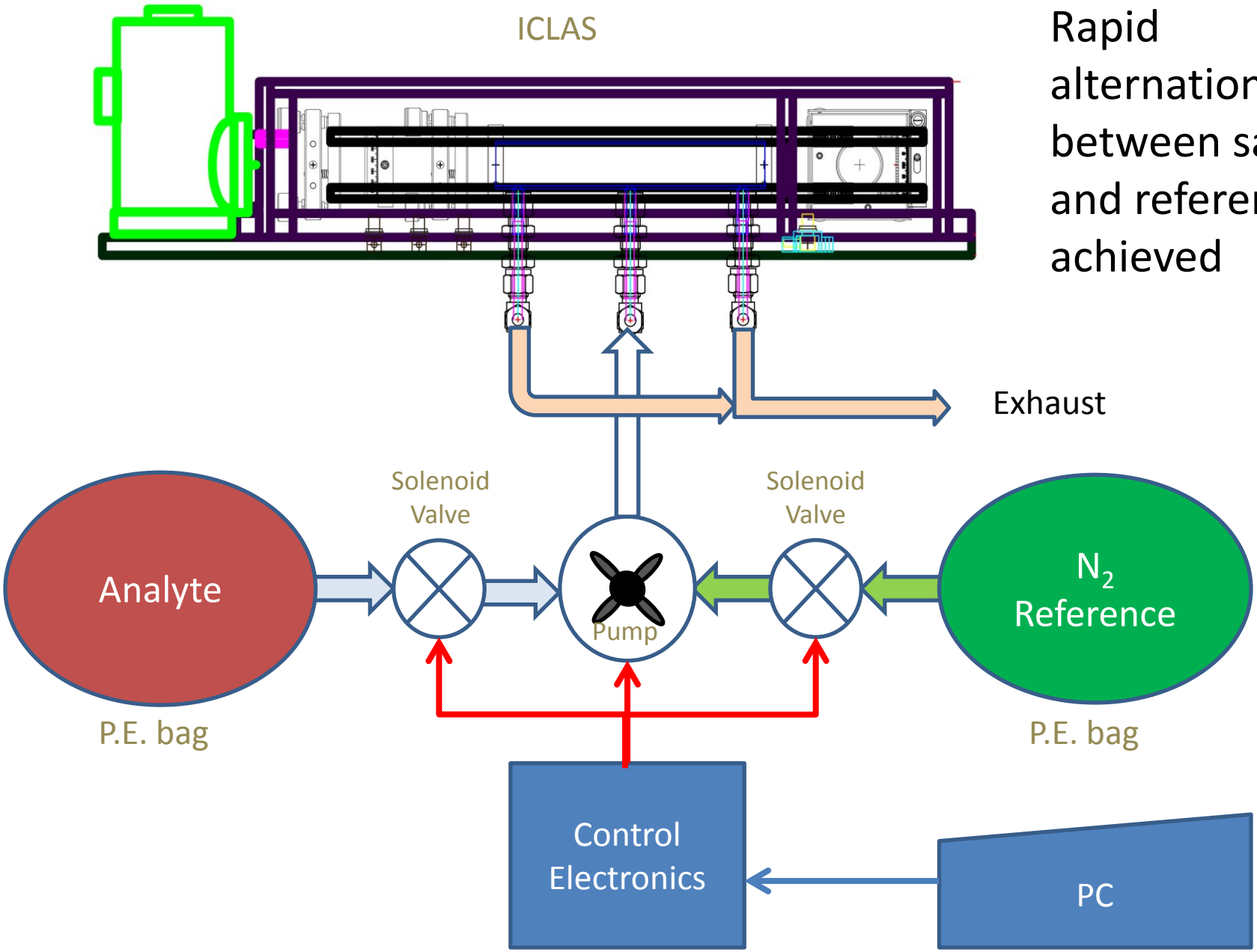

Vapor sample compartment
external mirror
QCL
Gas cell
detector
FP interferometer
QCL driver
Piezo driver
QCL
TEC controller
NI CRio computer control
and data acquisition system

Hyperdog is at Technical Readiness Level 4: Laboratory Brass Board

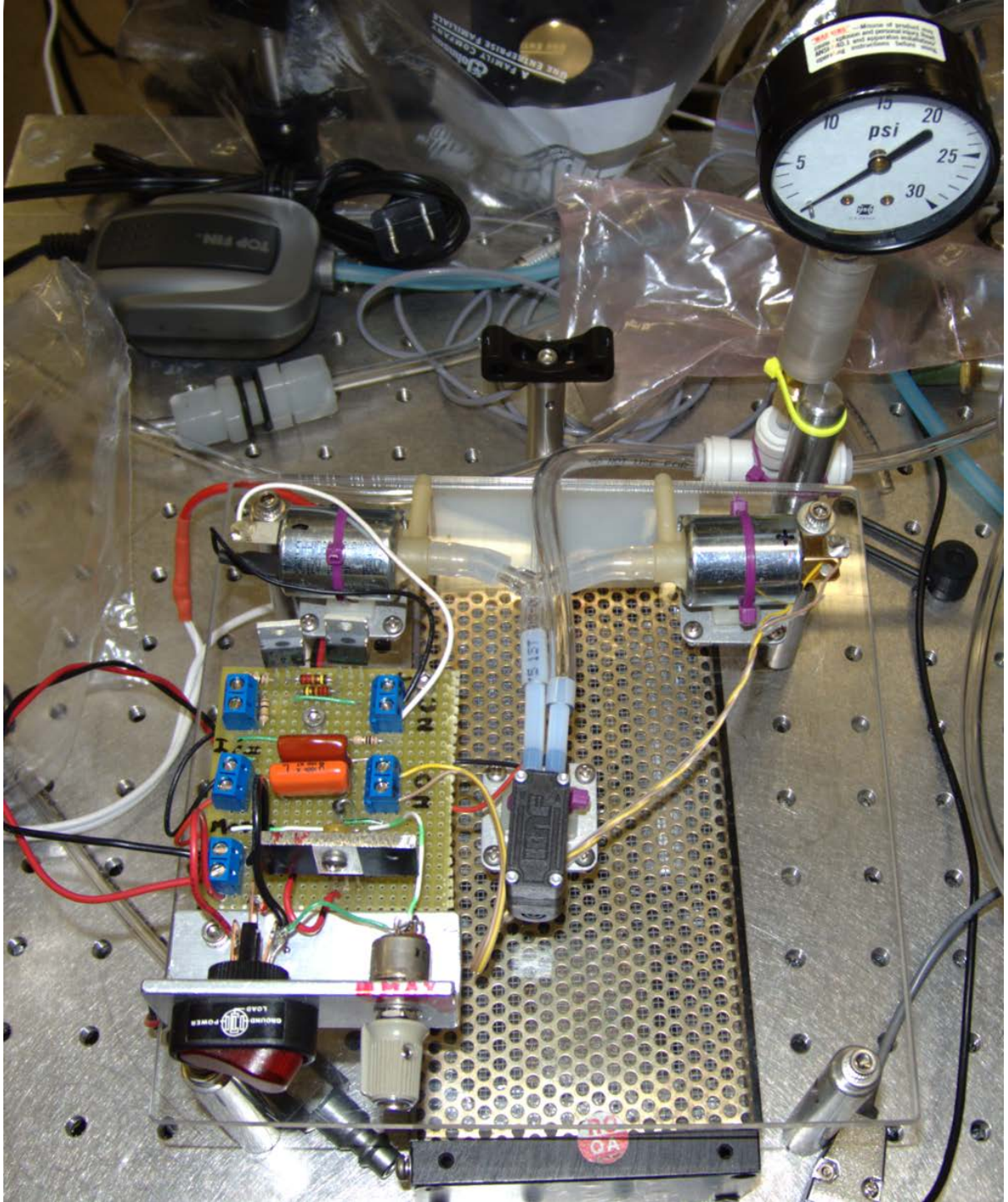


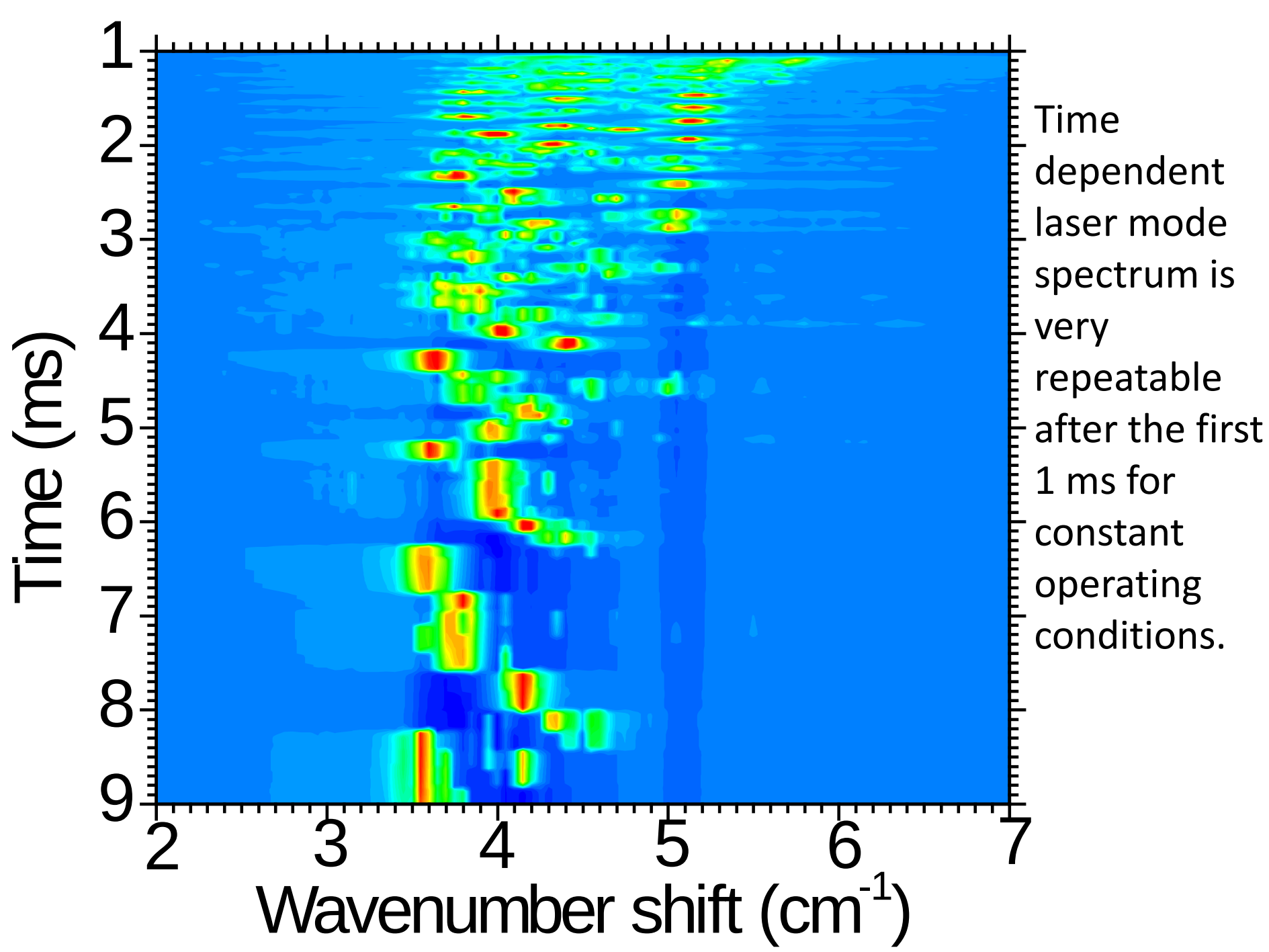

2.500in.
2.500in.
0.625
1.50
1.00
1.750in.
1.583in.
1.000in.
2.500in.
1.000in.
Piezo mount connectors
1.50
3.50
6.889in.
2.903in.
2.70
0.250in.


5V WW
9223
9264
VF-90
Module 0
Module 1
Module 2
Module 3
Module 4
Module 6
Module 7
NI - cRIO
Oscilloscope
AC coupled
2V/div
DC coupled
0.2V/div
Falling edge
0.198V/div
Channel 1
Channel 2
Ext. Trg.
ART Tube
MPStudio
LDX 3232
Ext. Mod.
Rear
Newport
350B
Rear
FB / Piezo
TEC
QCL
MCT
Detector
ICLAS

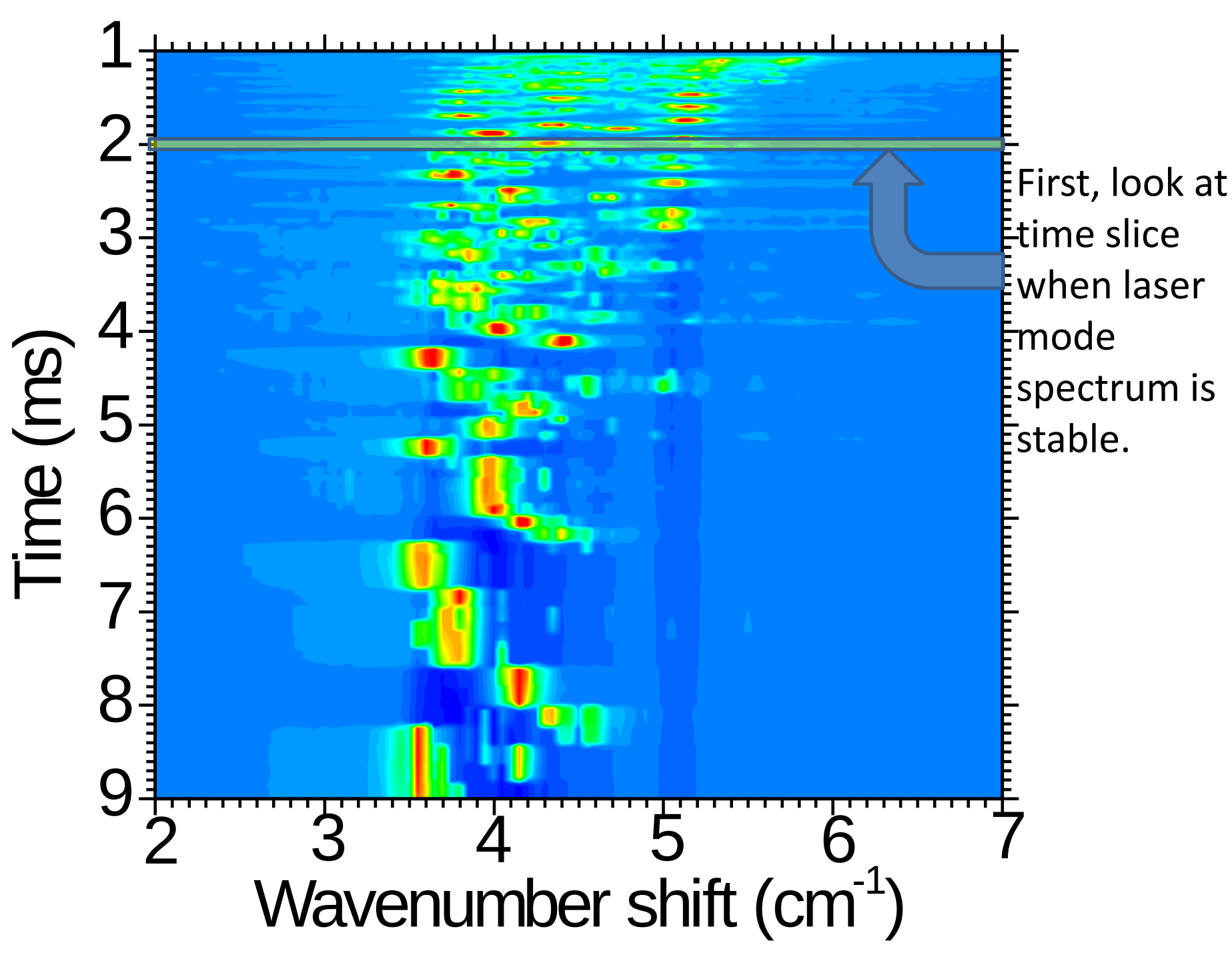


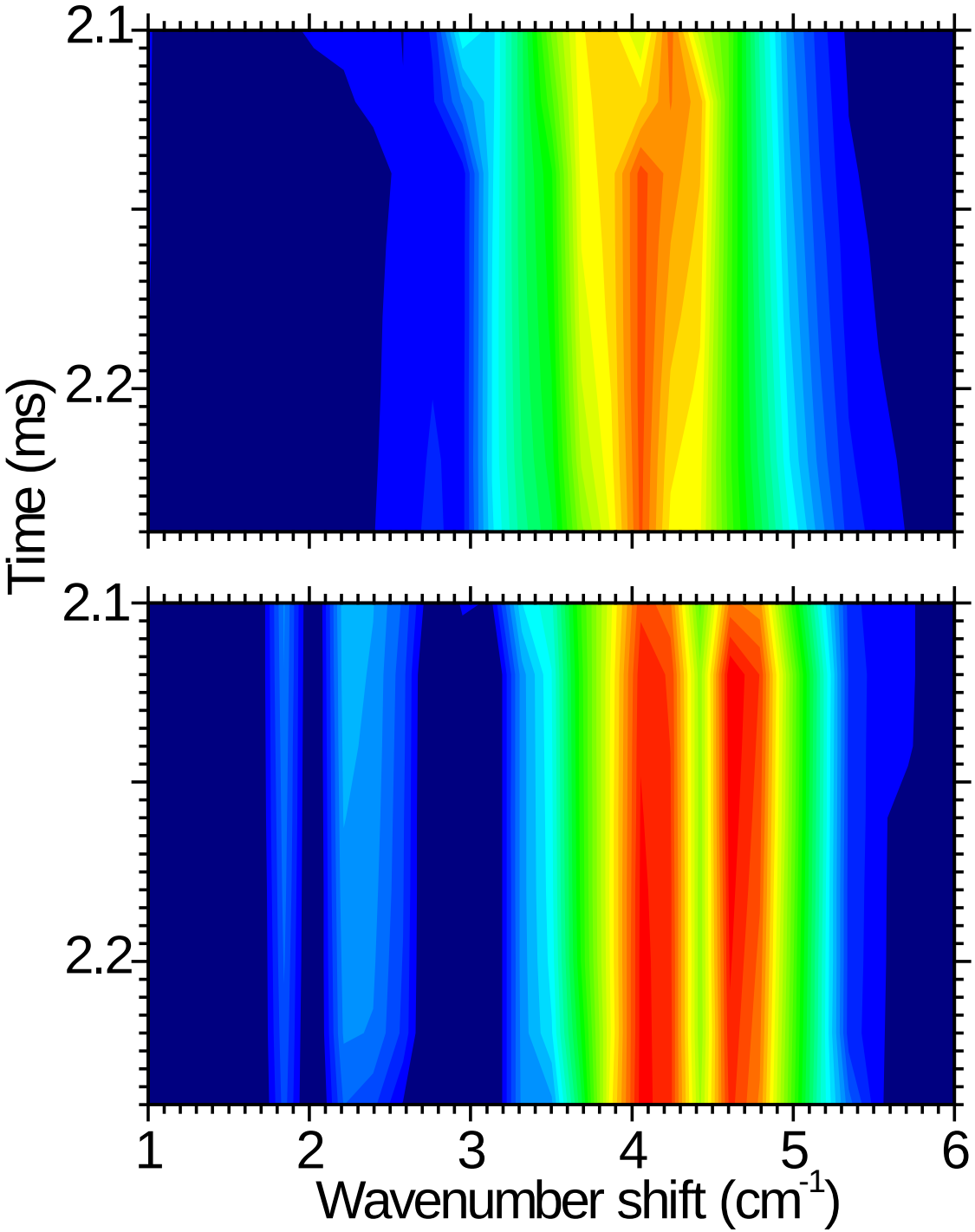
Rapid alternation between sample and reference is achieved


psi
5
10
15
20
25
30



Time dependent laser mode spectrum is very repeatable after the first 1 ms for constant operating conditions.

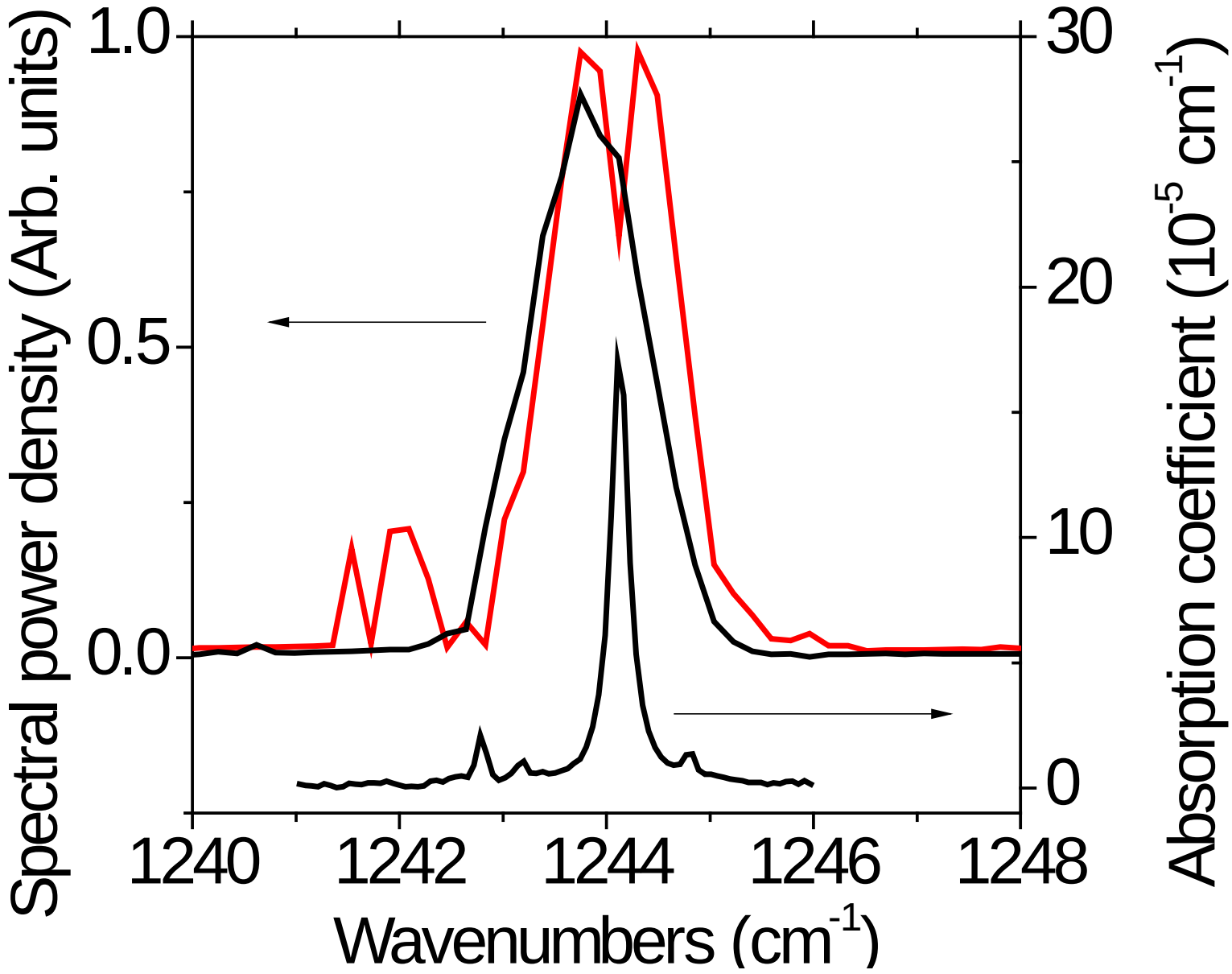

Time (ms)
1
2
3
4
5
6
7
8
9
2
3
4
5
6
7
Wavenumber shift (cm-1)
First, look at time slice when laser mode spectrum is stable.



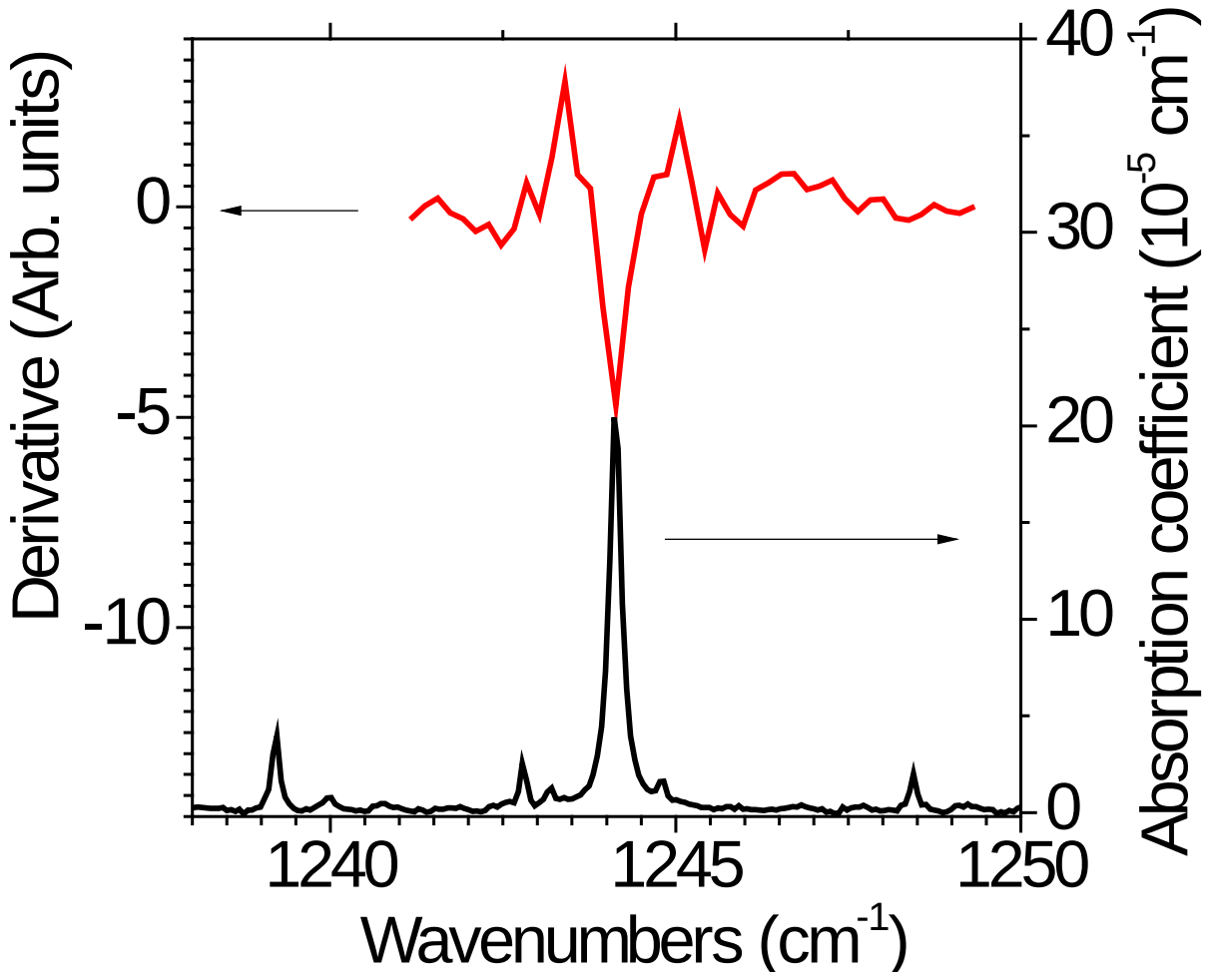
Dry nitrogen in the cavity

Wet nitrogen in the cavity

Integrate over 1.5 ms window



If instead we integrate over all times, and average different laser operation conditions, line shape is a derivative.



Hyperdog is sensitive to absorption coefficients of ~10^{-5} cm^{-1}.

- For molecules with strong cross section (10^{-17} cm^2), this is 40 ppb.
- Considering 25 kHz measurement bandwidth, the noise equivalent absorption coefficient is ~2 x 10^{-6} $cm^{-1}/Hz^{-1/2}$

This project was supported by

- Army Phase I and II SBIRs (Dr. Dwight Woolard PM)
- Florida High Technology Corridor (I-4) program
- Florida Space Institute
- Florida Space Grant Consortium.