Cavity ringdown spectroscopy

What if we do absorption spectroscopy over a very long range?

What if the absorption feature we need to measure is really weak or if you need very high precision?

- What do you think we can do?

What if the absorption feature we need to measure is really weak, or if you need very high precision?

- Integrate longer
- Use a more sensitive detector
- Cool the detector to lower thermal noise in the system
- Control laser frequency to high degree
- **USE A REALLY LONG PATH SO THAT THE ABSORPTION IS GREATER**
  - But what’s the limit of that? Can I make a path that’s a kilometer long?

Cavities! (not in your teeth hopefully)

- Two mirrors properly aligned such that they light is an incredibly high number of “bounces” in the mirror.
  - Gives a very long effective path length
  - High intensity in the laser cavity

But how does it work?

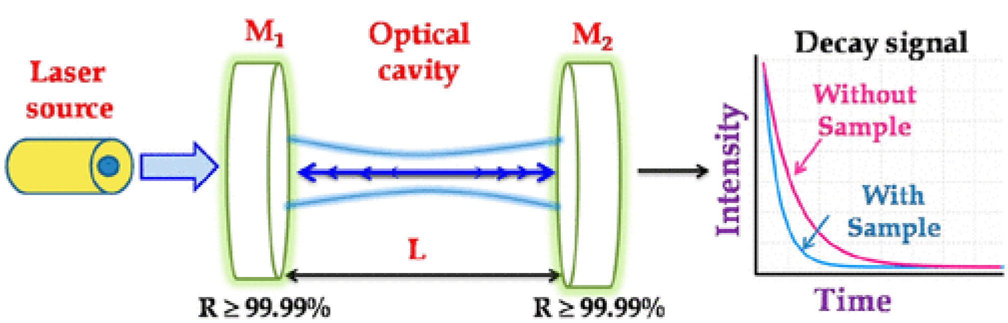
- A laser pulse bounces around the cavity and a little energy from it leaks out each round trip
- You can approximate the peaks of each bounce together as an exponential decay
- Light intensity is an exponential function of extinction coefficient in the cavity

$$I_{\text{out}} = I_{\text{in}} \exp\left[-\left\{\frac{(1-R)c}{L}t + \begin{pmatrix}\text{absorption loss for}\\ \text{sample per round trip}\end{pmatrix}\begin{pmatrix}\text{total number of}\\ \text{round trips}\end{pmatrix}\right\}\right]$$

$$= I_{\text{in}} \exp\left[-\left\{\frac{(1-R)c}{L}t + (2\alpha d)\left(\frac{tc}{2L}\right)\right\}\right]$$

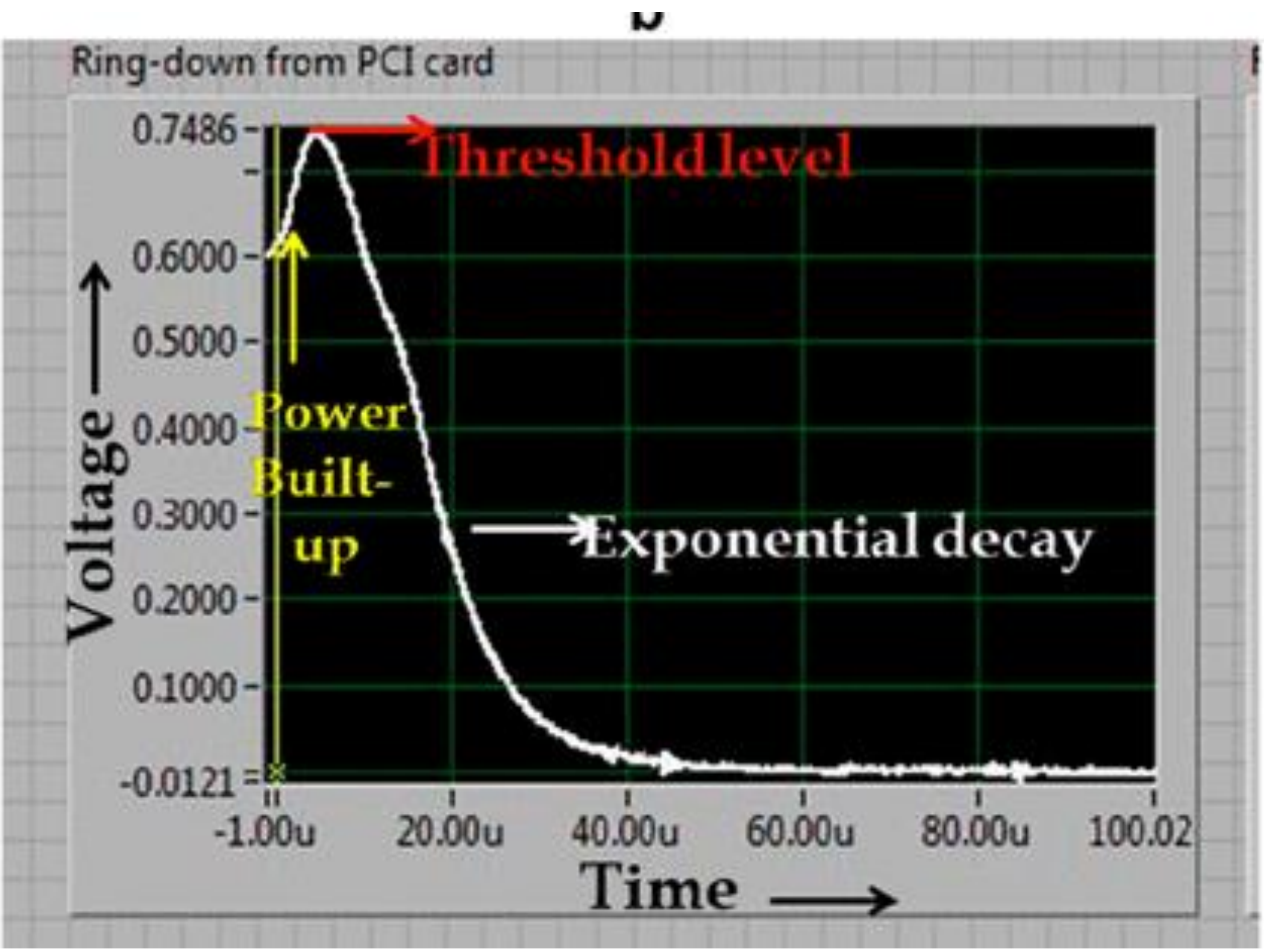
$$= I_{\text{in}} \exp\left[-\frac{tc}{L}\{(1-R) + (\alpha d)\}\right]$$

$$= I_{\text{in}} \exp[-{}^{t}/_{\tau}]; \qquad \text{where } \tau = \frac{L}{[(1-R)+\alpha d]c}$$



How do we actually get the data from that exponential0

- Take the natural log of the exponential decay
- Fit a line to it
- Solve for the absorption



Problems

- Very narrowband measurements
- Slow since you need to record multiple ringdowns
- **VERY FINNICKY TO SETUP**
  - You have at least four mirrors that need to be set up just-so to actually get it where you need it
- Requires some way to modulate the cavity or power within it
  - Pulsed laser
    - Diode lasers are great for this because optical feedback into it, can lock it to a frequency; See “external cavity diode lasers”
  - Modulate cavity off resonance
- Need a fast detector
- Need some really good, high reflectance mirrors
  - Normally we have 99.9% reflective , to do this well you need 99.999% reflective
- Need to match the lasers’ spatial modes to the spatial modes of the cavity

What You're gonna build