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Mid-Infrared Cavity Ringdown Spectroscopy with a cw diode laser

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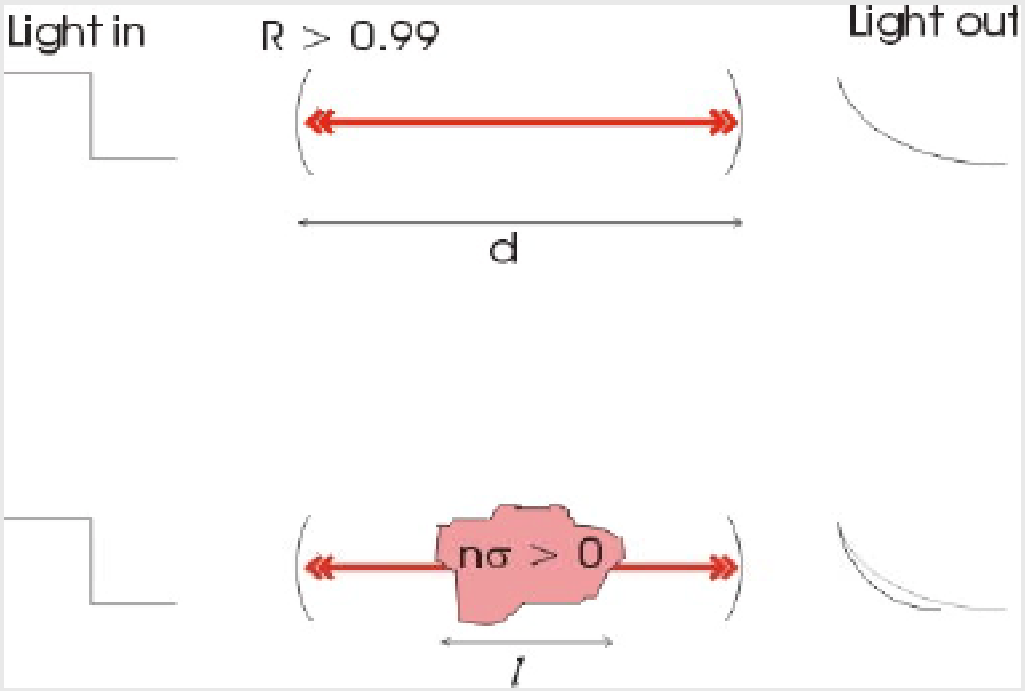
Cavity Ringdown reminder:



$$\tau_o = \frac{d}{c(1-R)}$$

$$\tau = \frac{d}{c(1-R+n\sigma l)}$$

$$n\sigma l = \frac{d}{c}\frac{\Delta\tau}{\tau_0^{\,2}}$$

Design considerations: *LIGHT SOURCE*

- **Need a coherent light source -> tunable helium cooled IR diode laser system (laser Components L5800)**

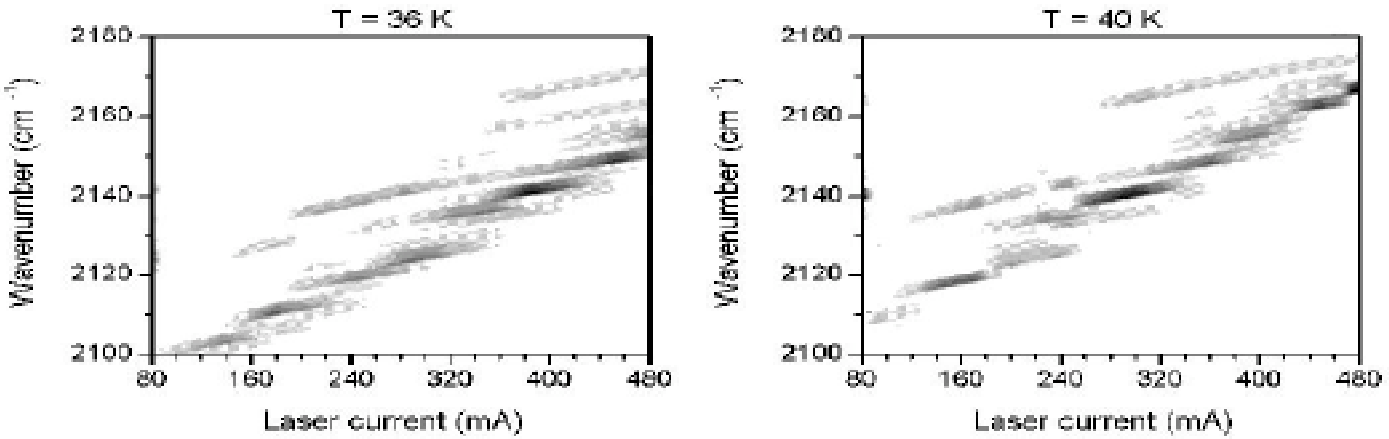
  λ=4 - 16 μm

  low power ~ 0.1 mW

  narrow band width (5-100 MHz)

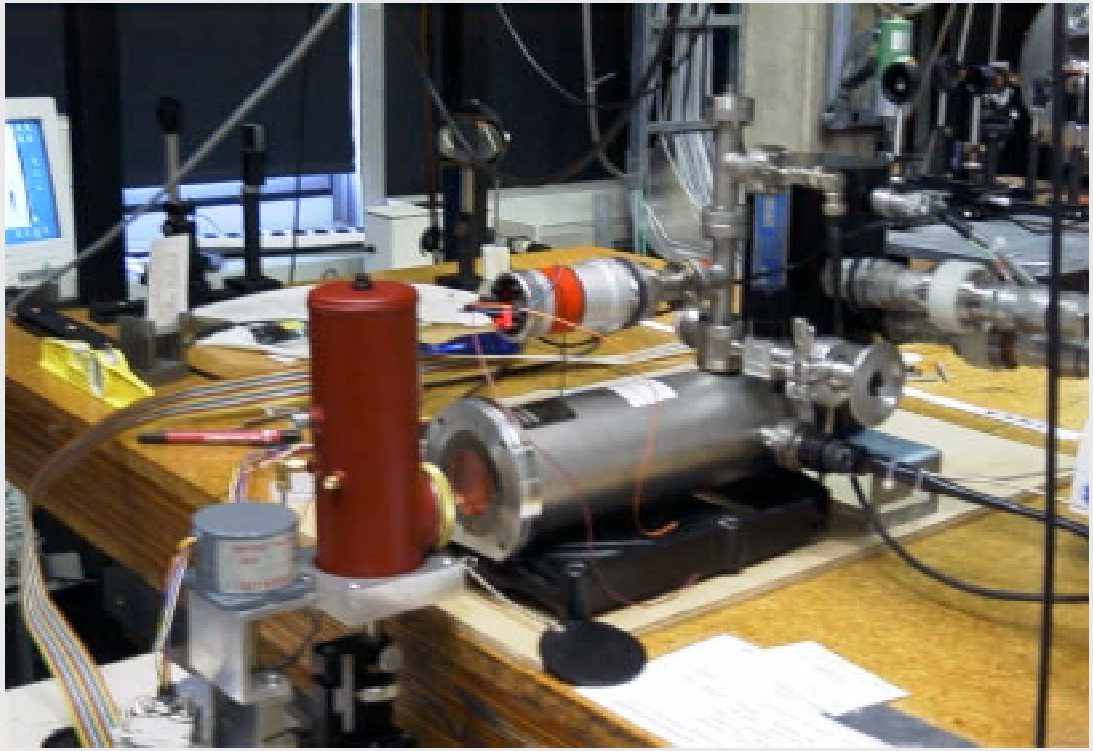
- **Alignment and laser characterization are tricky -> invisible beam need IR detector**

Mode charts at 36 K and 40 K:



The relative laser output power is a function of the laser current the grating position at a constant temperature

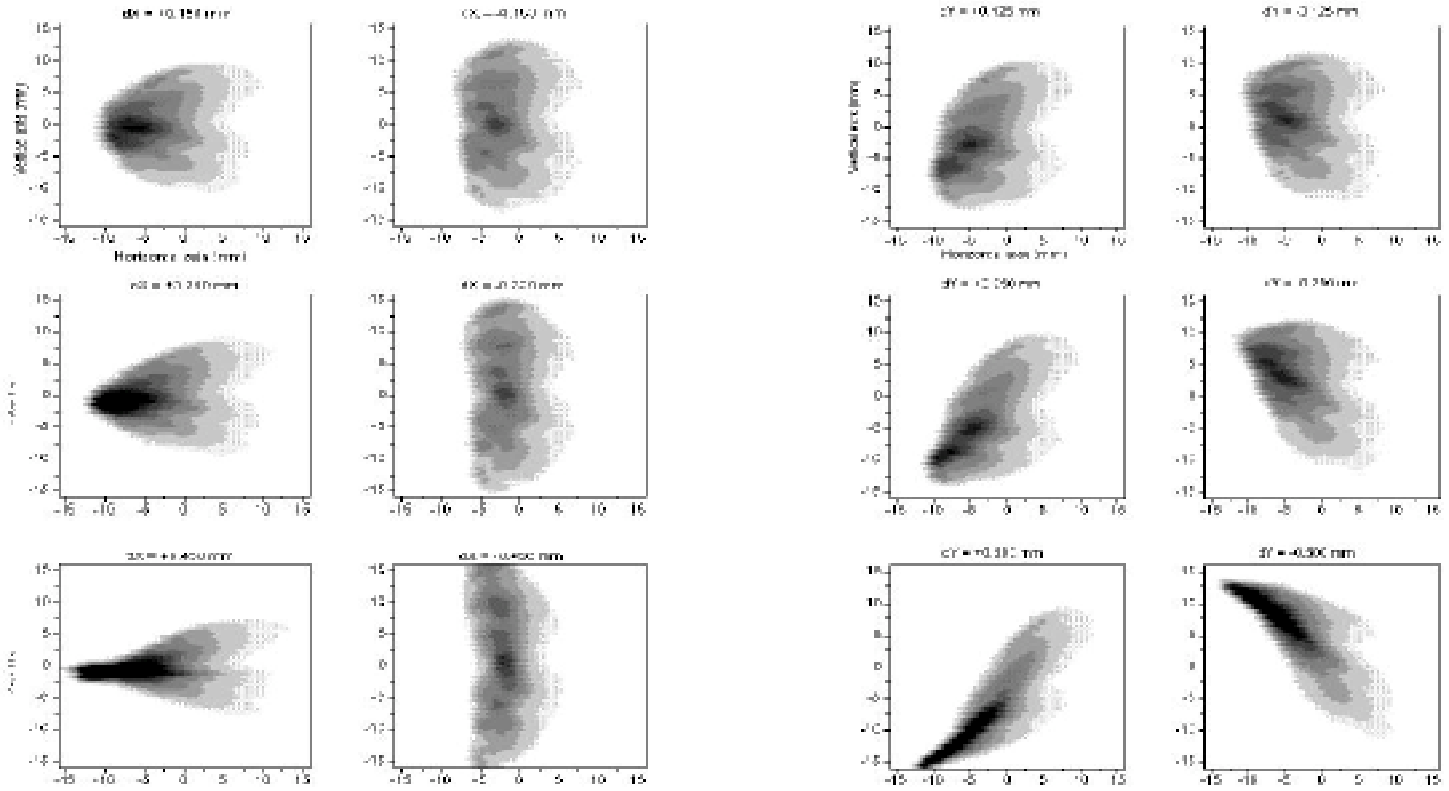
Beam detection device = IR beam profiler:



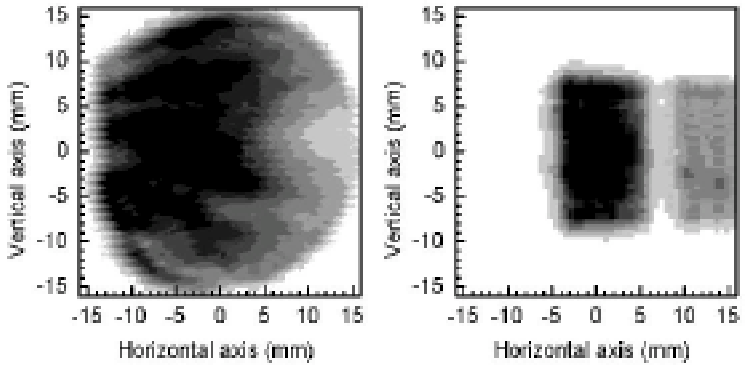
Detection area = 0.01 sq.cm

Max.spectral response at 14 μm

Beam profiles:



Mode selector device performances:



mirrors not suitable for laser beam size

laser power reduced by 4 at the output

Improvements under achievement:

-use of flat gold coated mirrors
-enlargement of device apertures
-better knowledge of the laser

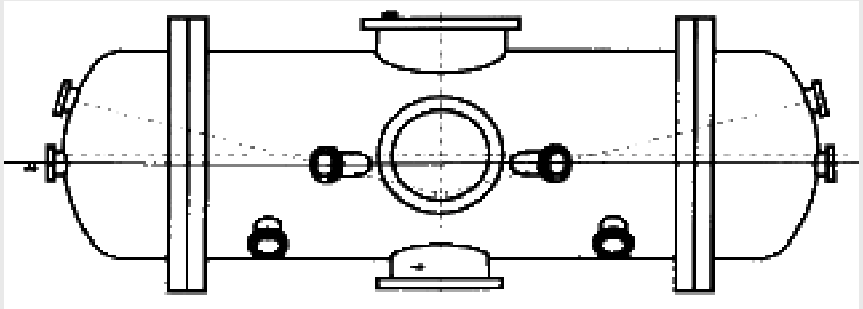
Design considerations: *CAVITY*

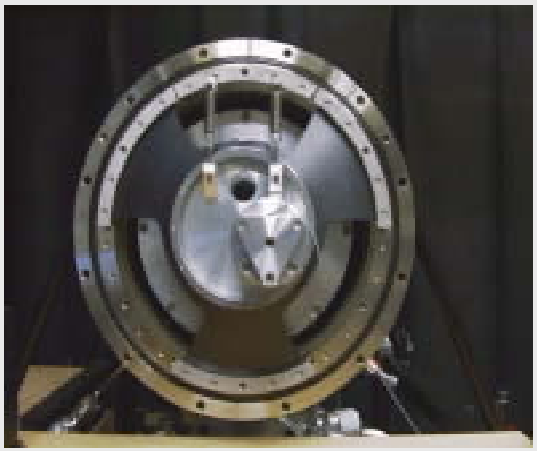
- Use of a stable confocal cavity, i.e R=d
- The two ZnSe high reflective mirrors must be far awa from the discharge
- The Free Spectral range should be:

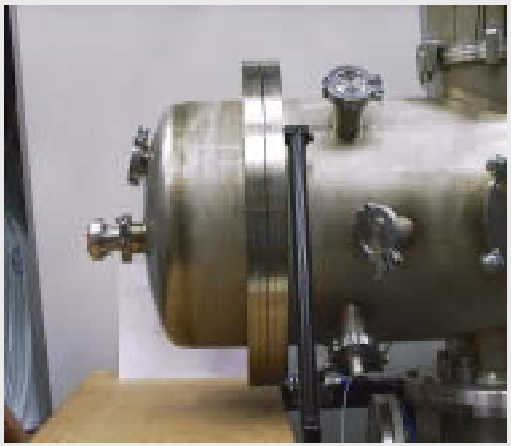
$\frac{c}{4d} > 50MHz$ -> d<1.5 m

- The cavity length should match the laser wavelength
- The mirrors should be in the vacuum vessel

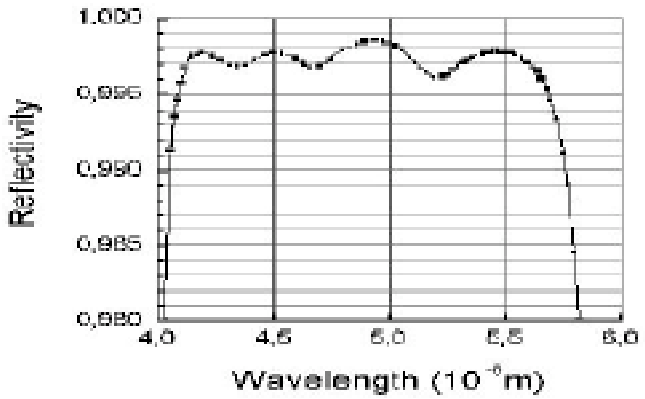
The design:

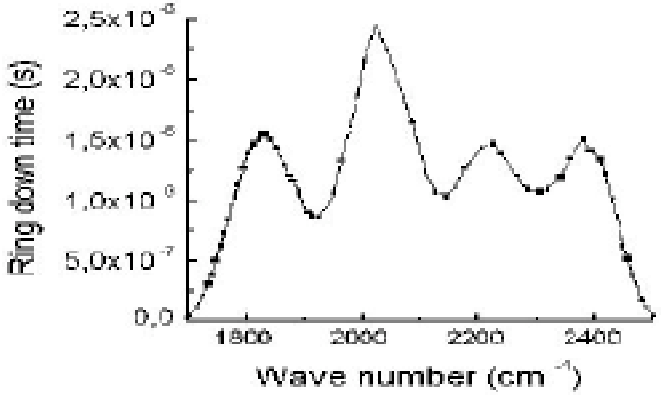






The mirrors:

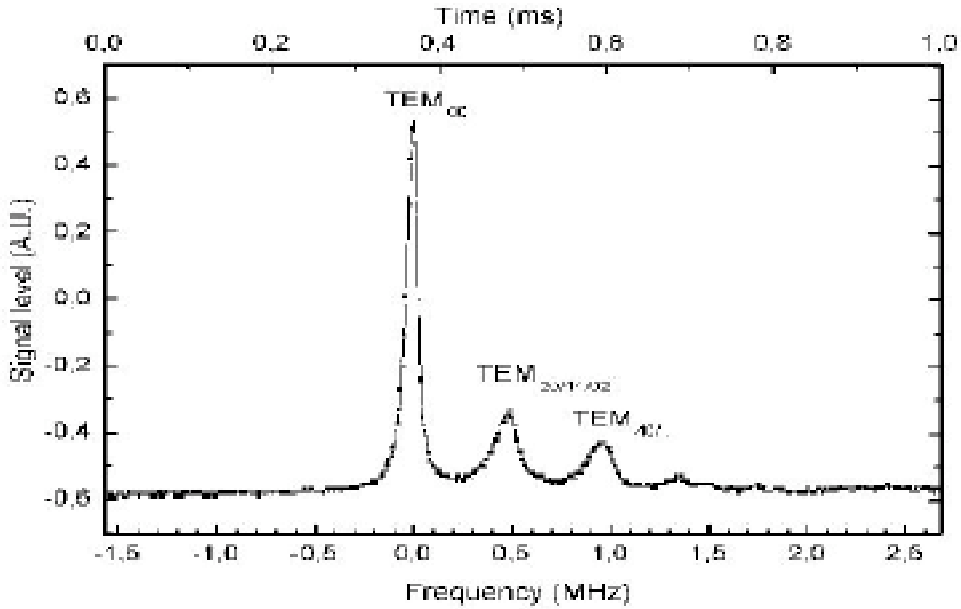




High reflectivity (R>0.996 for 4.2 - 5.6 μm)

Finite transmission (1-R)

Axial and transverse modes:

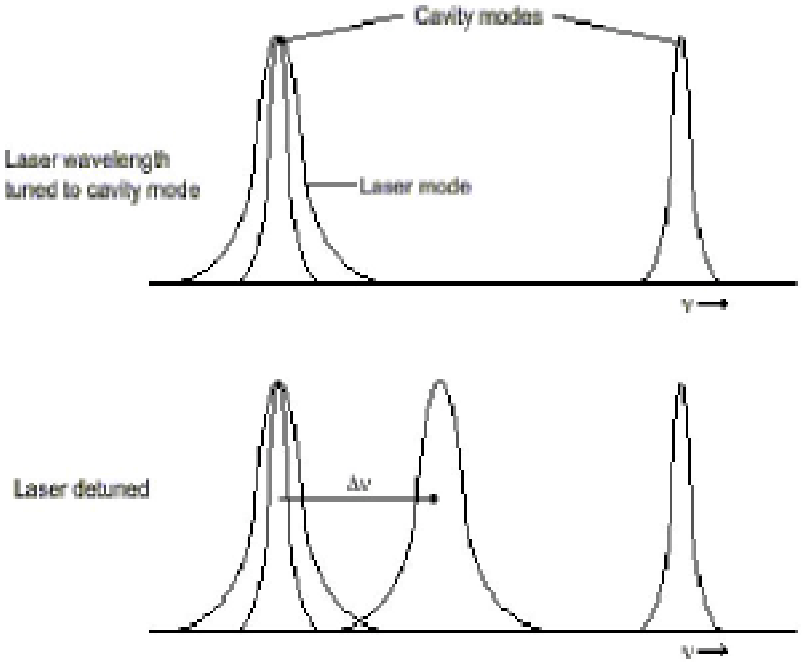


Use of a CO laser

Even transverse modes should coincide with fondamental modes in a perfect confocal cavity

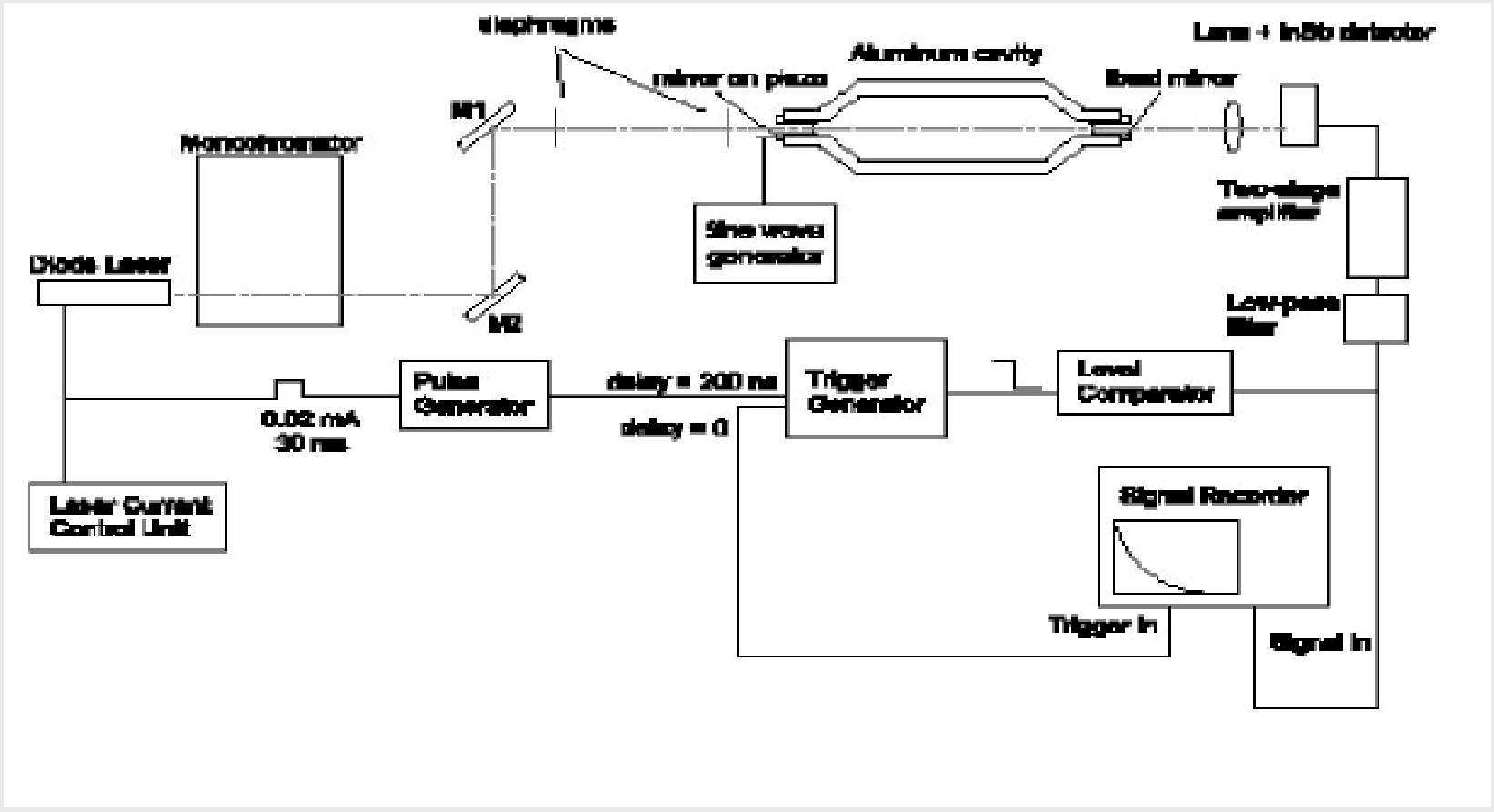
-> error in cavity length

Laser diode control:

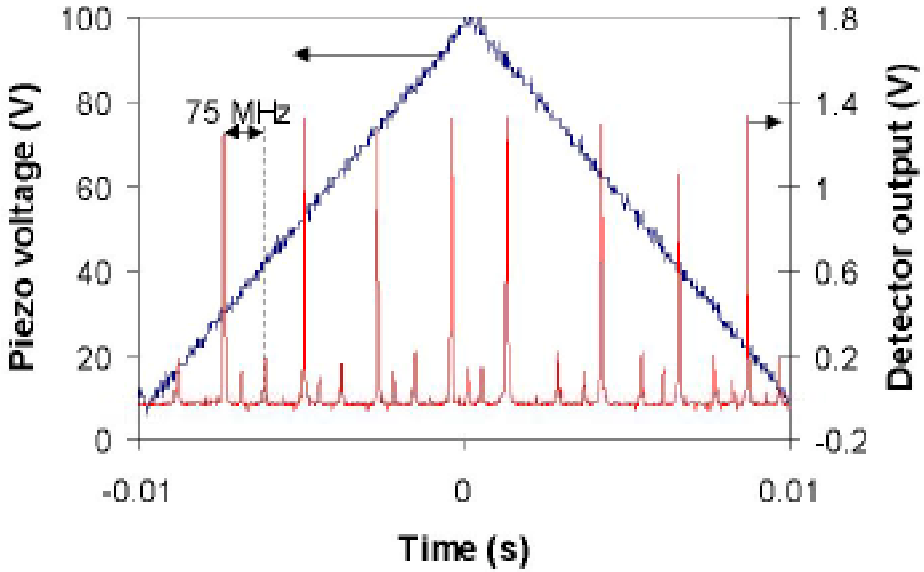


Chopping the laser = detuning the wavelength

Experimental set-up:



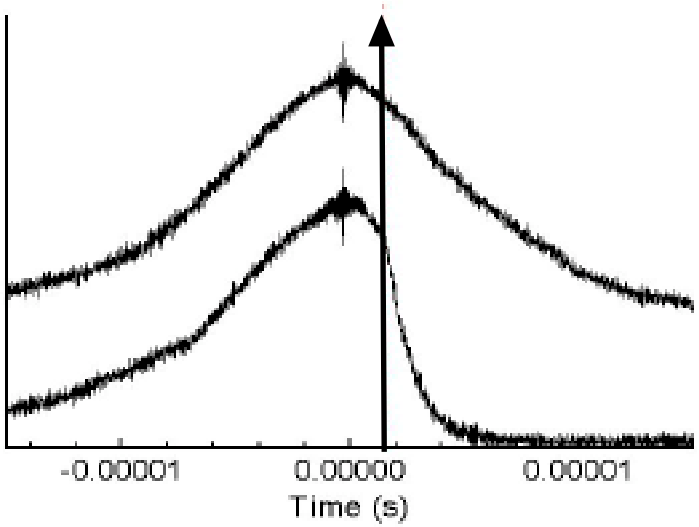
Optical cavity characterization:



Measured with CO laser

F=1000

Detuning the laser:



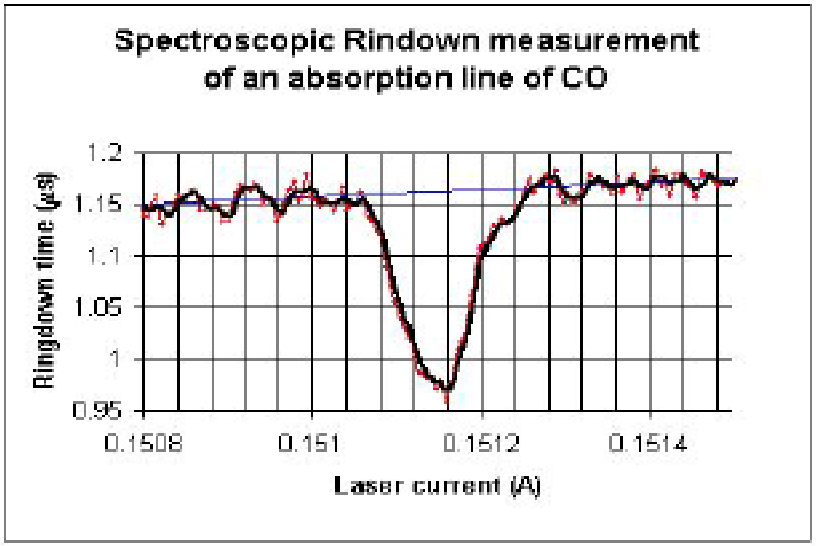
Cavity mode with and without detuning

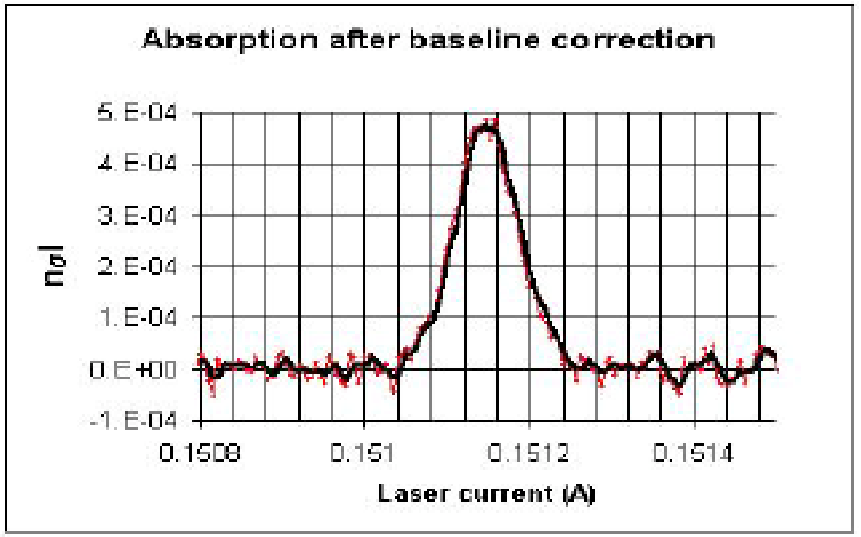
Laser detuned 30 MHz ca. 50 s

Ringdown time:

$$\tau = 1.2\mu s$$

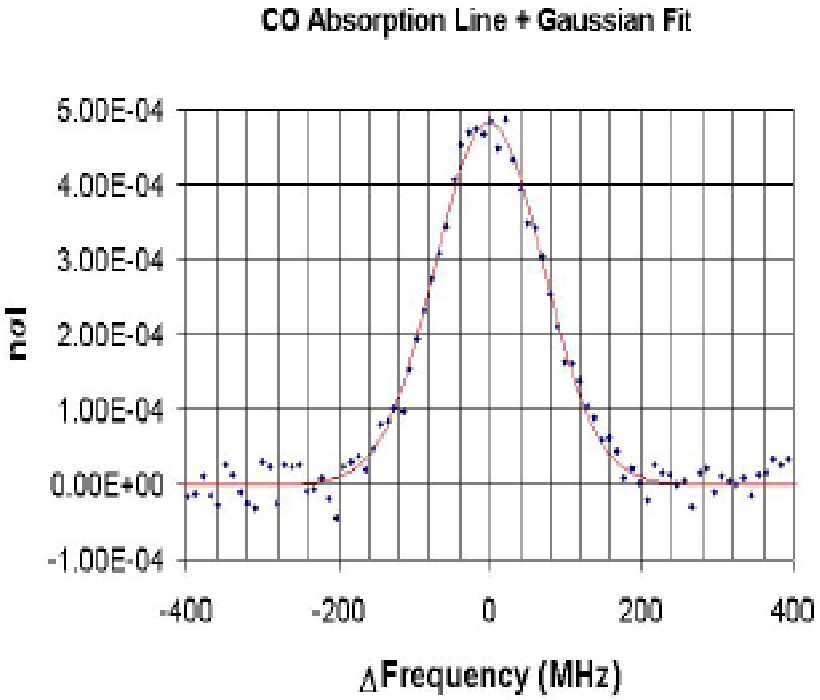
Results:





$$n\sigma l = \frac{d}{c}\frac{\Delta\tau}{\tau^2{}_0}$$

Results:

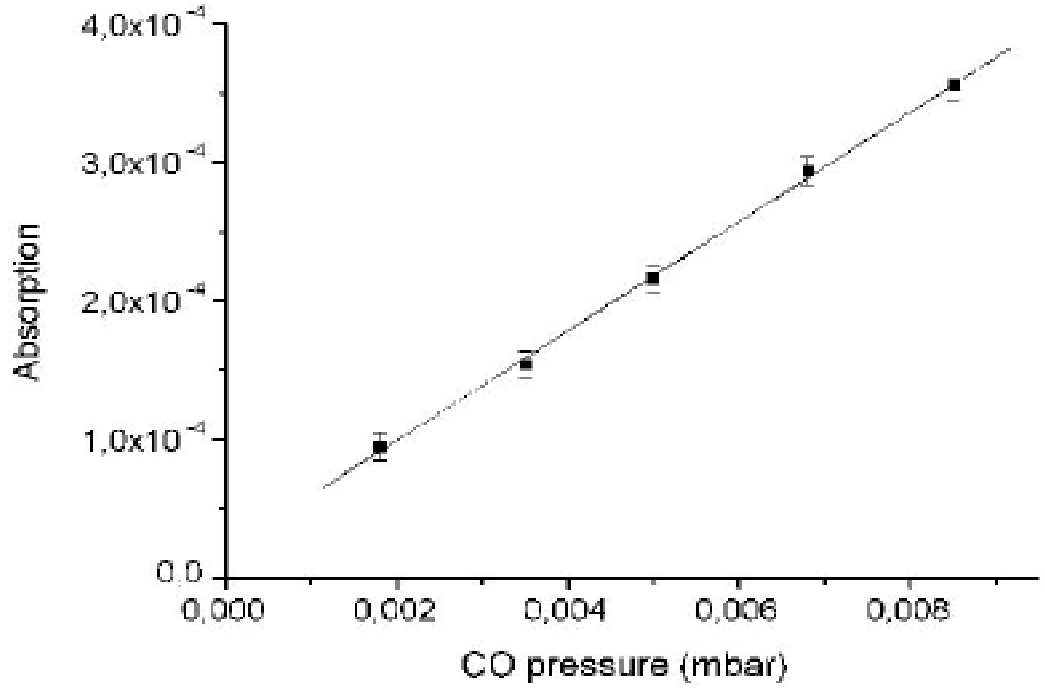


$$F_0 = 64.373THz = 2147.20497cm^{-1} = 4.6572\mu m$$

$$\Delta F_{1/e} = 202MHz$$

$$\Delta F_{doppler} = 175MHz \Rightarrow laserlinewidth = 50MHz$$

Results: *CO PRESSURE DEPENDANCE*

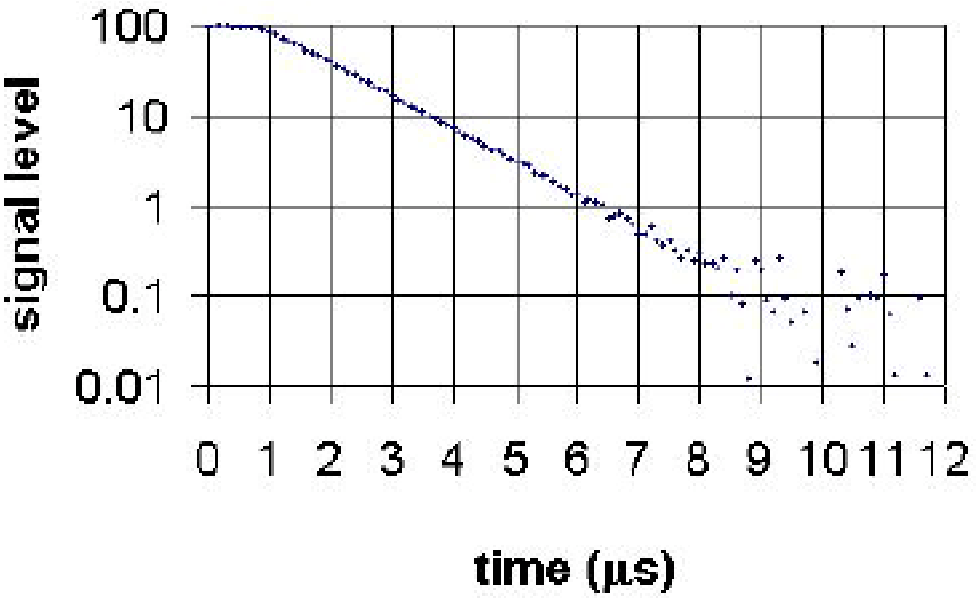


Detection limit :

$$< 10^{-9} mbar (10^{12} m^{-3})$$

Pressure is total CO pressure - Absorption by C12O17 isotope

Perspective: *TIME RESOLVED MEASUREMENTS*

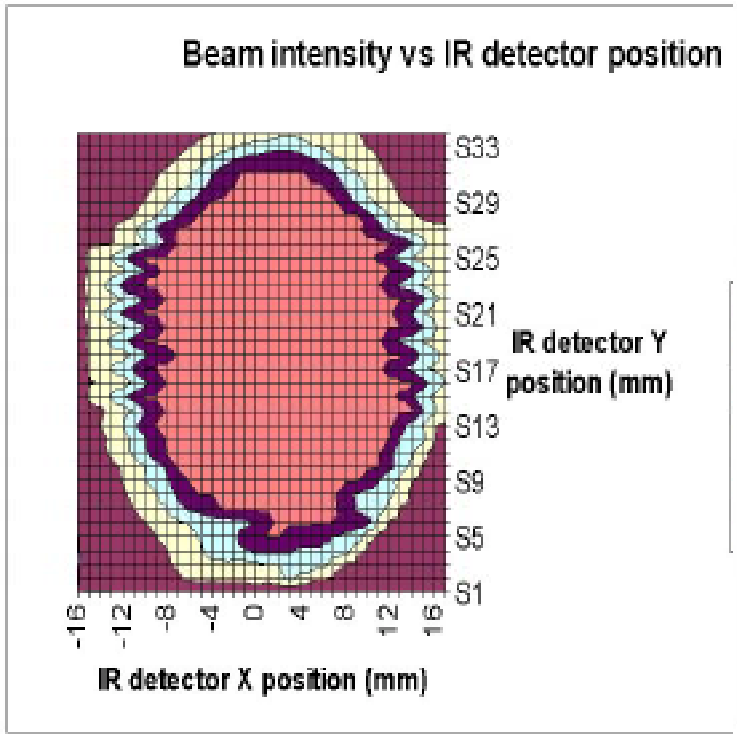


Measurement < 30 μs

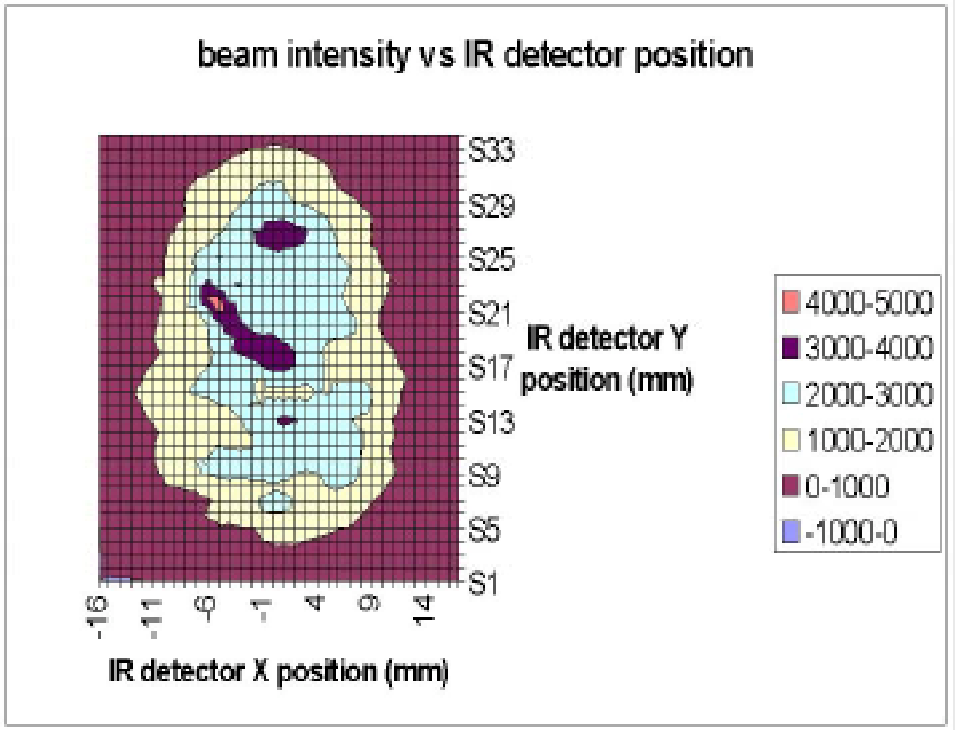
CO laser at 5.518 μm

τ=1.54 μs

Improvements: *LASER CHARACTERIZATION*

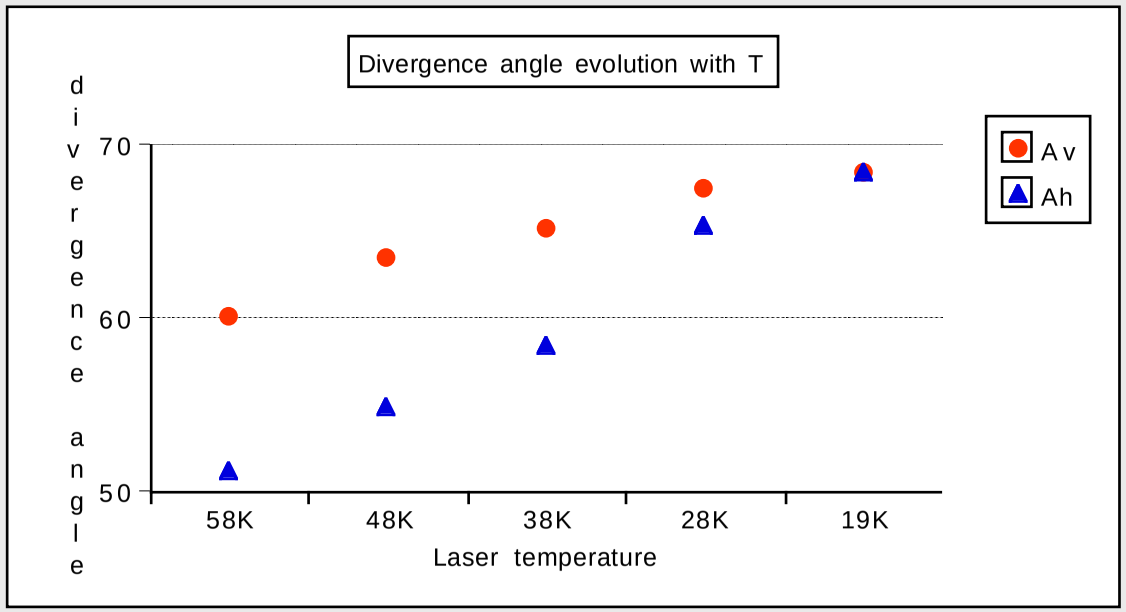


19K



58K

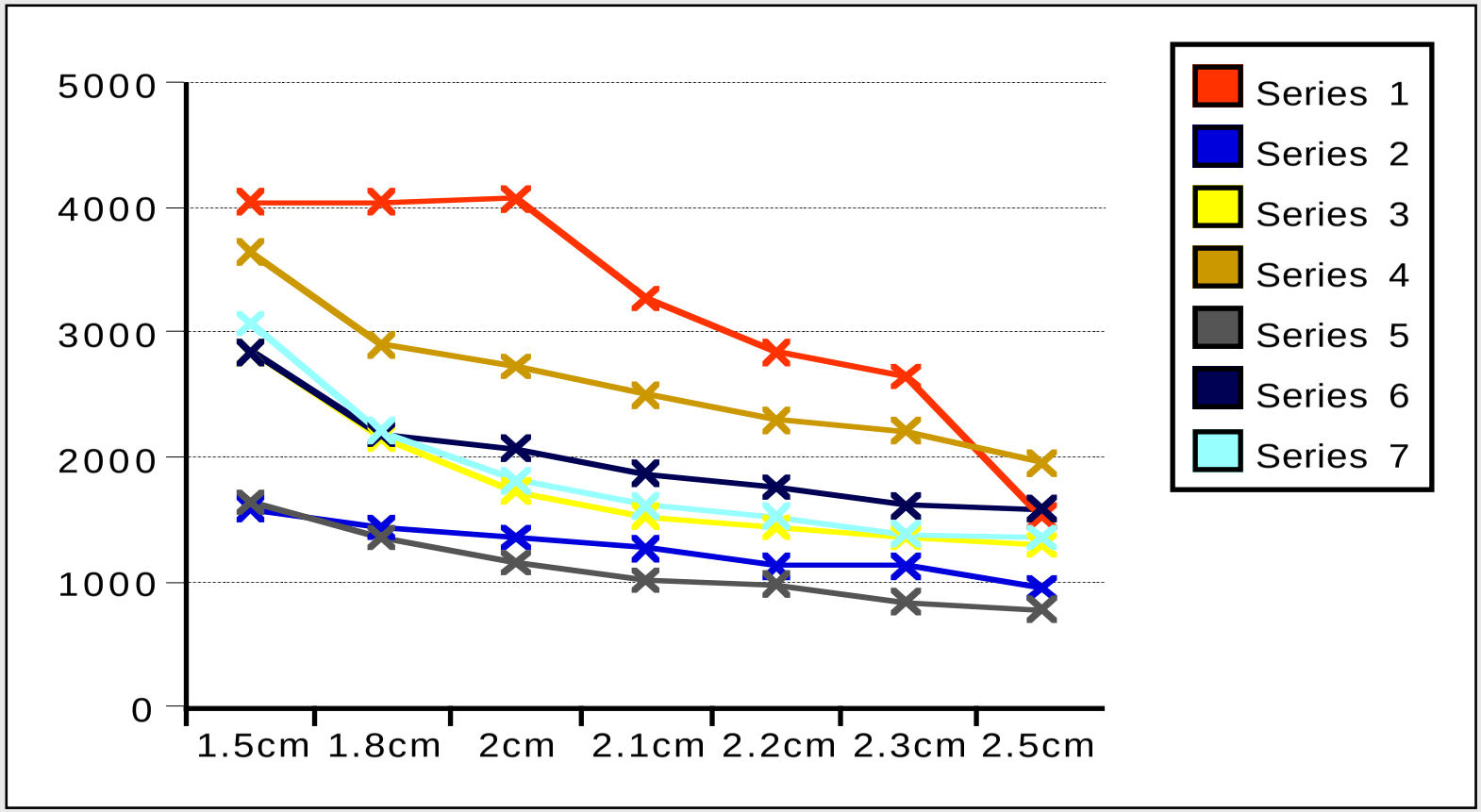
Laser beam divergence angle evolution towards temperature



IR detector is ~2.5 cm from laser active region output

diode #1

Position of the active region inside the cold head:



Information needed for further experiment:

- Laser intensity needed inside cavity (related to the saturation parameter)
- What do we want for a laser beam shape: elliptic or circular?
- What temperature of operation should we work at (related to the mode chart mode matching)?
- Pressure in the coldhead appears to be quite high. Lowest temperature reached in the past used to be better (12K instead of 19K currently).
- Would it be pertinent to buy a new laser (4 kEuro)?

Conclusions:

- The CRDS at mid-infrared with a cw laser diode does work
- At that point, the detection limit for CO is $10^{12}\ m^{-3}$
- Time resolution is around the millisecond range. Can probably be improved the microsecond range
- Sensitivity (preliminary):

$$n\sigma l_{\min} = 10^{-5}$$