"Utilization of a watch tuning fork for highly sensitive photoacoustic spectroscopy"

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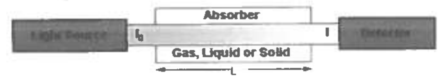
- Motivation and Technology Issues
- NIR Diode Laser-based PAS Gas Sensor
- Performance of PAS based Methane Sensor
- Summary and Outlook

Absorption Spectroscopy



Beer's Law

$$I(\nu)=I_0 \cdot e^{-\alpha(\nu) \cdot P_a \cdot L}$$

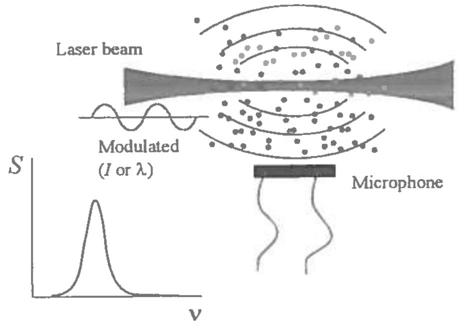
$\alpha(\nu)$ - absorption coefficient [cm^{-1} atm^{-1}]; L – path length [cm]
ν - frequency [cm^{-1}]; P_a- partial pressure [atm]

Molecular Absorption Coefficient

$$\alpha(\nu)= C \cdot S \cdot g(\nu - \nu_0)$$

C - total number of molecules of absorbing gas/atm/cm^3 [molecule·cm^{-3} ·atm^{-1}]
S - molecular line intensity [cm ·$molecule^{-1}$]
$g(\nu - \nu_0)$ - normalized lineshape function [cm],(Gaussian, Lorentzian, Voigt)

Photoacoustic spectroscopy – background-free



Classic resonant PAS in gases

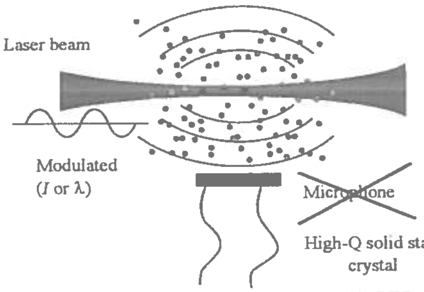
- Signal proportional to Q/f
- Energy accumulated in air
- Relatively low Q

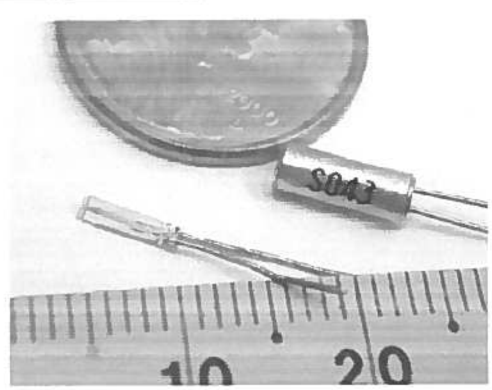
Examples: f=8000 Hz, Q=200 ⇒ Q/f=25 ms
f=4000 Hz, Q=18 ⇒ Q/f=4.5 ms

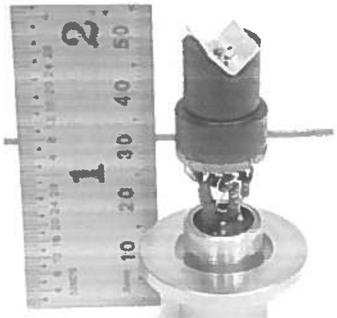
- Ambient noise, especially flow noise; S_n~1/f
- Resonant cell size ~λ/2; for f=1000 Hz λ=30 cm
- Signal inversely proportional to the mode volume

Solution: Store energy in a MICROPHONE instead of the GAS!

Quartz-assisted PAS (QAPAS)



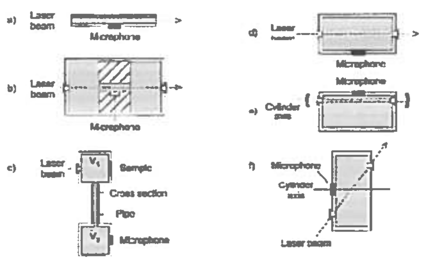




QEPAS vs. traditional PAS

- Typical Q=20000 in vacuum, 8000 at 1 atm pressure
  - Energy accumulation time Q/f= 250 ms (PAS: ~25 ms)
- Extremely small size – 5mm×1.4mm×0.2mm
  - Local probes
  - Small sample volume
- Low noise – limited by E=kT stored in a single mode
  - Thermal excitation is readily observed
- High operation frequency – immune to background noise

Acoustic resonators

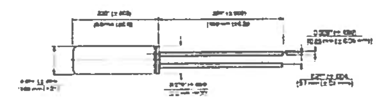


REVIEW ARTICLE

Practical solution – a watch tuning fork

RALTRON

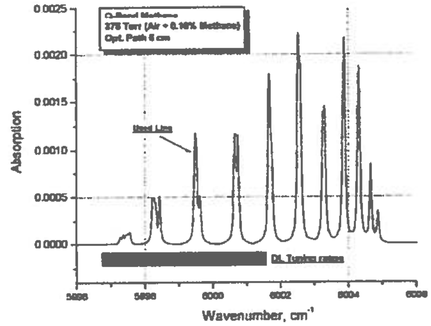
WATCH CRYSTAL TUNING FORKS



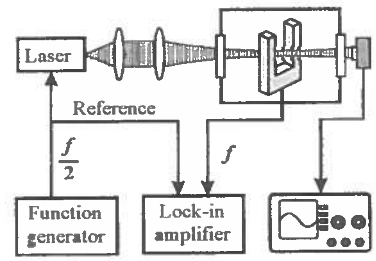
R26

Frequency: 32.768kHz ±30ppm Operating temperature: −10°C to +60°C
ESR: 35kohms max (R26), 50kohms max (R38)

Price: 1-50 $0.32 ea. (Newark Electronics)



Photoacoustic Spectroscopy with a Solid State Resonator



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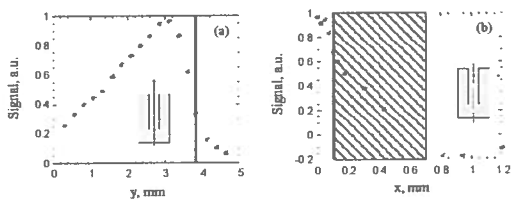

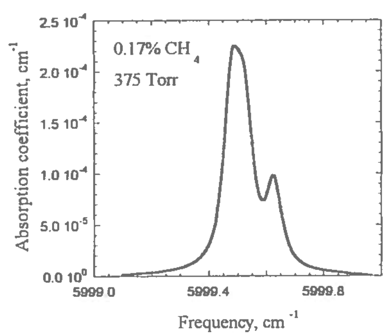

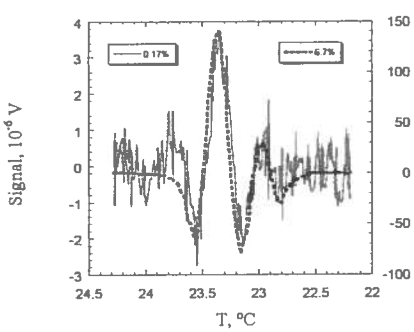

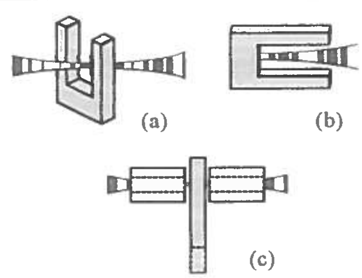

Configuration	a	b	c
Responsivity, V/(W·cm^{-1})	1.24	5.03	9.45
Detectivity, cm^{-1} W/√Hz	8.8×10^{-7}	2.2×10^{-7}	1.2×10^{-7}