Rapid Ultralow Pressure Manometry by Light Absorption Spectroscopy

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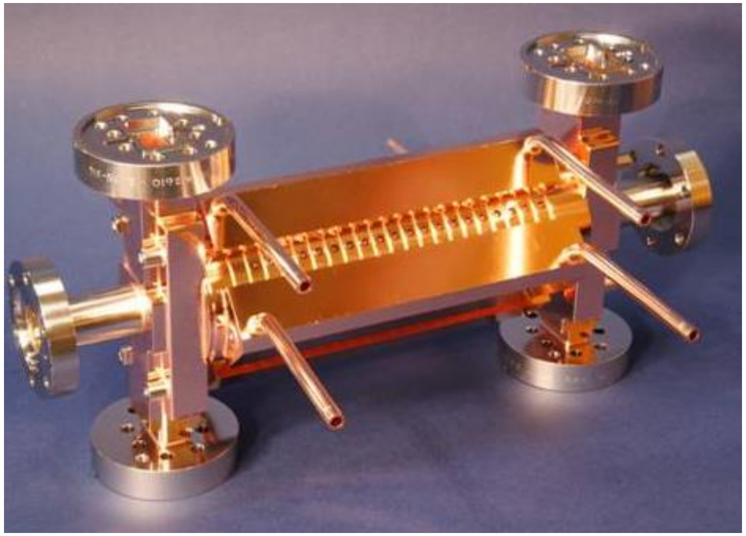
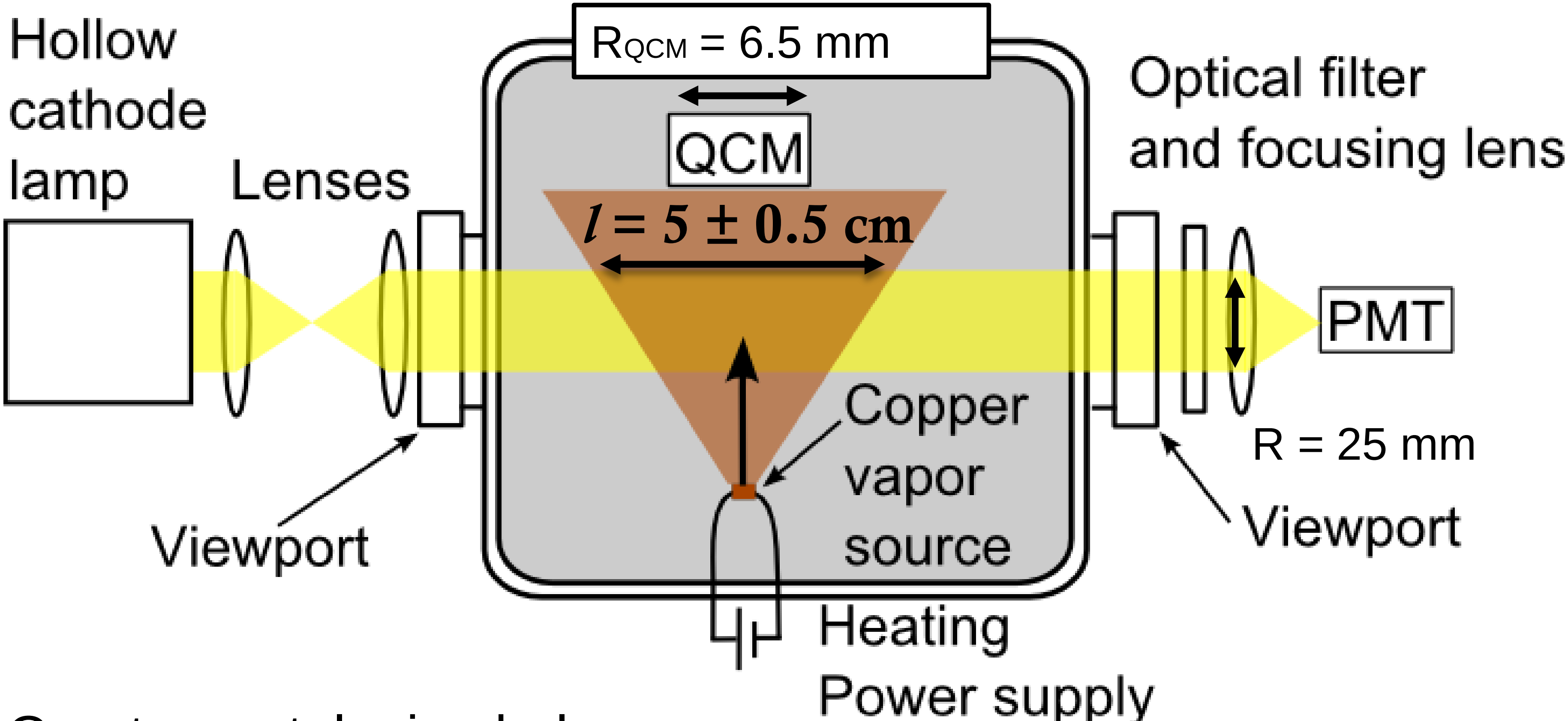
Motivation

- CLIC main beam vacuum requirements from beam dynamics: H_20, CO, CO_2 partial pressures < $3*10^{-9}$ mbar
- The RF causes outgassing in CLIC accelerator structures mainly to two mechanism: breakdown and dark current
- Expected pressure rise from simulations: several orders of magnitude on ~100 ns time scale. To be verified experimentally.
- Aim: develop method to measure partial pressure changes of ~10^{-8} mbar on ~100 ns time scale at a RF test stand (”Xbox”). For the moment focusing on absorption spectroscopy and Cu.



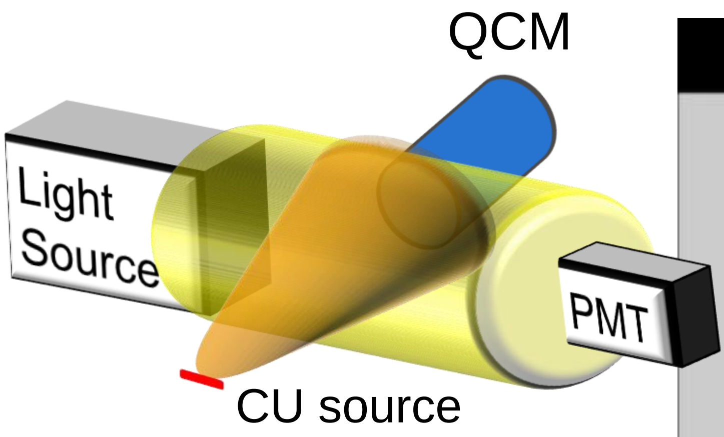
Test setup

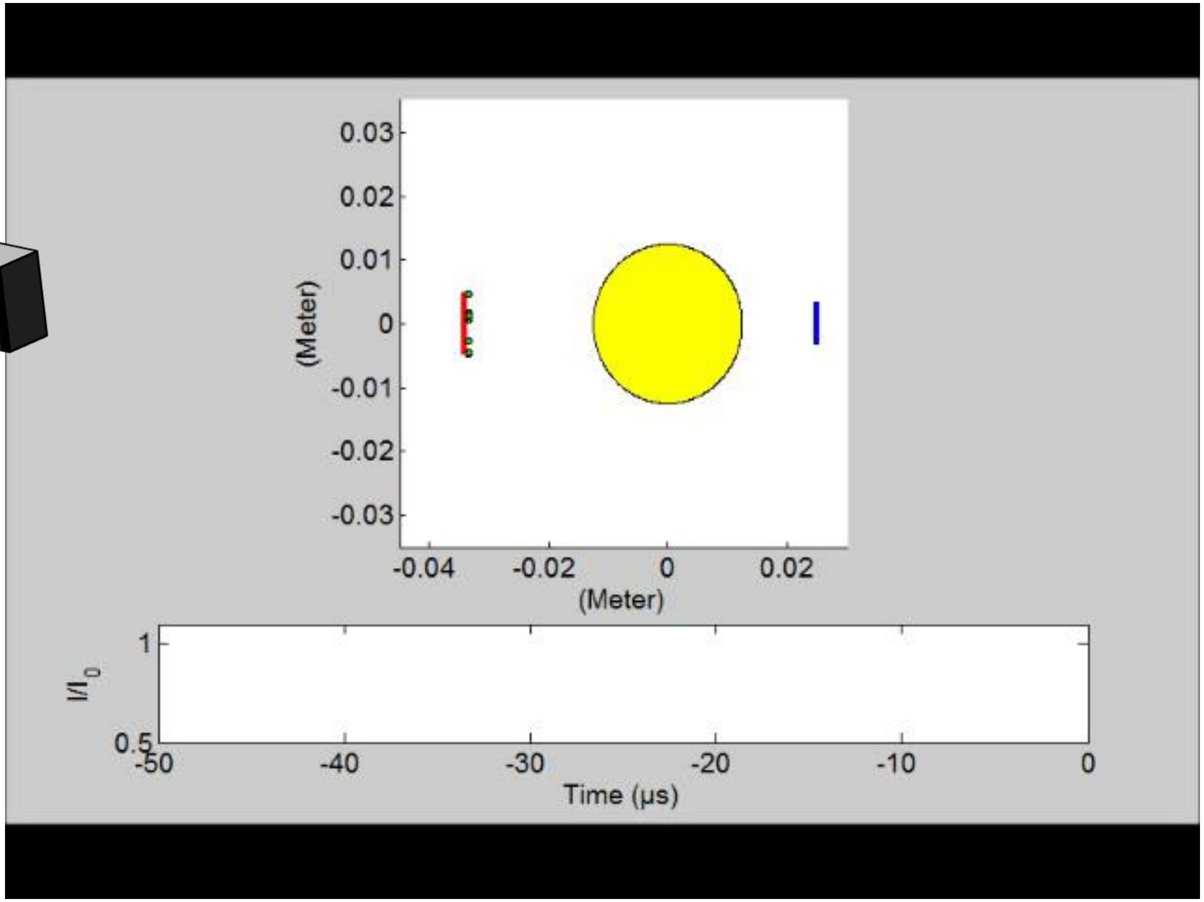


Quartz crystal microbalance (QCM) as reference

Photo multiplier tube (PMT)

Simulated Visualization

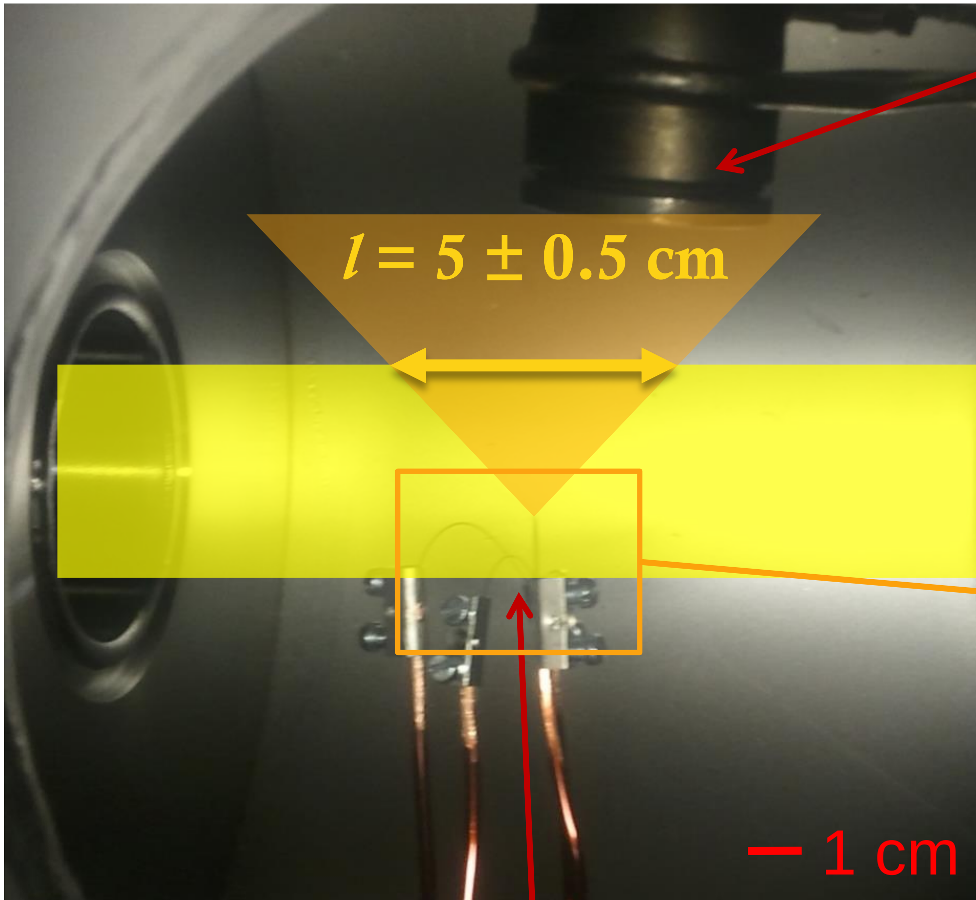


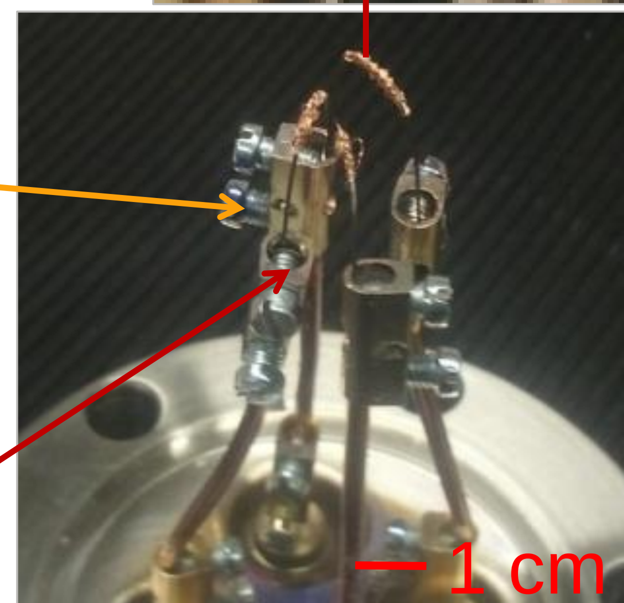


$$dp \propto N_{Cu} \propto \frac{I}{I_0}$$

Setup inside vacuum

QCM

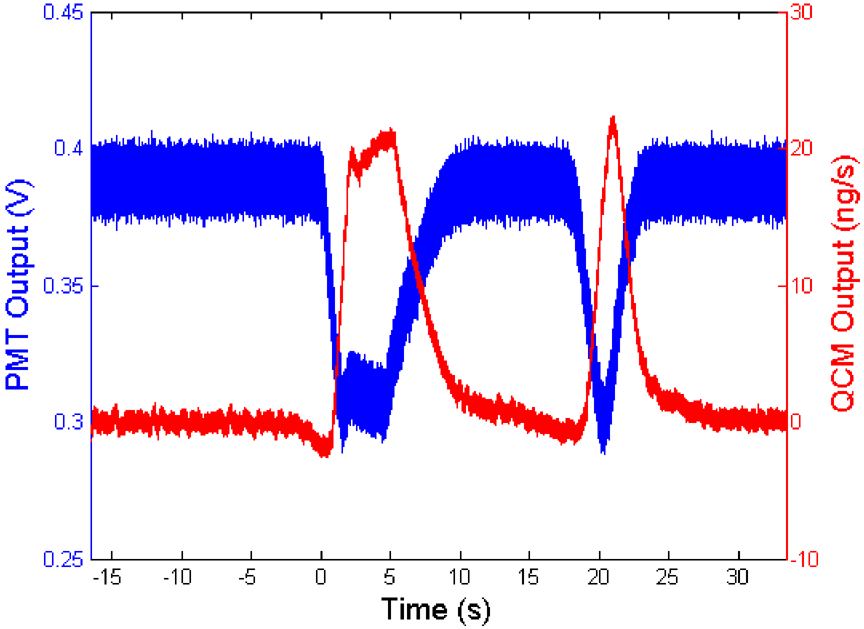




Cu vapour source:
Cu wire around W wire

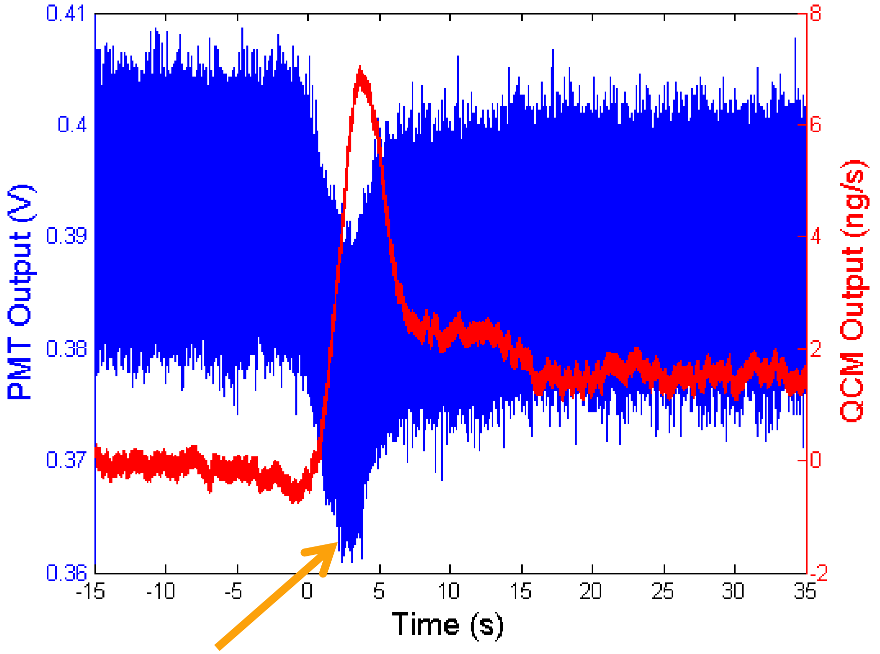
Results

Measurement 1



Sample rate: 100 ks/s
6 kHz low pass filter for PMT
1 Hz low pass filter for QCM

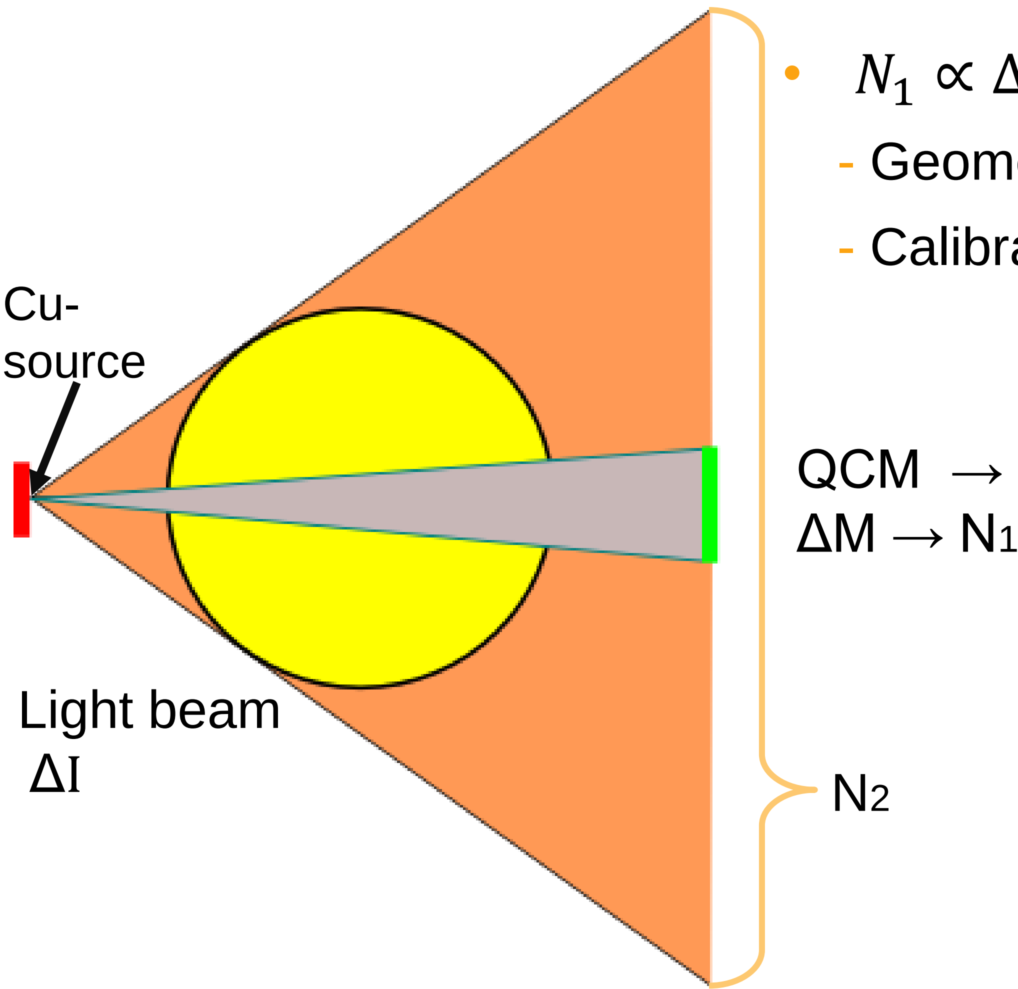
Measurement 2



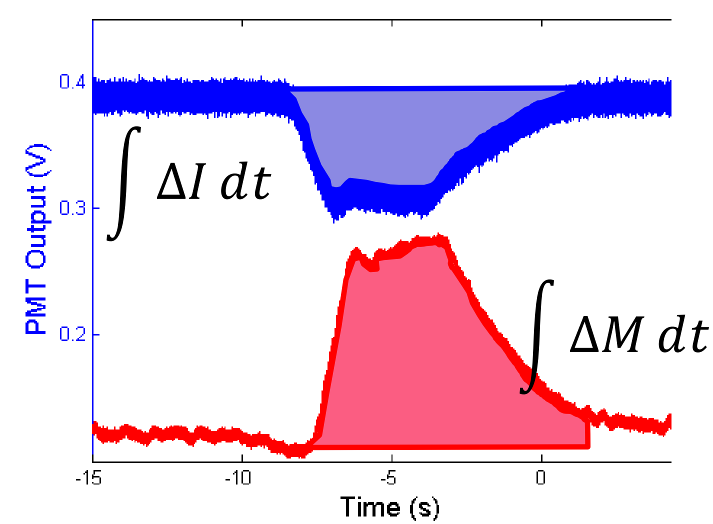
Change in intensity ~5%
≈ 2 * 10^{11} absorbances
≈ <u>10^{-4} mbar</u>

Calibration
(Relate intensity change to number of atoms)

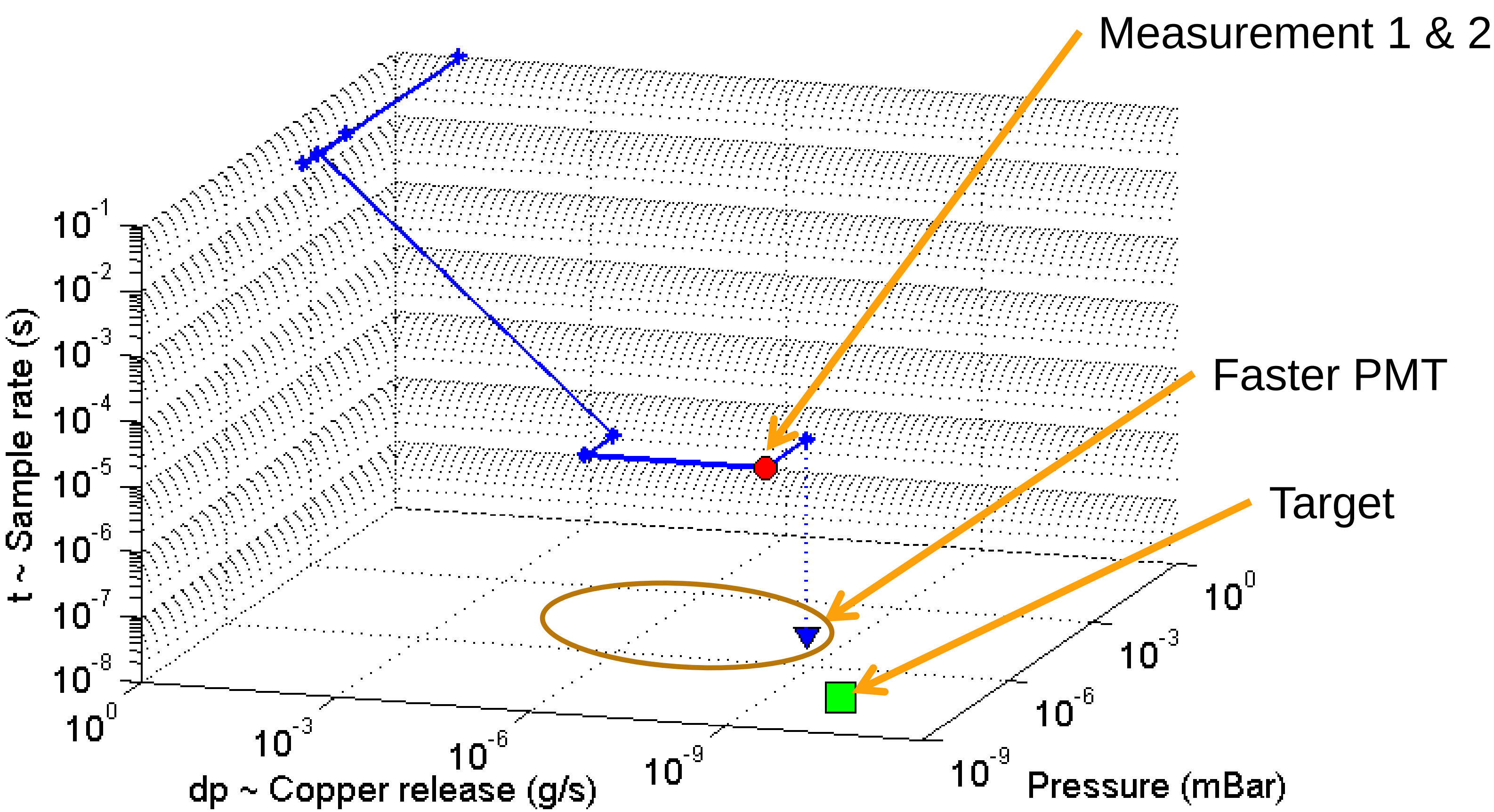
- $N_1 \propto \Delta M$ atoms was measured by QCM
  - Geometrical correction gives $N_2 \propto N_1 \propto \Delta M$
  - Calibration gives $\underline{\Delta I \ \propto \Delta M \propto N_1 \propto N_2}$



$$\int \Delta I \, dt \propto \int \Delta M \, dt = M$$



Progress
t – dP – P Diagram



1 ng/s = 10^{13} Cu atoms/s ≈ $5 \cdot 10^{-5}$ mbar

Conclusion

Achieved:

- **Measured few ng/s Cu at 10^{-5} mbar base pressure**

Challenges:

- **Faster response time**
- **Absolute calibration**

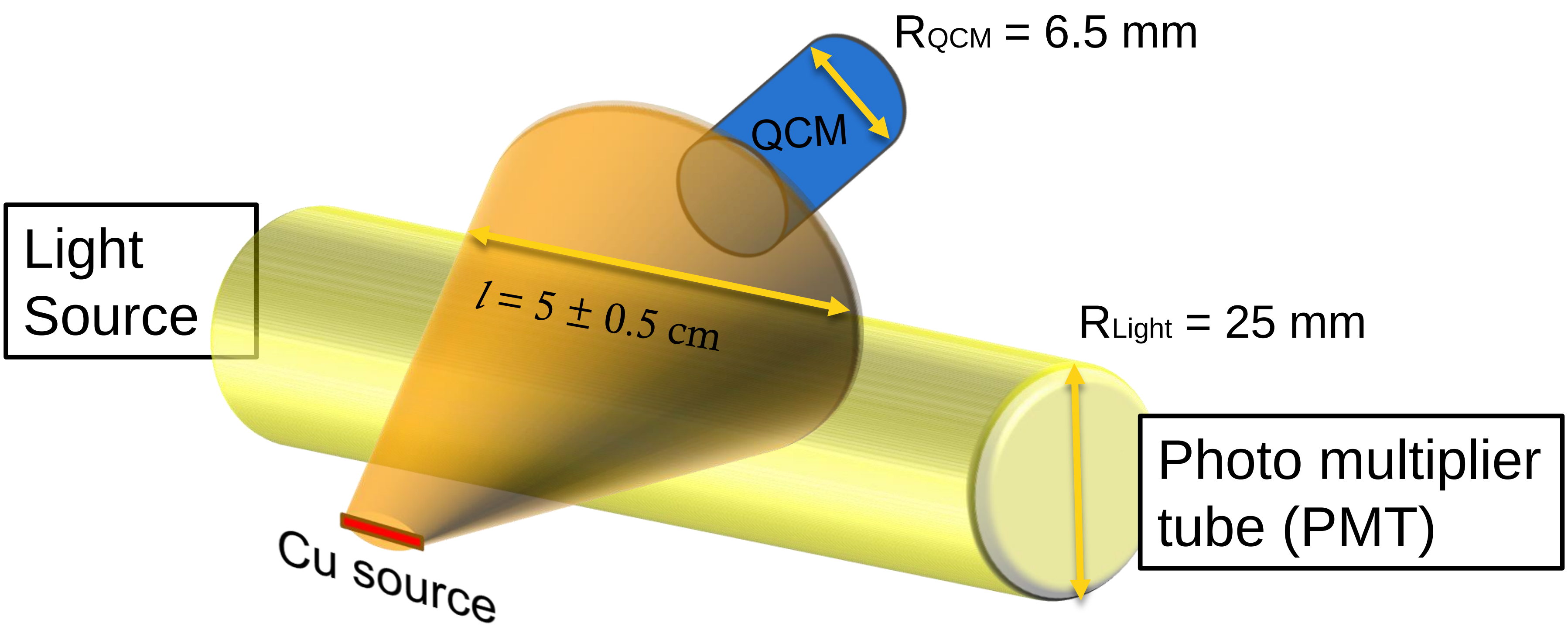
Interpretation of measurement:

- **Can one atom have multiple absorptions?**

Questions and Comments

Thank You!

Setup & Cross section dimension

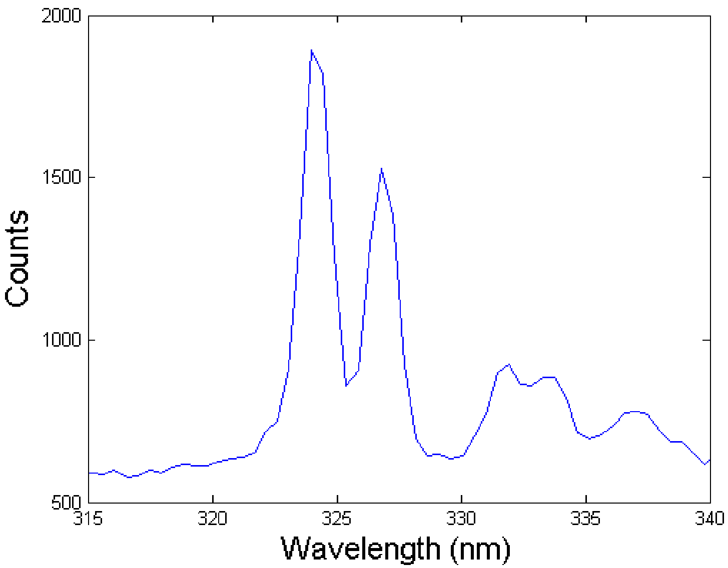


Absorption spectroscopy

- 324.8 nm and 327.4 nm wavelengths are strongly absorbed in copper vapor

- Light source must be stable
    - Copper hollow cathode lamp is suitable low cost light source

- Light intensity changes is measured with Photomultiplier tube (PMT), bandwidth 20 kHz

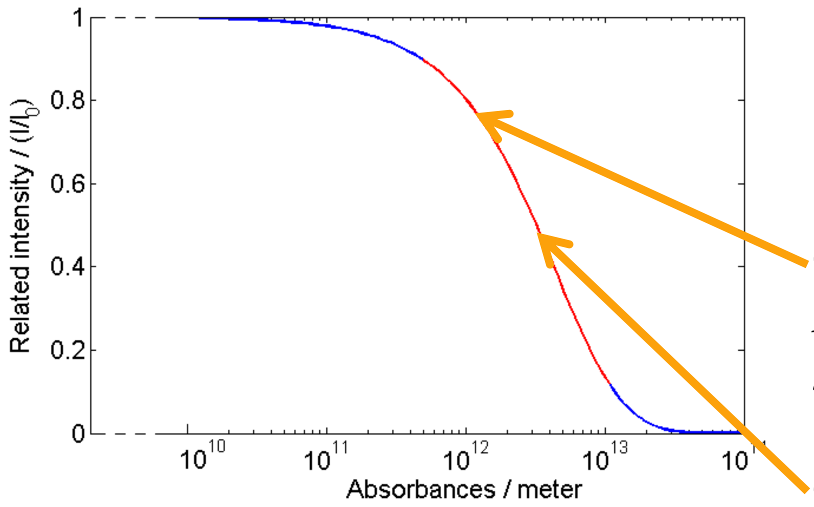


Beer-Lamberts law (Light absorbtion in copper vapour)

$$I = I_{0\,325} e^{-\sigma_{325} l N} + I_{0\,327} e^{-\sigma_{327} l N}$$

$\sigma_{325}, \sigma_{327}$ Cross section for 324.8 nm and 327.4 nm wavelengths

$I_{0\,325}, I_{0\,327}$ Emitted intensity of 324.8 nm and 327.4 nm wavelengths



l length of light beam in Cu vapor

N number of absorbing Cu atoms

Current operation area (Signal > |Noise|)

I = 90% - 10%

lN = 4.9 * 10^{11} - 1.2 * 10^{13} Absorbances/meter

Operation point sensitivity:

9 * 10^{11} Absorbances/meter