Remote Raman detection of chlorine gas

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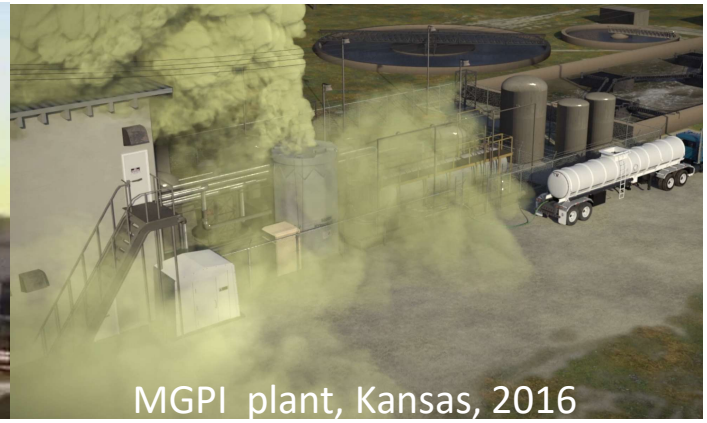
Motivation

- Remote measurements to detect chlorine gas
- Chlorine gas exposure:

➢ **Industrial**

manufacturing
storage
handling

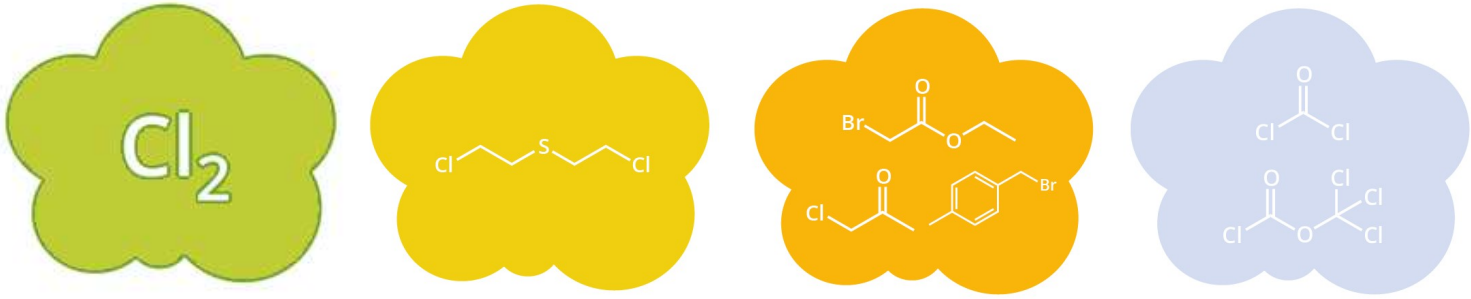


Changzhou, China 2021

Motivation

- Chlorine gas exposure:

➢ **Warfare agent -** chlorine, mustard gas, bromine and phosgene



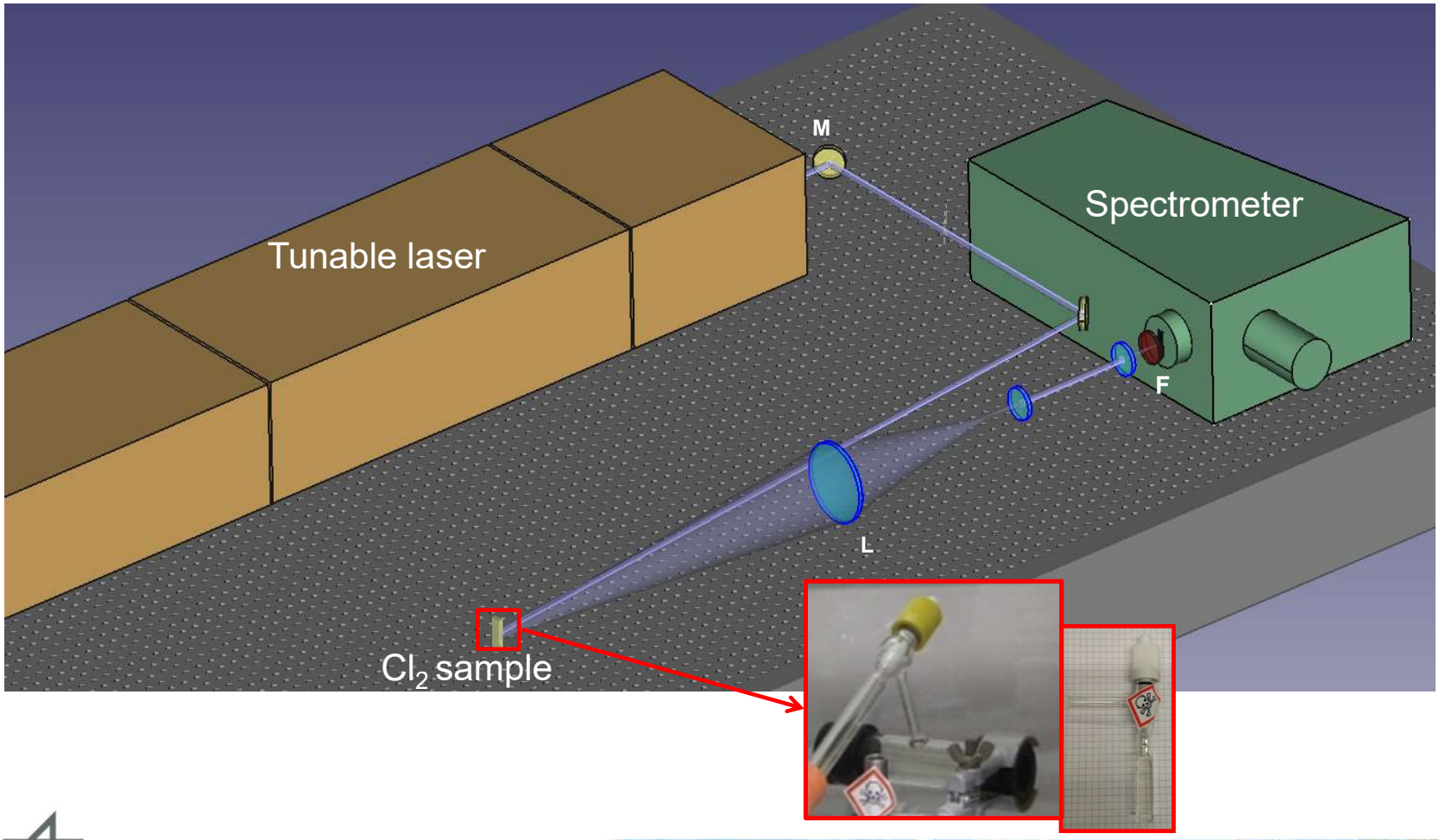
- Lethal doses:

Chlorine	6000 [mg min /m^3] - 2070 ppm min
Mustard gas	900 [mg min /m^3] - 230 ppm min
Tear gasses	30 mins temporary effect
Phosgene	3000 [mg min /m^3] - 740 ppm min

Introduction

- Remote detection set up optimized (distance of 60 cm)
- Changed excitation WL in the deep UV => To maximize Cl_2 signal
- Detection limits in acquisition times
- Solution for background interference => Lab test: Cl_2 must be enclosed
- **SYSTEM SETUP**
- **SAMPLE SETUP**
- **RESULTS**
- **CONCLUSION AND FUTURE DEVELOPMENTS**

System setup



- Nd:YAG laser
- dye laser
- mixing unit

- 190-900 nm, 1 mJ/pulse, 10Hz

- Liq. N_2 cooled spectr. 2400 grooves/mm

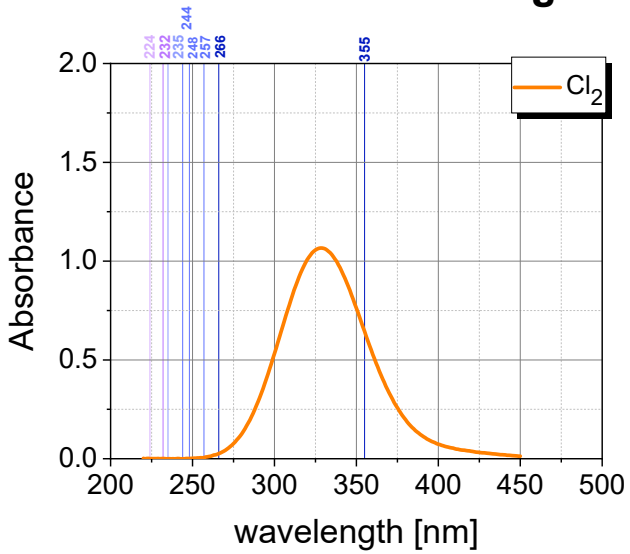
- 60 cm remote distance detection

- Laser filter

- Cl_2 35.94%

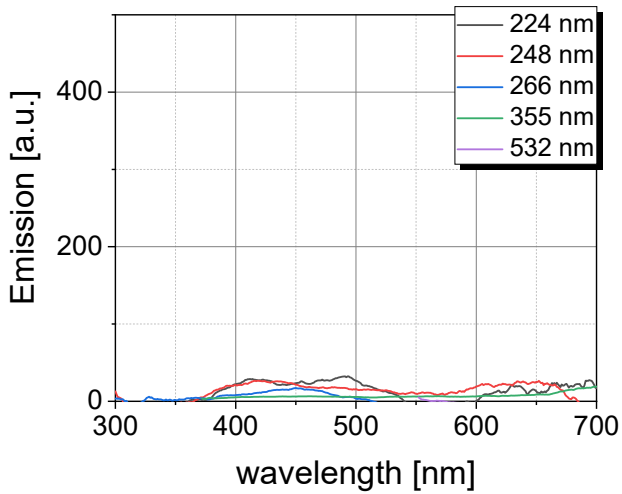
Results

Absorbance vs wavelength



- Edinburgh Instruments FS5 Spectrofluorometer
- 1nm step, 0.5 s sample time per wavelength
- max at 330 nm, FWHM 60 nm
- molar extinction coefficient, path length:
  $[Cl_2]$ = 36%

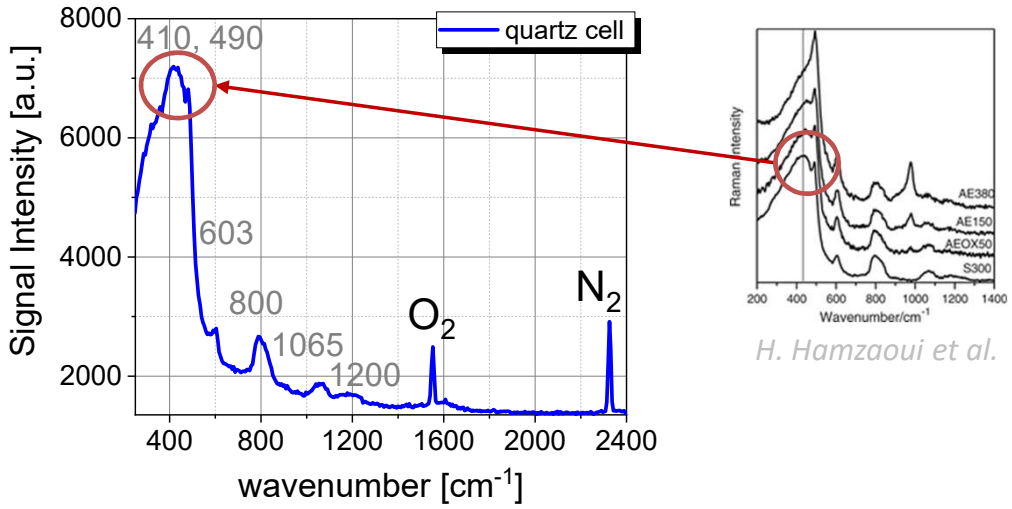
Fluorescence vs wavelength



- standard UV laser sources
- negligible fluorescence

Results

- **Quartz background signal**



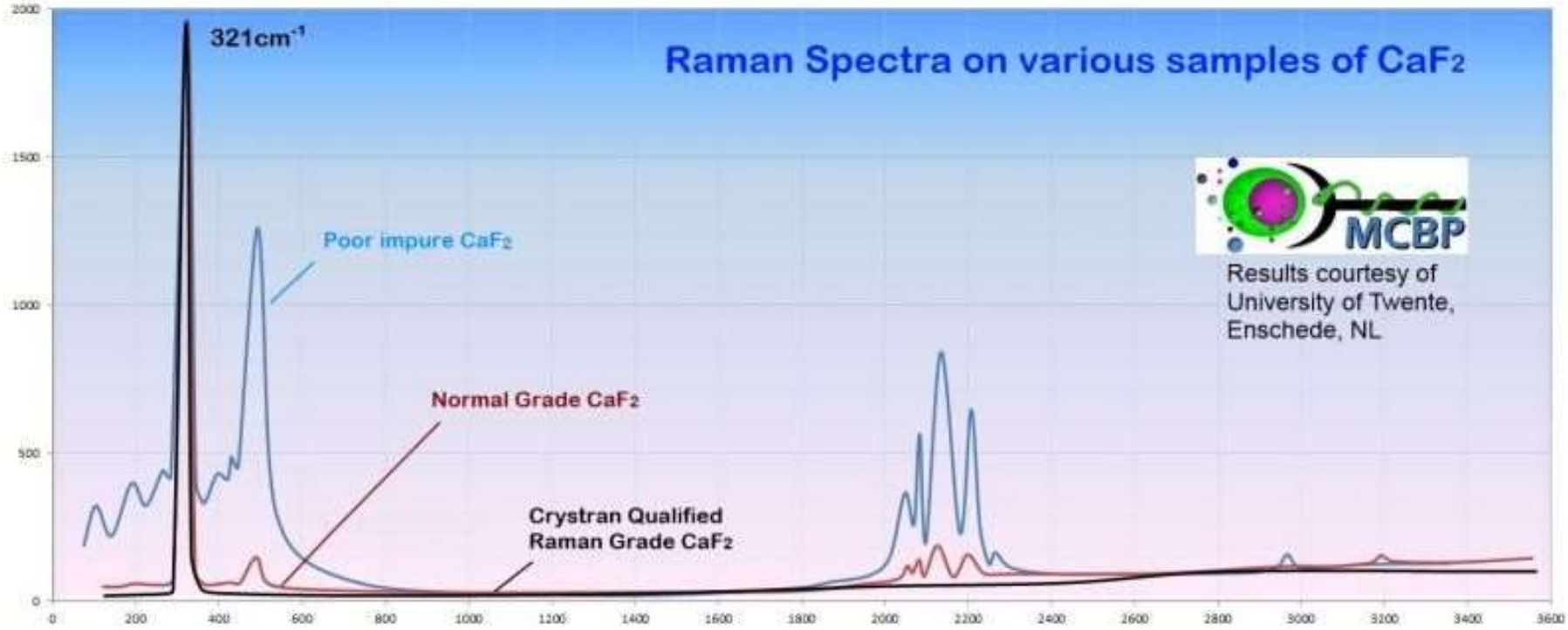
H. Hamzaoui et al.

empty quartz glass cell
as ref. background

- laser energy density below 6 mJ/cm^2
- 224, 232, 235 nm tested to maximize signal
- broad peak 410 cm^{-1} + sharp one 490 cm^{-1} , in agreement with literature

Results

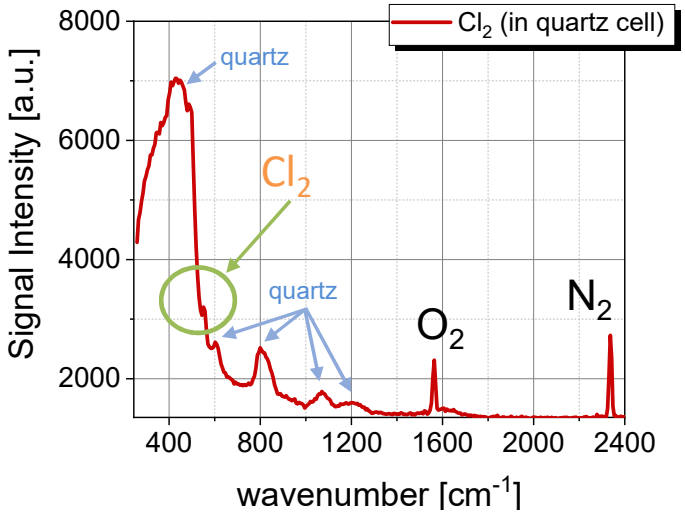
- **Special CaF_2 background signal**

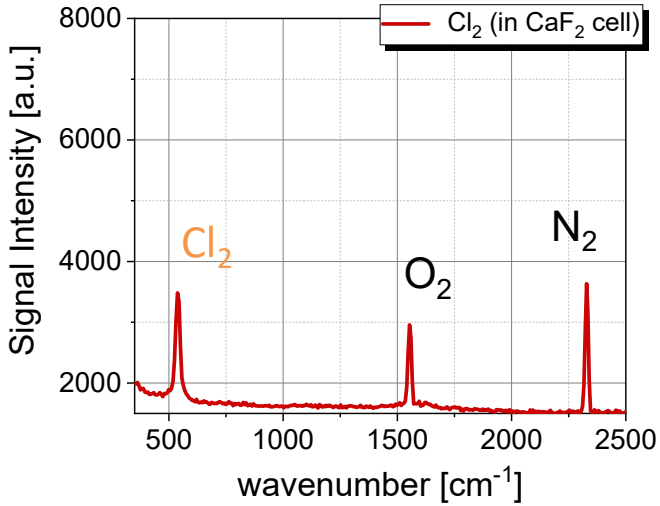


Results

New windows material, new cell

Cl_2 signal (- quartz bknd) **vs** **Cl_2 signal (- CaF_2 bknd)**



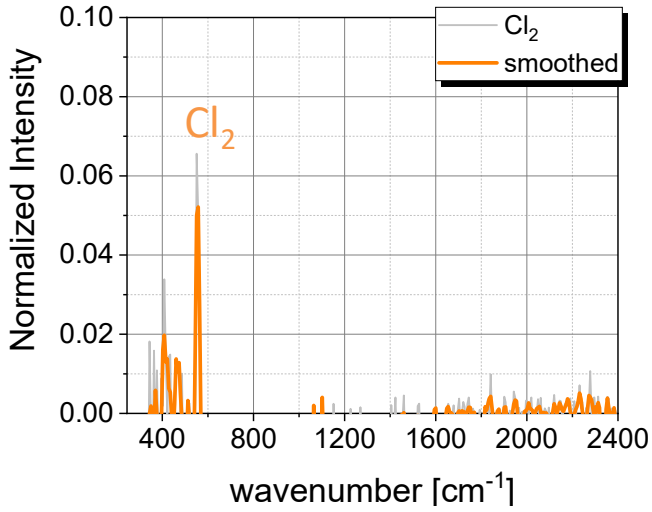


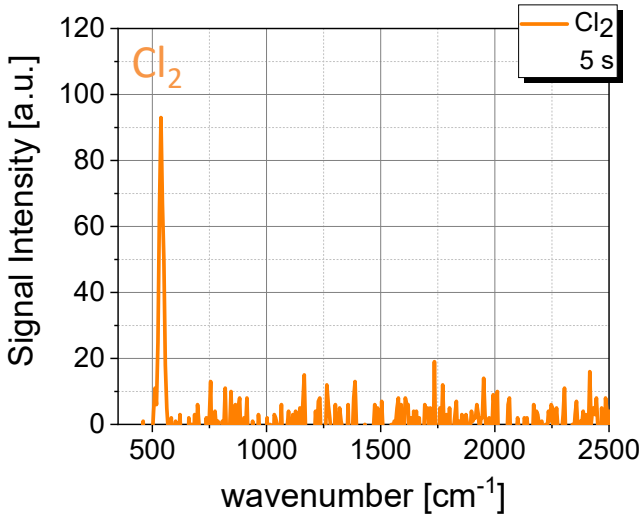
- quartz cell material overlapping with chlorine Raman signal
- Cl_2 sharp peak at 554 cm^{-1} (15 cm^{-1} FWHM)
- expected for Cl_2 at 554, 547, and 539 cm^{-1}

Results

New windows material, new cell

Cl_2 signal (- quartz bknd) **vs** **Cl_2 signal (- CaF_2 bknd)**

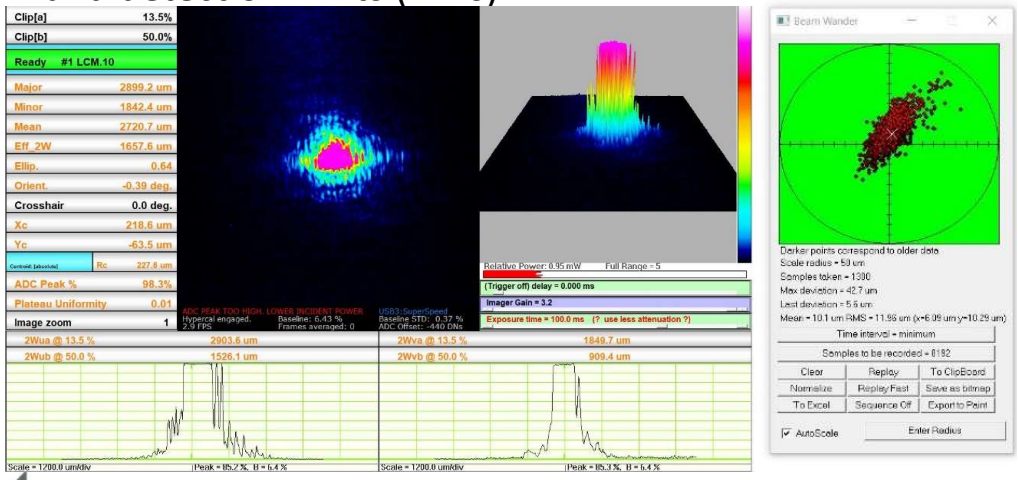


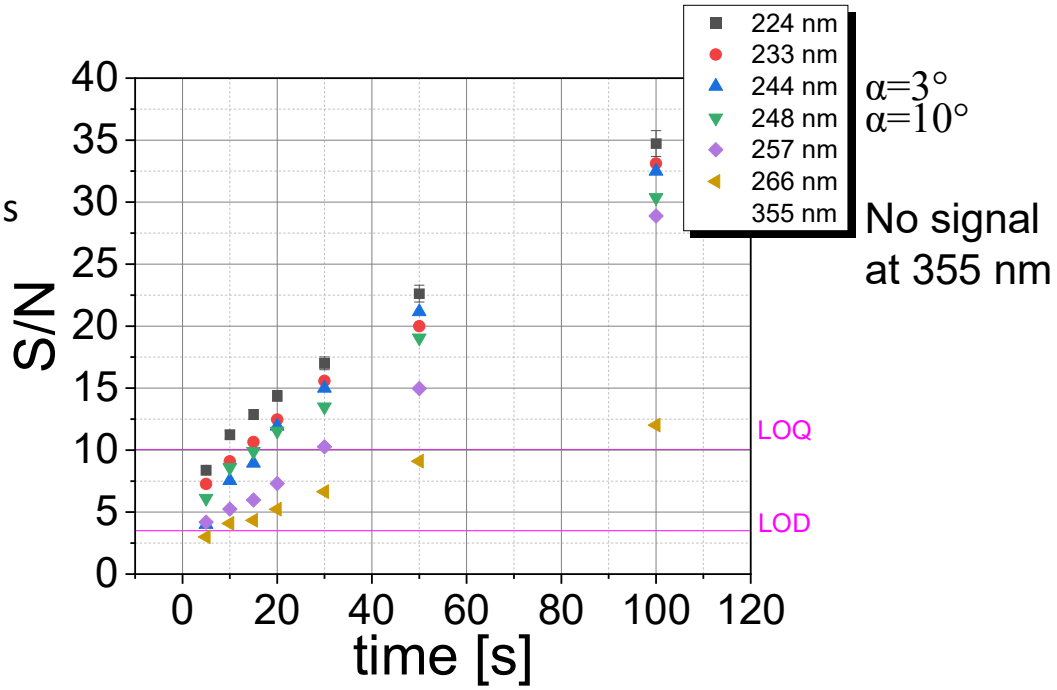


- broad peak quartz residual, in agreement with literature
- hard to separate the two
- remove cell not possible => change material

Results

- Avoid cell material interference around region of interest => Raman grade CaF_2, diamond
- detection limit lowered to 5s (instead of 50 s)
- Raman peak interference removed changing material
- not intensified camera => possible to lower concentrations and detection limits (< 1 s)





Conclusions & Future Developments

- Chlorine gas was detected in a remote Raman configuration: not standard setup

- Collimated configuration, 60 cm detection distance,
  laser energy density < 6 mJ/cm^2, acquisition time 5 s

- Solved quartz interference around region of interest (Raman peaks overlapping) => special Raman grade CaF_2 windows
- acquisition time reduced from 50 s to 5s changing windows to CaF_2

- Excitation wavelengths (224, 235, 244, 248, 257, 266, 355 nm) at 1mJ

- Reduce acquisition time using an ICCD detector
- Concentration limits

Thank you!

Questions

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