Tampere University

Real-Time Imaging Alpha Radiation Sources Via Radioluminescence in Nitrogen-flushed Glovebox

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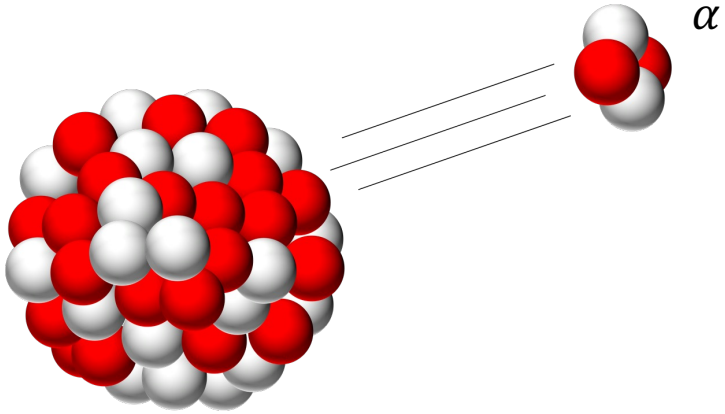
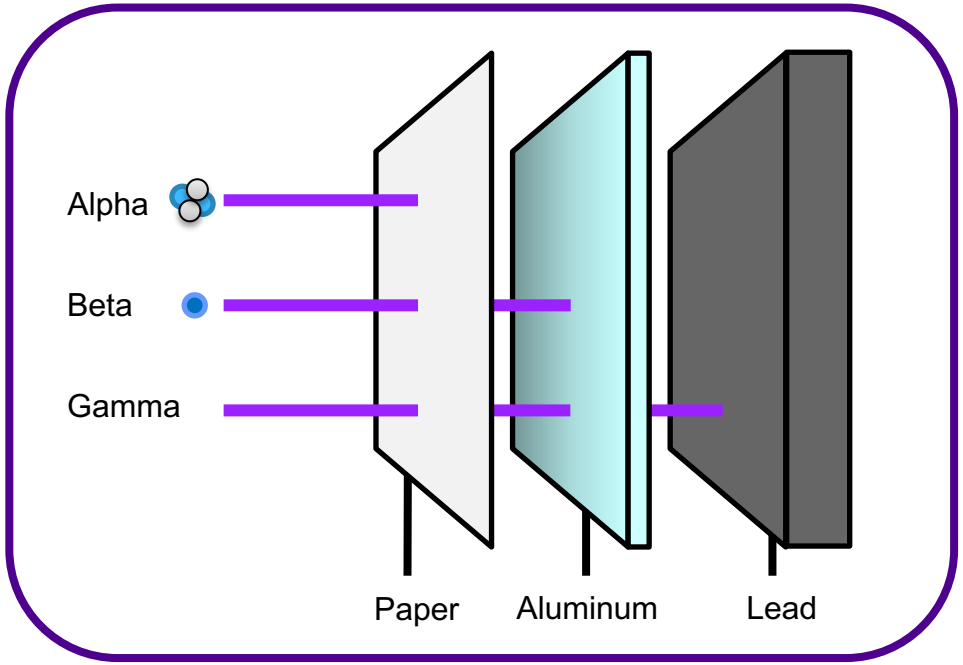
Alpha radiation



- Product of radioactive decay
- Highly ionizing
- Least penetrating
- Internal exposure extremely dangerous

- Short range in air ~ 4 cm
  - ➢ Inconvenient to detect directly



Current Detection Methods

Direct detection

Swipe sampling

Traditional detectors

- High sensitivity
- Hazardous to personnel
- Laborious

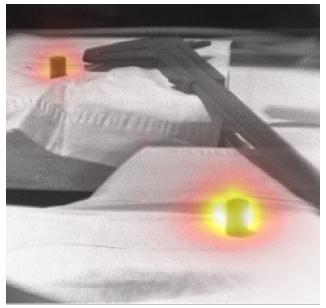
Remote detection

PMT-scanner

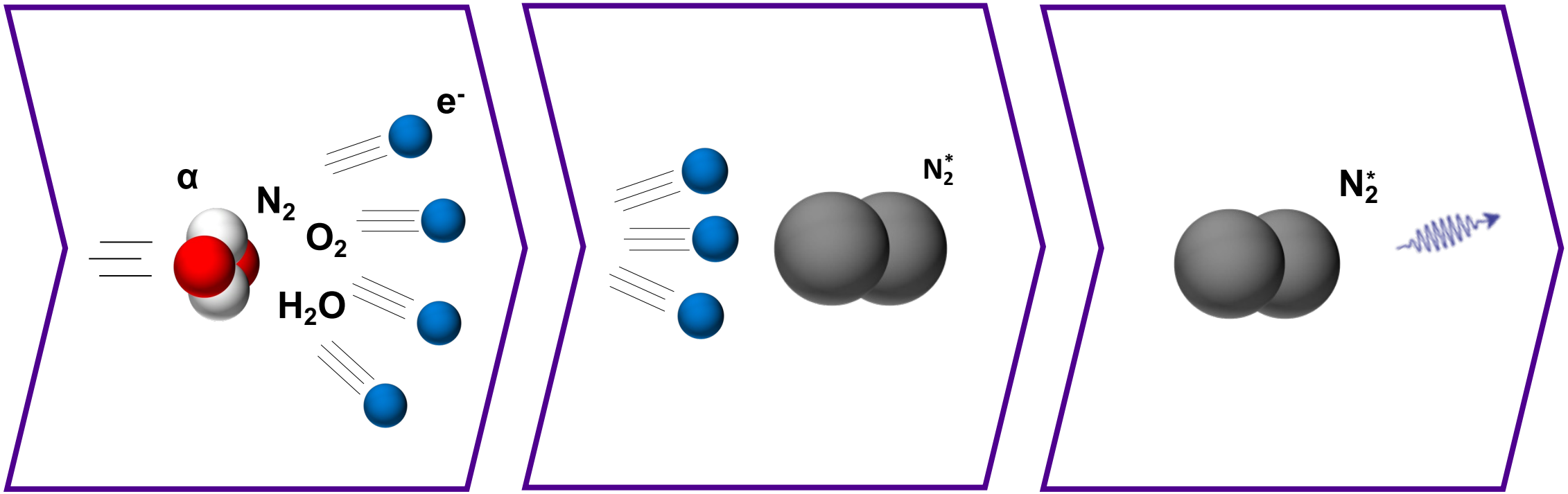
- Contamination mapping
- Timescale minutes–hours

Radioluminescence imaging

- Previous timescale minutes
- Real-time imaging to be demonstrated



Radioluminescence of Air



α-particles ionize molecules
-> Free electrons

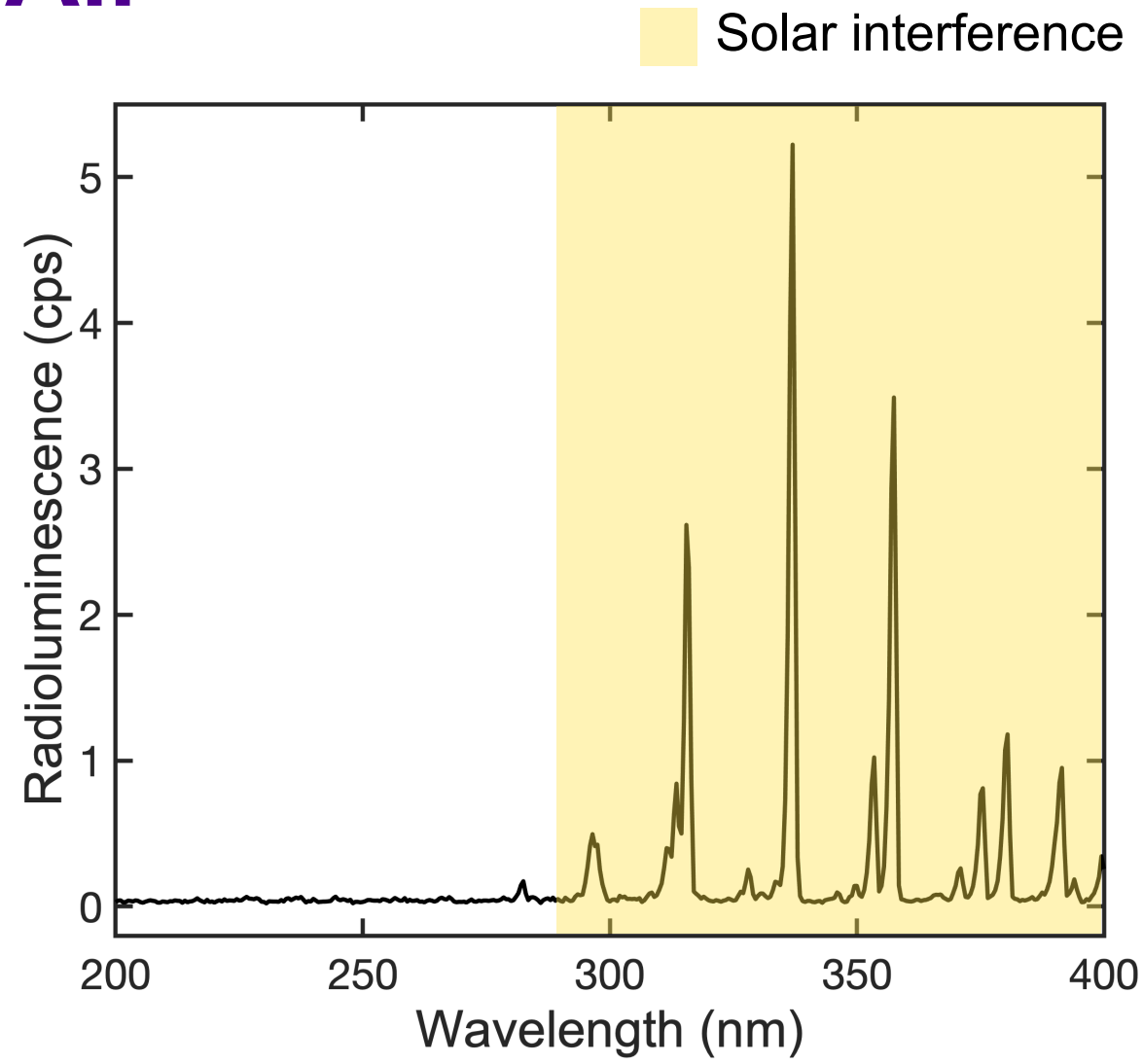
Free electrons excite N_2

N_2^* emit UV photons

Radioluminescence of Air

- Low conversion efficiency 6.7×10^{-5}
- < 1 % of light free of solar interference

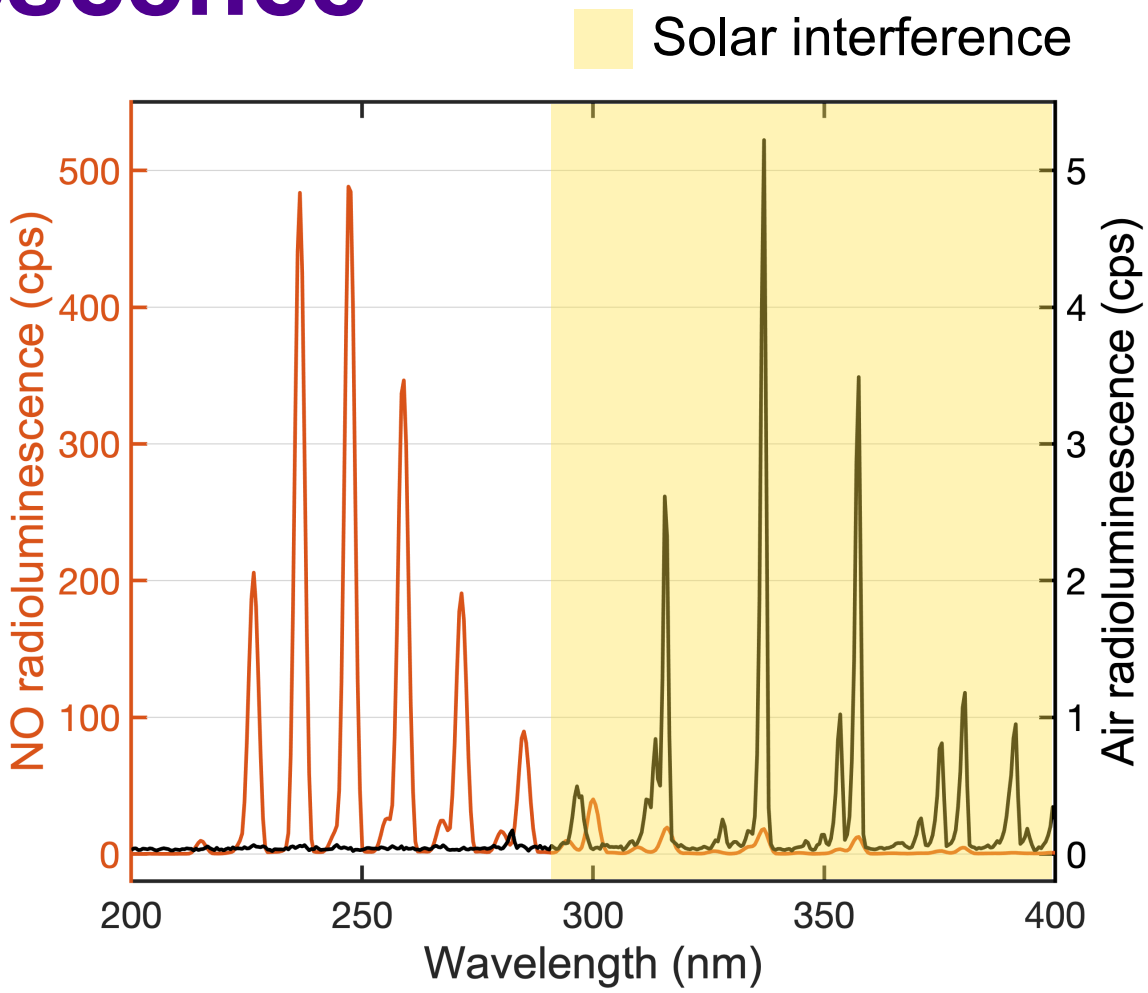
➢ Detection requires:
  - Little ambient light
  - Long exposure times



Enhancing Radioluminescence

- Signal enhanced in pure N_2 by factor 6
- Further enhancement in N_2 with NO
  - Signal enhanced by factor 150 in 50 ppm NO
  - Most light in solar blind region

➢ Enables rapid imaging in daylight conditions



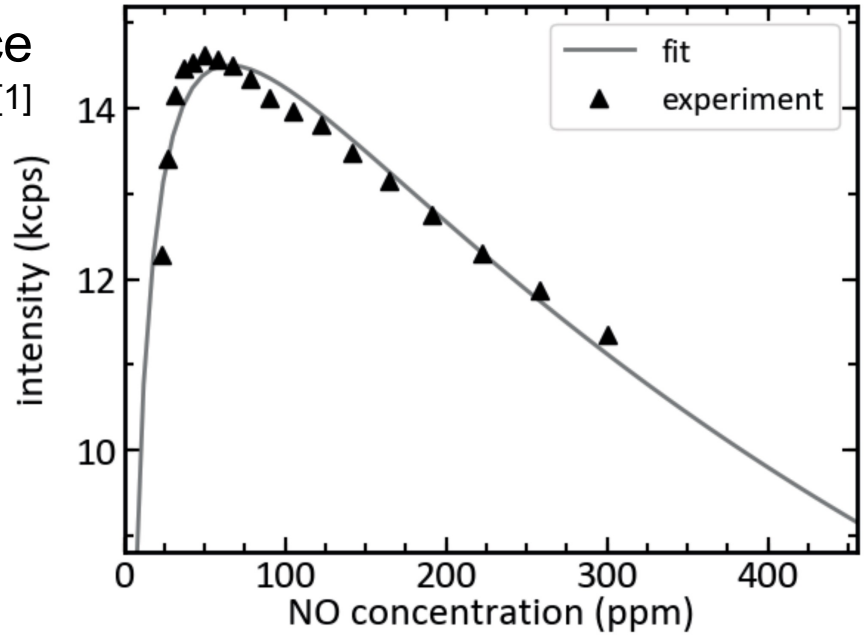
Radioluminescence of
50 ppm N_2/NO mixture and air

Effect of NO

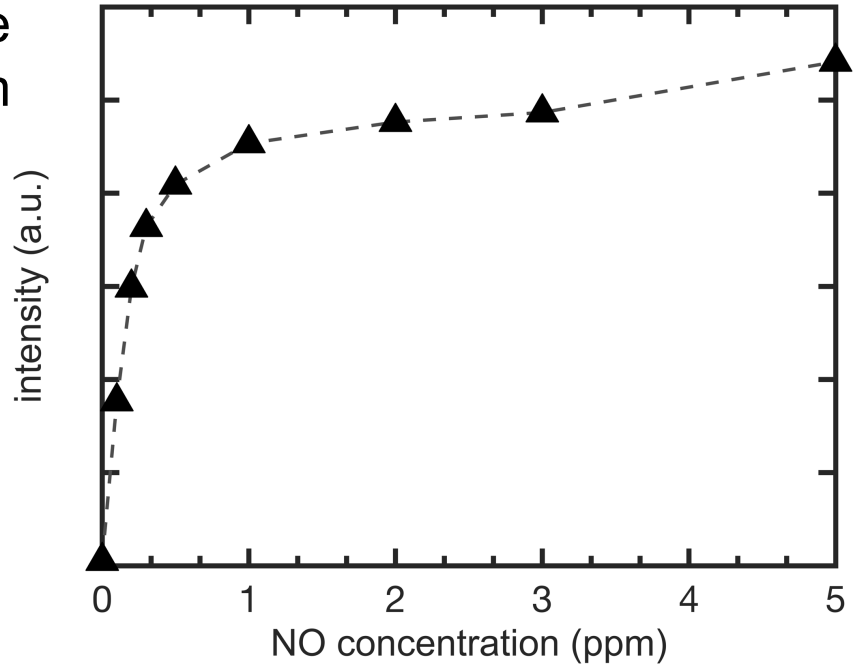
- High concentration of NO toxic
- 2 ppm admissible workplace limit

- 50 ppm optimal for radioluminescence
- Rapid imaging possible with much lower concentrations

Radioluminescnence at 236 nm [1]



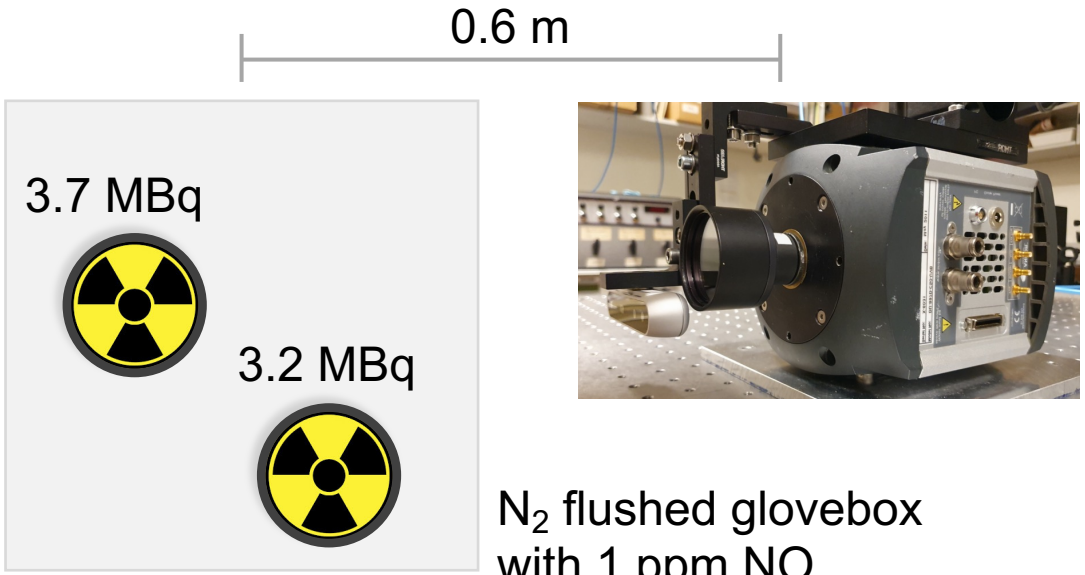
Radioluminescnence at 260–290 nm



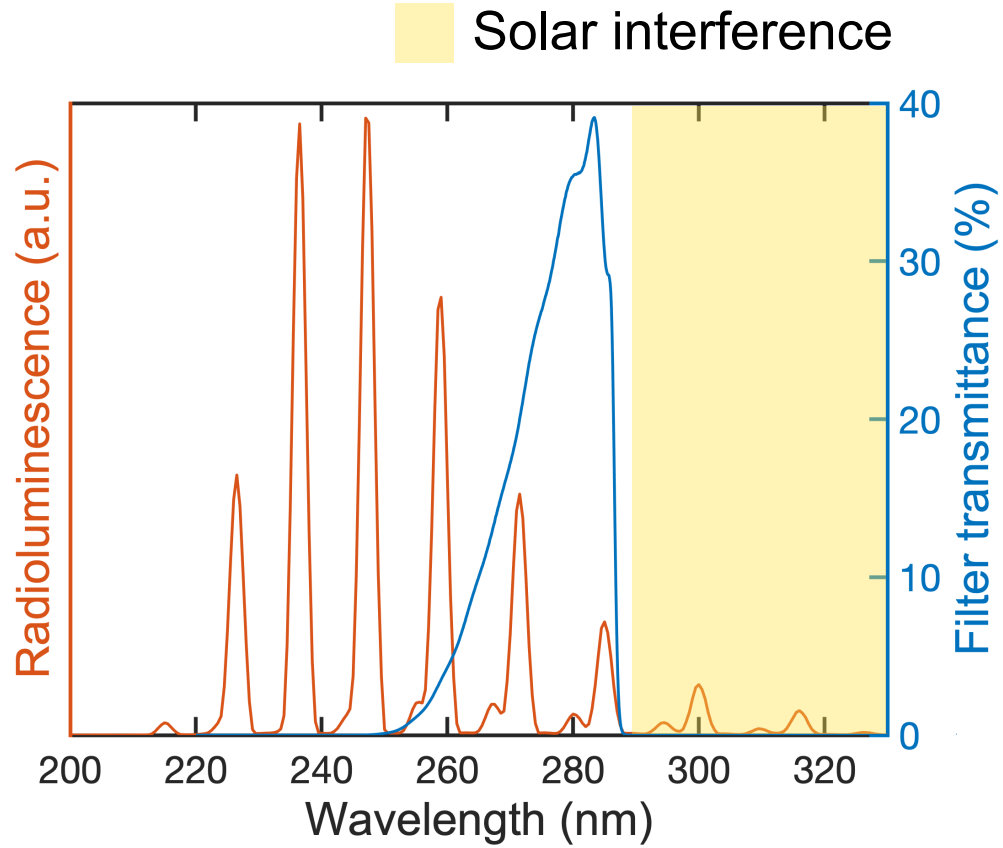
[1] T. Kerst and J. Toivonen. Intense radioluminescence of NO/N2 -mixture in solar blind spectral region. *Optics express* 26 (2018), 33764-33771

Imaging Setup

- EMCCD with UV transmissive filter
  - ➢ Radioluminescence heatmap
- 3D webcam
  - ➢ Background with depth information



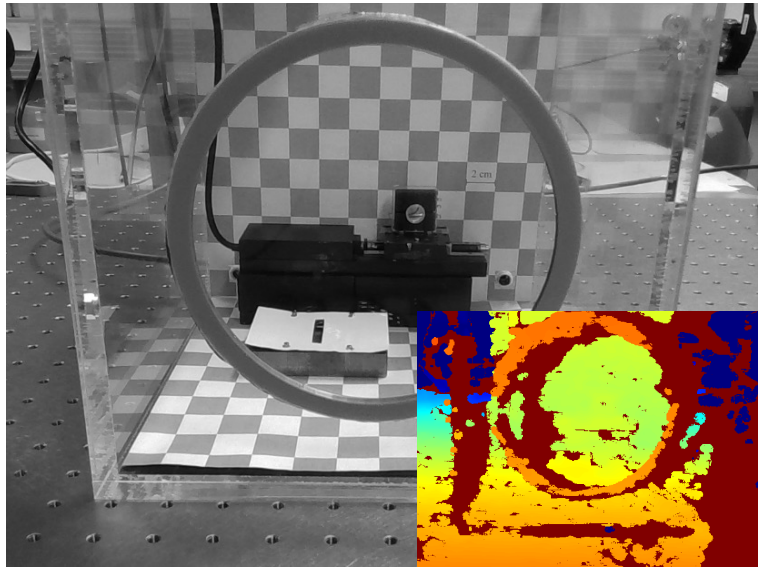
N_2 flushed glovebox with 1 ppm NO



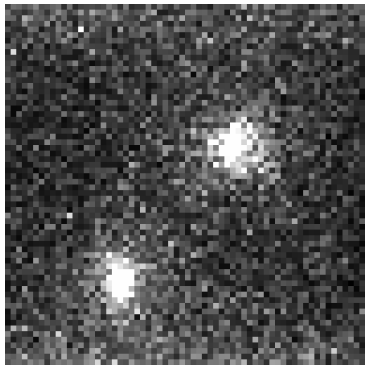
N_2/NO mixture radioluminescence and filter transmittance

Image Acquisition

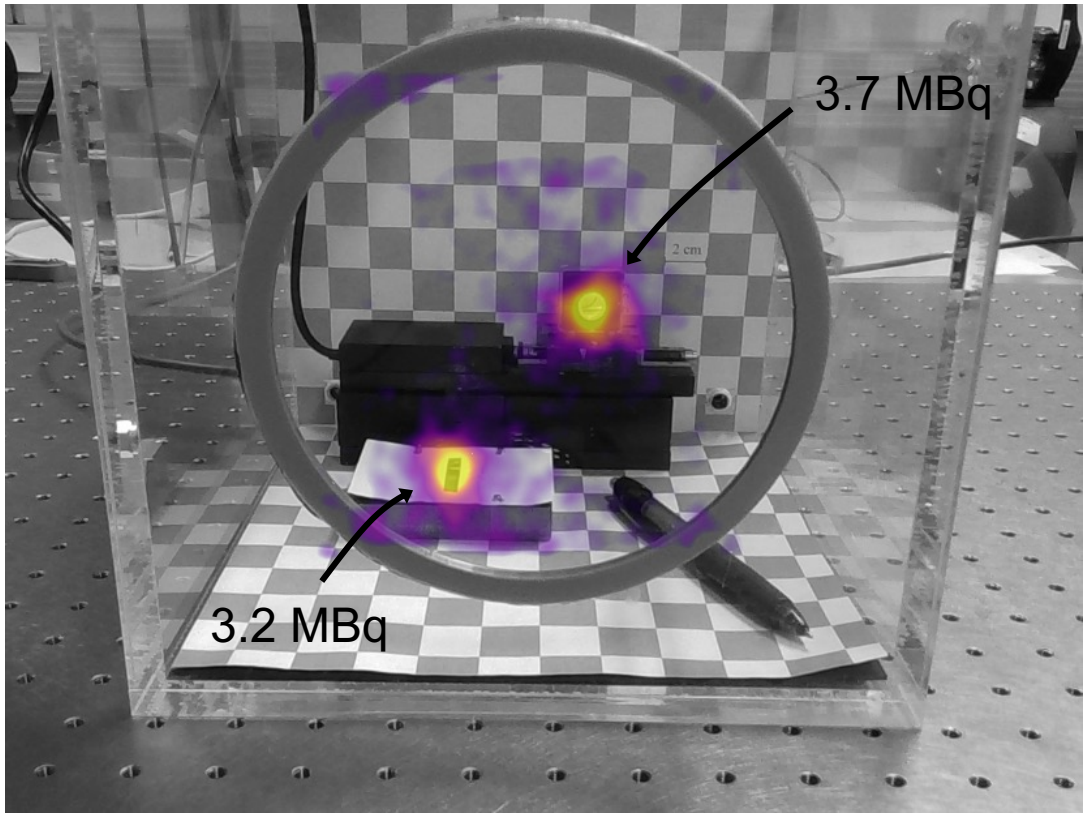
3D cam:
15 fps



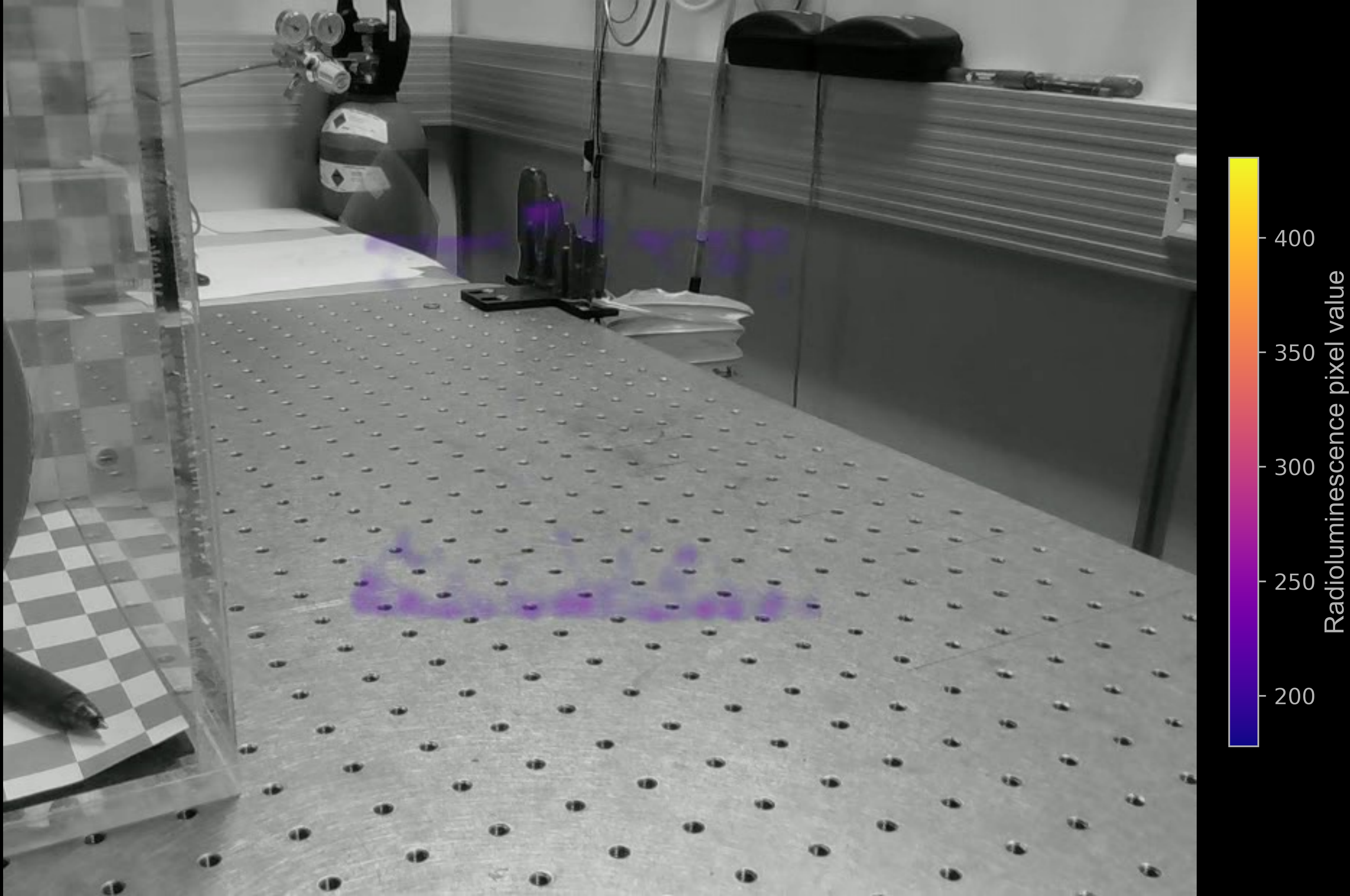
EMCCD:
2 fps



EMCCD frames registered to background using depth information



Gaussian filter and colormap applied to EMCCD frame

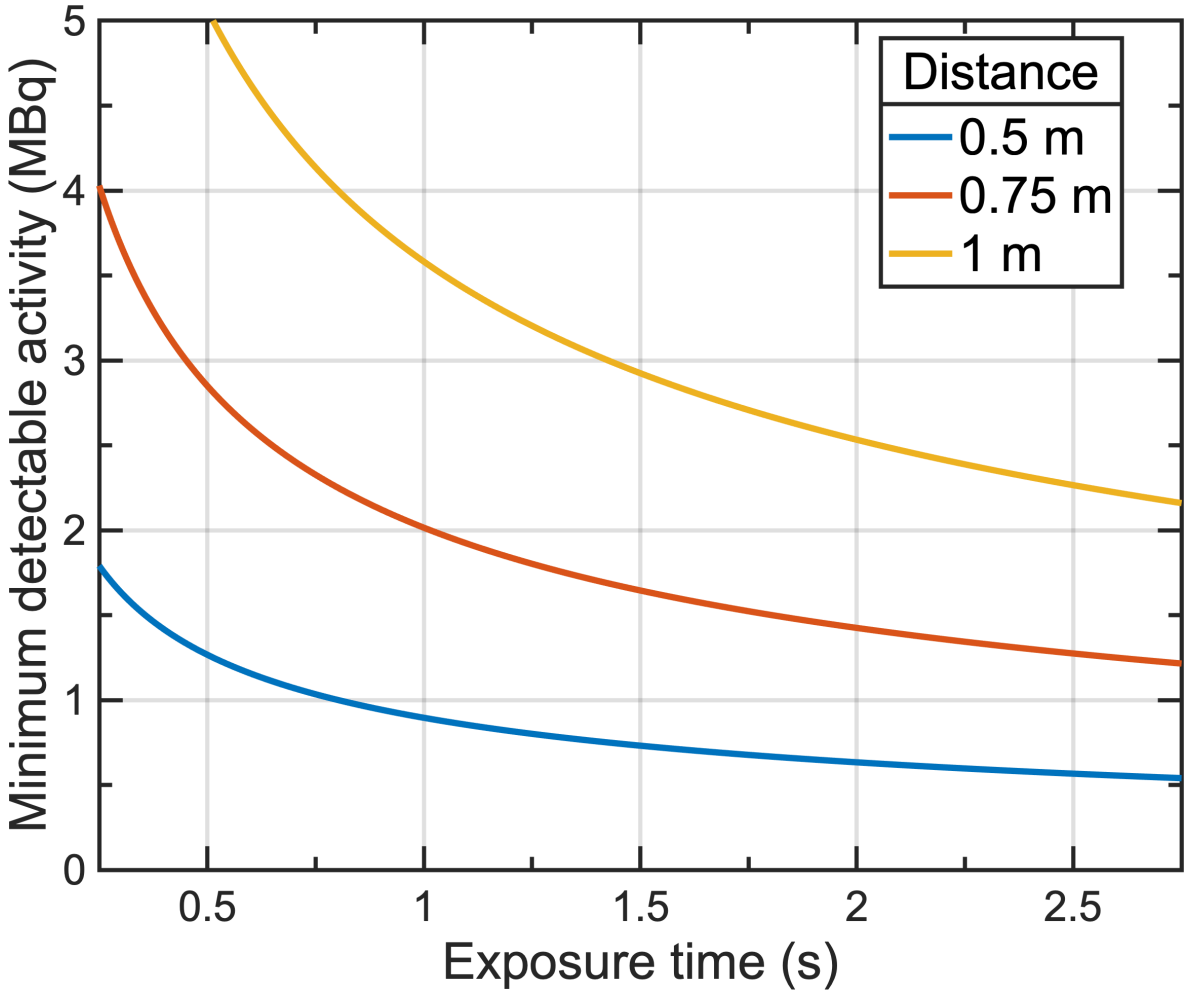

Radioluminescence pixel value
400
350
300
250
200

Performance

Source	SNR
3.7 MBq	5.4
3.2 MBq	5.5

- $SNR \propto \frac{source\ activity \cdot \sqrt{exposure\ time}}{detection\ distance^2}$
- Estimated detection limit $SNR = 3$

- Capacity to detect MBq level sources



Performance in 1 ppm N_2/NO mixture

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Discussion

	Minimum detectable activity	Acquisition timescale	Suited for
Real-time imaging	~ 1 MBq	~ 1 second	Live monitoring gloveboxes where highly active materials are handled
PMT-scanner	kBq–MBq depending on lighting	minutes–hours depending on area size	Field environment contamination mapping for larger activities
Direct detection	~ 1 Bq	minutes–days depending on area size	Decommissioning the smallest activities

Conclusion

- Demonstrated real-time imaging α sources
- Rapid imaging possible in N_2/NO atmosphere
- Monitoring gloveboxes where MBq level highly active materials are handled