EPR Dosimetry of Tooth Enamel For Low Dose Epidemiological Studies

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Outline:

- Objective
- EPR Overview
- EPR Measurements
- Spectra Manipulation
- Results & Analysis
- Conclusion

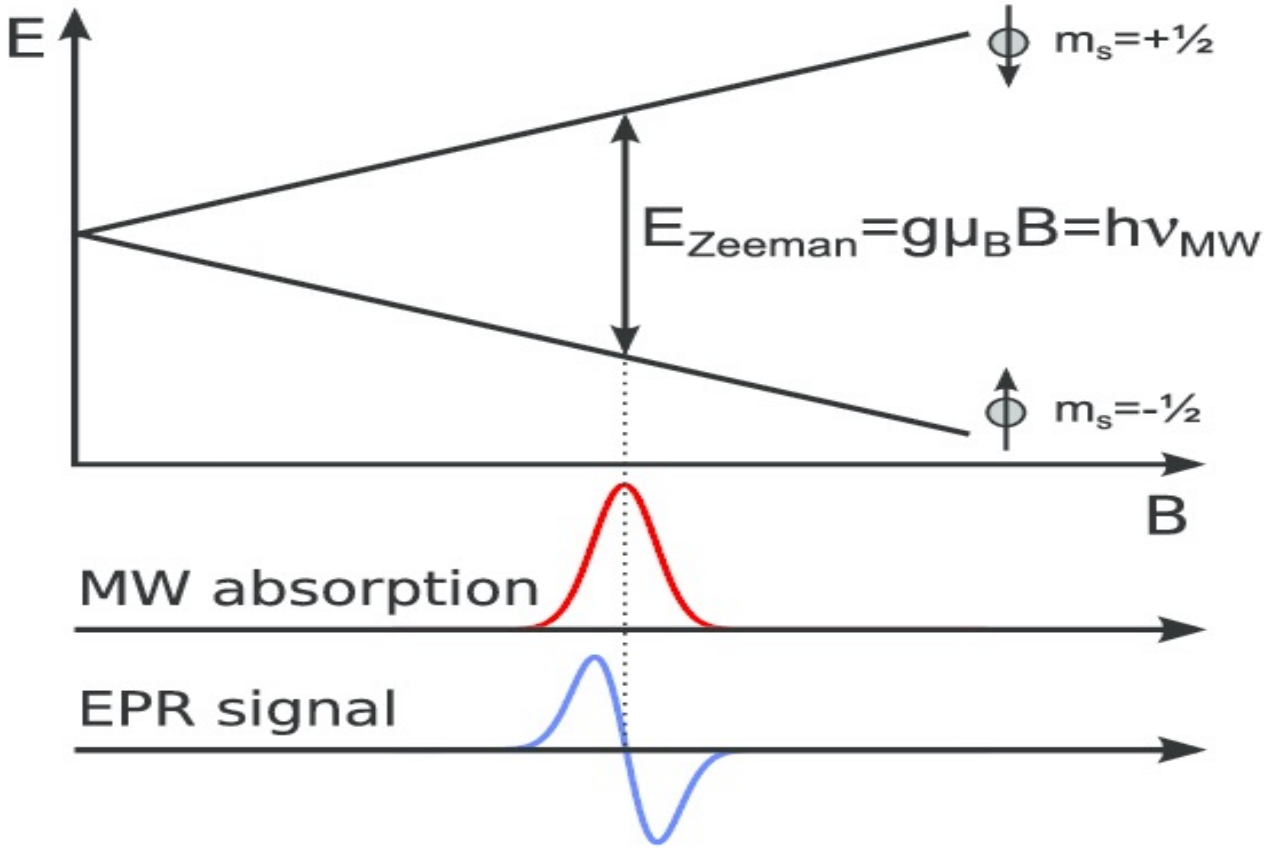
Objective

- The purpose of this work is to study tooth enamel reference samples that were prepared for an international intercomparison using electron paramagnetic resonance (EPR).
- Teeth serve as lifetime integrating gamma-ray dosimeters, therefore, useful for low dose epidemiological studies
- Using the proposed technique, only a small masses of tooth enamel samples is needed for dose reconstruction.

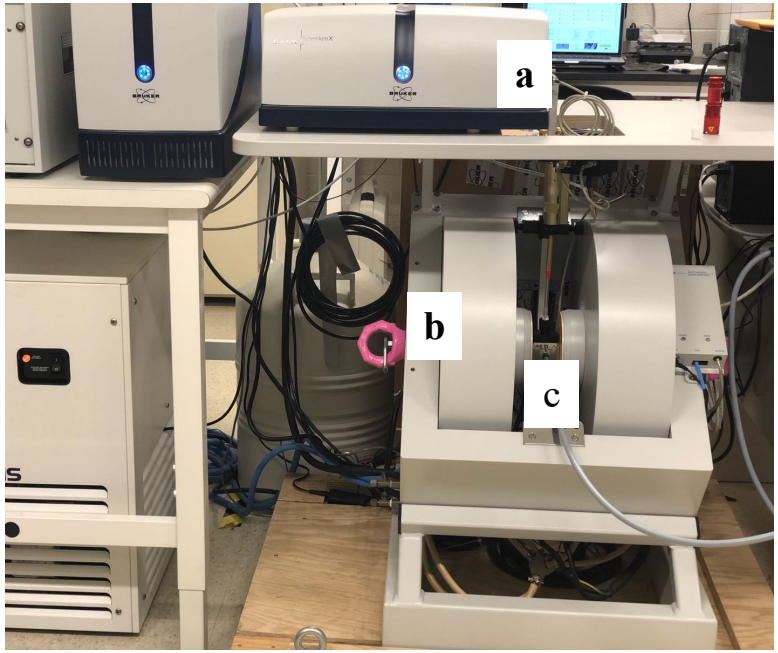
EPR Overview

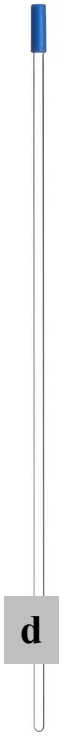
- Electron Paramagnetic Resonance (EPR) also known as Electron Spin Resonance (ESR)
- Spectroscopic technique used to study materials with unpaired electrons
- Non-destructive

EPR Overview



EPR Overview





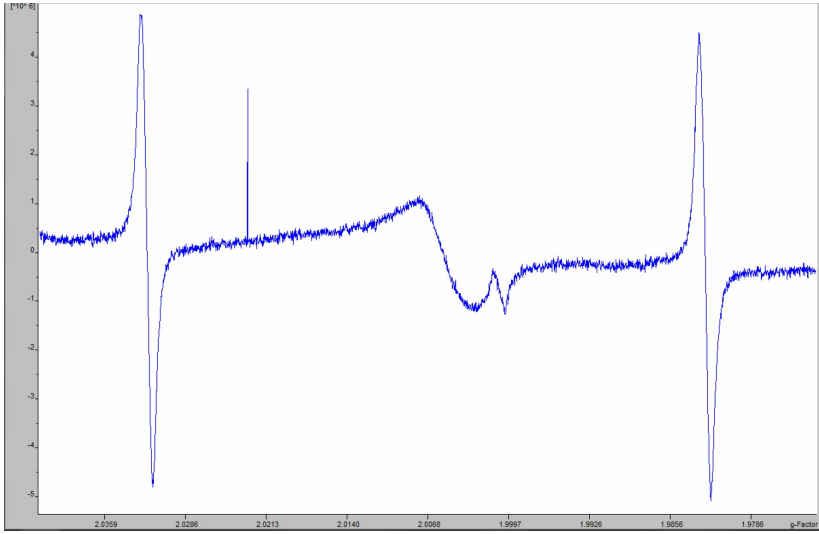
- Hardware components:
  - Microwave bridge (a)
  - Magnet (b)
  - Microwave resonator (cavity) (c)
  - EPR sample tube (d)
  - Computer

EPR Measurements

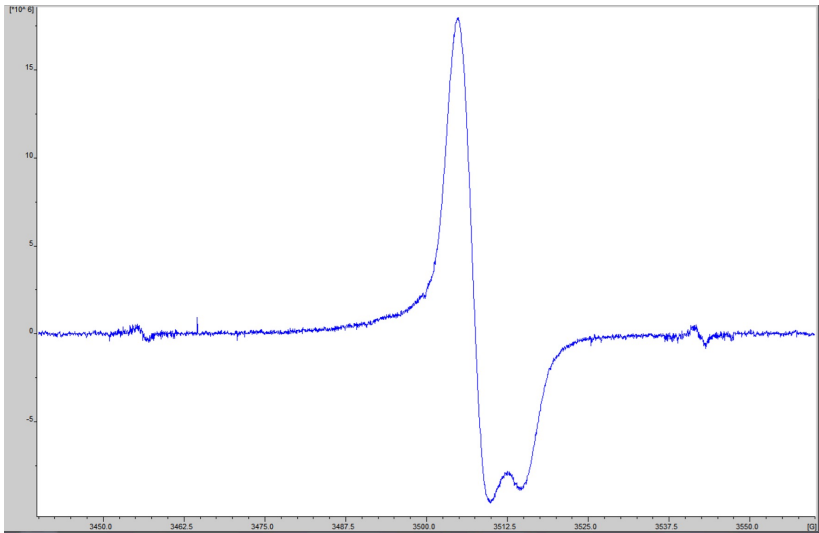
Samples

- Background samples
- Irradiated samples (known dose)
- Blind test samples (unknown doses)

Background / Native signal



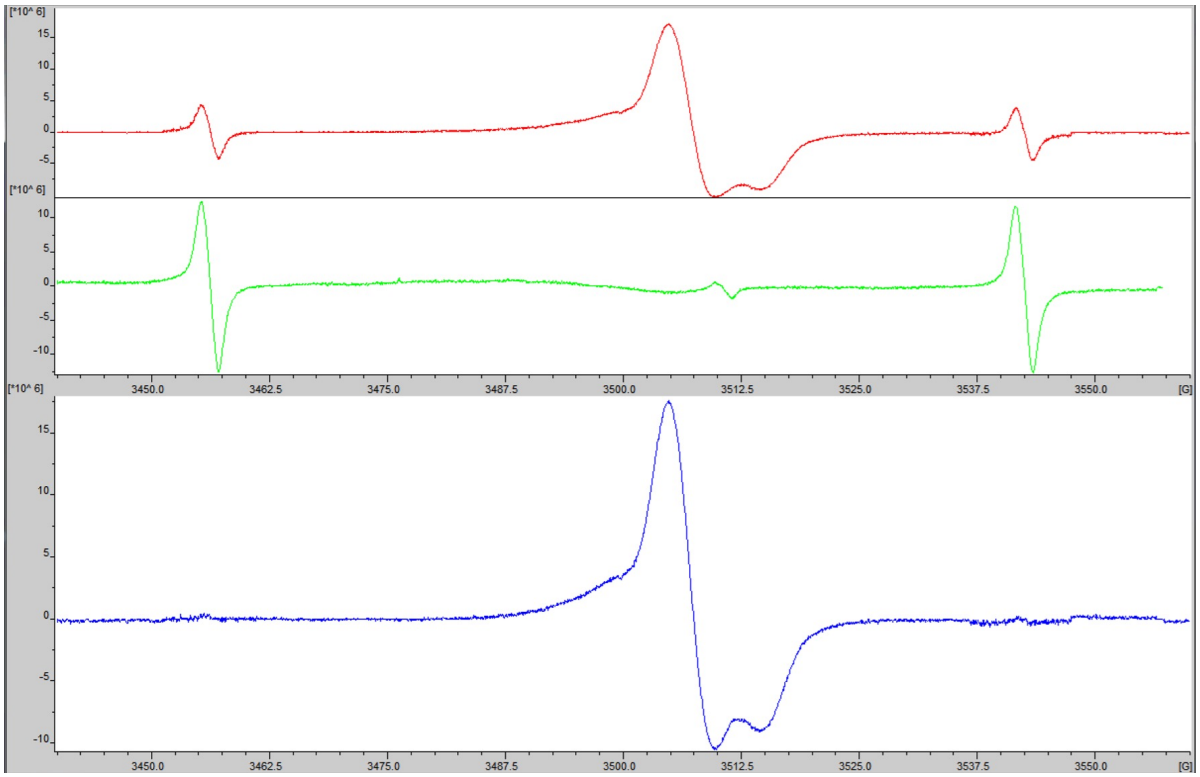
Irradiated sample signal



EPR Measurements

Measurement process

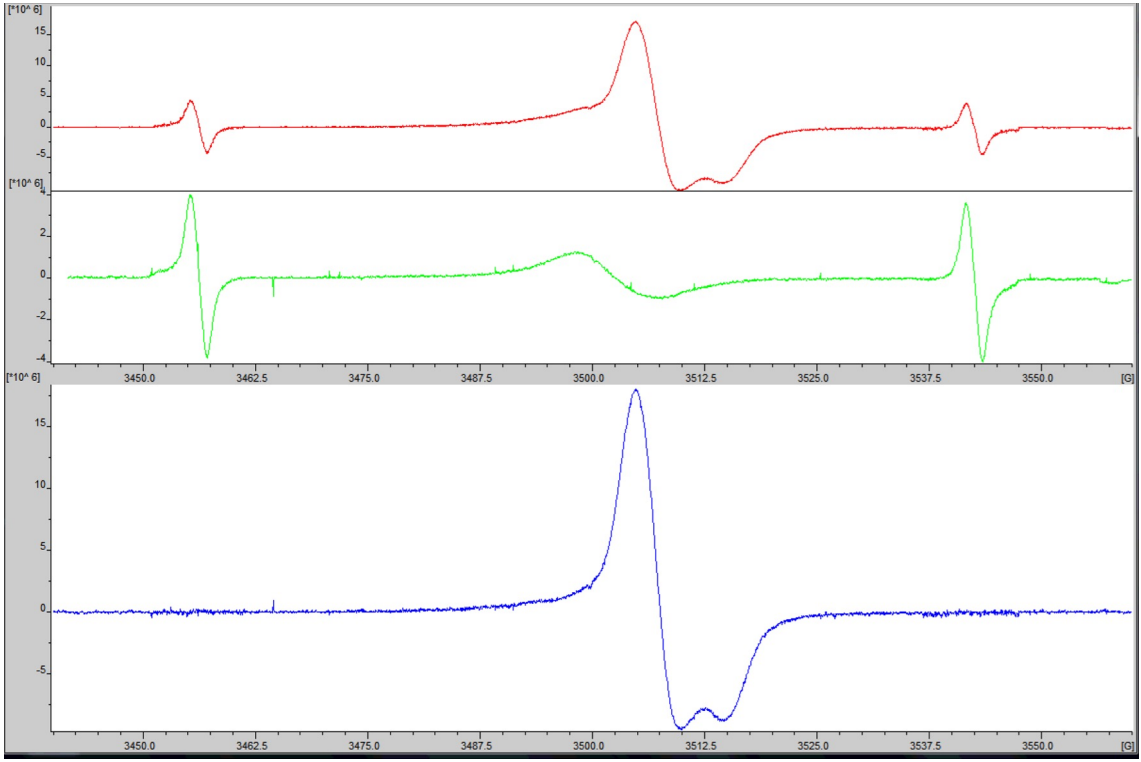
- ✓ Combining empty tube spectra to a make composite spectrum
- ✓ Empty tube subtraction



EPR Measurements

Measurement process

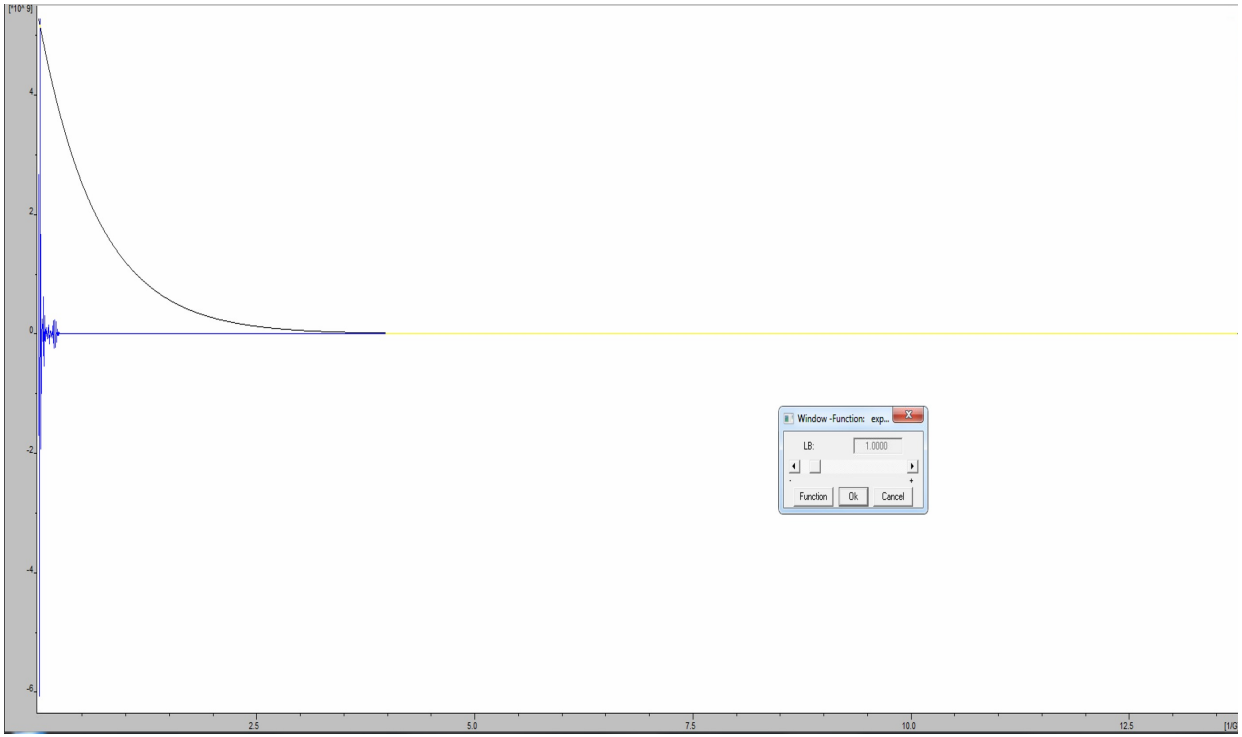
- ✓ Combining Background spectra to a make composite background spectrum
- ✓ Mass normalization
- ✓ Native signal subtraction



EPR Measurements

Measurement process

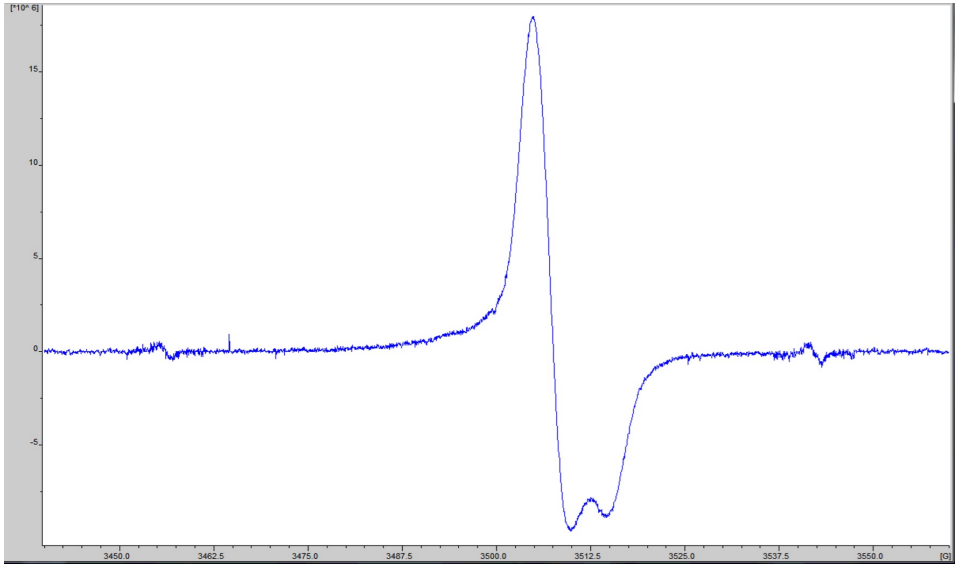
- ✓ Fourier transform
- ✓ Exponential function filter with unity argument.
- ✓ Inverse Fourier transform

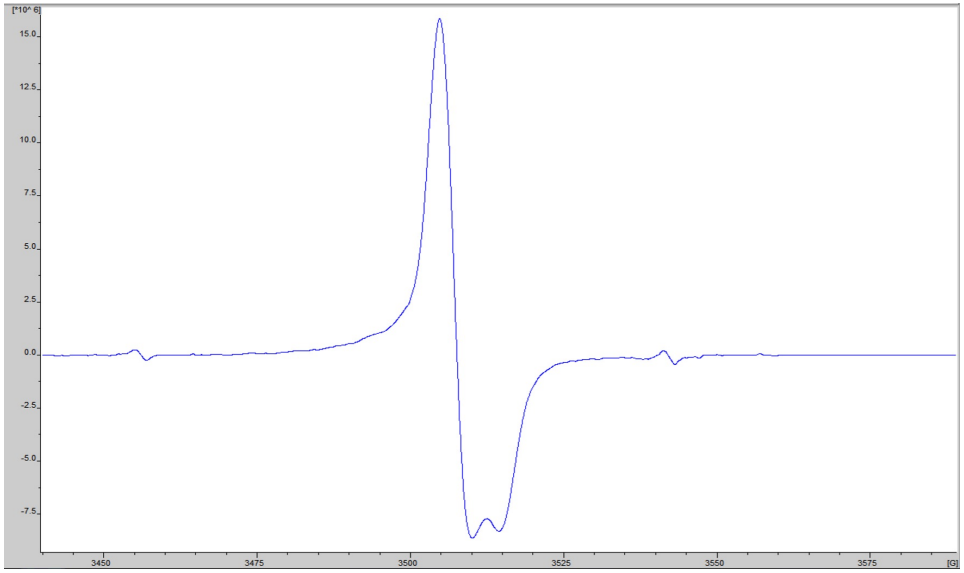


EPR Measurements

Measurement process

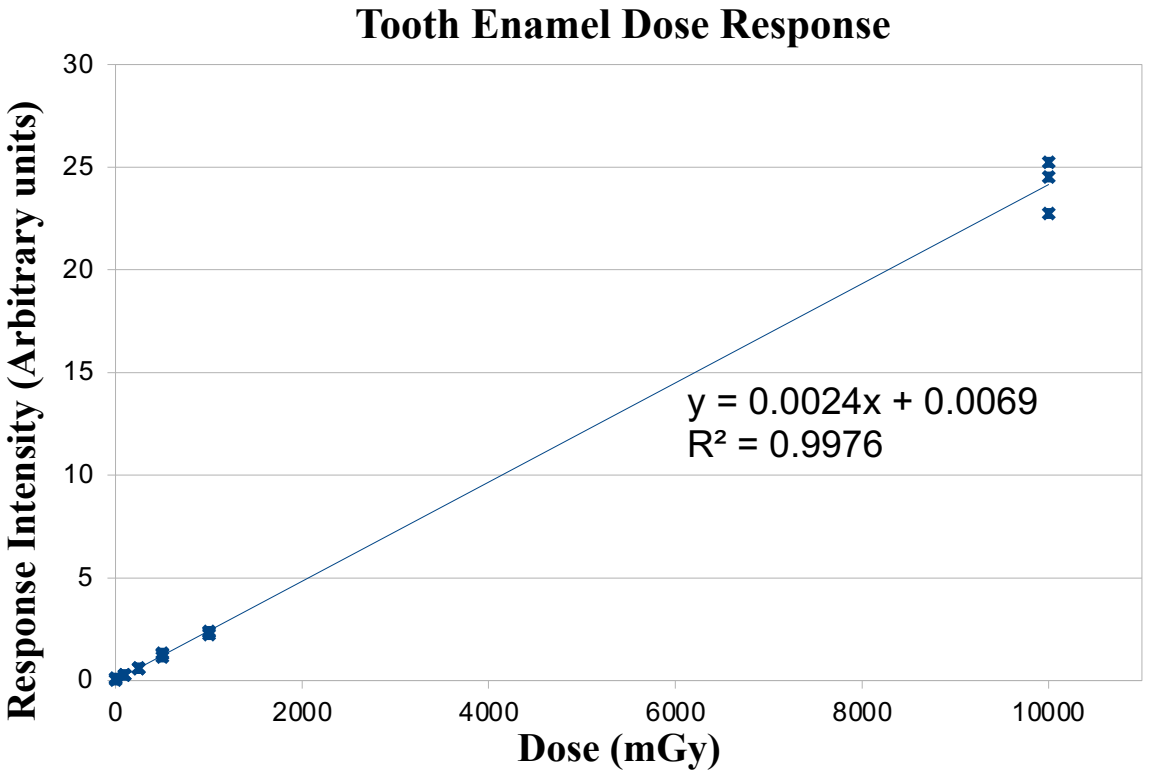
- ✓ Fourier transform
- ✓ Exponential fitting
- ✓ Inverse Fourier transform to get a smoothed signal





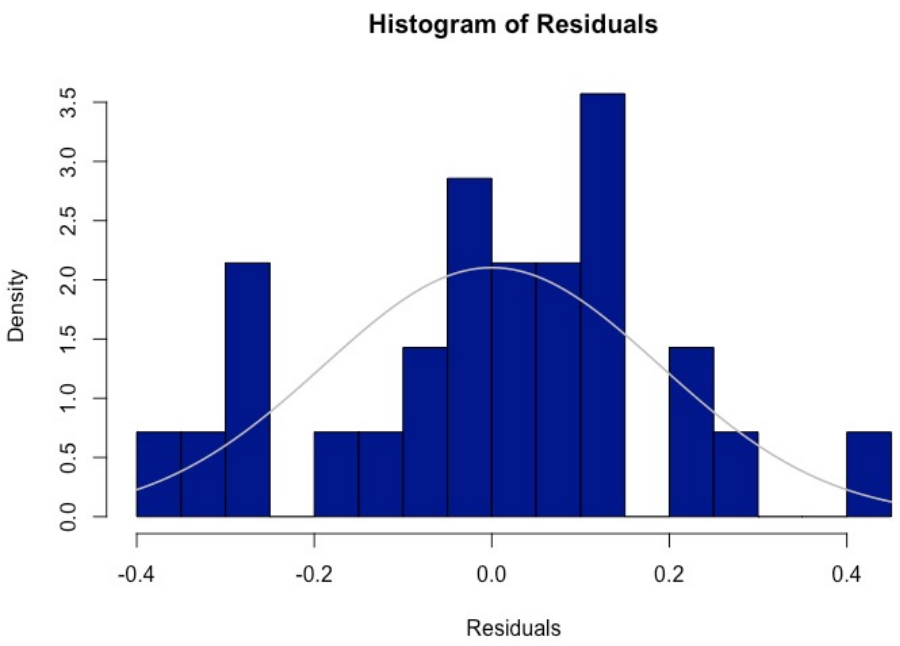
Results & Analysis

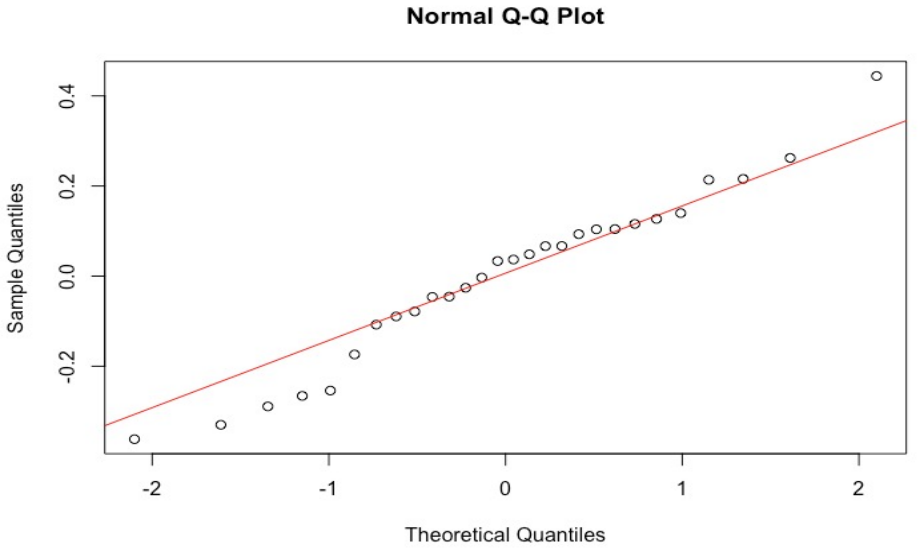
- Peak-to-Peak vs. Dose
- Linear regression used
- Slope: $0.002415 \pm 0.30 \times 10^{-4}$
- Y-intercept: 0.0069 ± 0.122576
- R-squared: 0.998



Results & Analysis

Statistical analysis





Sample	Average Dose Estimate (mGy)	Standard Deviation	Relative error (σ_{Dose}/Dose)
A	140	57	40%
B	155	30	19%
C	252	20	7.8%
E	6610	107	1.6%
O	639	53	8.2%

Conclusion

- Tooth enamel samples prepared for an international intercomparison was studied using EPR
- Obtained spectra were manipulated and analyzed
- Results showed linearity between dose and EPR signal intensity
- Statistical analysis of the residuals was performed to confirm the validity of the linear model used
- Results show that tooth enamel is a reliable Electron Paramagnetic dosimeter that was used for reconstruction of doses to atomic bomb victims in Japan and Chernobyl accident survivors

Thank You

Any Questions?

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In-Situ Sample Specific Dose Response Calibration for EPR Dosimetry

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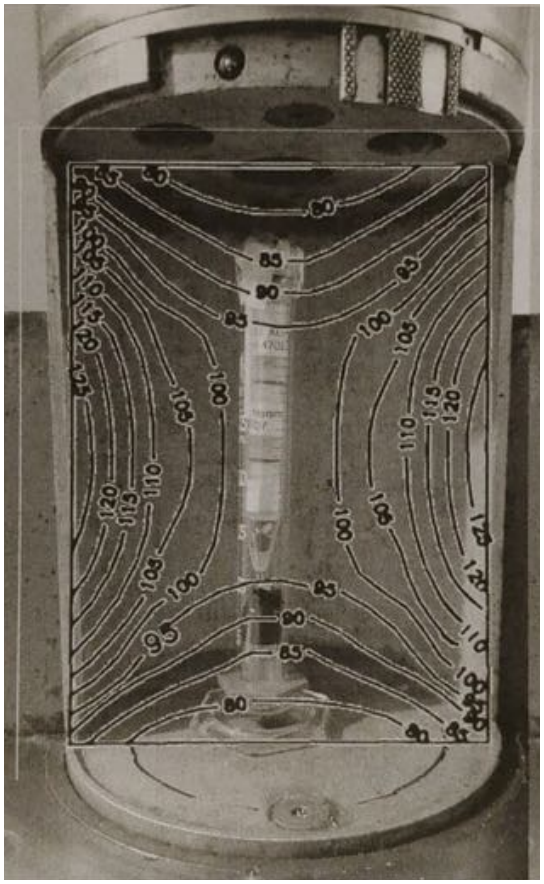
- Future work

Objective

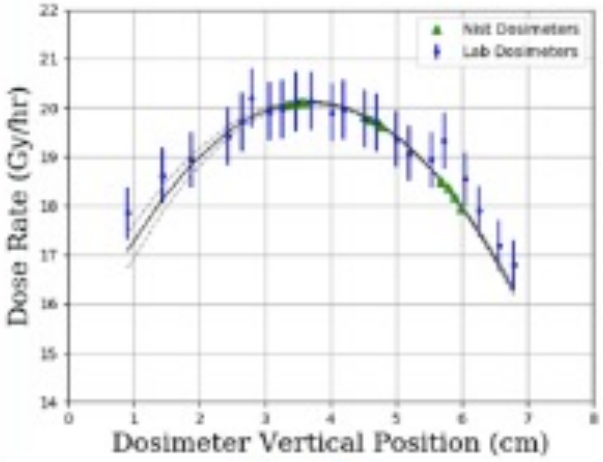
The purpose of this work is to study the potential use of a UV irradiation system to perform in-situ sample irradiation. The dose response of sugar irradiated using this system will be studied using electron paramagnetic resonance (EPR). This technique is useful for retrospective dosimetry of past exposures and for emergency response applications.

Sample Irradiation

Co-60 irradiation (previously used)



Sample position in the irradiator



Dose rate profile

Co-60 Irradiator

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Sample Irradiation

Co-60 irradiation

- Sugar and artificial sweetener samples
- Co-60 source
- Irradiation time proportional to intended dose

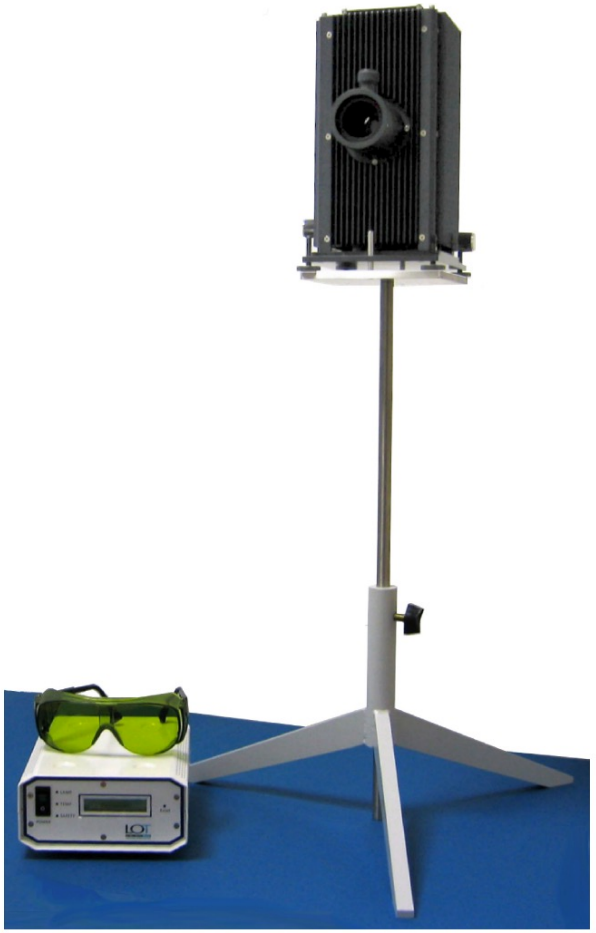
Sample position during irradiation

Dose (Gy)	Irradiation Duration
0.2	45 seconds
0.5	2 minutes
1.0	4 minutes
2.0	7 minutes
5.0	18 minutes
10.0	36 minutes

Sample Irradiation

UV Irradiation System

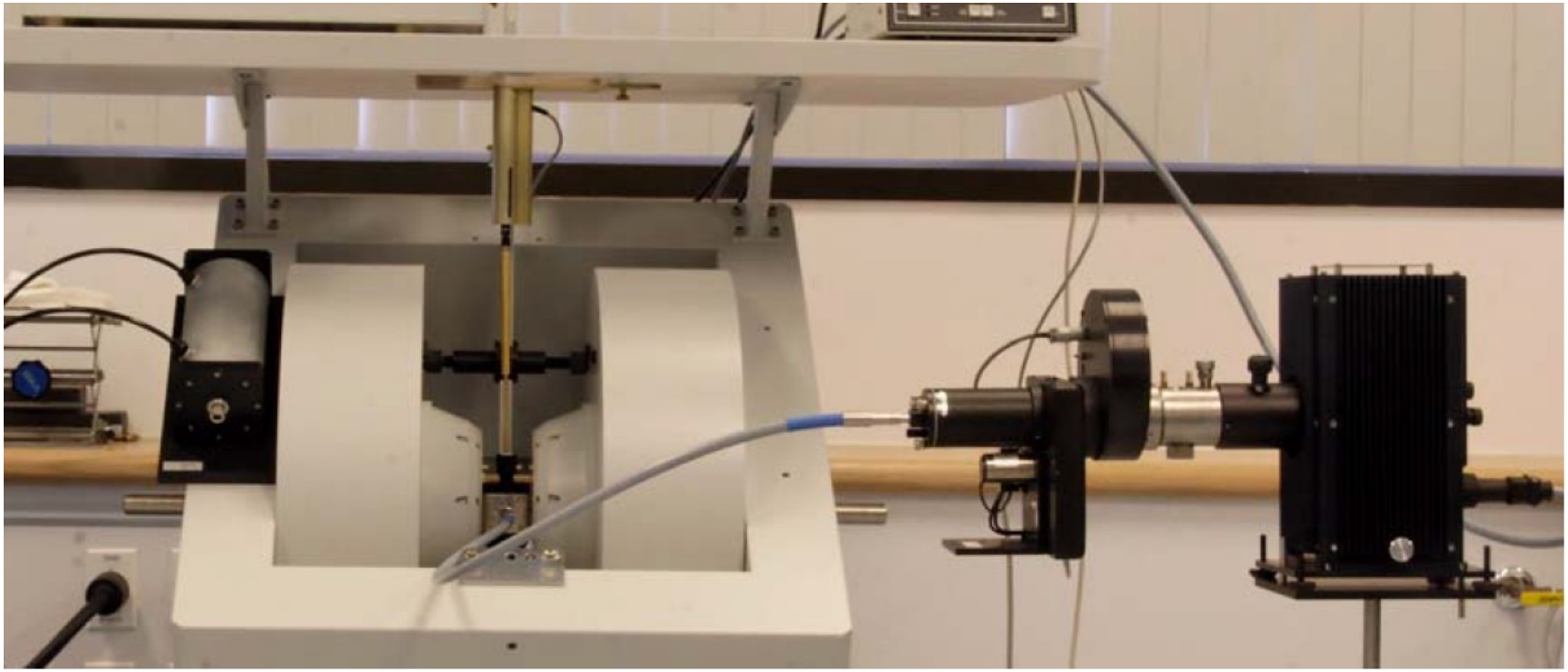
- In-situ irradiation of sample of interest in the microwave cavity
- Produces paramagnetic compounds via light irradiation
- Mercury lamp encapsulated in a protective housing
- Irradiation time proportional to intended dose



UV Irradiation System

Sample Irradiation

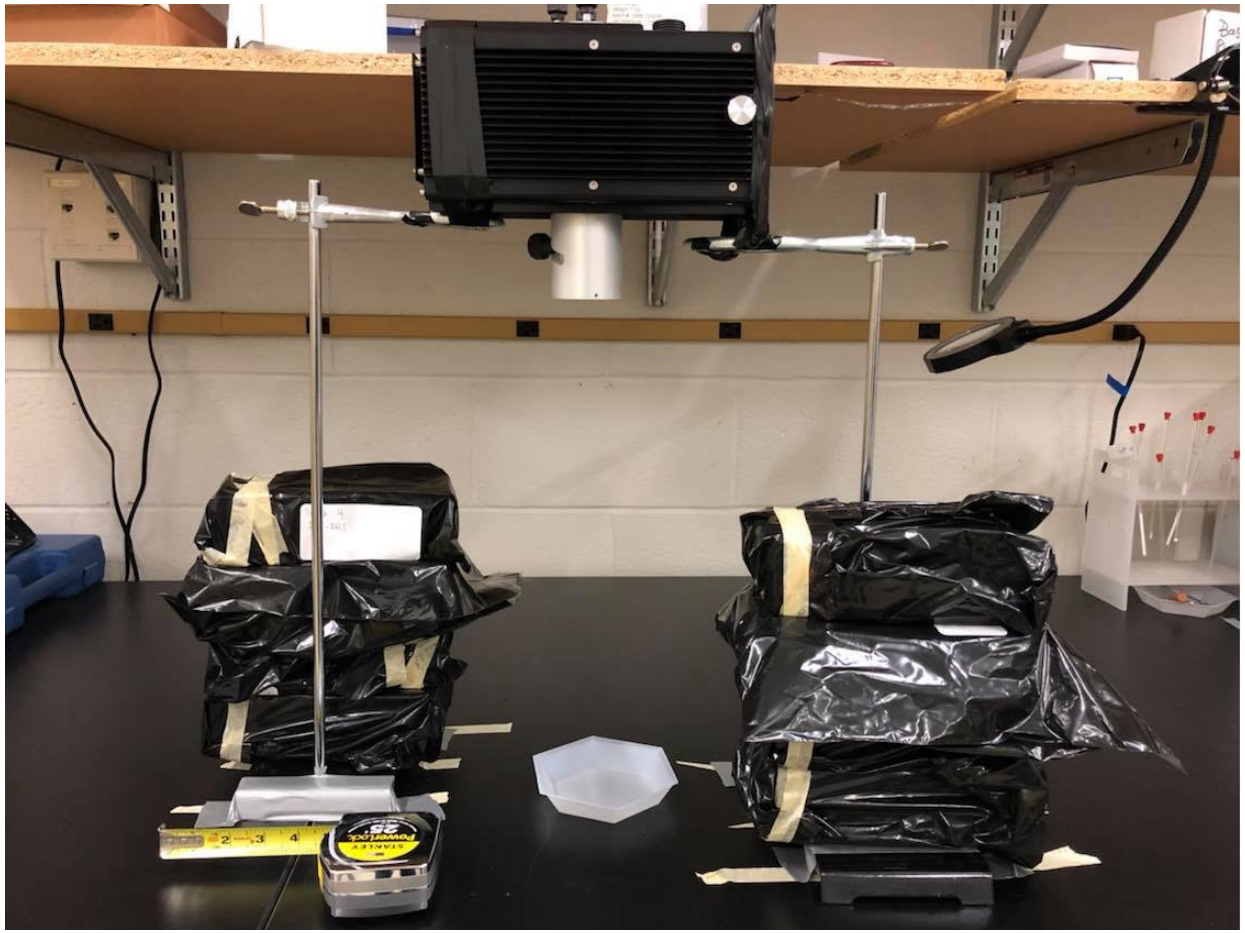
UV Irradiation System



In-Situ UV Irradiation System

Sample Irradiation

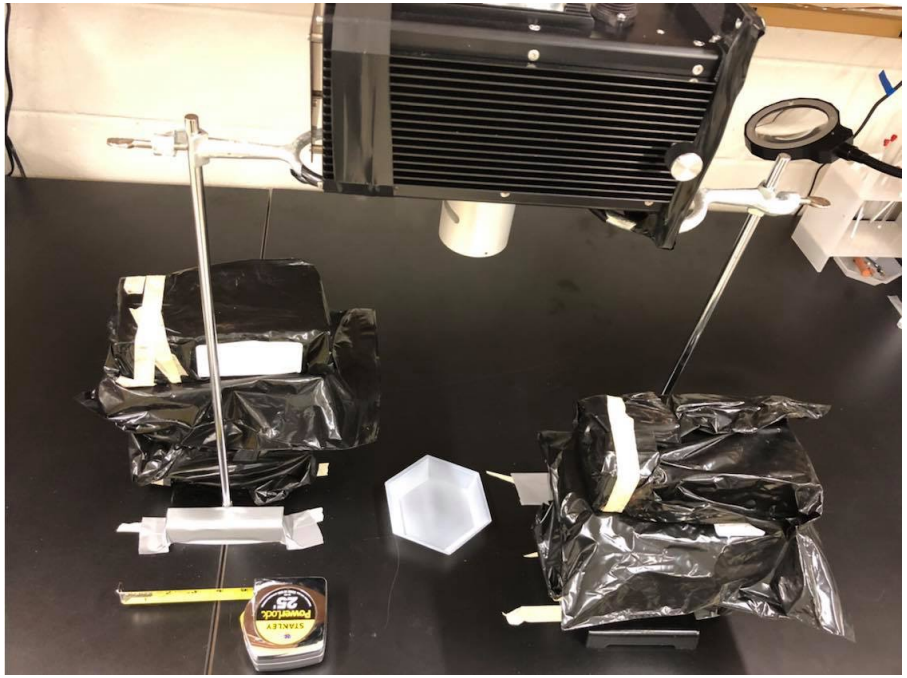
UV Irradiation System



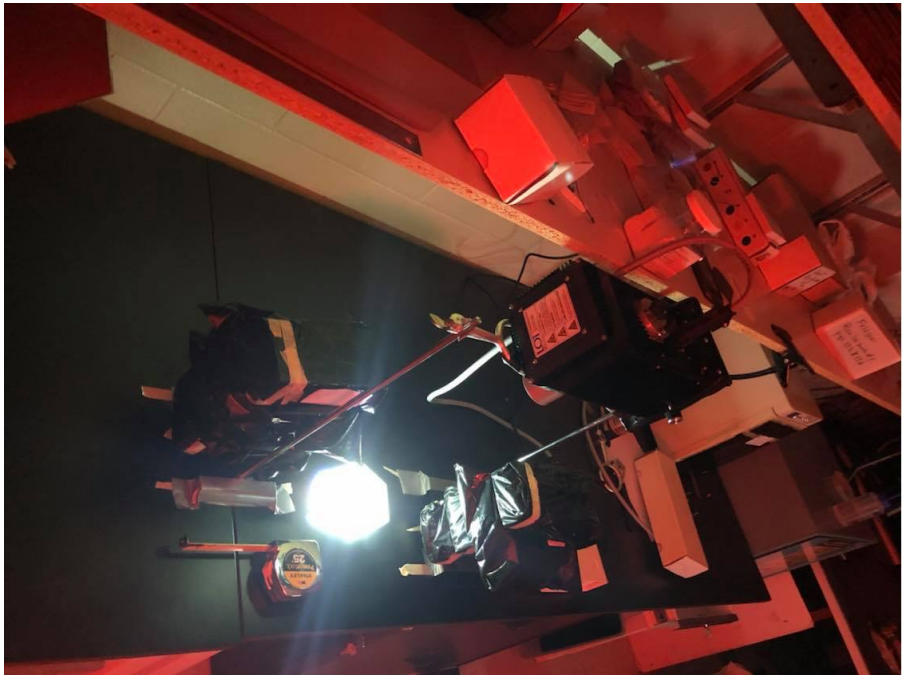
UV Irradiation System

Sample Irradiation

UV Irradiation System

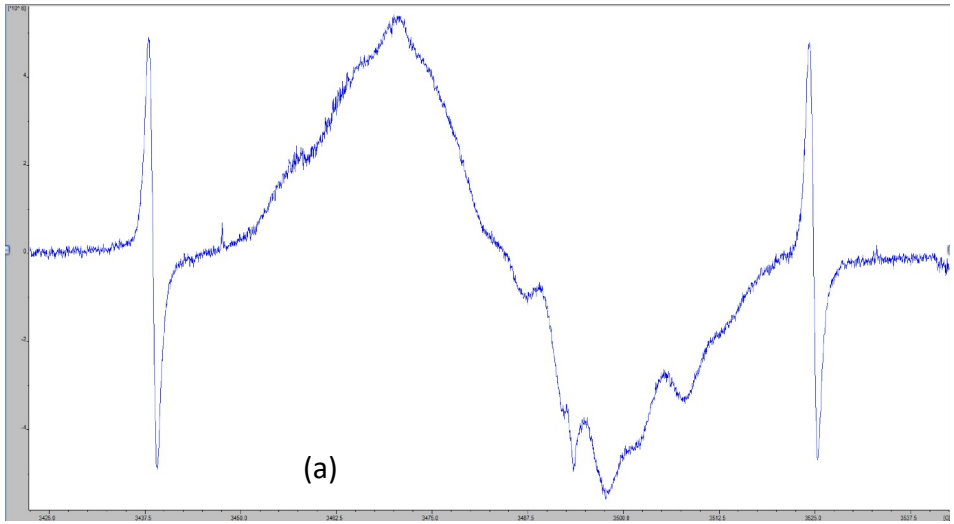


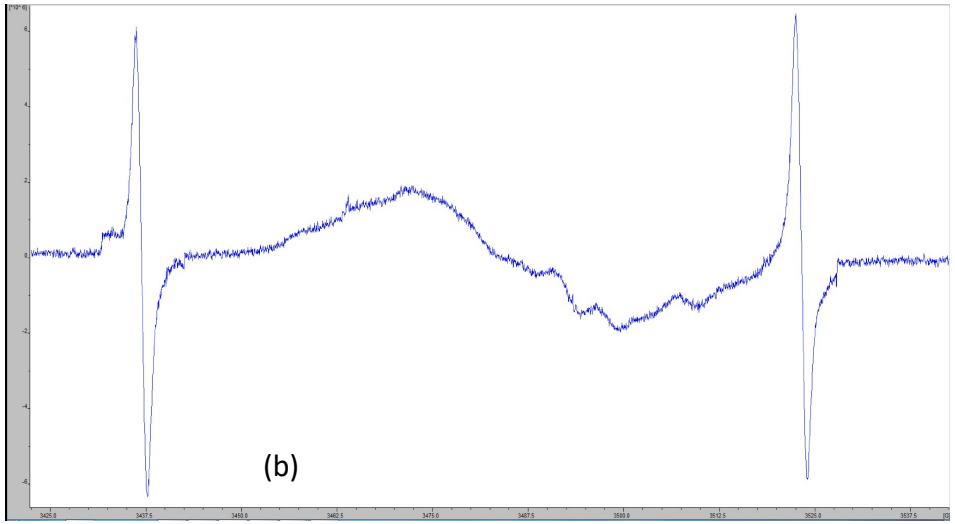
UV Irradiation System (off)



UV Irradiation System (on)

EPR Measurements

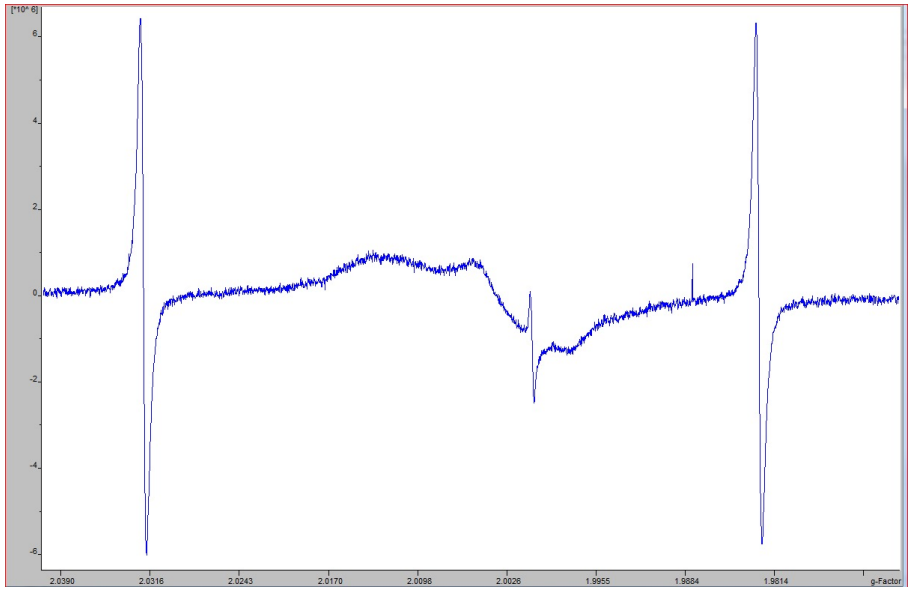




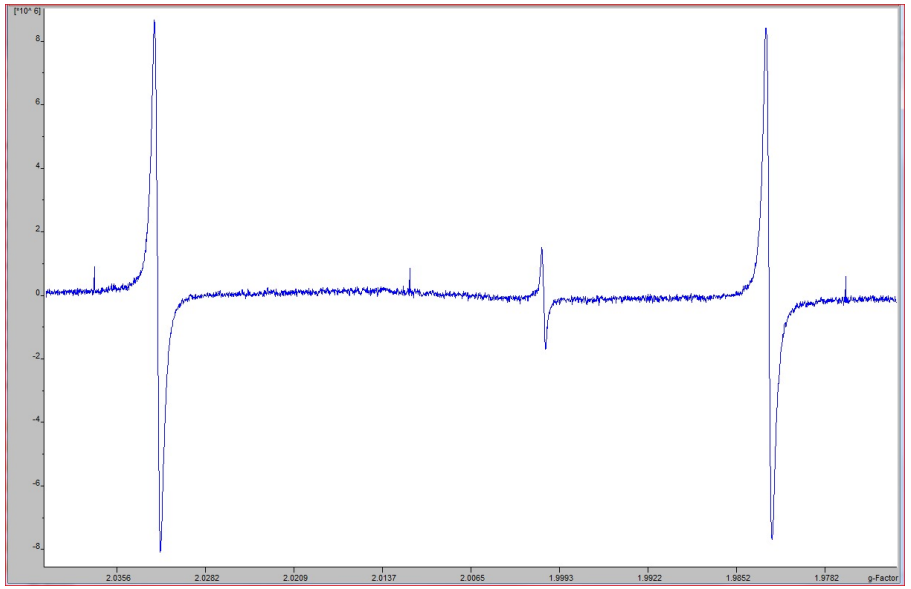
Sample EPR signal (a) high dose (b) low dose

Spectra Manipulation

Empty tube subtraction



(a)

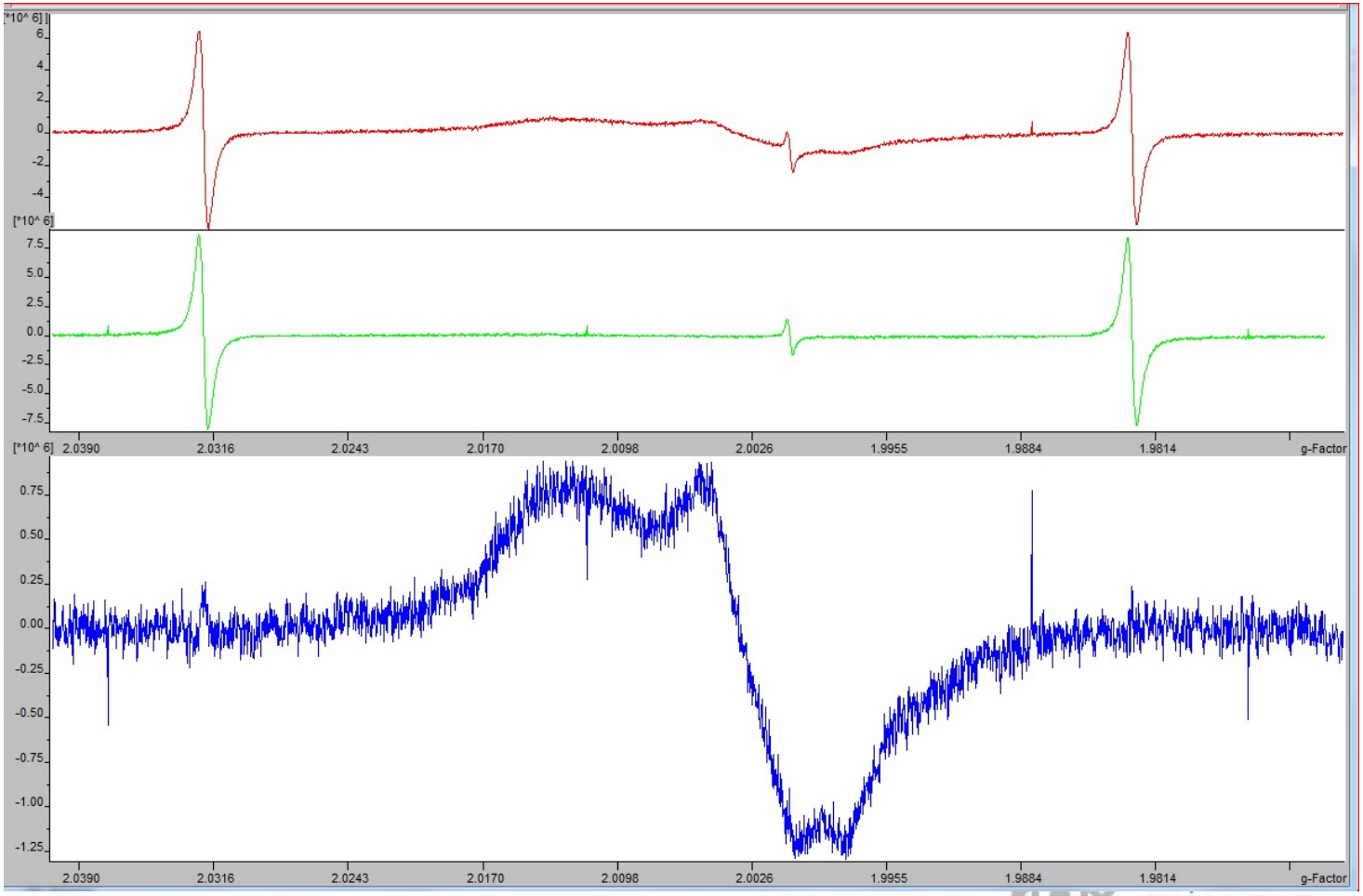


(b)

EPR signal (a) irradiated sample (b) Empty tube

Spectra Manipulation

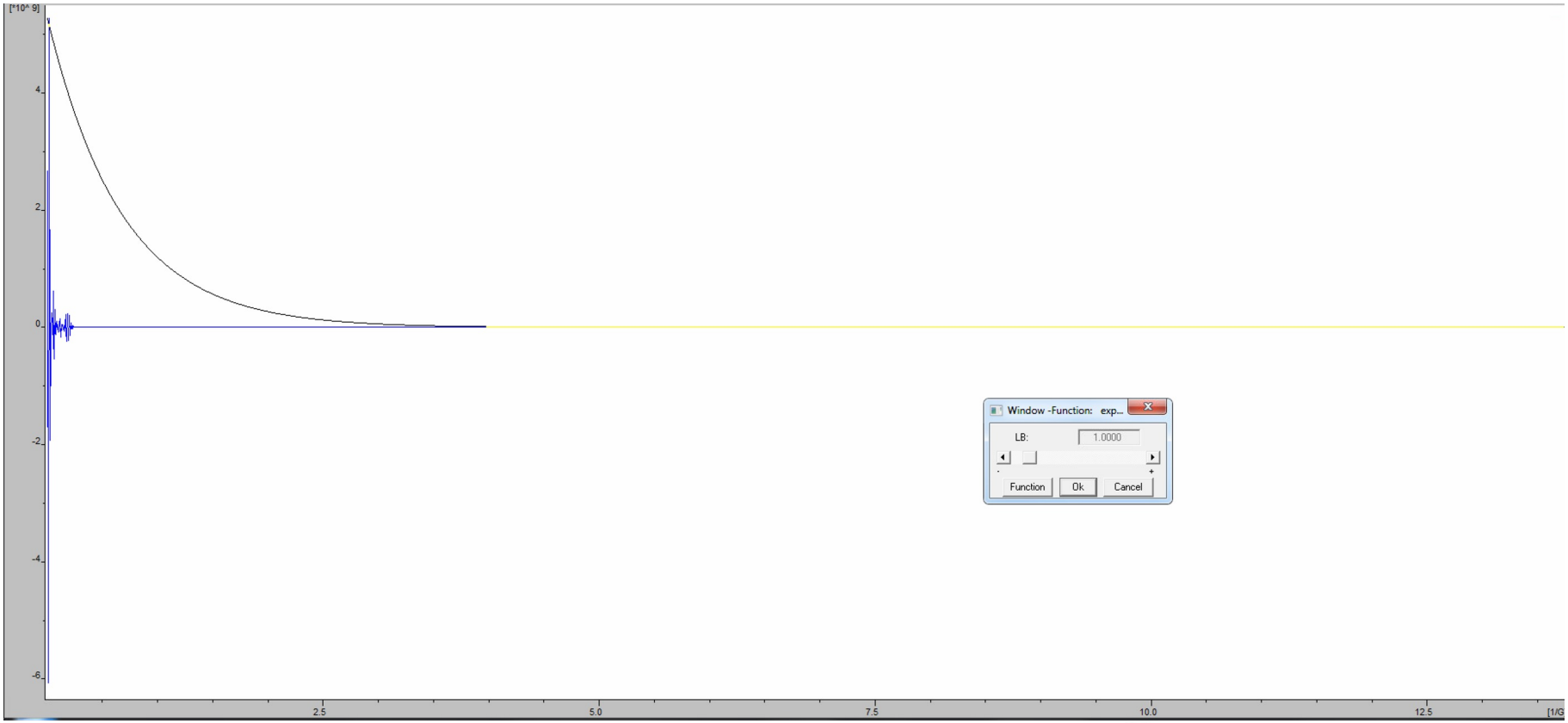
Empty tube subtraction



Empty tube subtraction

Spectra Manipulation

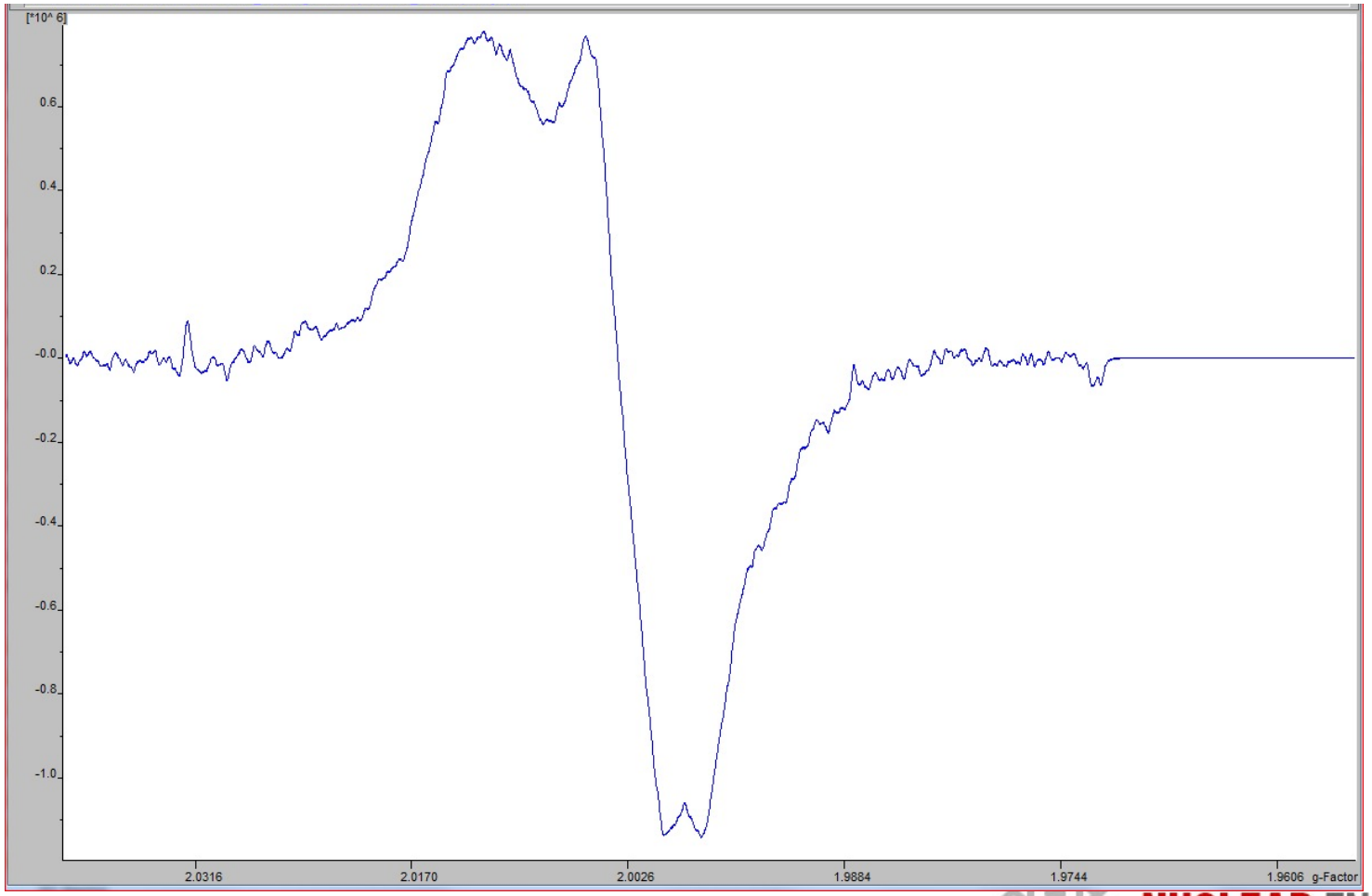
Fourier Transform



Exponential filtering with unity argument

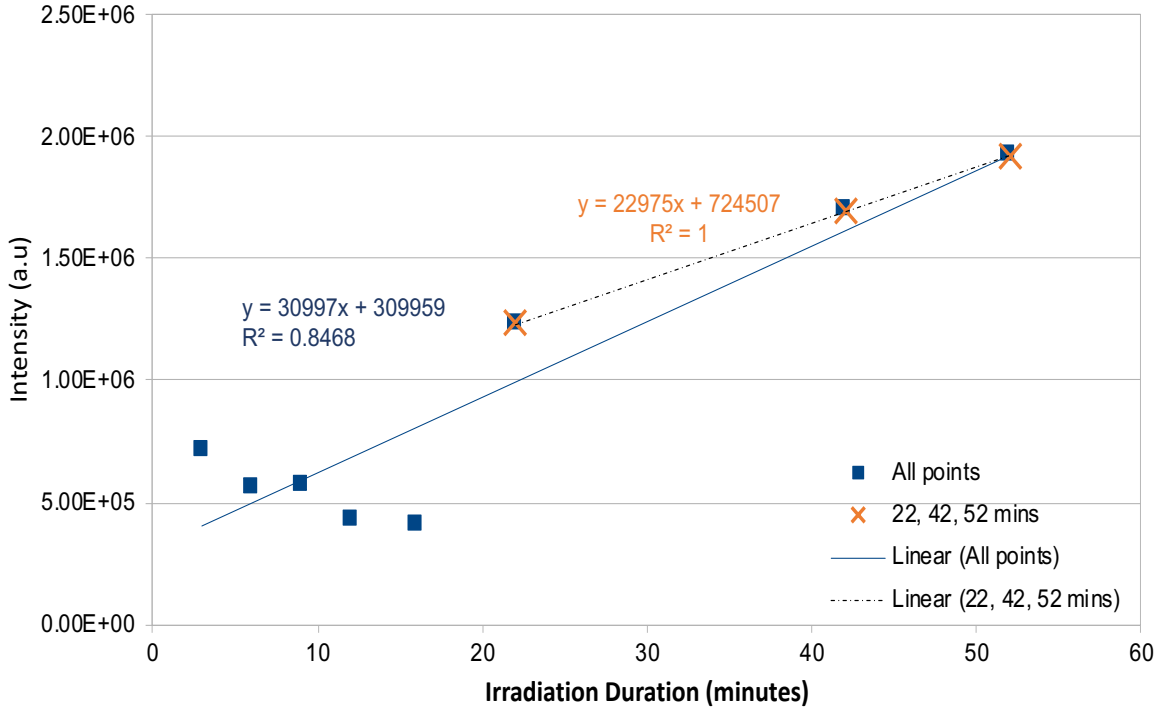
Spectra Manipulation

Inverse Fourier Transform



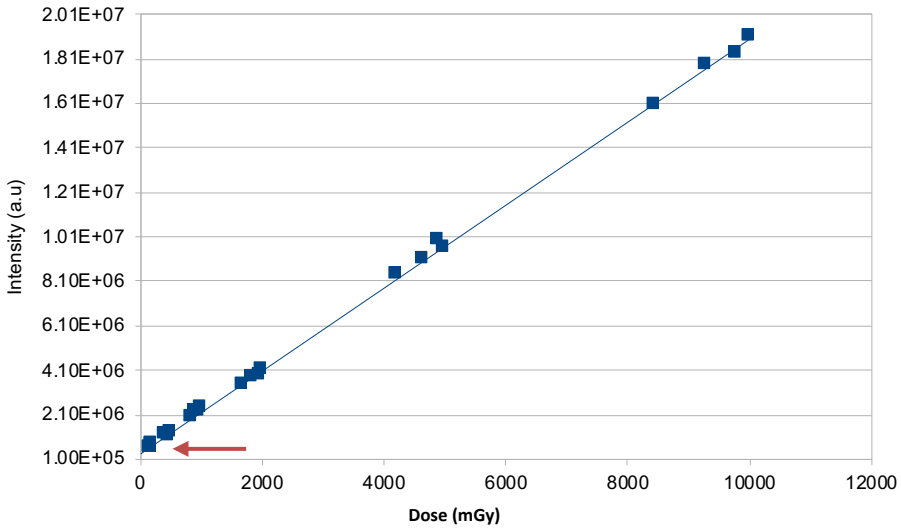
Results & Analysis

- Peak-to-Peak intensity vs. Irradiation duration
- Linear regression used
  - Full data set
  - Highest 3 data points
- R-squared:
  - Full data set: 0.8468
  - Highest 3 points: 1

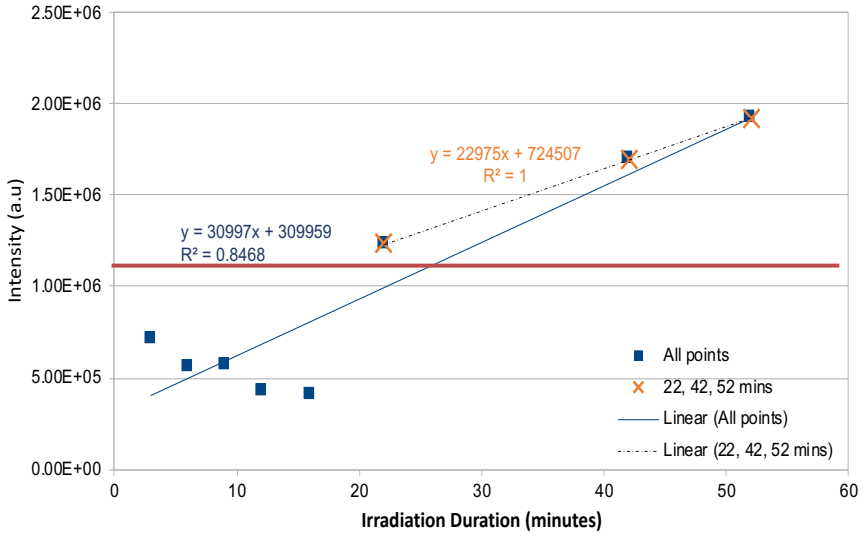


Results & Analysis

Comparison to known doses



Dose response of ^{60}Co irradiated samples



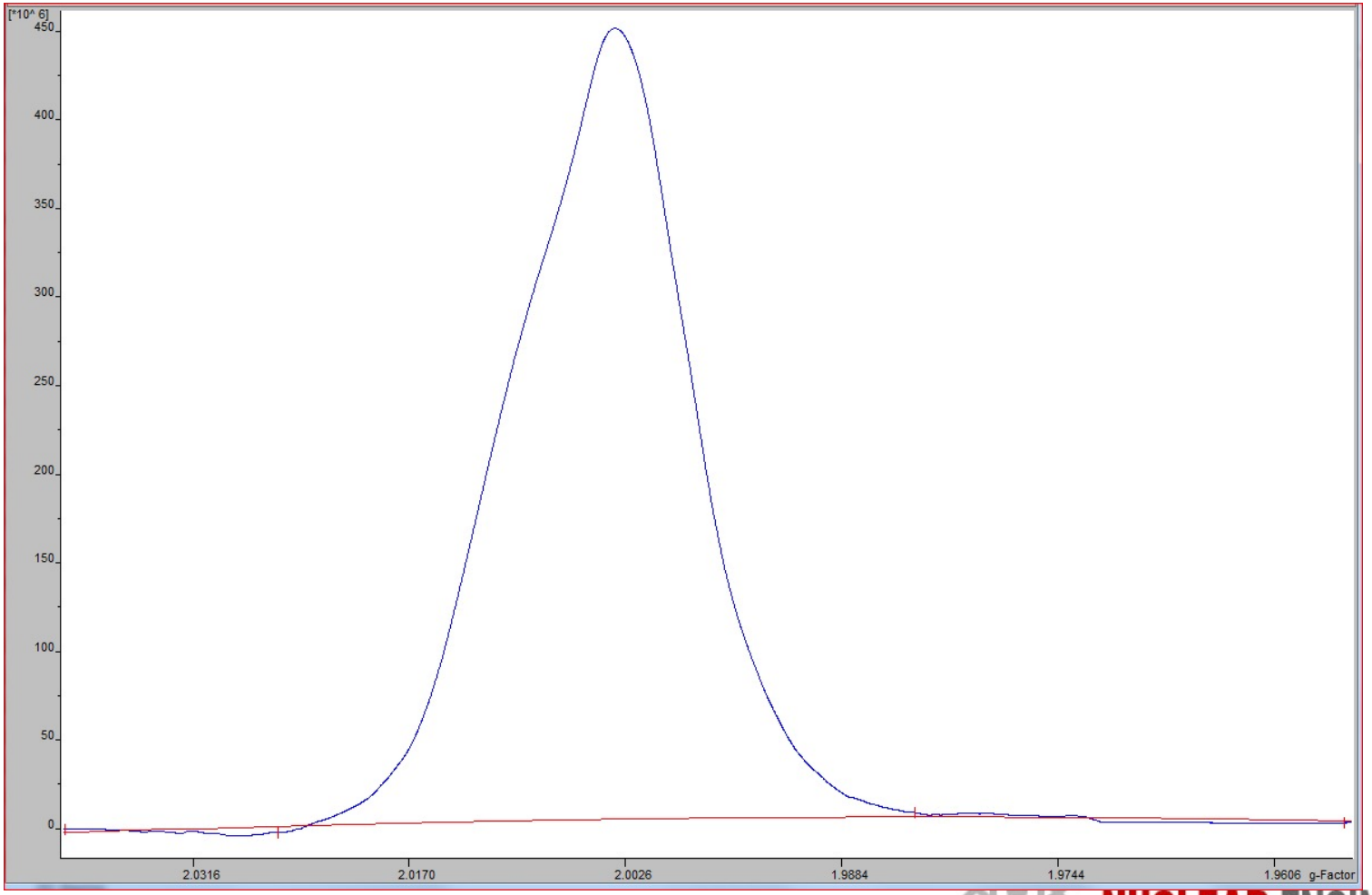
Response to UV irradiation system

- Minimum detectable dose:

  2 x 6E+05 = 1.2E+06 a.u

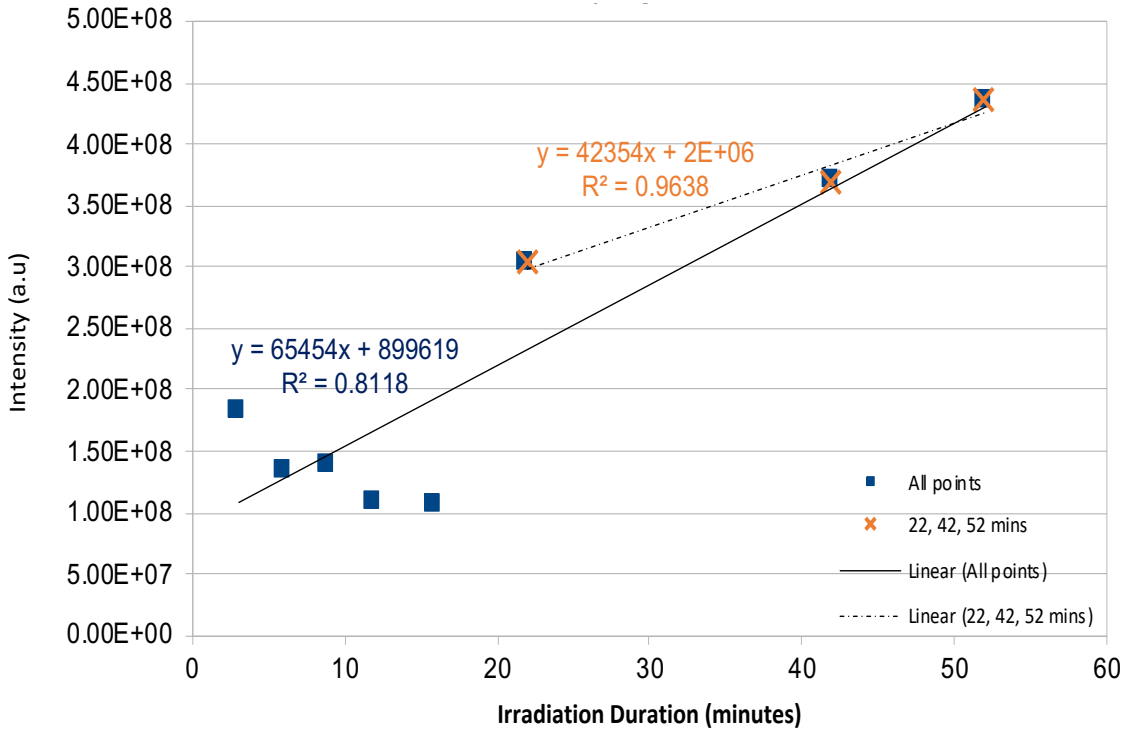
Spectra Manipulation

1st integral



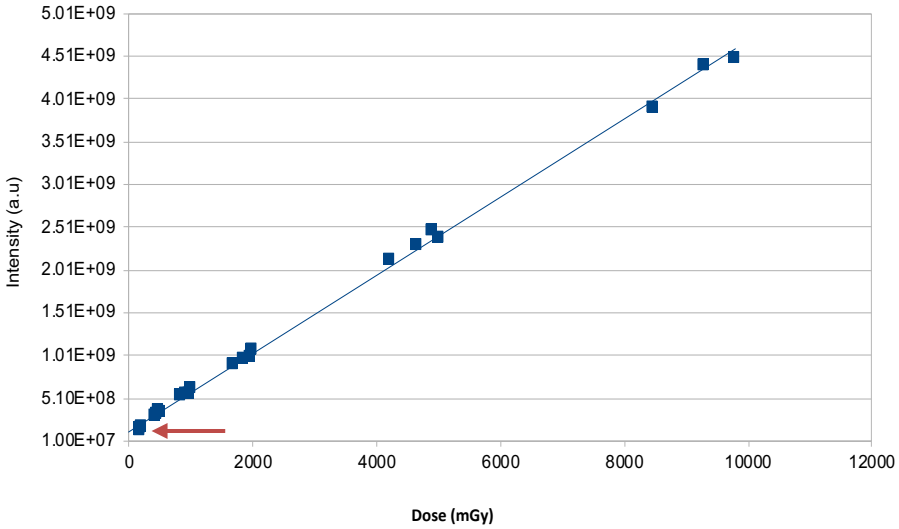
Results & Analysis

- Absorption peak intensity vs. Irradiation duration
- Linear regression used
  - Full data set
  - Highest 3 data points
- R-squared:
  - Full data set: 0.8118
  - Highest 3 points: 0.9638

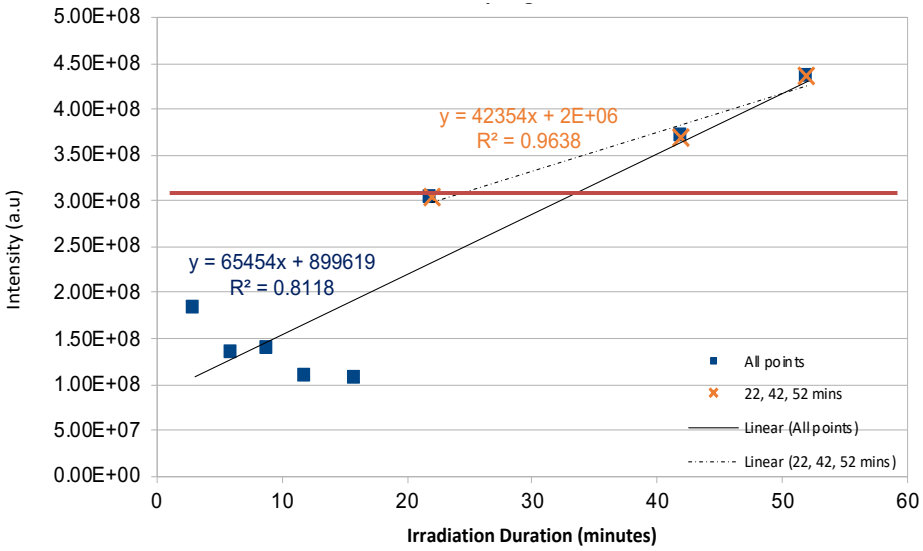


Results & Analysis

Comparison to known doses



Dose response of ^{60}Co irradiated samples



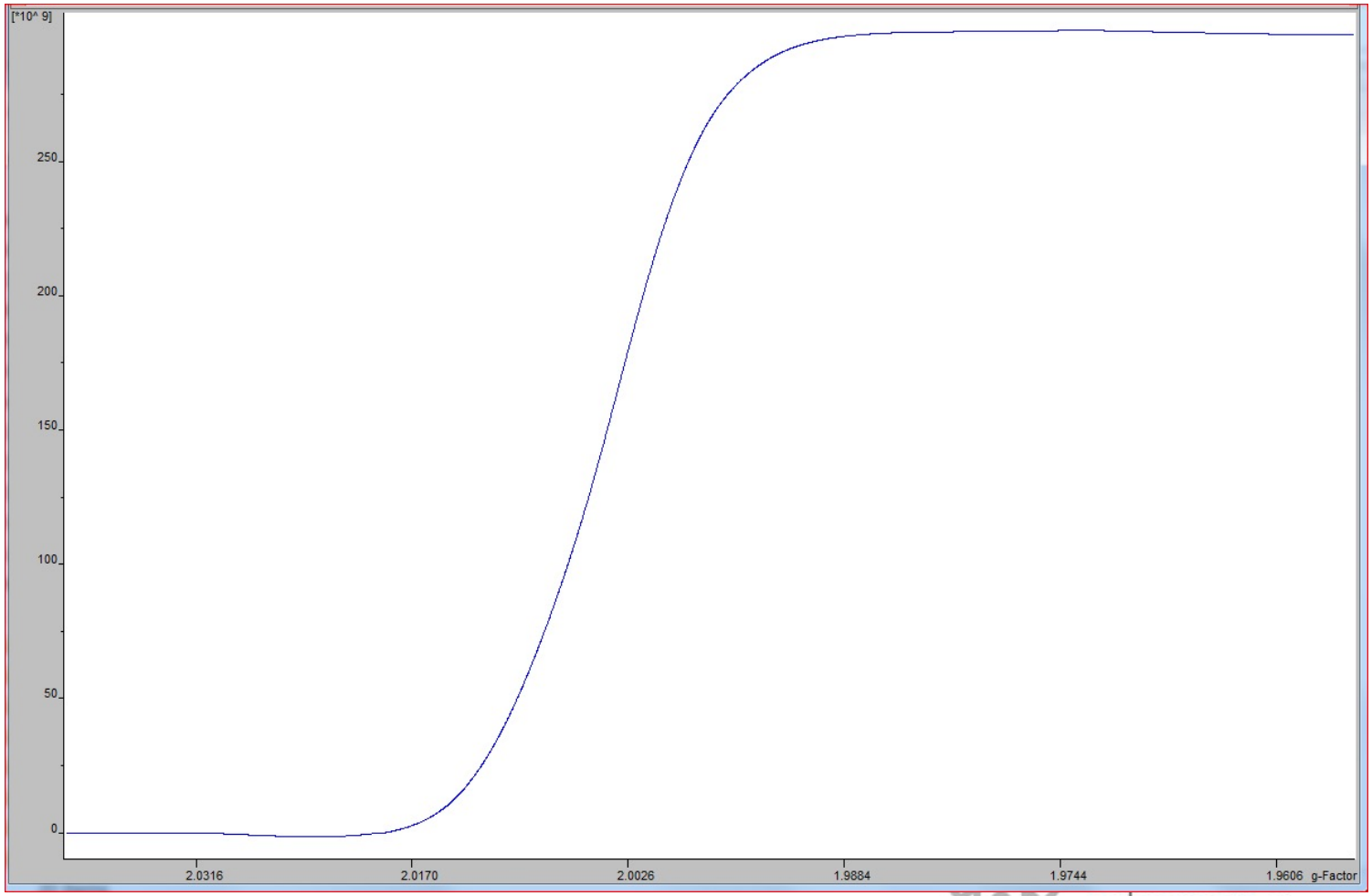
Response to UV irradiation system

- Minimum detectable dose:

  2 x 1.6E+08 = 3.2E+08 a.u

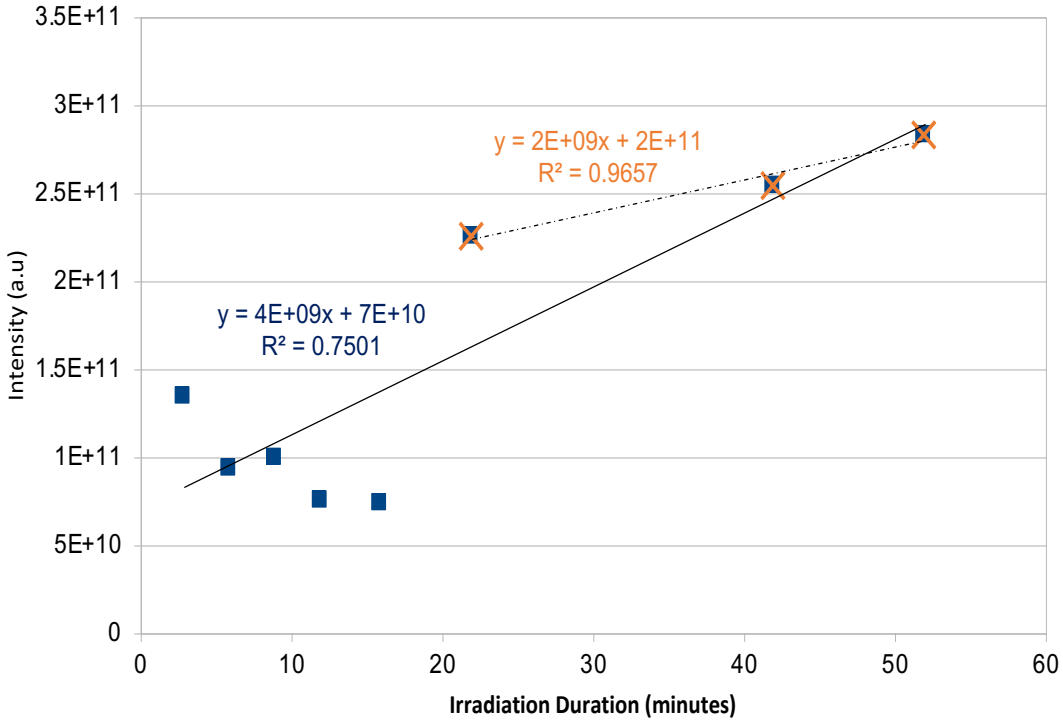
Spectra Manipulation

2nd integral



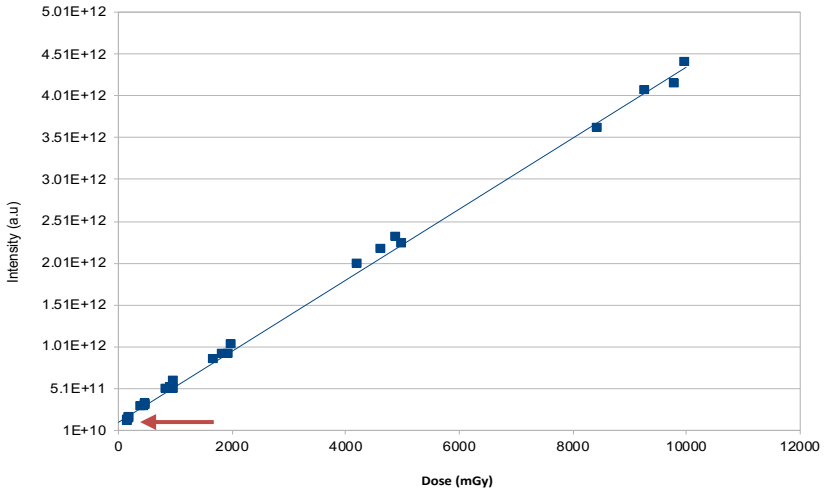
Results & Analysis

- Total absorption intensity vs. Irradiation duration
- Linear regression used
  - Full data set
  - Highest 3 data points
- R-squared:
  - Full data set: 0.7501
  - Highest 3 points: 0.9657

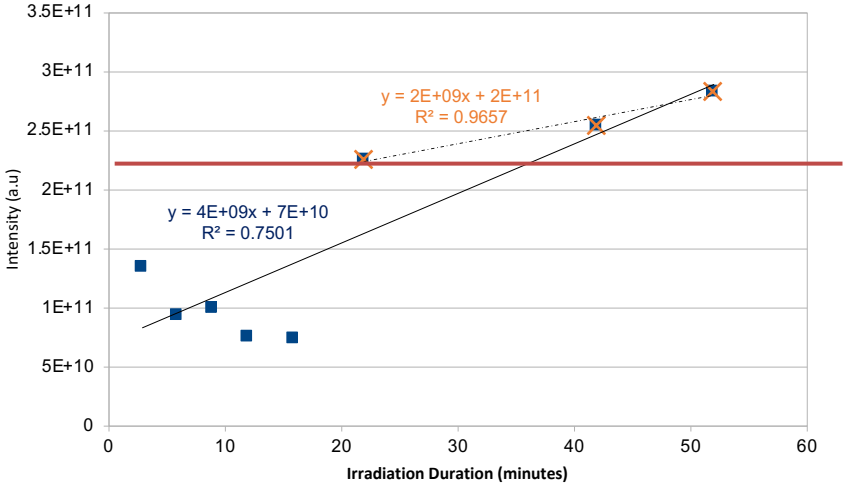


Results & Analysis

Comparison to known doses



Dose response of ^{60}Co irradiated samples



Response to UV irradiation system

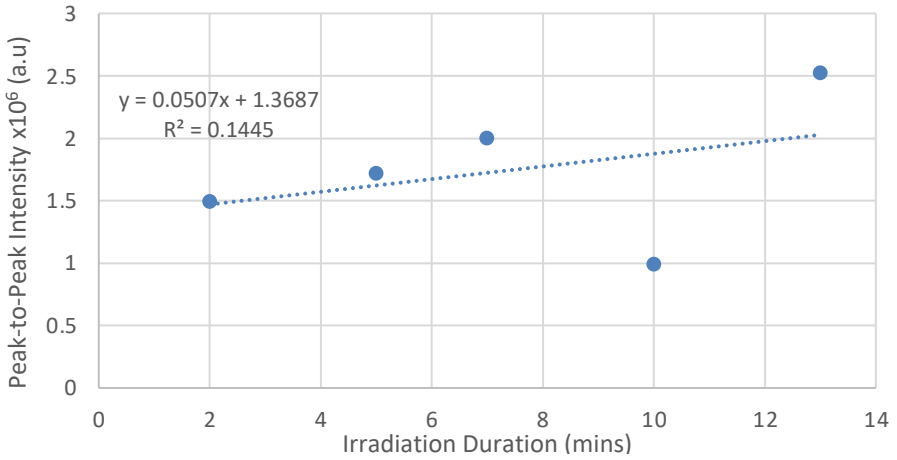
- Minimum detectable dose:

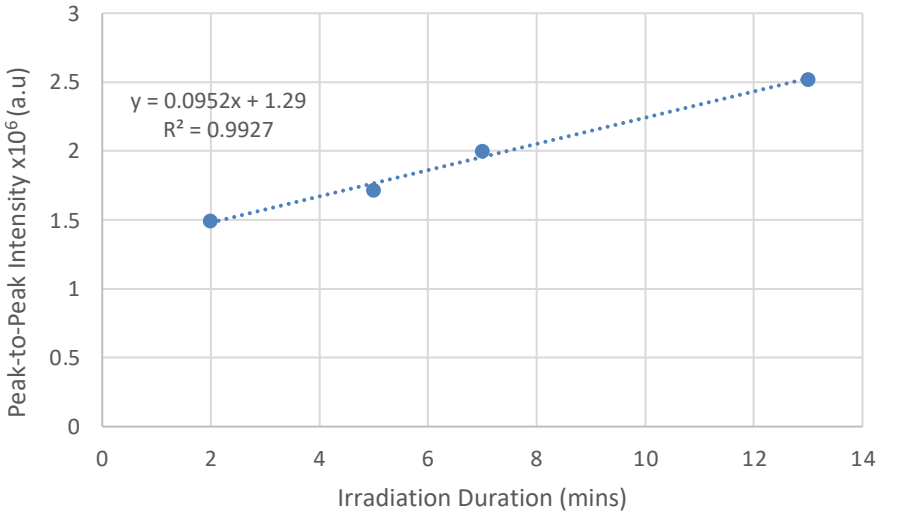
  2 x 1.1E+11 = 2.2E+11 a.u

Results & Analysis

Reduced source to sample distance

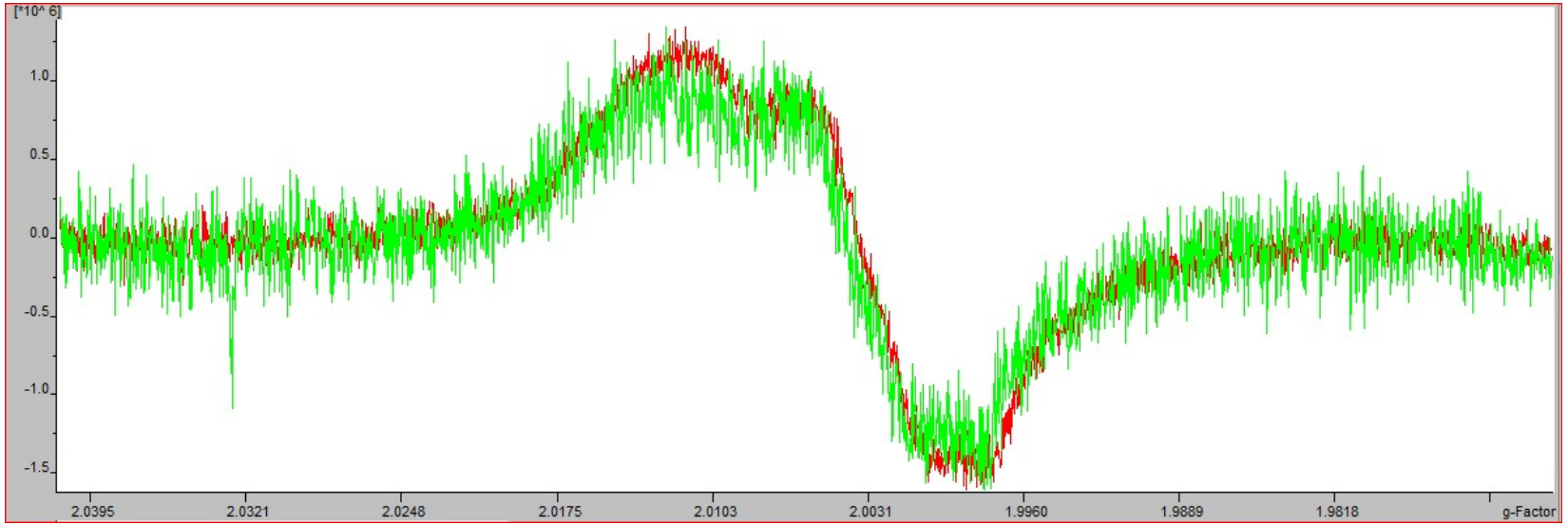
- Peak-to-Peak intensity vs. Irradiation duration
- Linear regression used
  - Full data set
  - Excluding the outlier
- R-squared:
  - Improves to 0.9927 by excluding the outlier



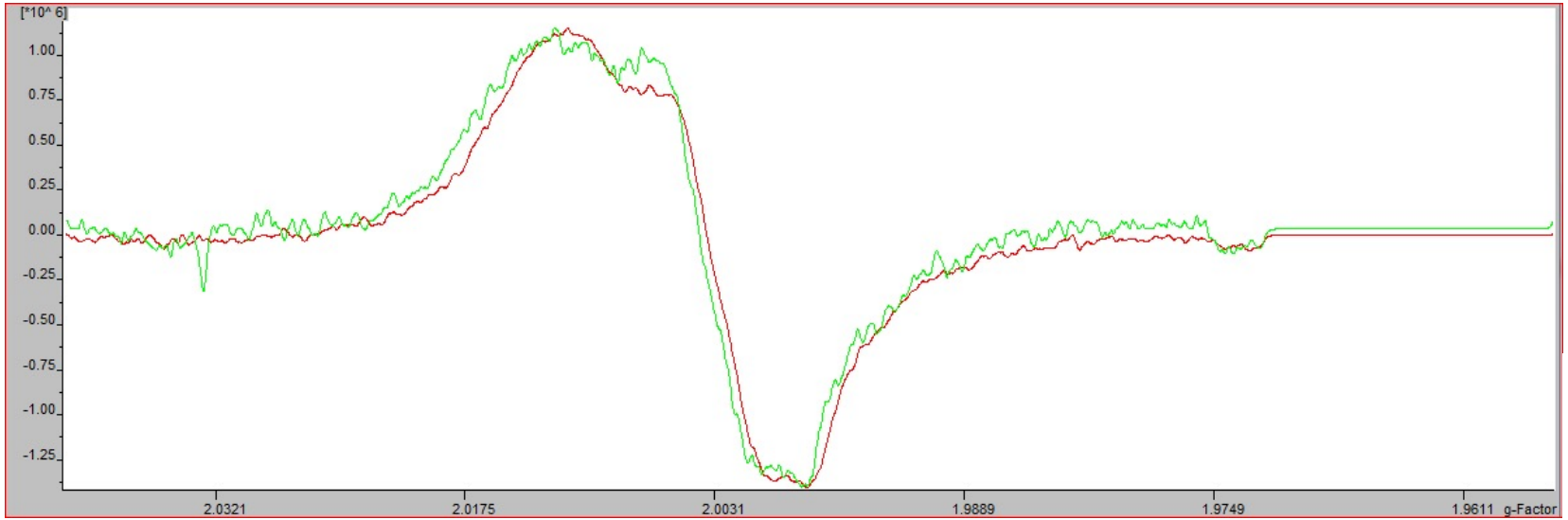


Results & Analysis

Reduced source to sample distance



10 mins
13 mins



10 mins
13 mins

Conclusions

- A preliminary experiment was performed to verify the ability to use a UV irradiation system for in-situ sample specific irradiation using commercial sugar samples
- Results showed no correlation between the intensities and the duration of irradiation at low exposure durations (below 22 minutes) at 17” distance
- Linear correlation becomes more evident at higher exposure durations (between 22 minutes and 52 minutes)
- Intensities were compared to a previously established dose response curve of ^{60}Co irradiated sugar samples
- Intensities of samples irradiated for less than 22 minutes correspond to doses below the detection limit.
- Reducing the distance between the source and the sample helped achieve higher intensities at lower irradiation duration

- EPR Dosimetry of Tooth Enamel For Low Dose Epidemiological Studies
- In-Situ Sample Specific Dose Response Calibration for EPR Dosimetry

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Questions?