# pIRIR fading test - Follow up tests

Dirk Mittelstraß

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This document re-evaluates some values and extends the component-removal approach. Please see **fading_test.pdf** for more details.

# 1 Data clean-up

We use the function `RLum.OSL_correction()` of the package `OSLdecomposition` (Mittelstraß et al. 2022) to perform consistency checks of the IRSL records and to remove the zero-stimulation parts. The correction procedure log is shown below.

```
CORRECTION STEP 1 ----- Check records for consistency in the detection settings -----
Frequency table of different sets of detection settings (Channels, Channel width):
  settings frequency record_type
1 220, 0.5       360        IRSL
2   220, 1       360       IRSL2
3 250, 0.4       162       IRSL3
RLum.Data.Curve@RecordType changed to IRSL2 or IRSL3 in sequence: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17
Further data manipulations are performed just on IRSL records
(time needed: 0.64 s)

CORRECTION STEP 2 ----- Remove not stimulated measurement parts -----
Measurement parts with stimulation light turned off detected and removed:
 5 s at the beginning and 0 s at the end.
-> Length of 360 IRSL records reduced from 110 s to 105 s
(time needed: 1.84 s)

CORRECTION STEP 3 ----- Limit measurement duration -----
Reduced length of 360 IRSL records from 105 s to 100 s
(time needed: 0.01 s)
```

We perform the code again but only for IRSL2 records to clean also 290°C IRSL records. We also separate the 50°C IRSL and 290°C IRSL measurements from each other and the TL and bleaching steps and put them in two data sets (not shown).

```
CORRECTION STEP 1 ----- Check records for consistency in the detection settings -----
All IRSL2 records have the same detection settings
(time needed: 0.25 s)

CORRECTION STEP 2 ----- Remove not stimulated measurement parts -----
Measurement parts with stimulation light turned off detected and removed:
 10 s at the beginning and 0 s at the end.
-> Length of 360 IRSL2 records reduced from 220 s to 210 s
(time needed: 2.05 s)

CORRECTION STEP 3 ----- Limit measurement duration -----
```

```
Reduced length of 360 IRSL2 records from 210 s to 200 s
(time needed: 0.01 s)
```

# 2 Classic fading test

## 2.1 Fading of IRSL at 50°C

As expected, the fading rate is quite high. In the analyses of the data sets, much lower De values were observed for the IRSL measurements than for the pIR-IRSL measurements. The high fading rate provides a possible reason for this.

We test if the fading value decrease if the signal integral range is shifted to later channels. And indeed, the g-value decreases to lower values.

```
Fading with signal integral 0 - 1.5 sec and background integral 50 - 100 sec

 IRSL at 50°C   g-value (norm. 2 days):  4.179 ± 0.534 %/decade

Fading results for shifted integrals

 IRSL50: 0 - 2 sec  g-value (norm. 2 days):  3.715 ± 0.481 %/decade
 IRSL50: 2 - 5 sec  g-value (norm. 2 days):  2.925 ± 0.554 %/decade
 IRSL50: 5 - 10 sec     g-value (norm. 2 days):  2.981 ± 0.702 %/decade
 IRSL50: 10 - 20 sec    g-value (norm. 2 days):  2.669 ± 1.055 %/decade
 IRSL50: 20 - 50 sec    g-value (norm. 2 days):  -1.057 ± 1.9 %/decade
```

## 2.2 Fading of pIR-IRSL at 290°C

As expected, the fading values for the IRSL290 measurements are much lower. However, fading is still significant. Again, shifting the integral range decreases the g-value.

```
Fading with signal integral 0 - 3 sec and background integral 150 - 200 sec

 pIRIRSL at 290°C   g-value (norm. 2 days):  2.02 ± 0.241 %/decade

Fading results for shifted integrals

 pIRIRSL: 0 - 2 sec     g-value (norm. 2 days):  2.153 ± 0.292 %/decade
 pIRIRSL: 2 - 5 sec     g-value (norm. 2 days):  1.541 ± 0.331 %/decade
 pIRIRSL: 5 - 10 sec    g-value (norm. 2 days):  1.639 ± 0.399 %/decade
 pIRIRSL: 10 - 20 sec   g-value (norm. 2 days):  0.926 ± 0.577 %/decade
 pIRIRSL: 20 - 50 sec   g-value (norm. 2 days):  0.552 ± 0.931 %/decade
```

# 3 Fading per component

## 3.1 Components of IRSL at 50°C

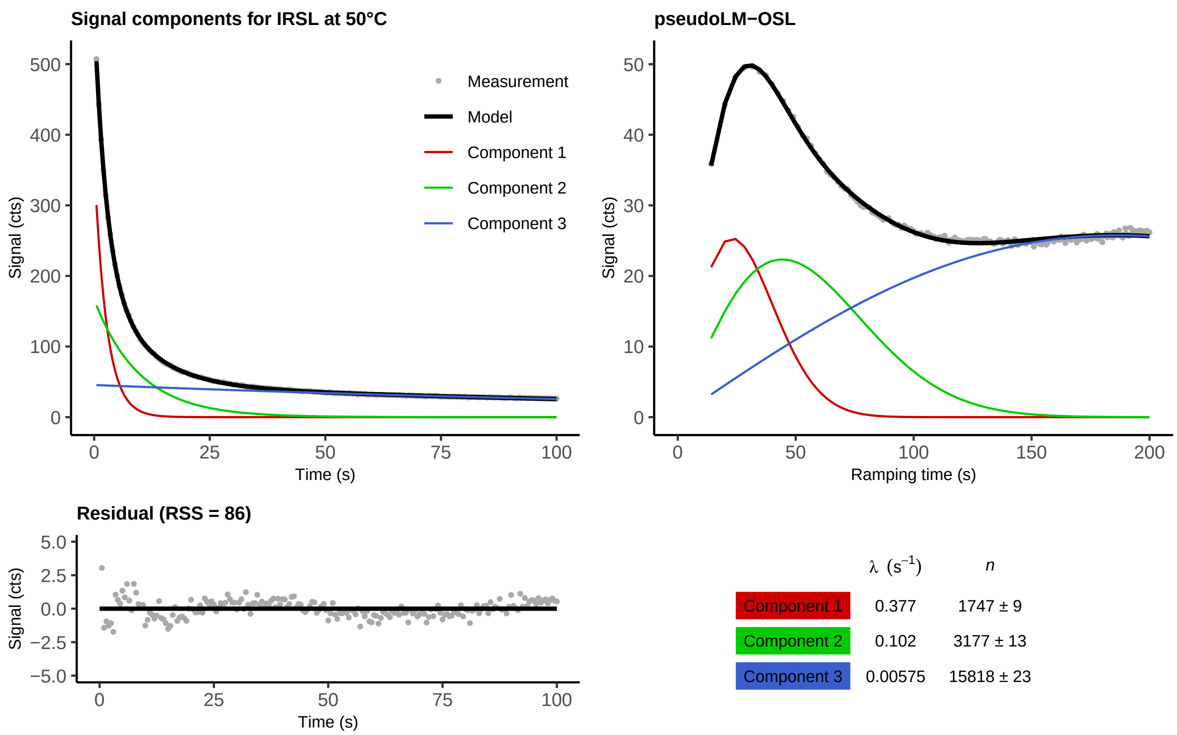
1. Fitting of the average IRSL curve with `RLum.OSL_global_fitting()`
2. Decomposing all IRSL curves into its signal components with `RLum.OSL_decomposition()`
3. Building LxTx tables with the component intensities as Lx and Tx values
4. Calculating component-wise g-values with `analyse_FadingMeasurement()` by using the LxTx tables as input

```
STEP 1.1 ----- Build global average curve from all CW-OSL curves -----
Built global average curve from arithmetic means from first 200 data points of all 360 IRSL records
(time needed: 1.76 s)

STEP 1.2 ----- Perform multi-exponential curve fitting -----

Decay rates (s^-1):
Cycle       Comp. 1     Comp. 2     Comp. 3          RSS     F-value
K = 1        0.1068                            1.871e+05         Inf
K = 2        0.2421     0.01207                     3586        5016
K = 3        0.3774      0.1021    0.005749        85.42        3975
Left loop because maximum number of allowed components K is reached
-> The F-test suggests the K = 3 model

Photoionisation cross sections (cm^2):
Cycle     Comp. 1              Comp. 2              Comp. 3
K = 1    7.13e-19
K = 2    1.62e-18             8.06e-20
K = 3    2.52e-18             6.82e-19             3.84e-20
(time needed: 1.77 s)
```




```
STEP 2.1 ----- Define signal bin intervals -----
Find intervals with lowest component cross correlation by maximising the denominator determinant in Cramers rule:
Maximum determinant = 0.1106 with interval dividing channels at i = 9, 53
(time needed: 0.27 s)

STEP 2.2 ----- Decompose each  IRSL  curve -----
Calculate signal intensity n in each IRSL  by ' det+nls ' algorithm with empiric error estimation
Table of input decay constants and signal bin intervals for [decompose_OSLcurve()]:
         name      lambda t.start t.end ch.start ch.end
1 Component 1 0.377412416     0.0   4.5        1      9
2 Component 2 0.102117901     4.5  26.5       10     53
3 Component 3 0.005748696    26.5 100.0       54    200


..................
Successfully decomposed 360 records
(time needed: 1.25 s)

Component-wise fading results:

 IRSL50 comp. 1     g-value (norm. 2 days):  4.692 ± 0.569 %/decade
```

```
 IRSL50 comp. 2     g-value (norm. 2 days):  2.494 ± 0.578 %/decade
 IRSL50 comp. 3     g-value (norm. 2 days):  0.992 ± 0.185 %/decade
```

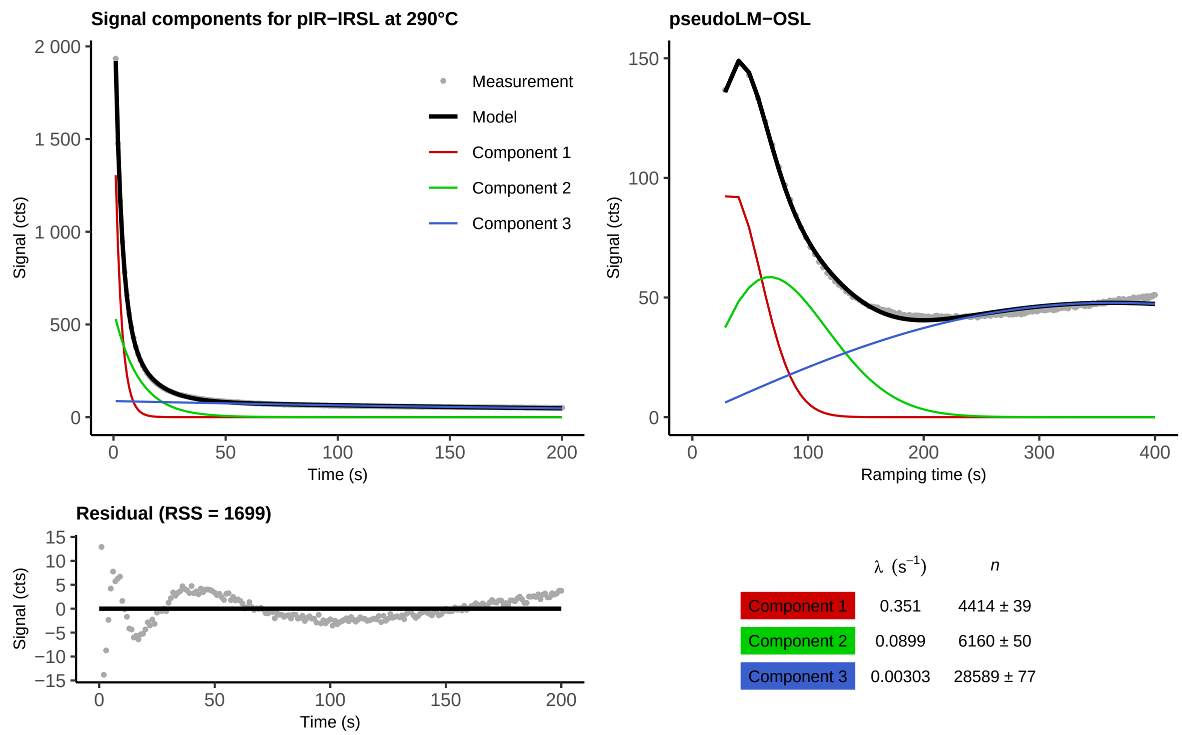
## 3.2 Components of pIR-IRSL at 290°C

```
STEP 1.1 ----- Build global average curve from all CW-OSL curves -----
Built global average curve from arithmetic means from first 200 data points of all 360 IRSL2 records
(time needed: 1.93 s)

STEP 1.2 ----- Perform multi-exponential curve fitting -----

Decay rates (s^-1):
Cycle       Comp. 1     Comp. 2     Comp. 3         RSS     F-value
K = 1        0.1591                              9.815e+05         Inf
K = 2        0.2274    0.006932                  5.257e+04        1732
K = 3        0.3505     0.08985    0.003028        1691        2918
Left loop because maximum number of allowed components K is reached
-> The F-test suggests the K = 3 model

Photoionisation cross sections (cm^2):
Cycle     Comp. 1              Comp. 2              Comp. 3
K = 1    1.06e-18
K = 2    1.52e-18             4.63e-20
K = 3    2.34e-18             6e-19                2.02e-20
(time needed: 1.83 s)
```




```
STEP 2.1 ----- Define signal bin intervals -----
Find intervals with lowest component cross correlation by maximising the denominator determinant in Cramers rule:
Maximum determinant = 0.1489 with interval dividing channels at i = 5, 36
(time needed: 0.24 s)

STEP 2.2 ----- Decompose each  IRSL2  curve -----
Calculate signal intensity n in each IRSL2  by ' det+nls ' algorithm with empiric error estimation
Table of input decay constants and signal bin intervals for [decompose_OSLcurve()]:
         name      lambda t.start t.end ch.start ch.end
1 Component 1 0.350521825       0     5        1      5
2 Component 2 0.089852577       5    36        6     36
3 Component 3 0.003028065      36   200       37    200



..................
Successfully decomposed 360 records
(time needed: 1.26 s)

Component-wise fading results:

 pIRIR comp. 1  g-value (norm. 2 days):  2.47 ± 0.288 %/decade
```

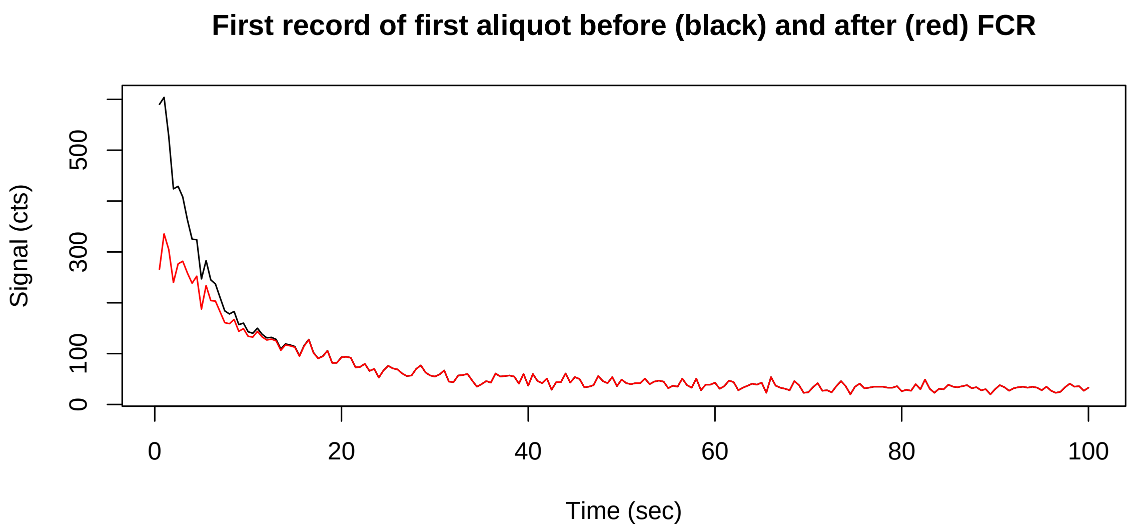
```
pIRIR comp. 2  g-value (norm. 2 days):  1.021 ± 0.39 %/decade
pIRIR comp. 3  g-value (norm. 2 days):  1.06 ± 0.152 %/decade
```

# 4 Component removal

## 4.1 Fading of IRSL at 50°C

Although the fast component removal leads to an alteration of the measurement curves and the fading results, the g-value of the initial signal is **not** decreased.

```
FCR fading with signal integral 0 - 10 sec and background integral 50 - 100 sec
```




```
 FCR-IRSL at 50°C   g-value (norm. 2 days):  3.261 ± 0.598 %/decade
```

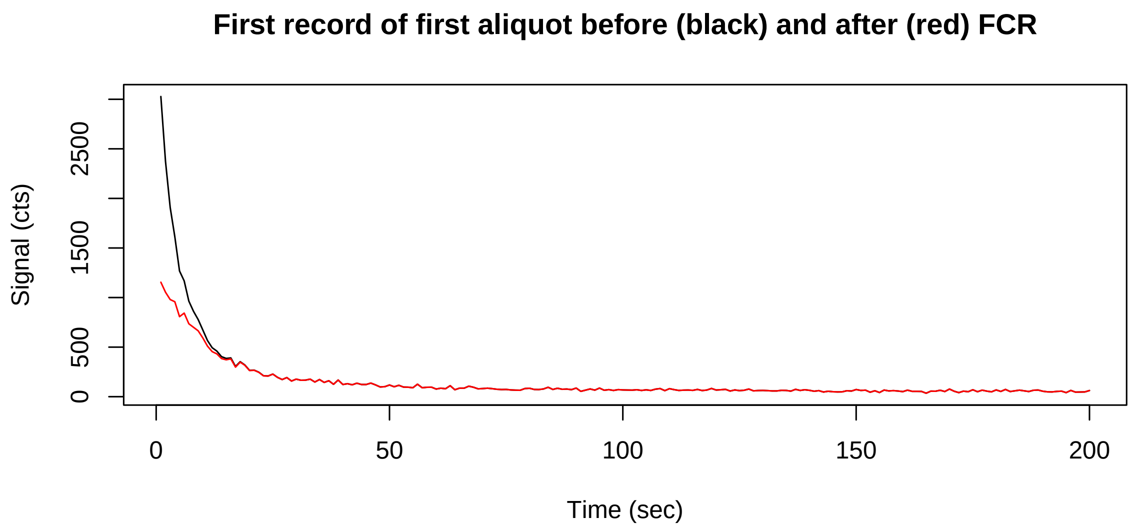
```
Fading results for shifted integrals
```

```
 FCR-IRSL50: 0 - 2 sec  g-value (norm. 2 days):  5.039 ± 1.256 %/decade
 FCR-IRSL50: 2 - 5 sec  g-value (norm. 2 days):  2.594 ± 0.857 %/decade
 FCR-IRSL50: 5 - 10 sec     g-value (norm. 2 days):  3.04 ± 0.877 %/decade
 FCR-IRSL50: 10 - 20 sec    g-value (norm. 2 days):  2.632 ± 1.133 %/decade
 FCR-IRSL50: 20 - 50 sec    g-value (norm. 2 days):  -1.063 ± 1.847 %/decade
```

### 4.2 Fading of pIR-IRSL at 290°C

As expected, removing the fast component decreases the g-value significantly.

```
FCR fading with signal integral 0 - 10 sec and background integral 150 - 200 sec
```




```
 FCR-pIR-IRSL at 290°C  g-value (norm. 2 days):  1.072 ± 0.359 %/decade
```

```
Fading results for shifted integrals
```

```
 FCR-pIRIRSL: 0 - 2 sec     g-value (norm. 2 days):  0.316 ± 0.885 %/decade
 FCR-pIRIRSL: 2 - 5 sec     g-value (norm. 2 days):  0.554 ± 0.652 %/decade
 FCR-pIRIRSL: 5 - 10 sec    g-value (norm. 2 days):  1.444 ± 0.521 %/decade
 FCR-pIRIRSL: 10 - 20 sec   g-value (norm. 2 days):  0.813 ± 0.63 %/decade
 FCR-pIRIRSL: 20 - 50 sec   g-value (norm. 2 days):  0.548 ± 0.897 %/decade
```

# 5 Overview

Table 1: Overview of Fading test results

| test | signal | background | g_value | g_value_err | tc | g_2days | g_2days_err | rho | rho_err |
|---|---|---|---|---|---|---|---|---|---|
| IRSL at 50°C | 0 - 1.5 sec | 50 - 100 sec | 3.811 | 0.529 | 1735 | 4.179 | 0.534 | 2.761e-06 | 3.466e-07 |
| IRSL50: 0 - 2 sec | 0 - 2 sec | 50 - 100 sec | 3.440 | 0.476 | 1735 | 3.715 | 0.481 | 2.481e-06 | 3.362e-07 |
| IRSL50: 2 - 5 sec | 2 - 5 sec | 50 - 100 sec | 2.741 | 0.548 | 1735 | 2.925 | 0.554 | 1.956e-06 | 3.867e-07 |
| IRSL50: 5 - 10 sec | 5 - 10 sec | 50 - 100 sec | 2.820 | 0.692 | 1735 | 2.981 | 0.702 | 2.021e-06 | 5.053e-07 |
| IRSL50: 10 - 20 sec | 10 - 20 sec | 50 - 100 sec | 2.599 | 1.033 | 1735 | 2.669 | 1.055 | 1.798e-06 | 7.91e-07 |
| IRSL50: 20 - 50 sec | 20 - 50 sec | 50 - 100 sec | -1.111 | 1.830 | 1735 | -1.057 | 1.900 | -9.266e-07 | 1.188e-06 |
| pIRIRSL at 290°C | 0 - 3 sec | 150 - 200 sec | 1.949 | 0.240 | 1947 | 2.020 | 0.241 | 1.36e-06 | 1.742e-07 |
| pIRIRSL: 0 - 2 sec | 0 - 2 sec | 150 - 200 sec | 2.066 | 0.291 | 1947 | 2.153 | 0.292 | 1.46e-06 | 2.035e-07 |
| pIRIRSL: 2 - 5 sec | 2 - 5 sec | 150 - 200 sec | 1.484 | 0.329 | 1947 | 1.541 | 0.331 | 1.069e-06 | 2.371e-07 |
| pIRIRSL: 5 - 10 sec | 5 - 10 sec | 150 - 200 sec | 1.562 | 0.396 | 1947 | 1.639 | 0.399 | 1.116e-06 | 2.865e-07 |
| pIRIRSL: 10 - 20 sec | 10 - 20 sec | 150 - 200 sec | 0.913 | 0.570 | 1947 | 0.926 | 0.577 | 6.408e-07 | 4.066e-07 |
| pIRIRSL: 20 - 50 sec | 20 - 50 sec | 150 - 200 sec | 0.576 | 0.915 | 1947 | 0.552 | 0.931 | 4.152e-07 | 5.88e-07 |
| IRSL50 comp. 1 | NA | NA | 4.325 | 0.562 | 1235 | 4.692 | 0.569 | 3.105e-06 | 4.495e-07 |
| IRSL50 comp. 2 | NA | NA | 2.351 | 0.571 | 1235 | 2.494 | 0.578 | 1.693e-06 | 4.232e-07 |
| IRSL50 comp. 3 | NA | NA | 0.970 | 0.184 | 1235 | 0.992 | 0.185 | 6.833e-07 | 1.347e-07 |
| pIRIR comp. 1 | NA | NA | 2.348 | 0.286 | 1447 | 2.470 | 0.288 | 1.659e-06 | 2.074e-07 |
| pIRIR comp. 2 | NA | NA | 0.998 | 0.387 | 1447 | 1.021 | 0.390 | 7.106e-07 | 2.715e-07 |
| pIRIR comp. 3 | NA | NA | 1.026 | 0.151 | 1447 | 1.060 | 0.152 | 7.299e-07 | 1.063e-07 |
| FCR-IRSL at 50°C | 0 - 10 sec | 50 - 100 sec | 3.037 | 0.591 | 1735 | 3.261 | 0.598 | 2.162e-06 | 4.106e-07 |
| FCR-IRSL50: 0 - 2 sec | 0 - 2 sec | 50 - 100 sec | 4.510 | 1.225 | 1735 | 5.039 | 1.256 | 3.346e-06 | 9.355e-07 |
| FCR-IRSL50: 2 - 5 sec | 2 - 5 sec | 50 - 100 sec | 2.461 | 0.842 | 1735 | 2.594 | 0.857 | 1.738e-06 | 6.224e-07 |
| FCR-IRSL50: 5 - 10 sec | 5 - 10 sec | 50 - 100 sec | 2.946 | 0.862 | 1735 | 3.040 | 0.877 | 2.058e-06 | 6.047e-07 |
| FCR-IRSL50: 10 - 20 sec | 10 - 20 sec | 50 - 100 sec | 2.540 | 1.108 | 1735 | 2.632 | 1.133 | 1.741e-06 | 7.944e-07 |
| FCR-IRSL50: 20 - 50 sec | 20 - 50 sec | 50 - 100 sec | -1.272 | 1.781 | 1735 | -1.063 | 1.847 | -7.292e-07 | 1.187e-06 |
| FCR-pIR-IRSL at 290°C | 0 - 10 sec | 150 - 200 sec | 1.069 | 0.357 | 1947 | 1.072 | 0.359 | 7.496e-07 | 2.626e-07 |
| FCR-pIRIRSL: 0 - 2 sec | 0 - 2 sec | 150 - 200 sec | 0.332 | 0.870 | 1947 | 0.316 | 0.885 | 2.636e-07 | 6.082e-07 |
| FCR-pIRIRSL: 2 - 5 sec | 2 - 5 sec | 150 - 200 sec | 0.559 | 0.643 | 1947 | 0.554 | 0.652 | 3.866e-07 | 4.444e-07 |
| FCR-pIRIRSL: 5 - 10 sec | 5 - 10 sec | 150 - 200 sec | 1.405 | 0.516 | 1947 | 1.444 | 0.521 | 9.755e-07 | 3.743e-07 |
| FCR-pIRIRSL: 10 - 20 sec | 10 - 20 sec | 150 - 200 sec | 0.787 | 0.622 | 1947 | 0.813 | 0.630 | 5.625e-07 | 4.343e-07 |
| FCR-pIRIRSL: 20 - 50 sec | 20 - 50 sec | 150 - 200 sec | 0.530 | 0.882 | 1947 | 0.548 | 0.897 | 3.806e-07 | 6.115e-07 |