EER File Format

Version 3.0

# Version History

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| --- | --- | --- | --- |
| **Version** | **Date** | **Changes** | **Author(s)** |
| 1.0 | 30 Aug 2019 | Initial version | P. Bootsma |
| 2.0 | 02 Dec 2019 | Added 7-bit compression | A. Dumitrescu |
| 2.1 | 10 Dec 2019 | Added Final image directory | M. Balasubramanian |
| 2.2 | 17 Jan 2020 | Added acquisition metadata | A. Dumitrescu,  P. Bootsma |
| 2.3 | 25 Feb 2021 | Added orientation | D. van der Steen |
| 2.4 | 1 April 2021 | Update acquisition metadata | L. Oosterhof |
| 2.5 | 4 April 2021 | Update Fields | D. van der Steen |
| 2.6 | 11 May 2021 | Sensor pixel size units changed to meters | G. Singla |
| 2.7 | 18 May 2021 | Update acquisition metadata | G. Singla |
| 2.8 | 20 May 2021 | Added camera name | D. van der Steen |
| 2.9 | 15 Sep 2021 | Removing camera type from metadata | G. Singla |
| 3.0 | 03 Mar 2023 | Added compression details | D. van der Steen |

# References

|  |  |  |
| --- | --- | --- |
| **No** | **Title** | **Author(s)** |
| [TIFF] | TIFF Revision 6.0 | Adobe Systems Inc. |
| [BIGTIFF] | The BigTIFF File Format | Aware Systems |

# Introduction

Some cameras can produce EER encoded images. These images are stored in a file format called the EER file format, identified by the extension “.eer”. EER files are based on BigTIFF, but define a number of extensions to this format to store all EER-related information in one file.

The EER file writer, and also the exact file format are still in development. This document describes the currently implemented file format. The following features are planned for future inclusion in EER files:

* Gain reference data
* Defect mask
* Frame metadata

Note that these are the current plans, and that plans can change.

# BigTIFF Container Format

The EER file format is an extension of the BigTIFF file format defined by Aware Systems [BIGTIFF]. BigTIFF is an extension of the regular TIFF file format [TIFF] to support files of more than 4 gigabyte. EER files add a custom compression scheme for the EER data and custom tags to include the relevant metadata.

This document describes how EER data is stored within the BigTIFF container format. Interpretation of the data is outside of the scope of this document. The LibTIFF library [http://simplesystems.org/libtiff] can read BigTIFF files, and therefore also EER files.

TIFF is a flexible container format by nature, and readers should adhere to a set of requirements as specified in section 7 of the TIFF standard. The following requirements are the most important ones to ensure future extensibility of the file format:

* Entries with unknown tag number or field type must be ignored.
* Image file directories with an unexpected compression scheme must be skipped.

# Extensions

This section describes the extensions added to the BigTIFF container format.

## Compression schemes

The EER file format extends the default compression scheme of BigTIFF. This value is used in the compression field (tag 259) to indicate that an IFD contains EER compressed data (see Image File Directories).

The subpixel information is encoded in subpixel bits, the number of bits used may vary per compression scheme. The total number of subpixels can be derived based on the number of horizontal and vertical bits:

e.g., when using a subpixel depth of 2 for both horizontal and vertical the number of subpixels is:

## Fields

The EER file format adds several fields to BigTIFF. These fields can be present in IFDs as indicated later in this document.

|  |  |  |  |
| --- | --- | --- | --- |
| **Field** | **Tag** | **Type** | **Comment** |
| Acquisition Metadata | 65001 | STRING | A non-zero-terminated string containing metadata concerning the entire acquisition. |
| Final image metadata | 65006 | STRING | A non-zero terminated string containing metadata concerning the final image |
| Frame metadata | 65002 | STRING | A non-zero terminated string containing metadata concerning a single frame |

# Image File Directories

An EER file contains one or more image file directories (IFDs). Every IFD contains either an EER frame or other image data.

## EER Frames

EER compressed data is stored like a bilevel image in a regular TIFF. It is stored in one or more strips. If multiple strips are used, the entire frame can be reconstructed by concatenating the data in the separate strips. An EER frame contains required and optional fields. Unknown or unexpected fields must be ignored.

### Required fields

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Field** | **Tag** | **Type** | **Count** | **Comment** |
| Image Width | 256 | SHORT or LONG | 1 | The number of columns in the frame |
| Image Length | 257 | SHORT or LONG | 1 | The number of rows in the frame |
| Compression | 259 | SHORT | 1 | The compression scheme used; the following values are possible:   * **65000**:   + 8-bit EER compressed data   + 2 bits horizontal subpixel information   + 2 bits vertical subpixel information * **65001**:   + 7-bit EER compressed data   + 2 bits horizontal subpixel information   + 2 bits vertical subpixel information * **65002**: EER compressed format is in the “Compression Details” (see optional fields) |
| Rows Per Strip | 278 | SHORT or LONG | 1 | The number of rows in each strip (except possibly the last strip, which can contain less rows) |
| Strip Offsets | 273 | SHORT, LONG or LONG8 | 1 | For each strip, the byte offset of that strip |
| Strip Byte Counts | 279 | SHORT, LONG or LONG8 | 1 | For each strip, the number of bytes in that strip |
| Orientation | 274 | SHORT | 1 | The orientation of the frame |

### Optional fields

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Field** | **Tag** | **Type** | **Count** | **Comment** |
| Run Length Encoding Bit Depth | 65007 | SHORT | 1 | Only available when **65002** in “Compression” tag is used. The number of bits for the RLE skip count. |
| Subpixel Horizontal Bit Depth | 65008 | SHORT | 1 | Only available when **65002** in “Compression” tag is used. The number of bits to provide horizontal subpixel information. |
| Subpixel Vertical Bit Depth | 65009 | SHORT | 1 | Only available when **65002** in “Compression” tag is used. The number of bits to provide vertical subpixel information. |

### Camera compression details

The compression version used per camera may differ, the following versions are used:

|  |  |  |
| --- | --- | --- |
| **Camera name** | **Compression Version** | **Supported until** |
| Falcon4 | 65001; 7-bit/subpixel bits 2 vertical and horizontal | 2025 |
| Falcon4i | 65001; 7-bit/subpixel bits 2 vertical and horizontal | 2025 |
| FalconC | 65002; 7-bit/subpixel 1 bit vertical and horizontal |  |

### Optional fields

There are no optional fields specific to EER.

## Final Image

An IFD containing the final pipeline image is included as part of the EER file if a final image was recorded with the acquisition. When included, the final image is always in the first IFD of the EER file. The presence of a final image in the first IFD is identified by the compression tag, which is set to no compression in case of a final image, as opposed to EER frames. Currently, the EER file format only supports EER frames and one optional final image frame.

### Required fields

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Field** | **Tag** | **Type** | **Count** | **Comment** |
| Image Width | 256 | SHORT or LONG | 1 | The number of columns in the frame |
| Image Length | 257 | SHORT or LONG | 1 | The number of rows in the frame |
| Compression | 259 | SHORT | 1 | The compression scheme used; COMPRESSION\_NONE (1) for final image data |
| Bits per sample | 258 | SHORT | 1 | The number of bits per channel. For final image data, it is 16 bits per sample (2 bytes) |
| Rows Per Strip | 278 | SHORT or LONG | 1 | The number of rows in each strip (except possibly the last strip, which can contain less rows) |
| Strip Offsets | 273 | SHORT, LONG or LONG8 | 1 | For each strip, the byte offset of that strip |
| Strip Byte Counts | 279 | SHORT, LONG or LONG8 | 1 | For each strip, the number of bytes in that strip |
| Orientation | 274 | SHORT | 1 | The orientation of the frame. For final image data, it is always TOPLEFT |

# Metadata

Metadata is stored in tags for the acquisition, frames and the final image. These tags contain an XML string structured as follows:

<metadata>  
 <item name=”[name]” unit=”[unit]”>[value]</item>  
 <item name=”[name2]”>[value2]</item>  
 …  
</metadata>

The unit attribute may be omitted for values that do not have a unit.

## Acquisition metadata

In the first IFD metadata is written that applies to the entire acquisition. The metadata is written as a tag with ID 65001.

|  |  |  |
| --- | --- | --- |
| **Name** | **Unit** | **Comments** |
| acquisitionID |  | unique acquisition identifier (or label) used to identify the data set for access and offloading |
| cameraName |  | Camera name used for the acquisition |
| coincidenceCompensatedDose | e/pixel | The coincidence compensated dose per pixel for the entire acquisition |
| coincidenceCompensatedDoserate | e/pixel/s | The coincidence compensated dose rate per pixel for the entire acquisition |
| commercialName |  | The commercial name of the camera |
| eerGainReference |  | Relative location of the EER gain reference that was valid at the time of the EER acquisition |
| exposureTime | s | The duration of the acquisition |
| meanDoseRate | e/pixel/s | Average amount of electrons per pixel per second during the acquisition |
| numberOfFrames |  | Total number of frames in the acquisition |
| sensorImageHeight | pixels | The height of the sensor |
| sensorImageWidth | pixels | The width of the sensor |
| sensorPixelSize.height | m | The height of a pixel |
| sensorPixelSize.width | m | The width of a pixel |
| serialNumber |  | Serial number of the sensor. Used to identify the camera or relate set to EER gain references |
| timestamp | [ISO 8601](https://en.wikipedia.org/wiki/ISO_8601) | Time synchronized with the TEM PC including time zone information, in millisecond accuracy |
| totalDose | e/pixel | Average amount of electrons per pixel in the entire acquisition |
|  |  |  |

## Final image metadata

The first IFD will contain final image metadata when the final image is recorded. The metadata is written as a tag with ID 65006 and contains:

|  |  |  |
| --- | --- | --- |
| **Name** | **Unit** | **Comments** |
| roi.top |  | Top coordinate of the region of interest for the image in sensor coordinates, where 0 is the topmost pixel. |
| roi.left |  | Left coordinate of the region of interest for the image in sensor coordinates, where 0 is the leftmost pixel. |
| roi.bottom |  | Bottom coordinate of the region of interest for the image in sensor coordinates. The value is exclusive, so for a 4096 x 4096 image the top coordinate will be 0 and the bottom coordinate will be 4096. |
| roi.right |  | Right coordinate of the region of interest for the image in sensor coordinates. The value is exclusive, so for a 4096 x 4096 image the left coordinate will be 0 and the right coordinate will be 4096. |
| binning |  | The amount of pixels that have been binned together. |
| darkCorrection |  | A yes/no indication on whether the image is dark corrected |
| gainCorrection |  | A yes/no indication on whether the image is gain corrected. |
| numberOfFrames |  | The number of frames in the final image |
| timestamp | [ISO 8601](https://en.wikipedia.org/wiki/ISO_8601) | Time synchronized with the TEM PC including time zone information, in millisecond accuracy |
| pixelValueToCameraCounts |  | The conversion from a pixel value to a camera count |
| countsToElectrons |  | The conversion from camera counts to electrons.  The following formula gives the dose from 1 pixel: *pixelValue* x *pixelValueToCameraCounts* x *countsToElectrons* |
| exposureTime | s | The exposure time for the final image |
| meanPixelValue |  | The average pixel value of the final image |
| checksum |  | An indication on whether the checksum was valid. |
| driftCorrectionInformation.driftCorrected |  | A yes/no indication on whether drift correction was enabled. |
| driftCorrectionInformation.confidence |  | A confidence indication for the drift vectors ranging from 0 to 1. |
| driftCorrectionInformation.clipping |  | A yes/no indication on whether either vector was clipped. |
| driftCorrectionInformation.vectorXCoordinate |  | The drift in X direction |
| driftCorrectionInformation.vectorYCoordinate |  | The drift in Y direction |

## Frame metadata

All IFD’s, except for the final image, will contain frame metadata. The metadata is written as a tag with ID 65002 and contains:

|  |  |  |
| --- | --- | --- |
| **Name** | **Unit** | **Comments** |
| frameID |  | The sequence number of the frame in the total acquisition |
| timestamp |  | The time at which the frame was acquired, expressed as a ISO8601 representation with timezone indication. |
| orientation |  | The TIFF orientation value |
| decompressionAlgorithmVersion |  | The algorithm that was used to process the EER data. |
| pixelFormat |  | The pixel format |
| rleCodeLength |  | The run-length-encoding code length |
| nrOfSubPixelPerDirection |  | The number of sub pixels per pixel in width and height |
| dose | e/pixel | The average dose per pixel in the frame |