

MRC2014 File Format Specification

PN 306687

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1 Introduction

Thermo Scientific and FEI electron microscopy applications use the MRC2014 data format to store, view and process images. This document specifies:

- the format of the Extended Header blocks.
- the pixel sequence in the frame blocks.

2 The Main Header and Extended Headers in an MRC File

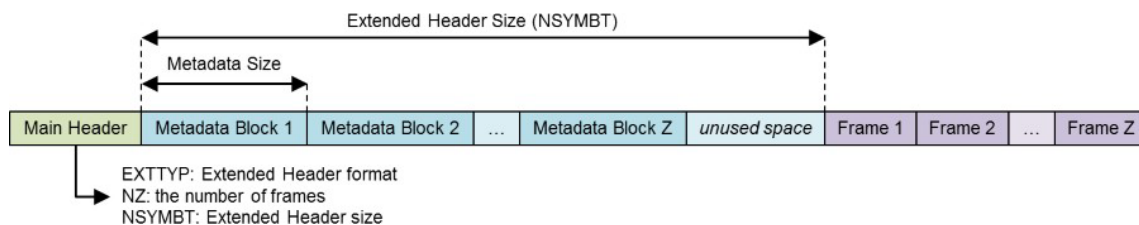
MRC files have a generic Main Header and an optional Extended Header.

- The Main Header contains generic image information, such as the image dimensions and the pixel format. For the specification of the main header, refer to [MRC/CCP4 File Format for Images and Volumes](#).
- The Extended Header contains application specific metadata. For Thermo Scientific and FEI products, the extended header contains information about:
 - The microscope state at acquisition time, such as magnification, accelerating voltage, stage position, beam shift and many other relevant parameters.
 - Image acquisition information, such as binning and exposure time.

Among others, the Main Header contains the following fields:

- `NZ`: the number of frames in the MRC file.
- `NSYMBT`: the reserved size for the Extended Header.
- `EXTTYP`: the format of the Extended Header: `FEI1` or `FEI2`.
The `FEI2` format is an extended version of the `FEI1` format.

For every frame in the file, the Extended Header contains one Metadata Block. The first element of each block contains the Metadata Block size. All Metadata Blocks in the Extended Header have the same size and contain the same fields. The sum of the Metadata Block sizes fits within the reserved size for the Extended Header.



3 The Extended Header Specification

The FEI1 and FEI2 Extended Header formats allow for the addition of new fields without breaking compatibility. When a new field is added, the `Metadata Size` and `Metadata Version` fields are updated. Image reading and processing software can use the `Metadata Size` value from the first Metadata Block to index the blocks for the other frames in the MRC file.

With the introduction of the FEI2 format, the format of the FEI1 Extended Header is frozen. For MRC files with an FEI1 Extended Header, image reading and processing software can assume the values of the `Metadata Size` and `Metadata Version` fields are 768 bytes and version number 0.

The tables below specify the content of the FEI1 and FEI2 Extended Headers for the MRC2014 file format. In these tables, the **Format** and **'IsPresent' flag** columns have to the following values:

- **Format:**
 - Bool: Boolean of 1 byte (0 = false, other value = true).
 - Int32: Signed integer of 4 bytes.
 - Int64: Signed integer of 8 bytes (only used in FEI2 Extended Header).
 - UInt32: Unsigned integer of 4 bytes.
 - Float64: Floating point number of 8 bytes.
- **IsPresent:**
UInt32 value that is used as a 32-bit / little-endian bitmask. If a metadata field is set, then the value of the *IsPresent* bit in the bitmask is 1.

3.1 FEI1 Extended Header Specification

Image, System and Application

Name	Offset (dec)	Offset (hex)	Format	IsPresent	Description
Metadata size	0	0x0000	Int32	NA	Metadata size [bytes] All Metadata Blocks in the file have the same size. <ul style="list-style-type: none"> FEI1: 768 bytes FEI2: updated for each version.
Metadata version	4	0x0004	Int32	NA	Version ID of the metadata format. All Metadata Blocks in the file have the same format. <ul style="list-style-type: none"> FEI1: 0 FEI2: initial value: 2 The value is updated for each new version.
Bitmask 1	8	0x0008	UInt32	NA	Individual bits indicate which metadata fields are set.
Timestamp	12	0x000C	Float64	Bitmask 1 – #0	Time when the image was taken. The used format is the DATE data type that is used in OLE automation by Microsoft: Microsoft OLE DATE data type specification
Microscope type	20	0x0014	16 chars	Bitmask 1 – #1	Identifier for microscope type (Krios, Talos, Titan, Metrios, etc.)
D-Number	36	0x0024	16 chars	Bitmask 1 – #2	Microscope identifier
Application	52	0x0034	16 chars	Bitmask 1 – #3	Application name
Application version	68	0x0044	16 chars	Bitmask 1 – #4	

Gun

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
HT	84	0x0054	Float64	Bitmask 1 – #5	High tension [Volt]
Dose	92	0x005C	Float64	Bitmask 1 – #6	Dose [electrons/m ²]

Stage

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Alpha tilt	100	0x0064	Float64	Bitmask 1 – #7	Holder Alpha tilt along axis [degr.]
Beta tilt	108	0x006C	Float64	Bitmask 1 – #8	Holder Beta tilt along axis [degr.]
X-Stage	116	0x0074	Float64	Bitmask 1 – #9	Stage X position [m]
Y-Stage	124	0x007C	Float64	Bitmask 1 – #10	Stage Y position [m]
Z-Stage	132	0x0084	Float64	Bitmask 1 – #11	Stage Z position [m]
Tilt axis angle	140	0x008C	Float64	Bitmask 1 – #12	Angle of tilt axis in image [degr.]
Dual axis rotation	148	0x0094	Float64	Bitmask 1 – #13	Measured rotation angle after b flip [degr.] (Tomography only)

Pixel Size

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Pixel size X	156	0x009C	Float64	Bitmask 1 – #14	Pixel size X [m]
Pixel size Y	164	0x00A4	Float64	Bitmask 1 – #15	Pixel size Y [m]

Optics

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Defocus	220	0x00DC	Float64	Bitmask 1 – #22	Defocus [m]
STEM Defocus	228	0x00E4	Float64	Bitmask 1 – #23	STEM defocus [m]
Applied defocus	236	0x00EC	Float64	Bitmask 1 – #24	Relative defocus applied by application [m]
Instrument mode	244	0x00F4	Int32	Bitmask 1 – #25	<ul style="list-style-type: none"> 1: TEM 2: STEM
Projection mode	248	0x00F8	Int32	Bitmask 1 – #26	<ul style="list-style-type: none"> 1: Diffraction 2: Imaging
Objective lens mode	252	0x00FC	16 chars	Bitmask 1 – #27	<ul style="list-style-type: none"> LM HM Lorentz
High magnification mode	268	0x010C	16 chars	Bitmask 1 – #28	<ul style="list-style-type: none"> Mi SA Mh
Probe mode	284	0x011C	Int32	Bitmask 1 – #29	<ul style="list-style-type: none"> 1: NanoProbe 2: MicroProbe
EFTEM On	288	0x0120	Bool	Bitmask 1 – #30	TRUE when the magnifications are adapted to the energy filter
Magnification	289	0x0121	Float64	Bitmask 1 – #31	Nominal magnification
Bitmask 2	297	0x0129	UInt32	NA	Individual bits indicate which metadata fields are set.
Camera length	301	0x012D	Float64	Bitmask 2 – #0	Nominal camera length [m]
Spot index	309	0x0135	Int32	Bitmask 2 – #1	-
Illuminated area	313	0x0139	Float64	Bitmask 2 – #2	<ul style="list-style-type: none"> TEM: beam diameter in meters STEM: not used Undefined on 2 lens condenser systems
Intensity	321	0x0141	Float64	Bitmask 2 – #3	Uncalibrated measure of beam diameter on 2 lens condenser systems
Convergence angle	329	0x0149	Float64	Bitmask 2 – #4	[degr.] Undefined on 2 lens condenser systems

Illumination mode	337	0x0151	16 chars	Bitmask 2 – #5	<ul style="list-style-type: none"> None Parallel Probe Free Undefined on 2 lens condenser systems
Wide convergence angle range	353	0x0161	Bool	Bitmask 2 – #6	Undefined on 2 lens condenser systems

EFTEM Imaging

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Slit inserted	354	0x0162	Bool	Bitmask 2 – #7	-
Slit width	355	0x0163	Float64	Bitmask 2 – #8	Slit width [eV]
Acceleration voltage offset	363	0x016B	Float64	Bitmask 2 – #9	[Volt]
Drift tube voltage	371	0x0173	Float64	Bitmask 2 – #10	[Volt]
Energy shift	379	0x017B	Float64	Bitmask 2 – #11	[eV]

Image Shifts

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Shift offset X	387	0x0183	Float64	Bitmask 2 – #12	Corrective image or beam shift relative to exposure preset (in logical units) <ul style="list-style-type: none"> TEM: pure image shift STEM: image-beamshift-
Shift offset Y	395	0x018B	Float64	Bitmask 2 – #13	
Shift X	403	0x0193	Float64	Bitmask 2 – #14	Applied shift due to optimized position and tracking (in logical units) <ul style="list-style-type: none"> TEM: image beam shift STEM: beam shift-
Shift Y	411	0x019B	Float64	Bitmask 2 – #15	

Camera

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Integration time	419	0x01A3	Float64	Bitmask 2 – #16	Camera or dose fraction exposure time
Binning Width	427	0x01AB	Int32	Bitmask 2 – #17	-
Binning Height	431	0x01AF	Int32	Bitmask 2 – #18	-
Camera name	435	0x01B3	16 chars	Bitmask 2 – #19	Name of the camera
Readout area left	451	0x01C3	Int32	Bitmask 2 – #20	-
Readout area top	455	0x01C7	Int32	Bitmask 2 – #21	-
Readout area right	459	0x01CB	Int32	Bitmask 2 – #22	-
Readout area bottom	463	0x01CF	Int32	Bitmask 2 – #23	-
Ceta noise reduction	467	0x01D3	Bool	Bitmask 2 – #24	-
Ceta frames summed	468	0x01D4	Int32	Bitmask 2 – #25	Number of frames summed for dynamic range
Direct detector electron counting	472	0x01D8	Bool	Bitmask 2 – #26	-
Direct detector align frames	473	0x01D9	Bool	Bitmask 2 – #27	-
Camera param reserved 0	474	0x01DA	Int32	Bitmask 2 – #28	-
Camera param reserved 1	478	0x01DE	Int32	Bitmask 2 – #29	-
Camera param reserved 2	482	0x01E2	Int32	Bitmask 2 – #30	-
Camera param reserved 3	486	0x01E6	Int32	Bitmask 2 – #31	-
Bitmask 3	490	0x01EA	UInt32	NA	Individual bits indicate which metadata fields are set.
Camera param reserved 4	494	0x01EE	Int32	Bitmask 3 – #0	-
Camera param reserved 5	498	0x01F2	Int32	Bitmask 3 – #1	-

Camera param reserved 6	502	0x01F6	Int32	Bitmask 3 – #2	-
Camera param reserved 7	506	0x01FA	Int32	Bitmask 3 – #3	-
Camera param reserved 8	510	0x01FE	Int32	Bitmask 3 – #4	-
Camera param reserved 9	514	0x0202	Int32	Bitmask 3 – #5	-
Phase Plate	518	0x0206	Bool	Bitmask 3 – #6	Indicates whether phase plate was used for data acquisition

STEM

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
STEM Detector name	519	0x0207	16 chars	Bitmask 3 – #7	-
Gain	535	0x0217	Float64	Bitmask 3 – #8	-
Offset	543	0x021F	Float64	Bitmask 3 – #9	-
STEM param reserved 0	551	0x0227	Int32	Bitmask 3 – #10	-
STEM param reserved 1	555	0x022B	Int32	Bitmask 3 – #11	-
STEM param reserved 2	559	0x022F	Int32	Bitmask 3 – #12	-
STEM param reserved 3	563	0x0233	Int32	Bitmask 3 – #13	-
STEM param reserved 4	567	0x0237	Int32	Bitmask 3 – #14	-

Scan settings

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Dwell time	571	0x023B	Float64	Bitmask 3 – #15	Dwell time per pixel [sec]
Frame time	579	0x0243	Float64	Bitmask 3 – #16	Frame time [sec] (currently it will not be used)
Scan size left	587	0x024B	Int32	Bitmask 3 – #17	-
Scan size top	591	0x024F	Int32	Bitmask 3 – #18	-
Scan size right	595	0x0253	Int32	Bitmask 3 – #19	-
Scan size bottom	599	0x0257	Int32	Bitmask 3 – #20	-
Full scan FOV X	603	0x025B	Float64	Bitmask 3 – #21	Field of view [m]
Full scan FOV Y	611	0x0263	Float64	Bitmask 3 – #22	-

EDX Elemental maps

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Element	619	0x026B	16 chars	Bitmask 3 – #23	-
Energy interval lower	635	0x027B	Float64	Bitmask 3 – #24	-
Energy interval higher	643	0x0283	Float64	Bitmask 3 – #25	-
Method	651	0x028B	Int32	Bitmask 3 – #26	-

Dose fractions

Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Is dose fraction	655	0x028F	Bool	Bitmask 3 – #27	-
Fraction number	656	0x0290	Int32	Bitmask 3 – #28	-
Start frame	660	0x0294	Int32	Bitmask 3 – #29	-
End frame	664	0x0298	Int32	Bitmask 3 – #30	-

Reconstruction

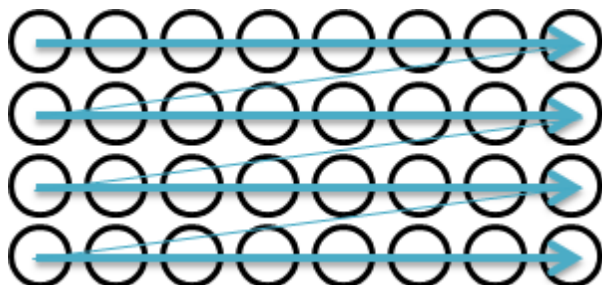
Name	Offset (dec)	Offset (hex)	Format	'Is Present' flag	Description
Input stack filename	668	0x029C	80 chars	Bitmask 3 – #31	-
Bitmask 4	748	0x02EC	UInt32	NA	Individual bits indicate which metadata fields are set.
Alpha tilt min	752	0x02F0	Float64	Bitmask 4 – #0	
Alpha tilt max	760	0x02F8	Float64	Bitmask 4 – #1	

3.2 FEI2 Version 2 Extension to the Extended Header Specification

Name	Offset (dec)	Offset (hex)	Format	IsPresent	Description
Scan rotation	768	0x0300	Float64	Bitmask 4 – #2	Rotation of the scan pattern in STEM mode [radians]
Diffraction pattern rotation	776	0x0308	Float64	Bitmask 4 – #3	Rotation of the diffraction pattern in diffraction mode [radians]
Image rotation	784	0x0310	Float64	Bitmask 4 – #4	Rotation of the image in imaging mode [radians]
Scan mode enumeration	792	0x0318	Int32	Bitmask 4 – #5	<ul style="list-style-type: none"> 0: Other 1: Raster 2: Serpentine raster
Acquisition time stamp	796	0x031C	Int64	Bitmask 4 – #6	Microseconds since 1970-01-01T00:00:00Z at which the image was acquired
Detector commercial name	804	0x0324	16 chars	Bitmask 4 – #7	Commercial name of the detector or camera
Start tilt angle	820	0x0334	Float64	Bitmask 4 – #8	Start tilt angle of a tomography series [degr.]
End tilt angle	828	0x033C	Float64	Bitmask 4 – #9	End tilt angle of a tomography series [degr.]
Tilt per image	836	0x0344	Float64	Bitmask 4 – #10	Tilt increment per image in a tomography series [degr.]
Tilt speed	844	0x034C	Float64	Bitmask 4 – #11	Tilt speed in a tomography series [degr./sec]
Beam center X pixel	852	0x0354	Int32	Bitmask 4 – #12	Beam center X on image [pixels]
Beam center Y pixel	856	0x0358	Int32	Bitmask 4 – #13	Beam center Y on image [pixels]
CFEG flash timestamp	860	0x035C	Int64	Bitmask 4 – #14	Microseconds since 1970-01-01T00:00:00Z at which the cold FEG was last flashed
Phase plate position index	868	0x0364	Int32	Bitmask 4 – #15	Position index of the phase plate aperture
Objective aperture name	872	0x0368	16 chars	Bitmask 4 – #16	Name of the inserted objective aperture

4 Pixel Sequence in the MRC2014 Format

In the MRC2014 files, the image pixel data is stored as rows from top to bottom, where each row is stored from left to right.



Most image viewers and image processing applications use the same pixel position sequence as the MRC file. Some image viewing and processing applications such as IMOD and Fiji/ImageJ use a pixel position sequence. In these applications, the image display may be mirrored and/or rotated.

4.1 The MRC Image Pixel Data Encoding for Thermo Scientific Ceta Cameras

If the image is acquired with a Ceta camera, then the MRC image pixel data encoding depends on the presence of the Ceta Speed Enhancement (Ceta-2).

Camera	MRC Pixel Data
Ceta without Speed Enhancement	32-bit floating point
Ceta with Speed Enhancement	16-bit signed integer

5 Copyright, Limited Rights and Revision History

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Revision Table

Revision	Date	Description of Changes
A	27-MAR-2019	First publication of the FEI1 MRC2014 specification as a separate document.
B	23-AUG-2019	Corrected EFTEM Imaging, Image Shifts and Camera sections.
C	23-JAN-2020	Corrected the following properties: <ul style="list-style-type: none"> • Optics > Projection mode • Optics > Probe mode
D	04-SEP-2020	Introduction of the FEI2 Version 2 Extended Header format.

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