Direct Electron
INNOVATION PROPELLING DISCOVERY

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Detected Electron Event Puddle (DEEP) Format Version 1

The detected electron event puddle (DEEP) data format is a binary representation of the signal generated by single electron detection events.

Unlike the electron event representation (EER) and ReCoDe L4-compression formats, the DEEP format includes each detection event's shape and intensity information.

Unlike the ReCoDe L1-compression format, the DEEP format groups pixel information into individual electron detection events instead of simply encoding all non-zero pixel intensities in a raster format for each frame.

All numeric values in the DEEP format are unsigned.

The header consists of 128 bytes:

Offset (Bytes)	Description	Size (Bytes)	Type	Comments
0	Unique identifier	4	long	= 13240
4	Version	2	short	DEEP file version number
6	Frame width	4	long	Width of each frame in pixels
10	Frame height	4	long	Height of each frame in pixels
14	Pixel bit-depth	2	short	Bit depth for intensity information
16	Number of frames	4	long	
20	Reserved	108	char[108]	= 0 Not used

The maximum allowable frame width and height is 8,192. Beyond this size, the frame start code (defined later) will duplicate an allowable value within an electron event puddle definition.

Locations within a frame are described by a pixel index, which is defined in row-major format:

$$pixelindex = width \times y + x$$

The number of bits necessary to specify all possible pixel index values within a frame is:

$$pixindbits = \text{ceiling}(\log_2(width \times height))$$

Following the header is data. Note that since the length of each frame is not known in advance, random access to frames in the file is not possible; frames must be accessed sequentially.

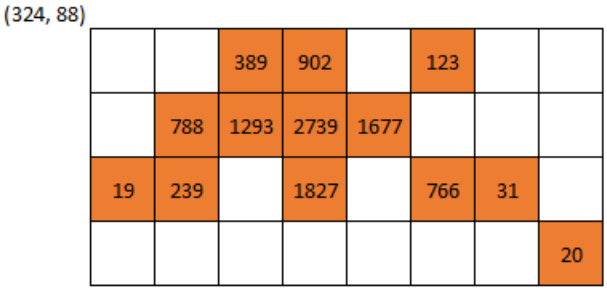
At the beginning of each frame is the frame start code:

Description	Size (Bits)	Comments
Frame start code	40	= 0xFFFFFFFFFF

Following the frame start code is the data, consisting of a stream of events, described as follows. Events are defined within a puddle bounding box, which is a box surrounding the entire electron event puddle. The maximum size of an electron event puddle is 16 × 16.

Description	Size (Bits)	Comments
Top-left corner pixel index	$pixindbits$	
Number of rows - 1 (m)	4	One less than the number of rows in the puddle bounding box.
Row 0		
Offset for row 0	4	Offset from the left edge of the puddle bounding box to the first non-zero pixel on row 0
Length of puddle on row 0	4	Number of pixels whose intensity will be specified on row 0
Pixel 0 intensity	$bitdepth$	
Pixel 1 intensity	$bitdepth$	
…		
Pixel n_0 intensity	$bitdepth$	
Row 1		
Offset for row 1	4	Offset from the left edge of the puddle bounding box to the first non-zero pixel on row 1
Length of puddle on row 1	4	Number of pixels whose intensity will be specified on row 1
Pixel 0 intensity	$bitdepth$	
Pixel 1 intensity	$bitdepth$	
…		
Pixel n_1 intensity	$bitdepth$	
…		
Row m		
Offset for row m	4	Offset from the left edge of the puddle bounding box to the first non-zero pixel on row m
Length of puddle on row m	4	Number of pixels whose intensity will be specified on row m
Pixel 0 intensity	$bitdepth$	
Pixel 1 intensity	$bitdepth$	
…		
Pixel n_m intensity	$bitdepth$	

For example, if the frame size is 1024 × 1024 (width × height), then the number of bits to specify a pixel index is 20. An event puddle that looks like the following would have the following definition:



Description & Decimal Value	Size (Bits)	Binary Value
Top-left corner pixel index = 88 × 1024 + 324 = 90436	20	00010110000101000100
Number of rows - 1= 4 -1 = 3	4	0011
Row 1		
Offset = 2	4	0010
Length of puddle = 4	4	0100
Pixel intensity = 389	12	000110000101
Pixel intensity = 902	12	001110000110
Pixel intensity = 0	12	000000000000
Pixel intensity = 123	12	000001111011
Row 2		
Offset = 1	4	0001
Length of puddle = 4	4	0100
Pixel intensity = 788	12	001100010100
Pixel intensity = 1293	12	010100001101
Pixel intensity = 2739	12	101010110011
Pixel intensity = 1677	12	011010001101
Row 3		
Offset = 0	4	0000
Length of puddle = 7	4	0111
Pixel intensity = 19	12	000000010011
Pixel intensity = 239	12	000011101111
Pixel intensity = 0	12	000000000000
Pixel intensity = 1827	12	011100100011
Pixel intensity = 0	12	000000000000
Pixel intensity = 766	12	001011111110
Pixel intensity = 31	12	000000011111
Row 4		
Offset = 7	4	0111
Length of puddle = 1	4	0100
Pixel intensity = 20	12	000000010100

At the end of each frame, if the frame does not end on 4-byte offset from the beginning of the file, then the end of the frame is padded as necessary.

Description	Size (Bits)	Comments
Frame padding start code	40	= 0xFFFFFFFFFE
Padding	x	= 0 for however many bits are necessary to end the frame at an offset from the beginning of the file that is a multiple of 4 bytes

Compared to a simpler format where the pixel index is a whole number of bytes and all pixels within the event puddle bounding box are stored as 16-bit integers, the DEEP format has >2× compression ratio.