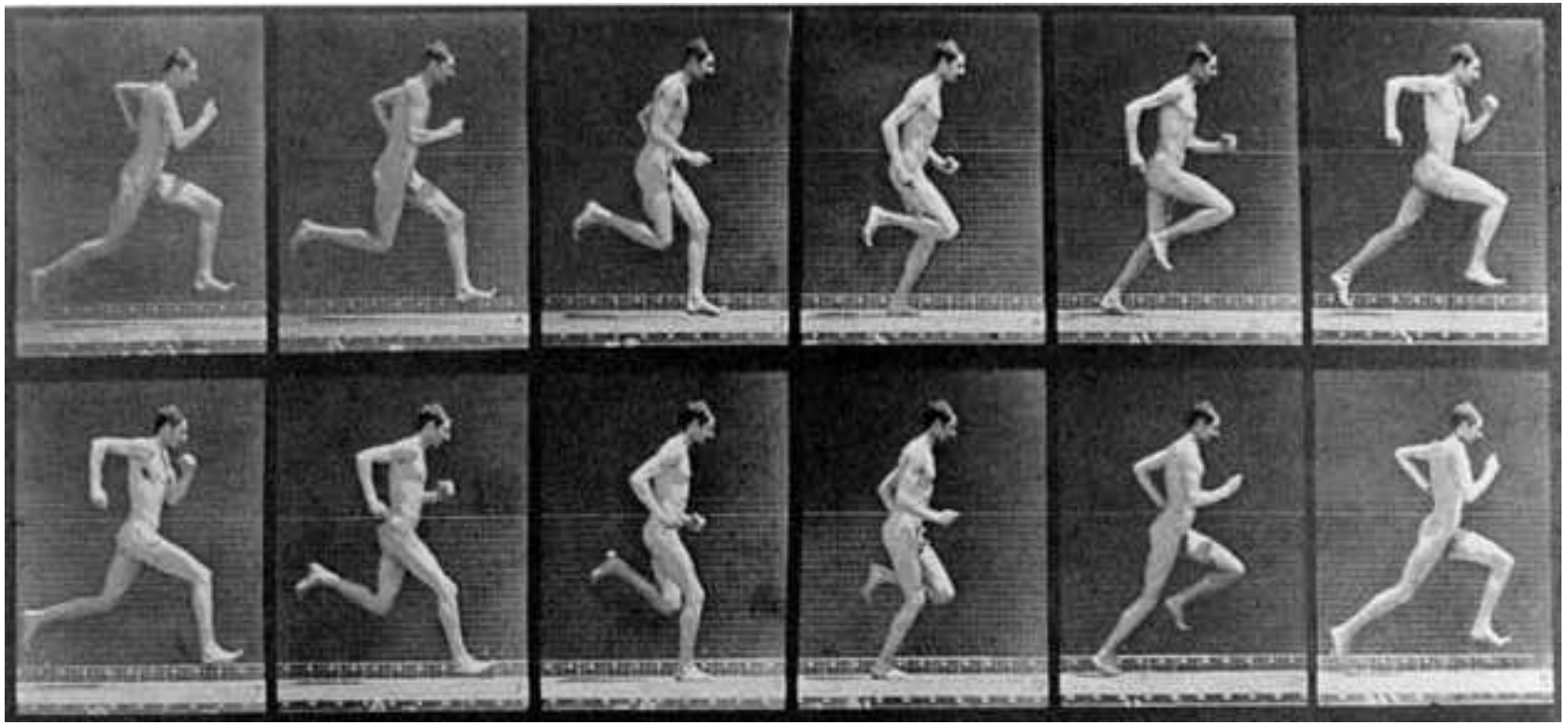
Motion-Blur Measurement & Evaluation



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Contents

Motivation

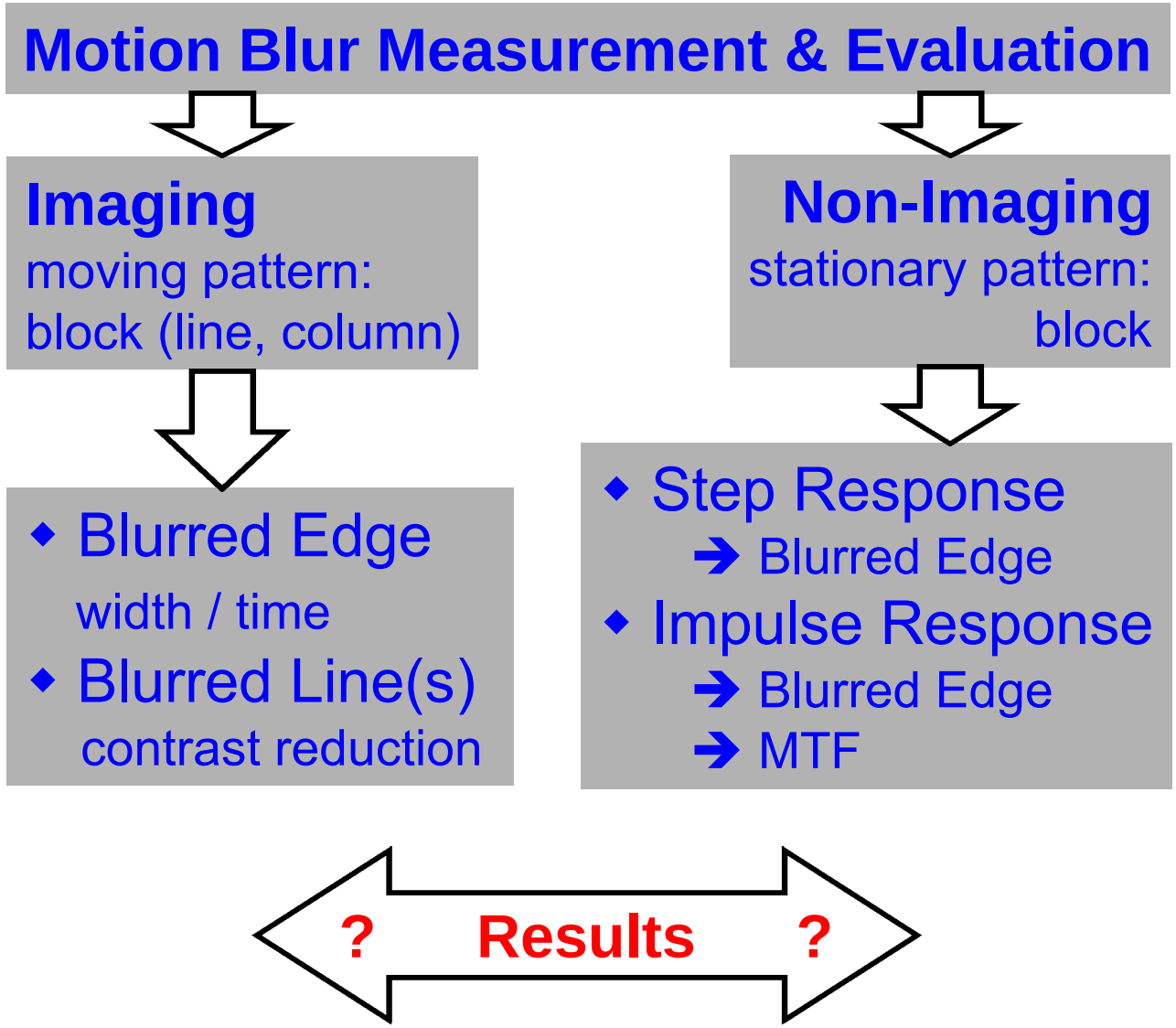
Motion artefacts

edge blur, ghosting, flickering, judder, color break-up, false contours, etc.

are existing , visible and disturbing.

No methods for measurement, evaluation and rating are yet defined and standardized.

Motion blur metrology currently being considered for standardization by FPDM (Vesa) and IEC TC 110 WG2.


Motion Blur Measurement & Evaluation
Imaging
moving pattern:
block (line, column)
Non-Imaging
stationary pattern:
block
◆ Blurred Edge
width / time
◆ Blurred Line(s)
contrast reduction
◆ Step Response
➔ Blurred Edge
◆ Impulse Response
➔ Blurred Edge
➔ MTF
? Results ?

Motion Blur Measurement & Evaluation

Imaging approaches

- direct measurement with a ***tracking camera***
  (linear tracking, rotating polygon mirror or galvano-scanner mirror),

- measurement with a ***fixed camera*** and re-arrangement according to the motion trajectory
  - high-speed camera with oversampling,
  - time delay & integration (TDI) camera for improved S/N ratio.

Non-imaging approaches

- measurement of ***temporal step response*** (temporal luminance transition) followed by numerical evaluation,

- measurement of ***impulse response*** followed by numerical evaluation.

➲ **Measurement of the *temporal step response* (i.e. temporal luminance transition at a fixed location) seems most versatile, since the conventional *characteristic response-times* can be obtained together with motion-blur characteristics.**

Attention: No lateral (in-plane) effects included in that measurement !!!

Characteristics
(preliminary list)

- blurred edge width — BEW = 90% - 10%

  extended blurred edge width — EBEW = BEW / 0.8

- normalized blurred edge width — NBEW = BEW / (advancement)
  dimension = 1

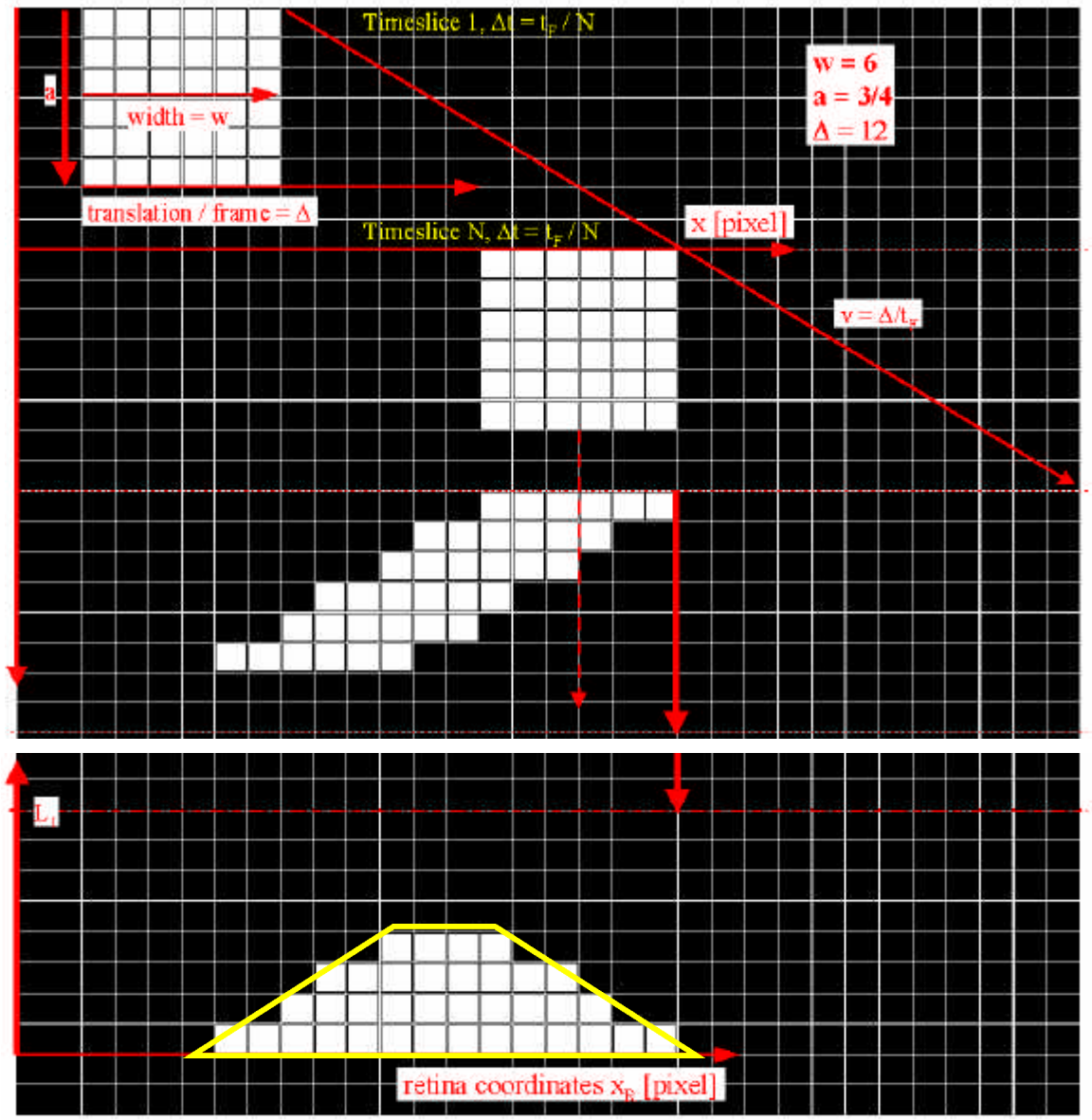
- normalized blurred edge time — NBET = BET / T-frame
  dimension = 1

- characteristics with consideration of the human visual system
  (e.g. spatial contrast sensitivity, etc)

- MTF related characteristics

- Dynamical contrast reduction

Model of Motion Perception



Parameters:

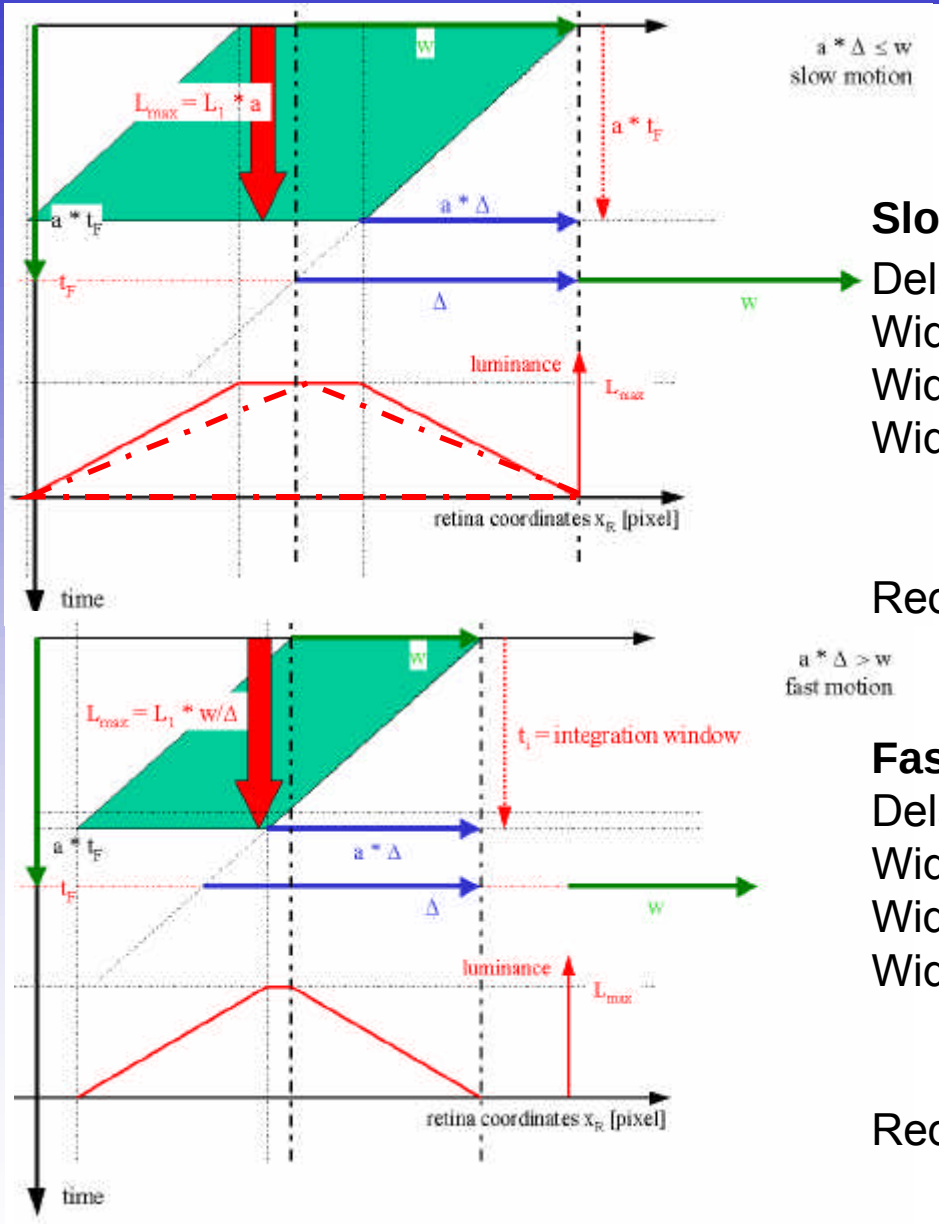
- width w (pixel),
- aperture a (≤ 1),
- advancement Δ
  (pixel / frame period).

Procedure:

- Re-arrangement of time-slices with respect to motion trajectory (continuous eye-tracking)
- integration over one frame period

➔ intensity profile on retina (= perceived image of moving target).

Model of Motion Perception



Profiles and characteristics (ideal hold-type display)

Slow motion: $\Delta \le w / a$

Delay of center, d	$d = \Delta \cdot a/2$
Width of plateau, p	$p = w - \Delta \cdot a$
Width of slope, s	$s = \Delta \cdot a$
Width of bar, w_P	$w_P = w + \Delta \cdot a$
	$w_P / w = 1 + \Delta / w \cdot a$

Reduction of peak luminance, L_P

$L_P = L_1 \cdot a$

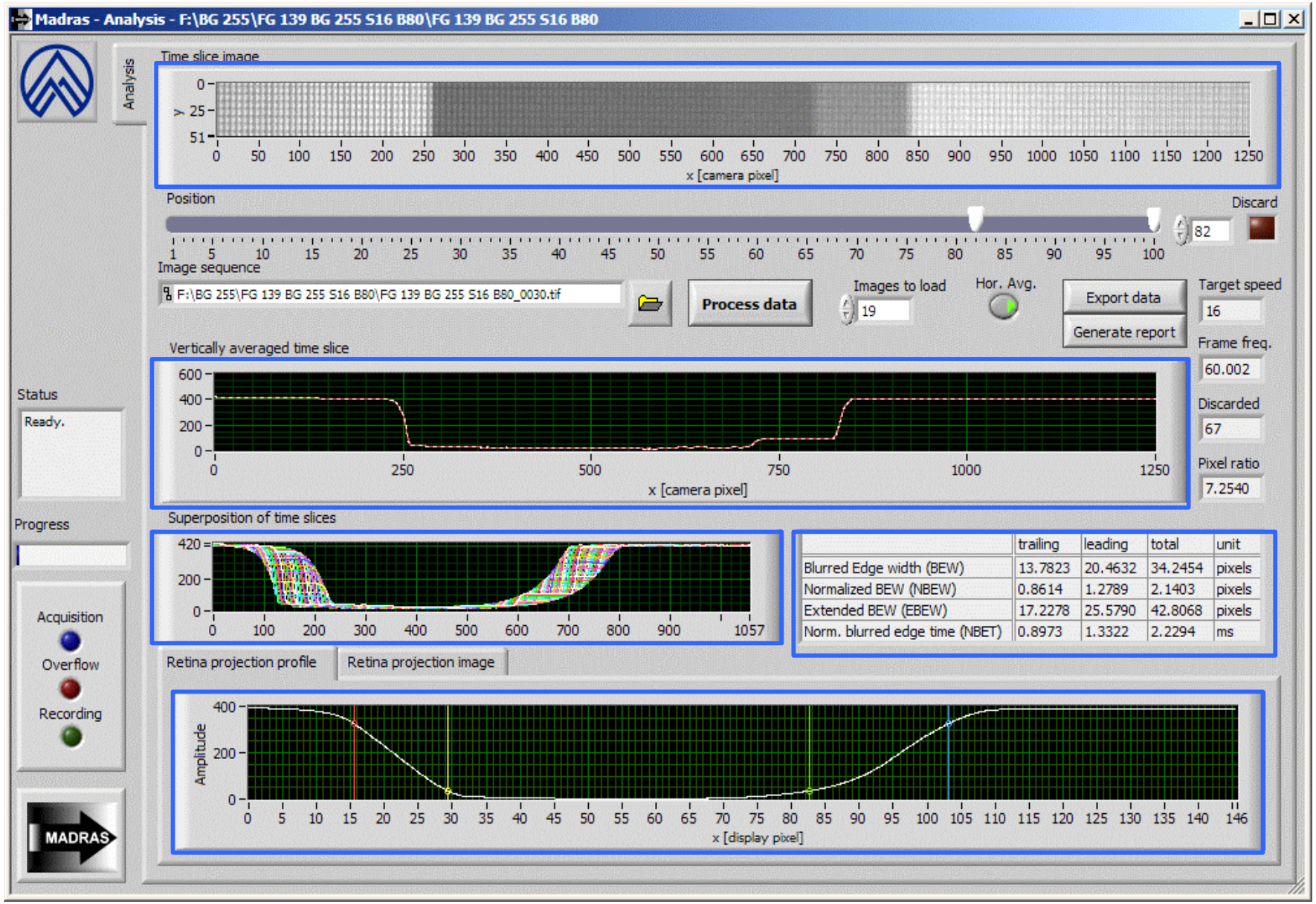
Fast motion: $\Delta > w / a$

Delay of center, d	$d = \Delta \cdot a/2$
Width of plateau, p	$p = \Delta \cdot a - w$
Width of slope, s	$s = w$
Width of bar, w_P	$w_P = w + \Delta \cdot a$
	$w_P / w = 1 + \Delta / w \cdot a$

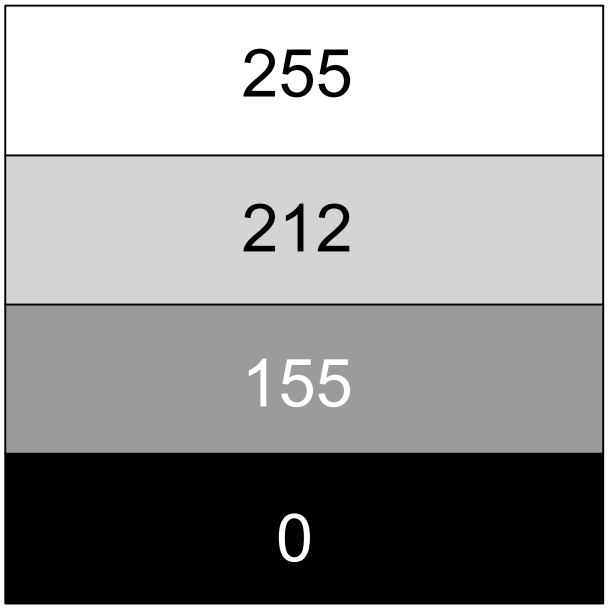
Reduction of peak luminance, L_P

$L_P = L_1 \cdot w/\Delta$

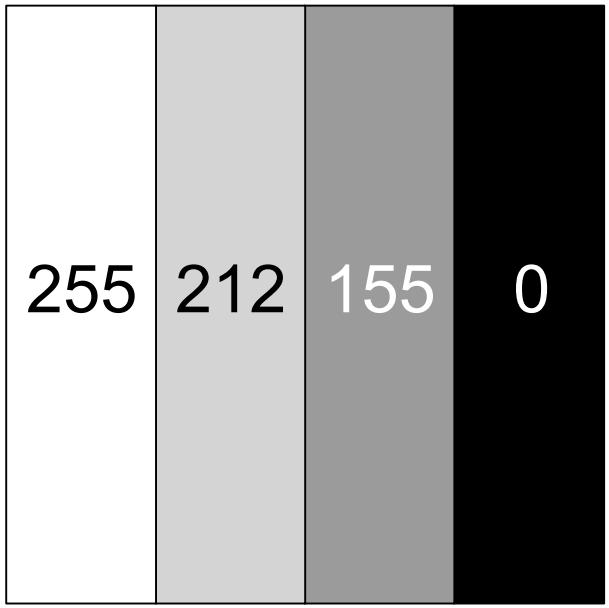
Motion Blur Analyzer - Evaluation



Gray-to-Gray Response Times



matrix of gray-to-gray transition times



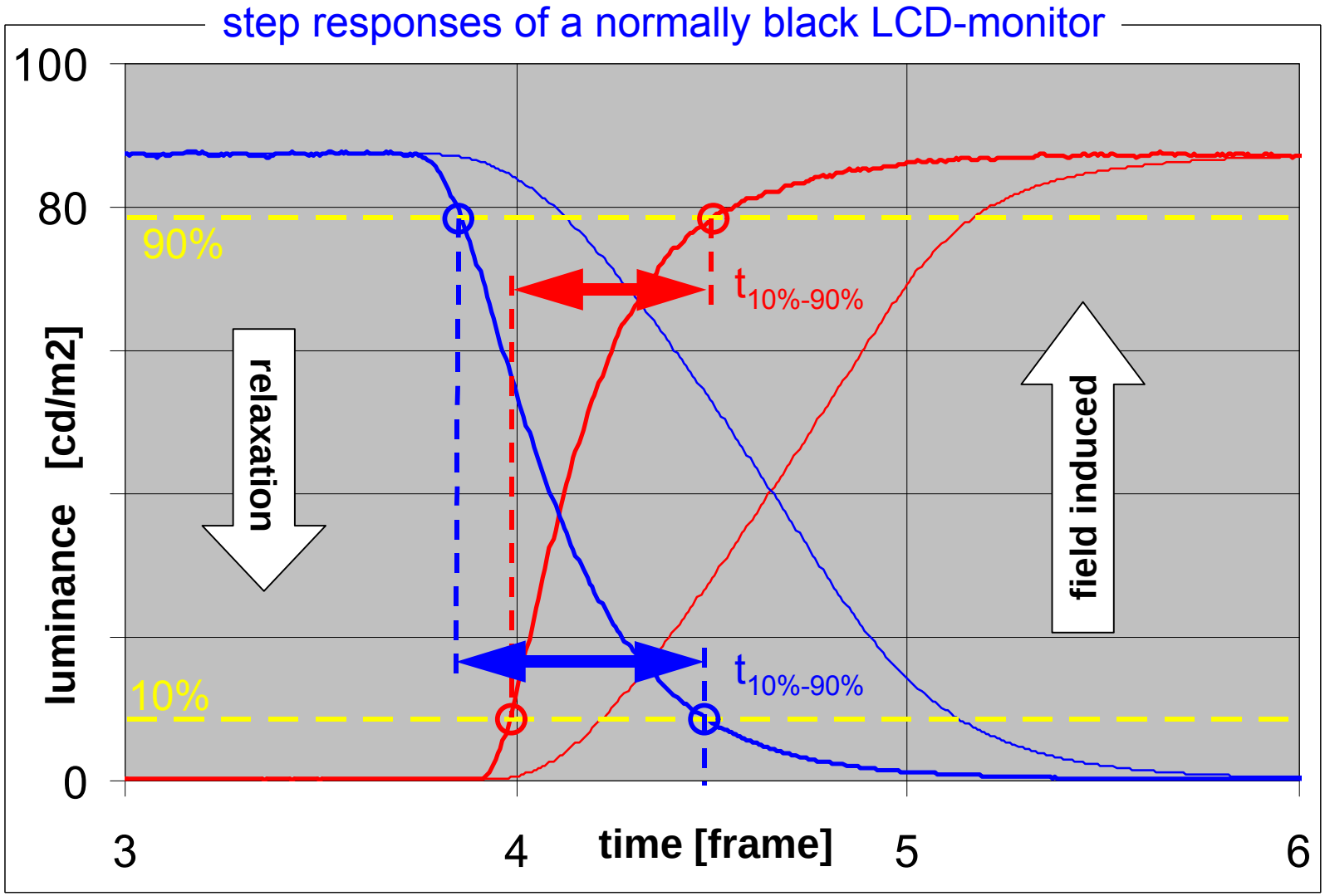
first test-pattern

second test-pattern

255 255	255 212	255 155	255 0
212 255	212 212	212 155	212 0
155 255	155 212	155 155	155 0
0 255	0 212	0 155	0 0

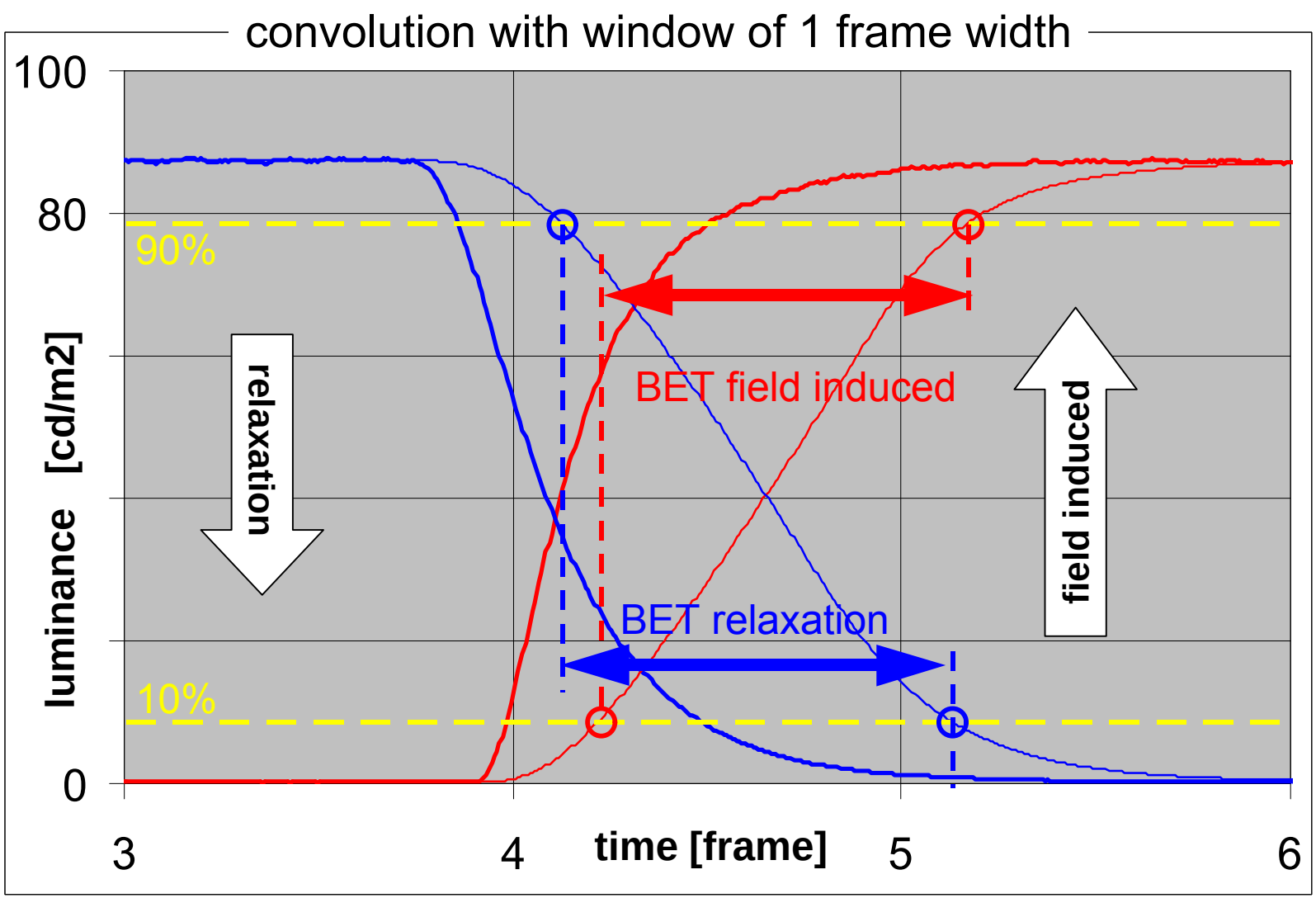
- allow for settling
- oversampling

Step Response



response characterized by transition between 10% and 90% variation

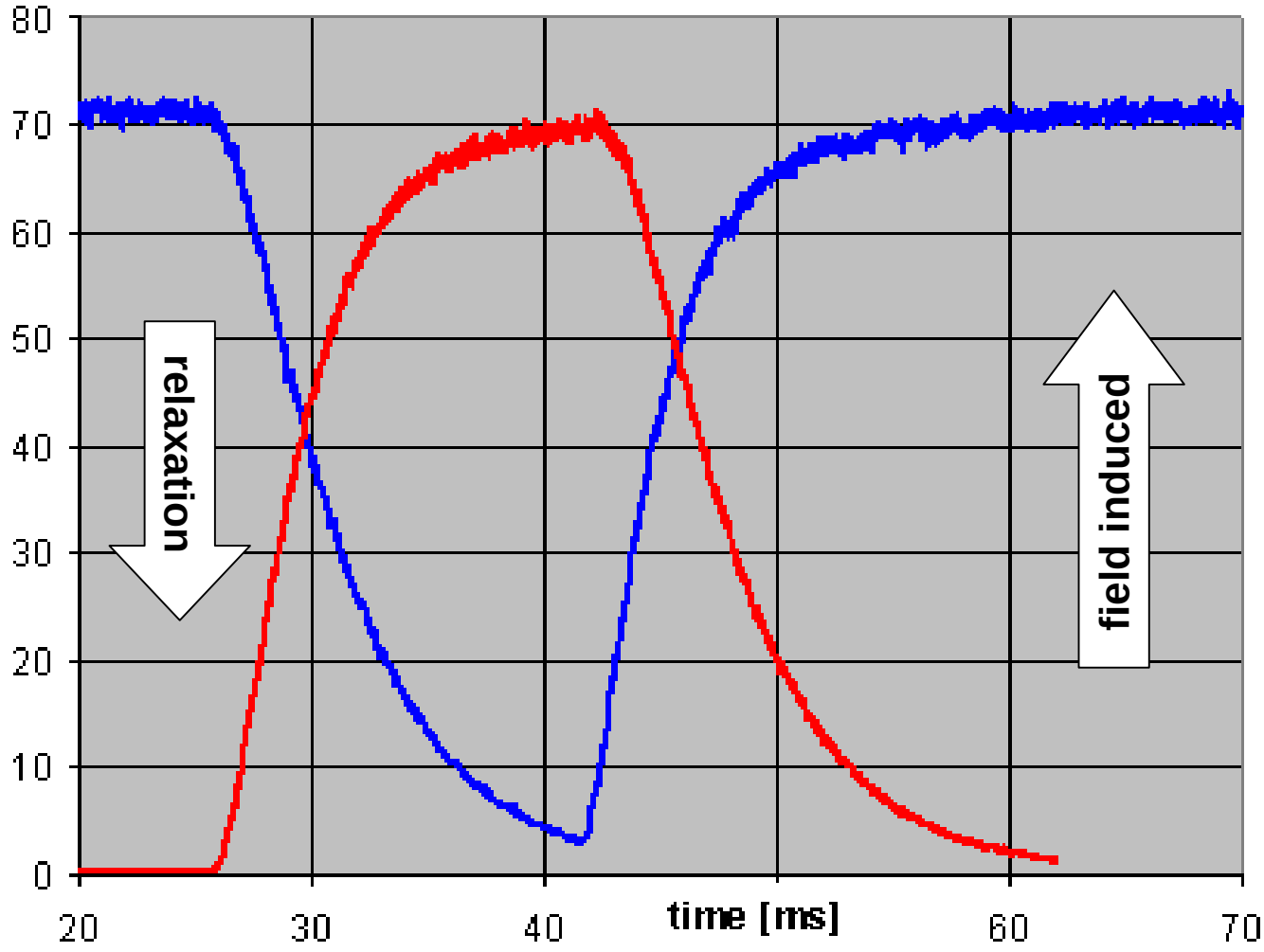
BET from Step Response



BET characterized by transition between 10% and 90% variation

Impulse Response

impulse responses of a normally black LCD-monitor



Blur-characteristics obtained from analysis of impulse responses shall be comparable to those obtained from step responses !

Impulse & Step Response

Blur-characteristics obtained from analysis of *impulse responses* shall be comparable to those obtained from *step responses* !

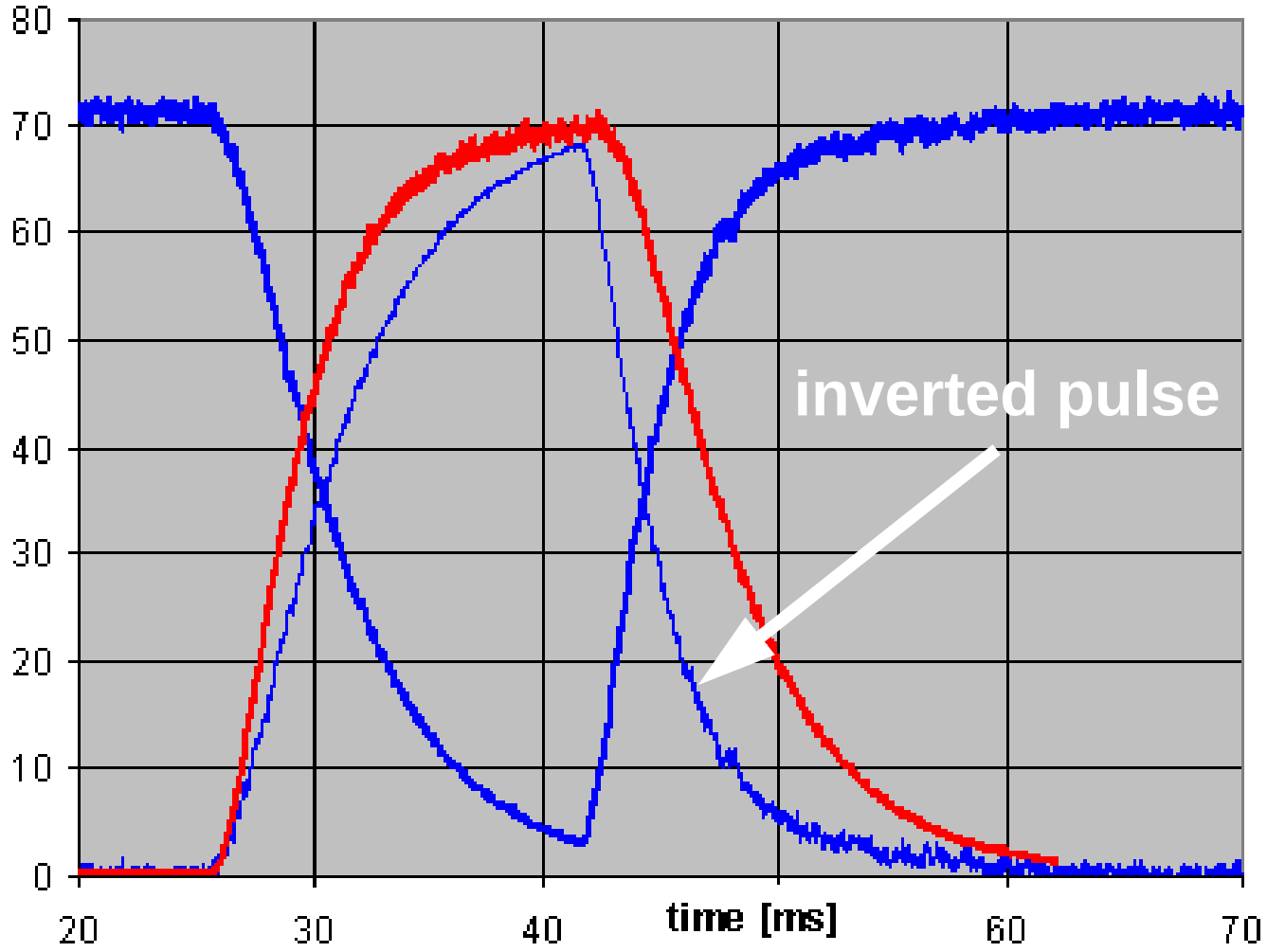
- **Step responses** are separate for *field-induced transitions* and for *relaxation transitions*.
- **Impulse responses** each combine a *field-induced transition* with a *relaxation transition*.

Separation of field-induced and relaxation part of impulse responses ?

Two separation and assembly methods are introduced:

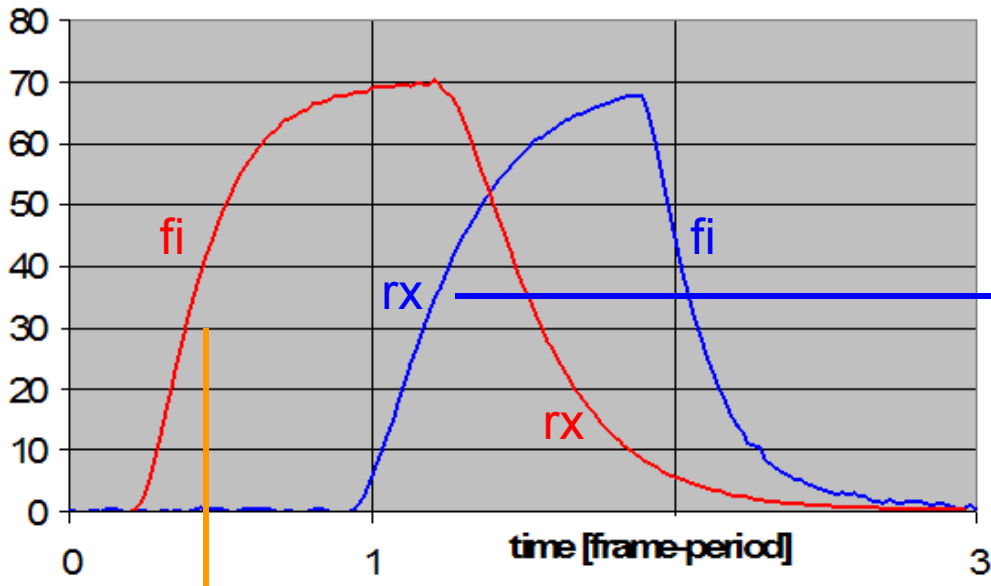
- auto-completion,
- cross-completion.

Impulse Response



impulse responses of an LCD-monitor
(IPS - normally black)

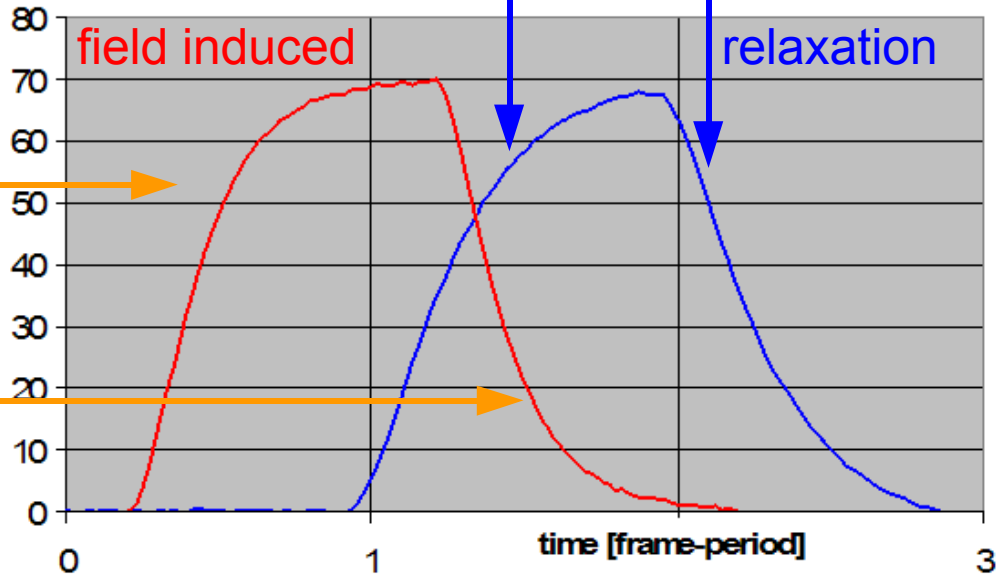
Impulse Response - Auto-Completion



4 slopes yield
4 completed pulses
only 2 shown here

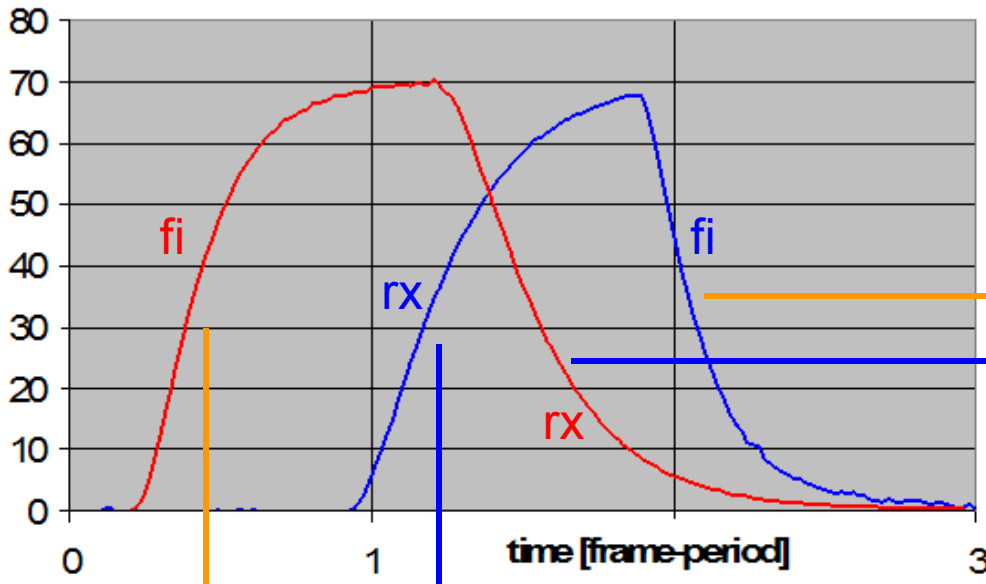
inversion

inversion



inversion required

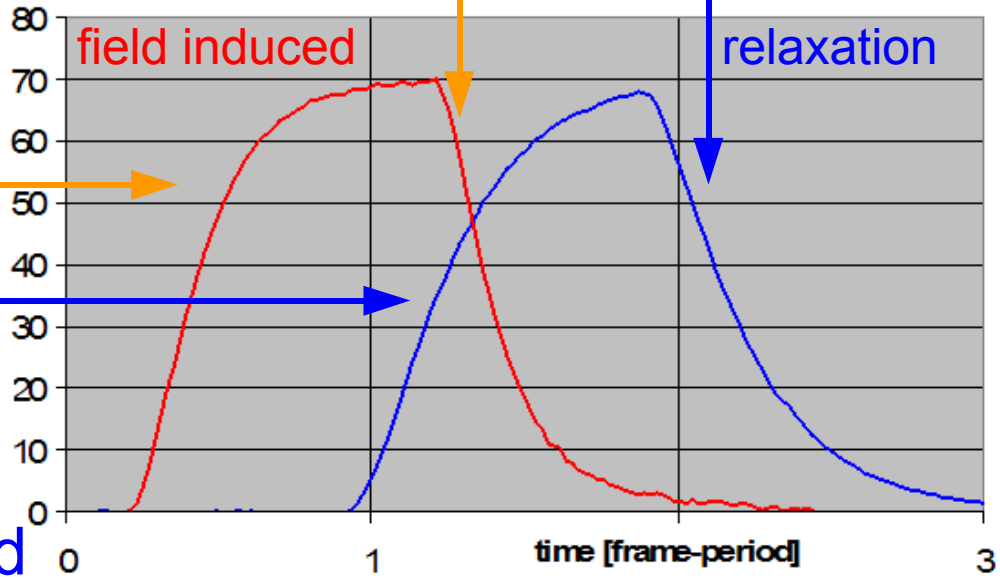
Impulse Response - Cross-Completion



4 slopes yield
2 completed pulses

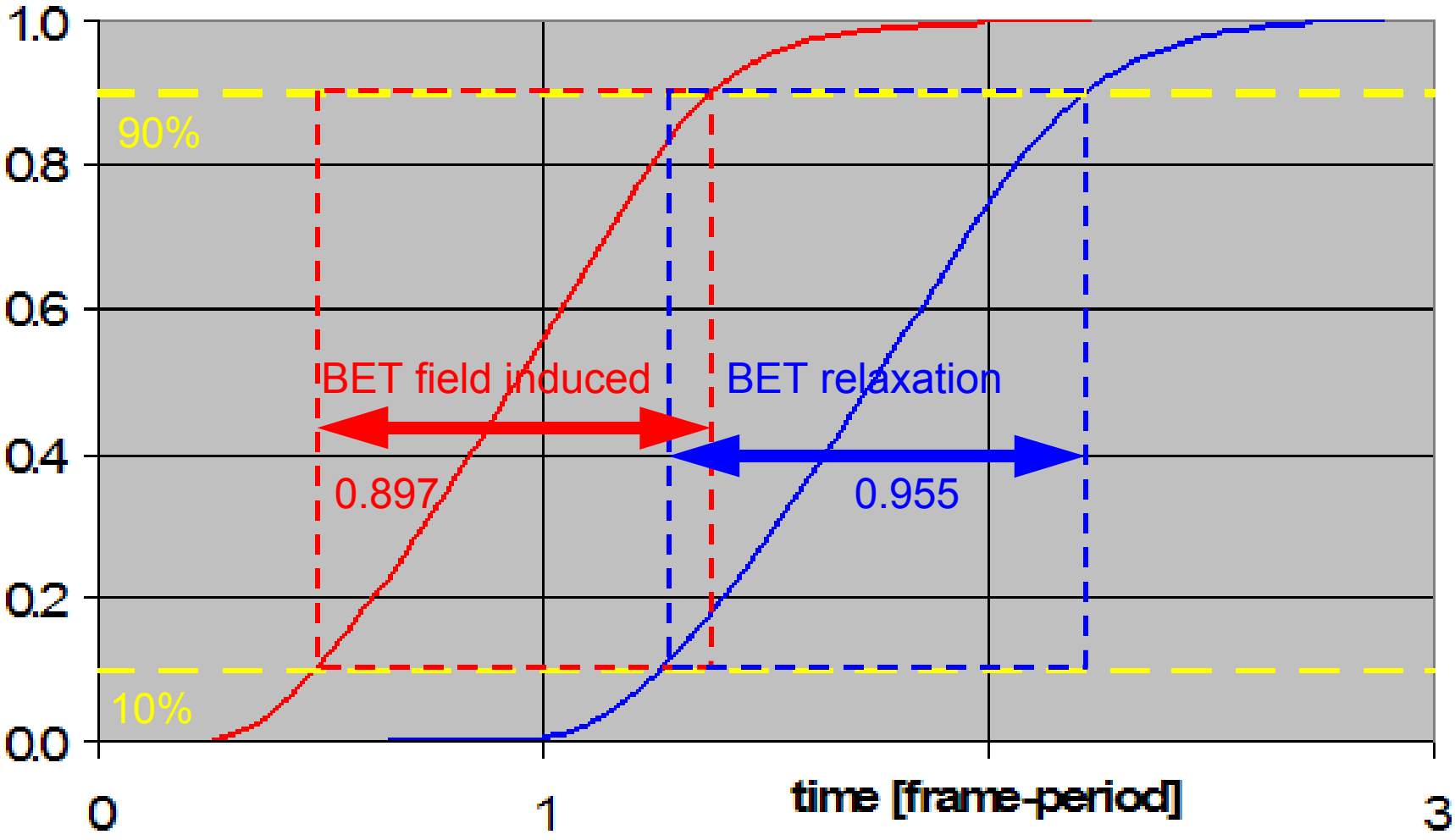
scaling

scaling



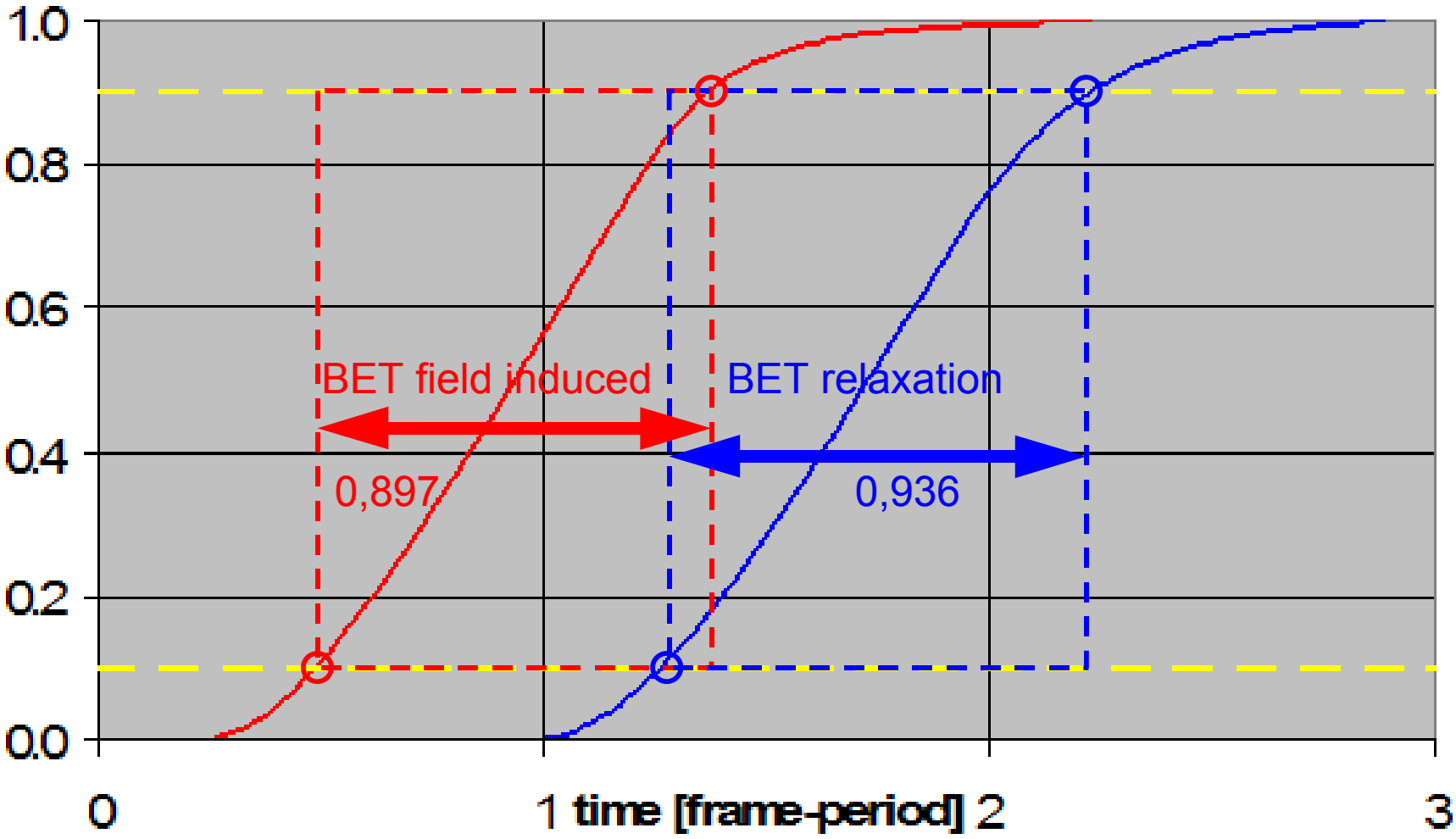
amplitude scaling required

BET from Impulse Response



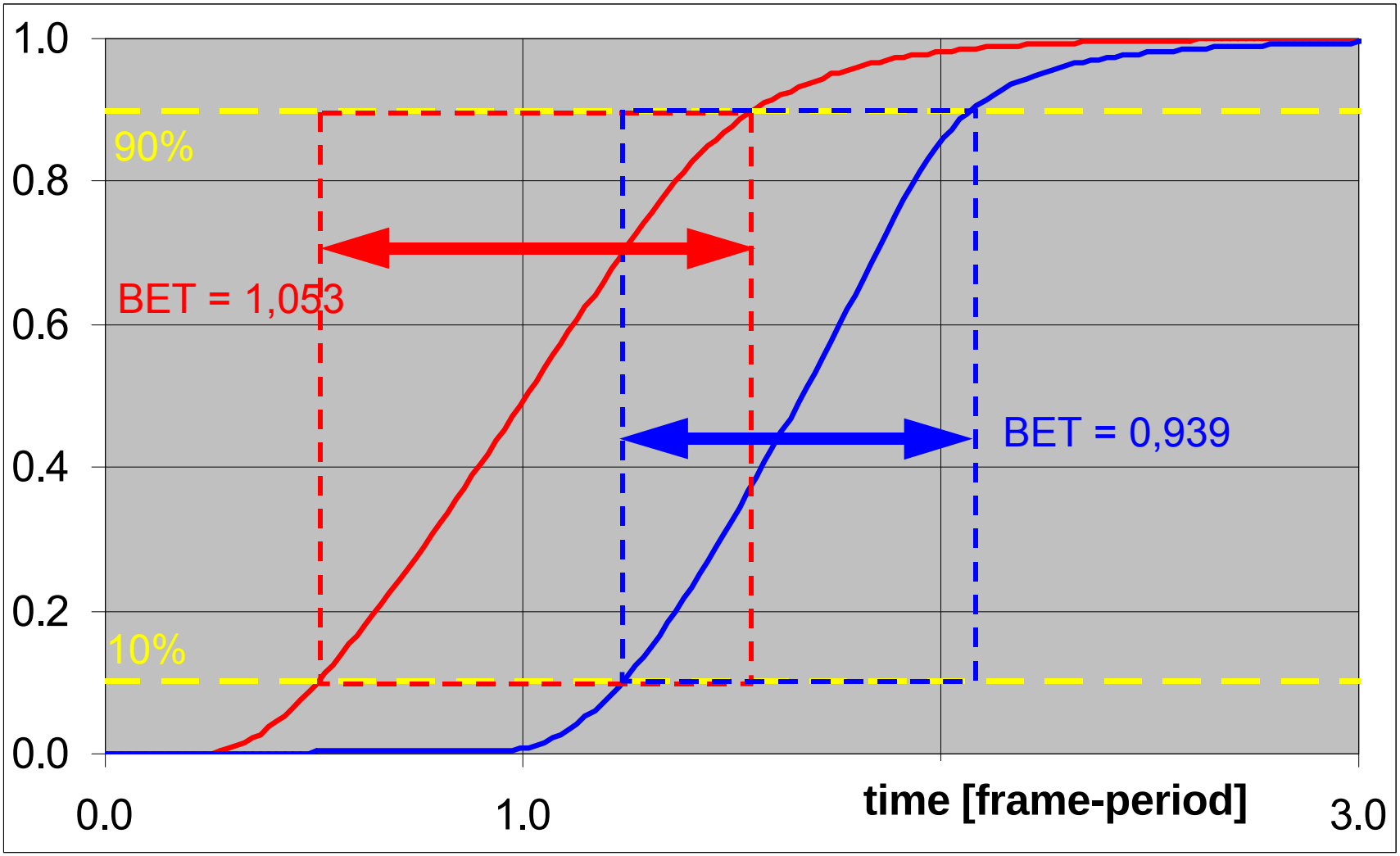
Evaluation of BET via integration of impulse responses (field-induced or relaxation), *cross-completion*.

BET from Impulse Response



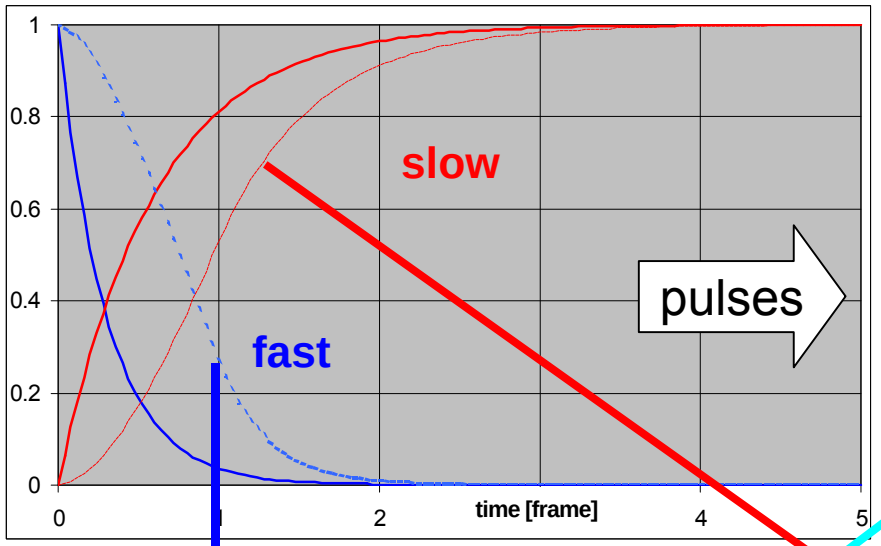
Evaluation of BET via integration of impulse responses (field-induced or relaxation), *auto-completion*.

BET from Impulse Response

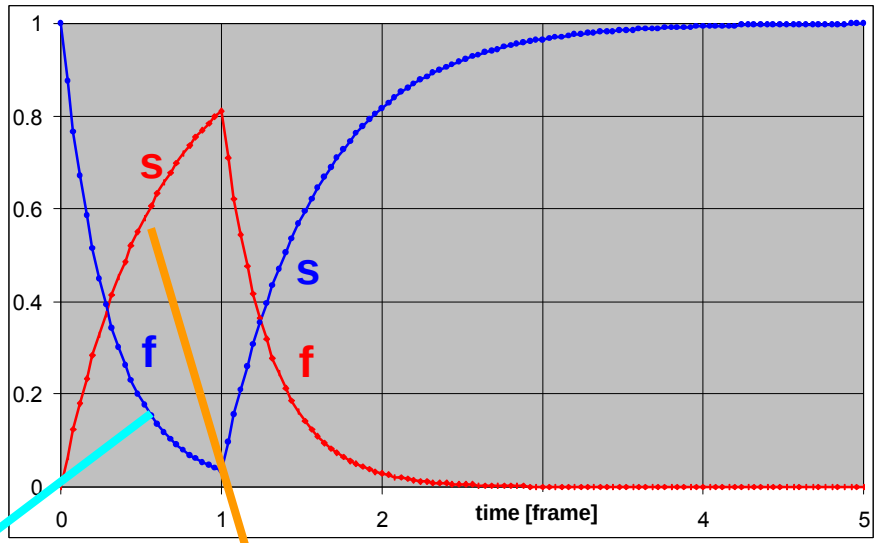


Evaluation of BET via integration of impulse responses
(field-induced or relaxation), without *completion*.

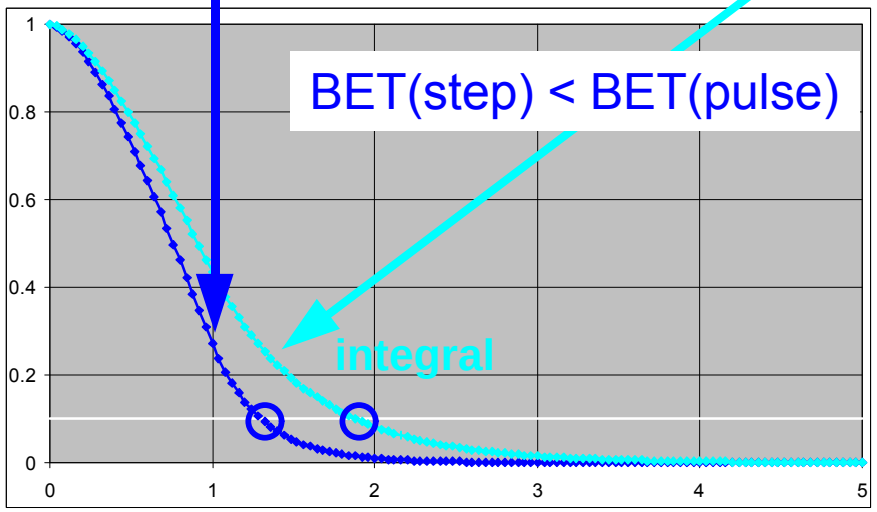
BET from Step & Impulse Response

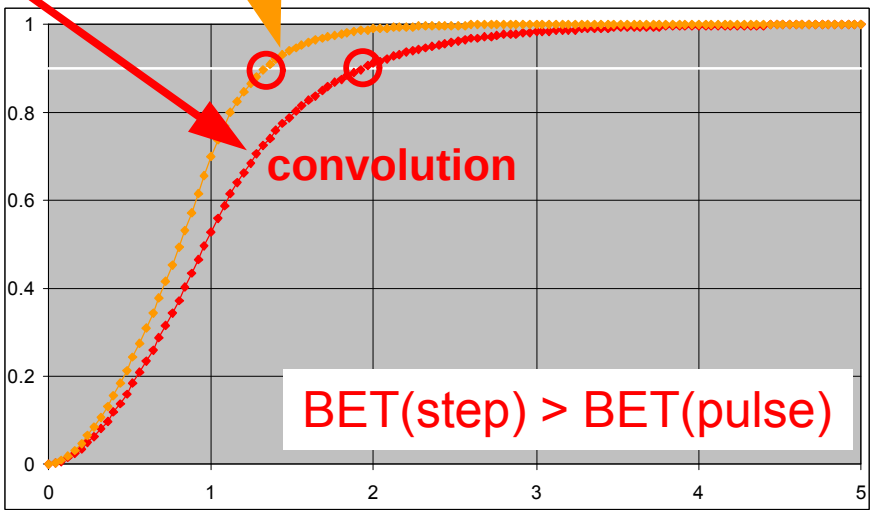


Step responses with $\tau_1 = 2 \cdot \tau_2$



Impulses from steps with $\tau_1 = 2 \cdot \tau_2$





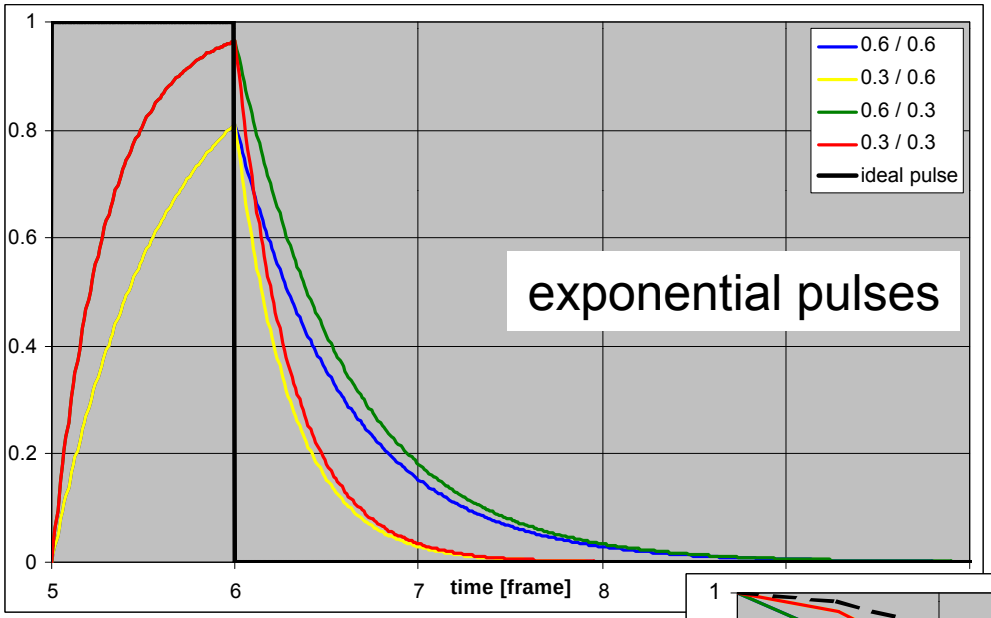
Convolution of step responses and integrals of impulses

NBETs in Comparison

Method		NBET relaxation	NBET field induced
Impulse response			
auto-completion	*poor data*	0,936	0,897
cross-completion	*manipulation*	0,955	0,897
no completion		1,053	0,939
Step response		1,097	0,985
Moving target			
Δ = 4 px / frame		1,144	1,124
Δ = 8 px / frame		1,105	1,035
Δ = 16 px / frame		1,077	0,989

rather symmetric blur characteristics in this example

MTF from Impulse Response



Impulses are calculated with two time constants (rise: τ_r, fall: τ_f).

symmetric: $\tau_r = \tau_f$ [frame time]

asymmetric: $\tau_r \neq \tau_f$

to evaluate the effect on the MTF

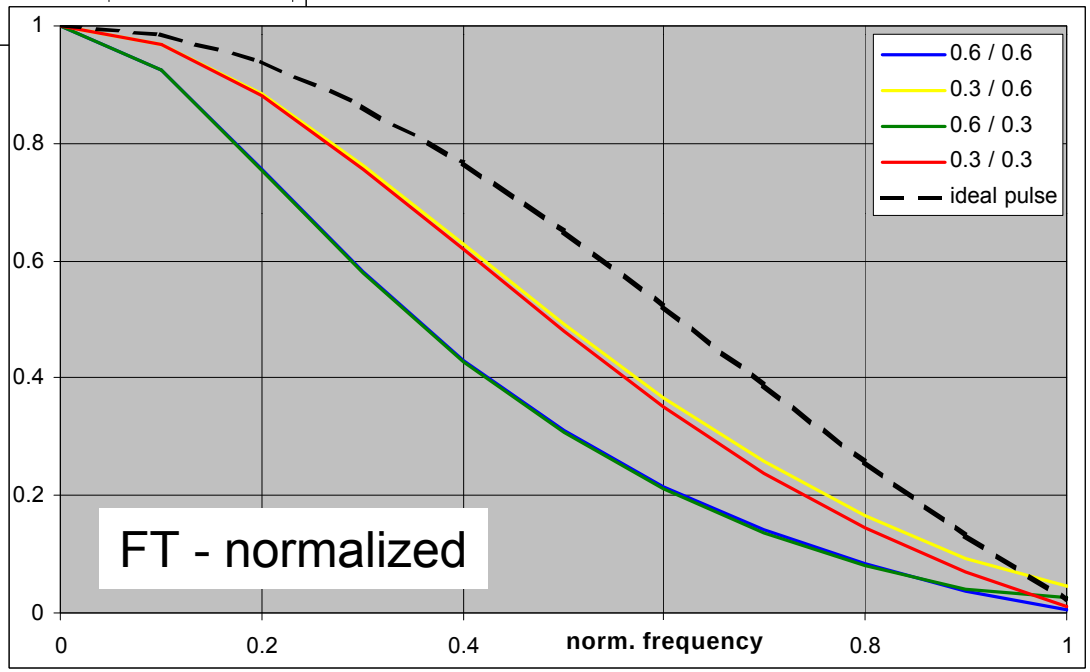
Falling edge seems to be the limiting factor !

$\tau_r = 0.3$ $\tau_f = 0.3$

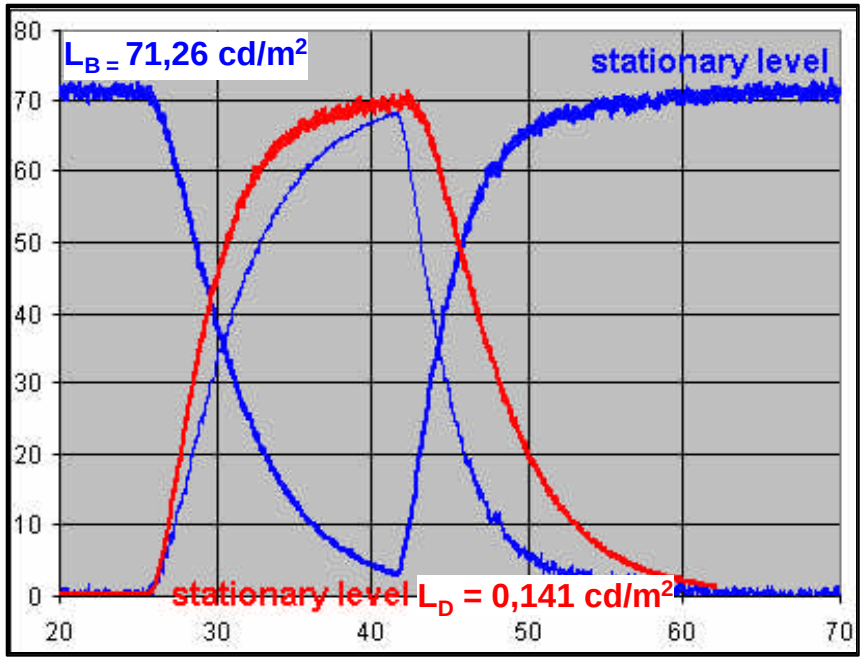
$\tau_r = 0.3$ $\tau_f = 0.6$

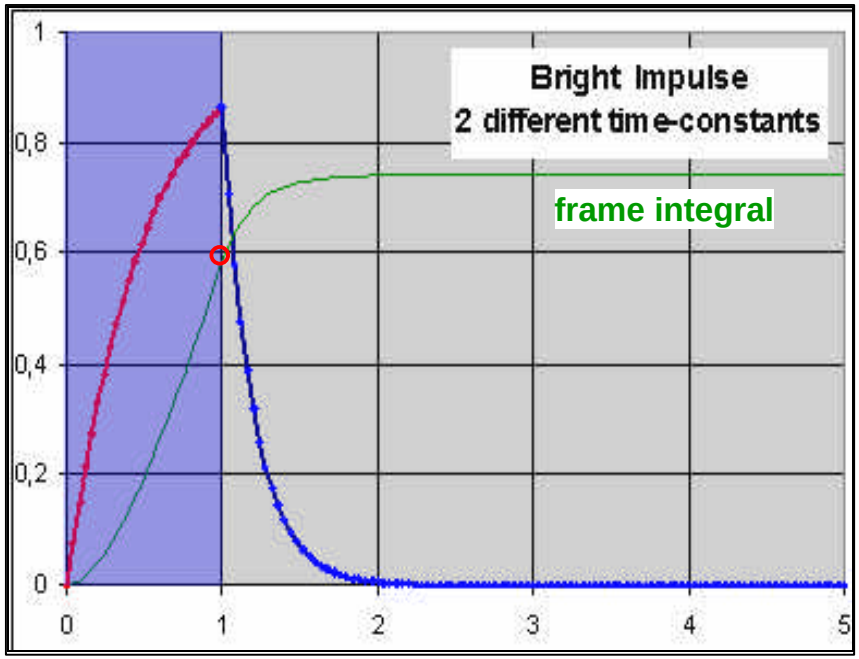
$\tau_r = 0.6$ $\tau_f = 0.3$

$\tau_r = 0.6$ $\tau_f = 0.6$



Dynamic Contrast Reduction





Equivalent to contrast reduction of a moving line with $\Delta > w$

Frame-integrated dynamic contrast

$$C_{dyn}(bright\ pulse) = \frac{I_B \cdot (L_B - L_D) + L_D}{L_D} = 404{,}5$$

$$C_{dyn}(dark\ pulse) = \frac{L_B}{(1 - I_D) \cdot (L_B - L_D) + L_D} = 2{,}5$$

Temporal Contrast Function

$$C_{dyn}(t) = \frac{L(t)}{L_D} \qquad Max = 489$$

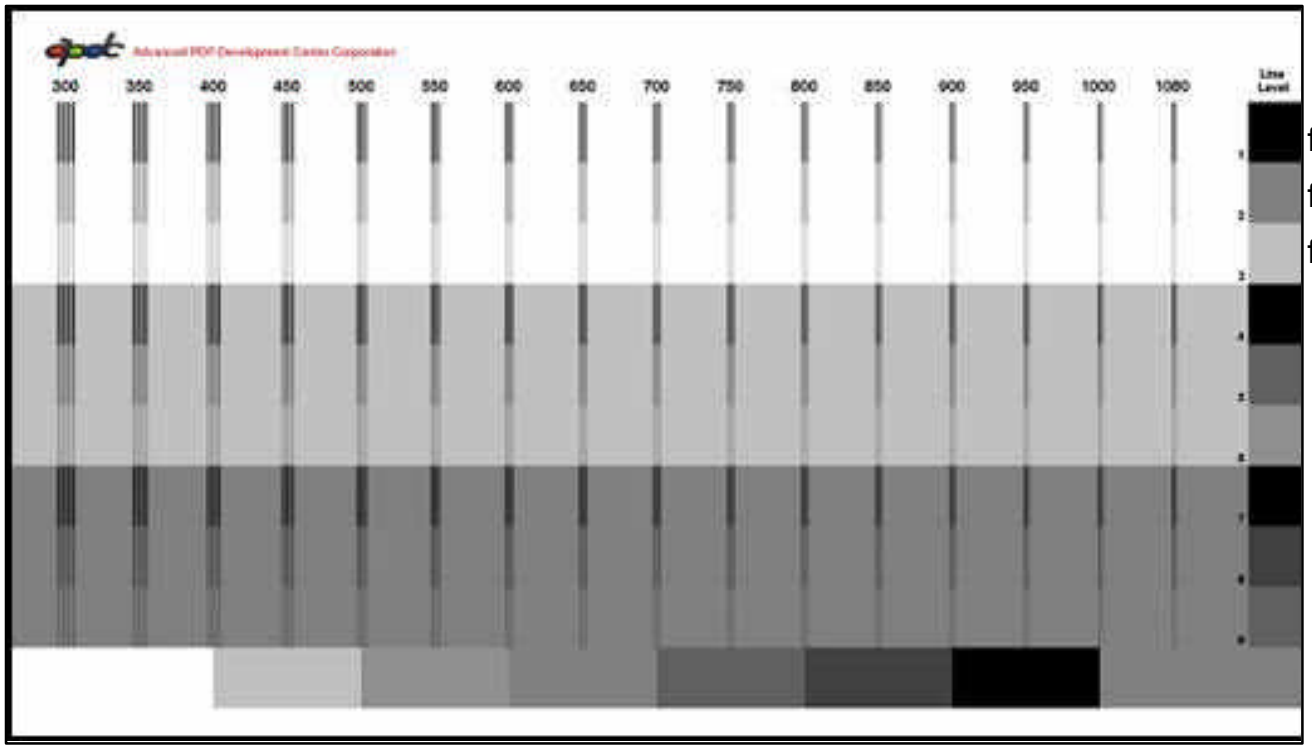
$$C_{dyn}(t) = \frac{L_B - L(t)}{L_D} \qquad Max = 477$$

Dynamic Contrast Reduction

background 1

background 2

background 3



foreground 1

foreground 2

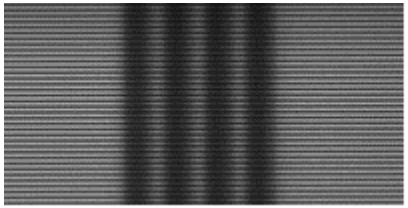
foreground 3

APDC Advanced PDP Develoment Center Corporation www.advanced-pdp.jp

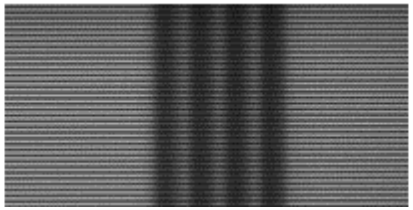
3 gray-levels line-patterns on 3 gray-level backgrounds.

- Measurement with pursuit camera,
- evaluation of contrast modulation.

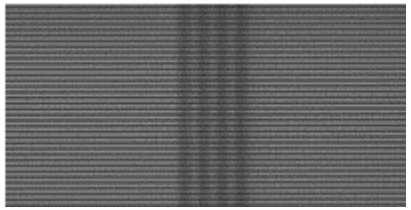
Dynamic Contrast Reduction



300



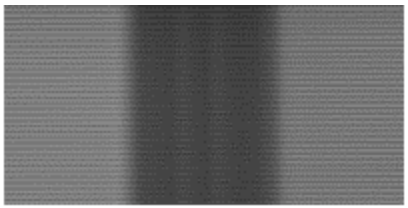
350



900 TV lines

900 TV lines can be resolved in this example

300



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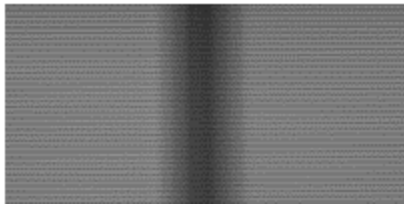

900 TV lines

300 TV lines can be resolved in this example

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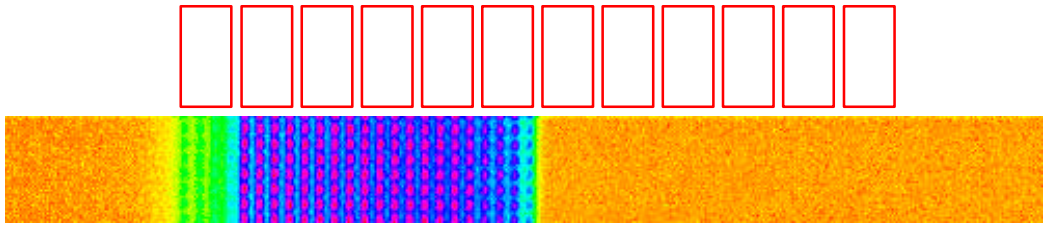
Impulse & Step Response

- **Impulse response** can be directly measured or obtained by differentiation of step response.
- **Impulse response** requires numerical processing for separation of field-induced and relaxation effects.
- **Impulse response** useful for evaluation of **MTF related characteristics**.
- **Impulse response** useful for evaluation of **dynamic contrast reduction**.

➲ Frame-integrated dynamic contrast reduction is a sensitive probe.

Lateral Artefacts

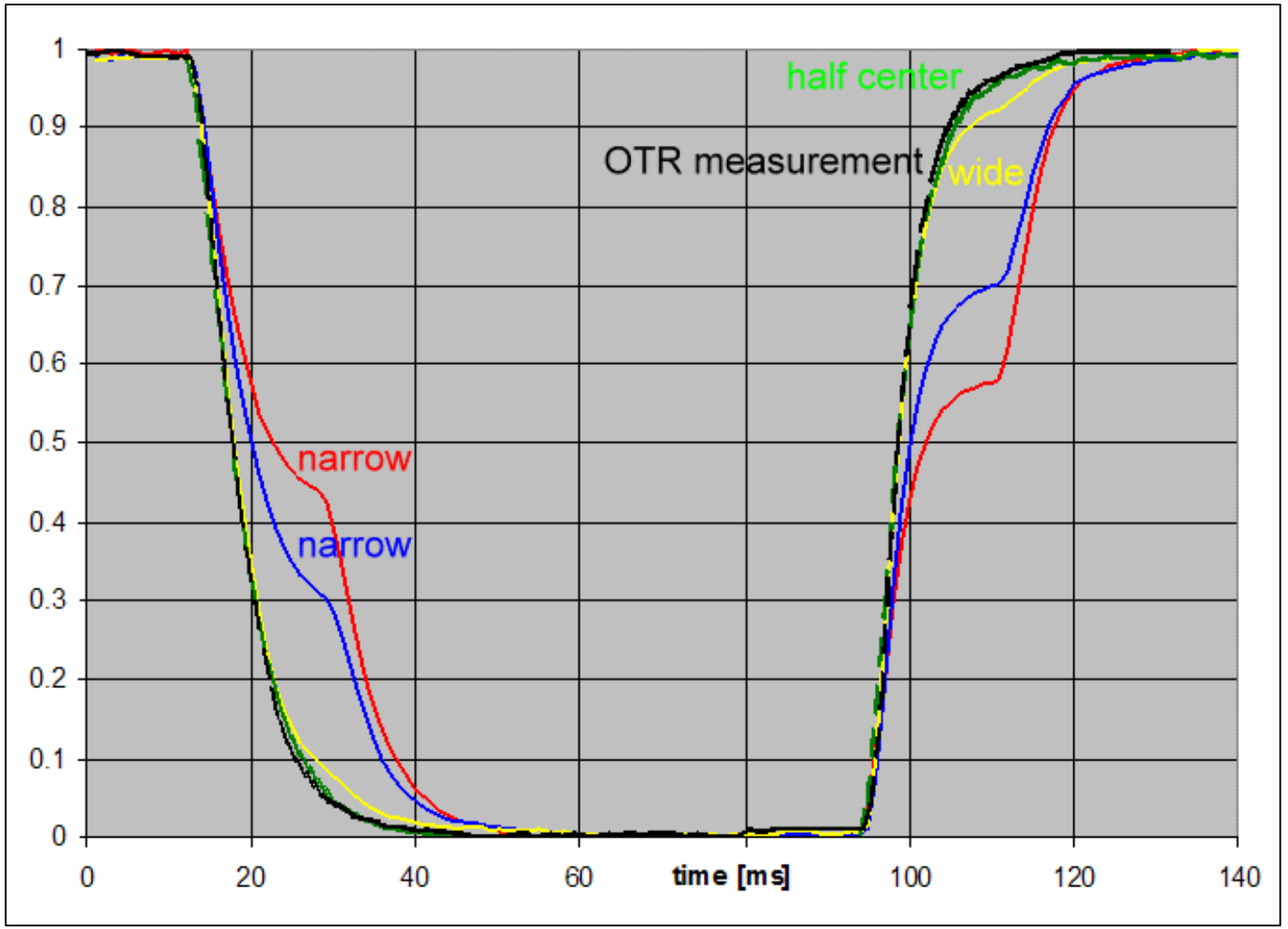


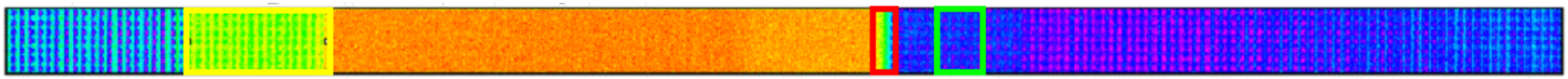
LCD monitor @ 60 Hz frame frequency
bright block target (RGB=255) on dark background (RGB=0)
block advancement = 4 px/frame, block width = 20 px
t_{xp} = 1ms

LED line - Reference Ticker @ 100 Hz frame frequency
block advancement = 1px/frame, aperture = 100%, ideal hold-type display

Caused by a phase difference between display timing and data acquisition, there are single transitional images with target fractions from both frames.

Lateral Artefacts





wide narrow half center

Results

Comparison of results obtained from convolution of step responses and results from MBA MADRAS measurements and evaluations

MADRAS S = 4				
Start / Finish	**0**	**91**	**139**	**255**
0		1.459	1.658	1.124
91	1.125		1.580	1.085
139	1.174	1.383		1.075
255	1.144	1.505	1.440	

Results shown for 3 velocities of target advancement, S.
Width of block-target = 5x the advancement / frame period.

Both bright block targets on darker background (BG) and vice versa have been used. The results which are expected to be identical actually happen to be somewhat different.

MADRAS S = 8				
Start / Finish	**0**	**91**	**139**	**255**
0		1.387	1.621	1.035
91	1.064		1.491	1.071
139	1.006	1.336		0.988
255	1.105	1.434	1.500	

NBETs from Step Responses				
Start / Finish	**0**	**91**	**139**	**255**
0		1.834	1.709	0.985
91	1.034		1.630	0.967
139	1.043	1.531		0.955
255	1.097	1.448	1.522	

MADRAS S = 16				
Start / Finish	**0**	**91**	**139**	**255**
0		1.405	1.403	0.989
91	1.009		1.556	1.004
139	0.997	1.339		0.980
255	1.077	1.373	1.393	

Relaxation
Field-induced

➲ There is an effect of the speed of target advancement,
NBETs seem to be generally decreasing with target speed.

Conclusions

Imaging approaches

- direct measurement with a ***tracking camera*** (TDI included)
  ➲ synchronization of motion is a key-issue,

- measurement with a ***fixed camera*** and oversampling,
  provides motion-blur characteristics together with step-responses
  (➔ response times: image formation time, gray-to-gray transitions times),
  and impulse-responses (MTF, BET, etc.).

  ➲ All parasitic lateral effects included !

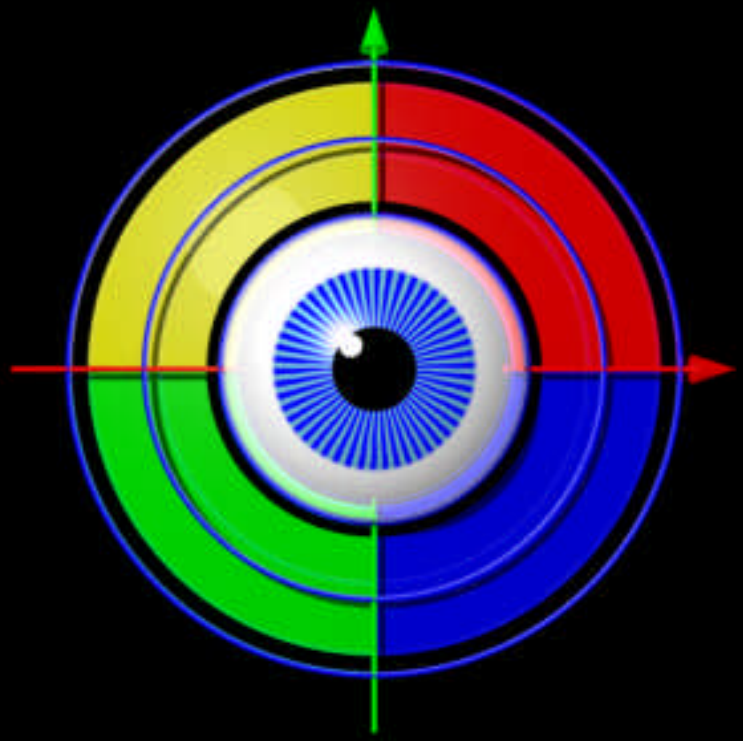
Non-imaging approaches

- measurement of ***temporal step responses***
  (temporal luminance transition) followed by numerical evaluation,

- measurement of ***impulse responses*** followed by numerical evaluation.

  ➲ No parasitic lateral effects included, but good 1^{rst} oder approximation !
  High temporal resolution and SNR possible.

Thank you for your attention !



DM&S: We measure what your eyes see...