Evaluation of Moving-Line Contrast Degradation without Motion

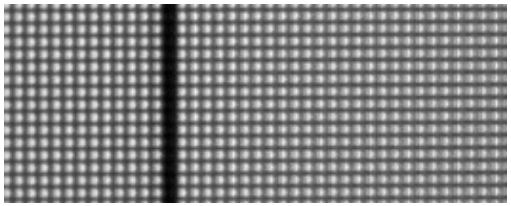
Michael E. Becker
Display-Metrology&Systems
Karlsruhe -Germany

Moving Lines on Hold-type Displays

Lines moving on flat panel displays (hold-type) behave strangely:

- they cause flicker,
- they tend to disappear,
- they are perceived as spreading,
- etc.

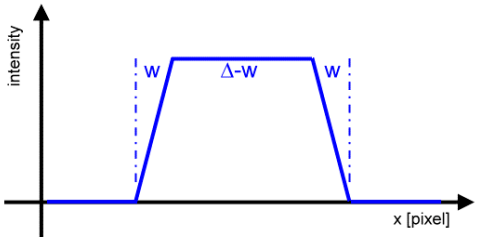
Can that sensitivity be used for
evaluation of the dynamical properties of flat panel displays ?



Dark line advancing on bright background,
IPS LCD-monitor, 60 Hz frame frequency,
1ms exposure time.

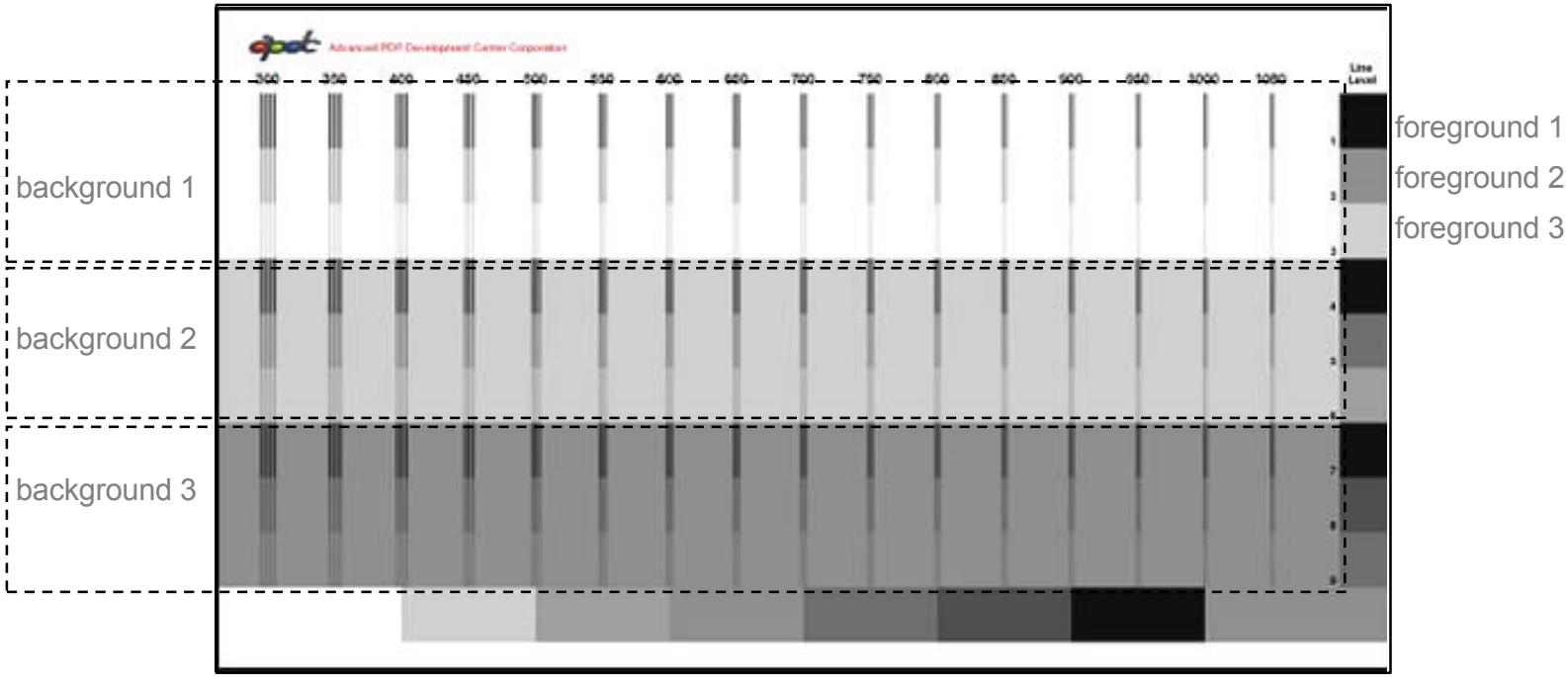
Human eye follows motion and
integrates over one frame period
⇨ perceived spreading of line

spreading of line ?



Spreading of line (w=1 pixel) on
ideal hold-type display: ~ Δ+1,
Δ: advancement per frame period

Moving Lines on Hold-type Displays

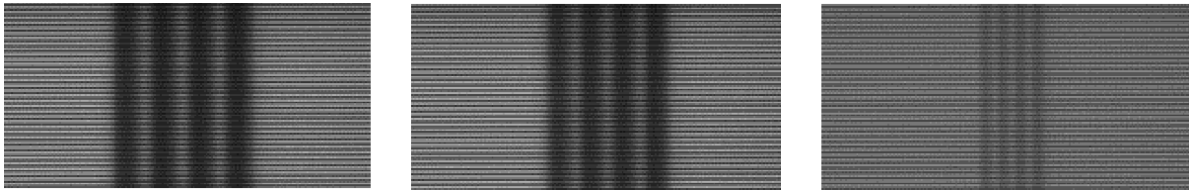


APDC Advanced PDP Develoment Center Corporation www.advanced-pdp.jp

3 gray-levels line-patterns on 3 gray-level backgrounds, variable spatial frequency (lines per pixel).

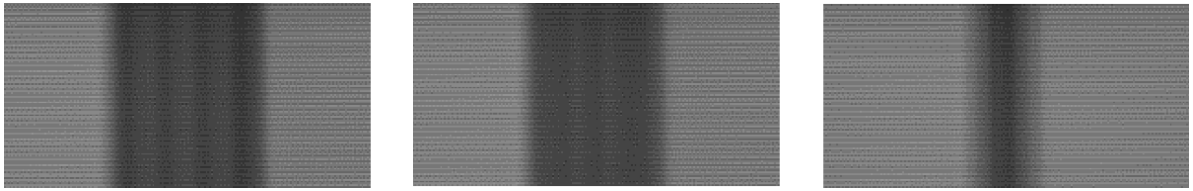
- measurement with pursuit camera,
- evaluation of spatial contrast modulation.

Moving Lines on Hold-type Displays



300 350 900 TV lines

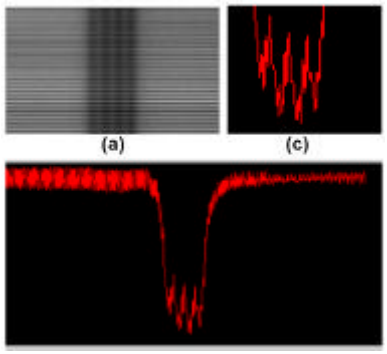
max. 900 TV lines can be resolved on this display



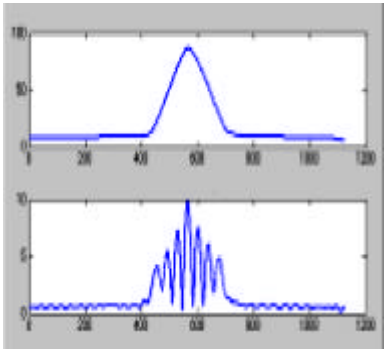
300 350 900 TV lines

max. 300 TV lines can be resolved on this display

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



high resolution image from tracking camera

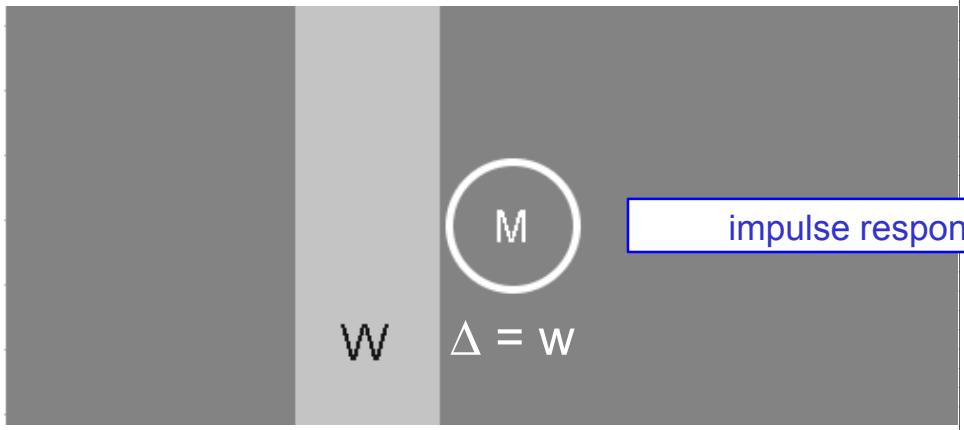


evaluation via Fourier transformation

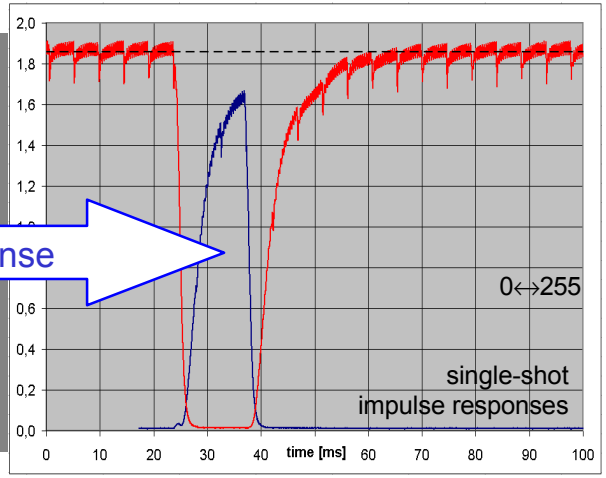
from I. I. Kawahara, M. Kasahara, T. Shinoda, IDW'07

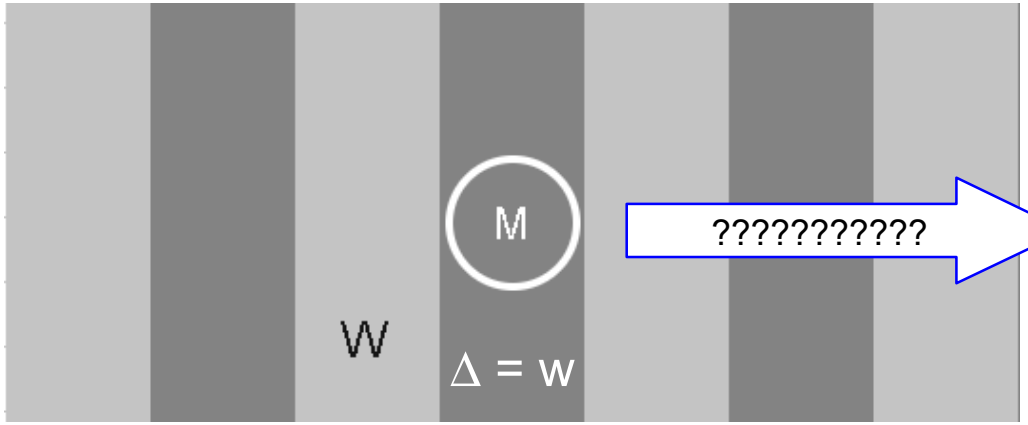
Moving Lines on Hold-type Displays

How can we measure the contrast degradation of lines in motion without high-magnification tracking camera systems ?



impulse response

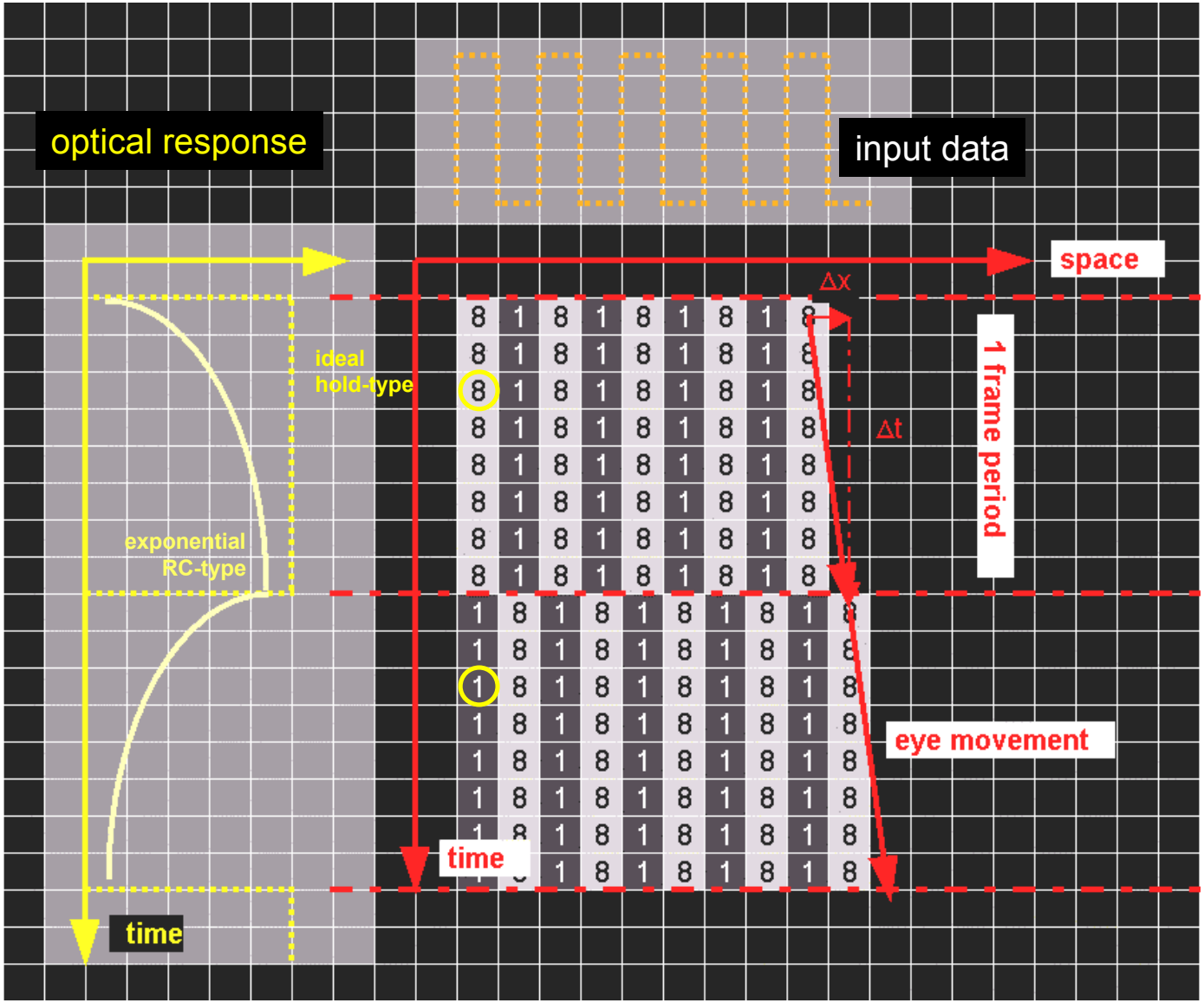




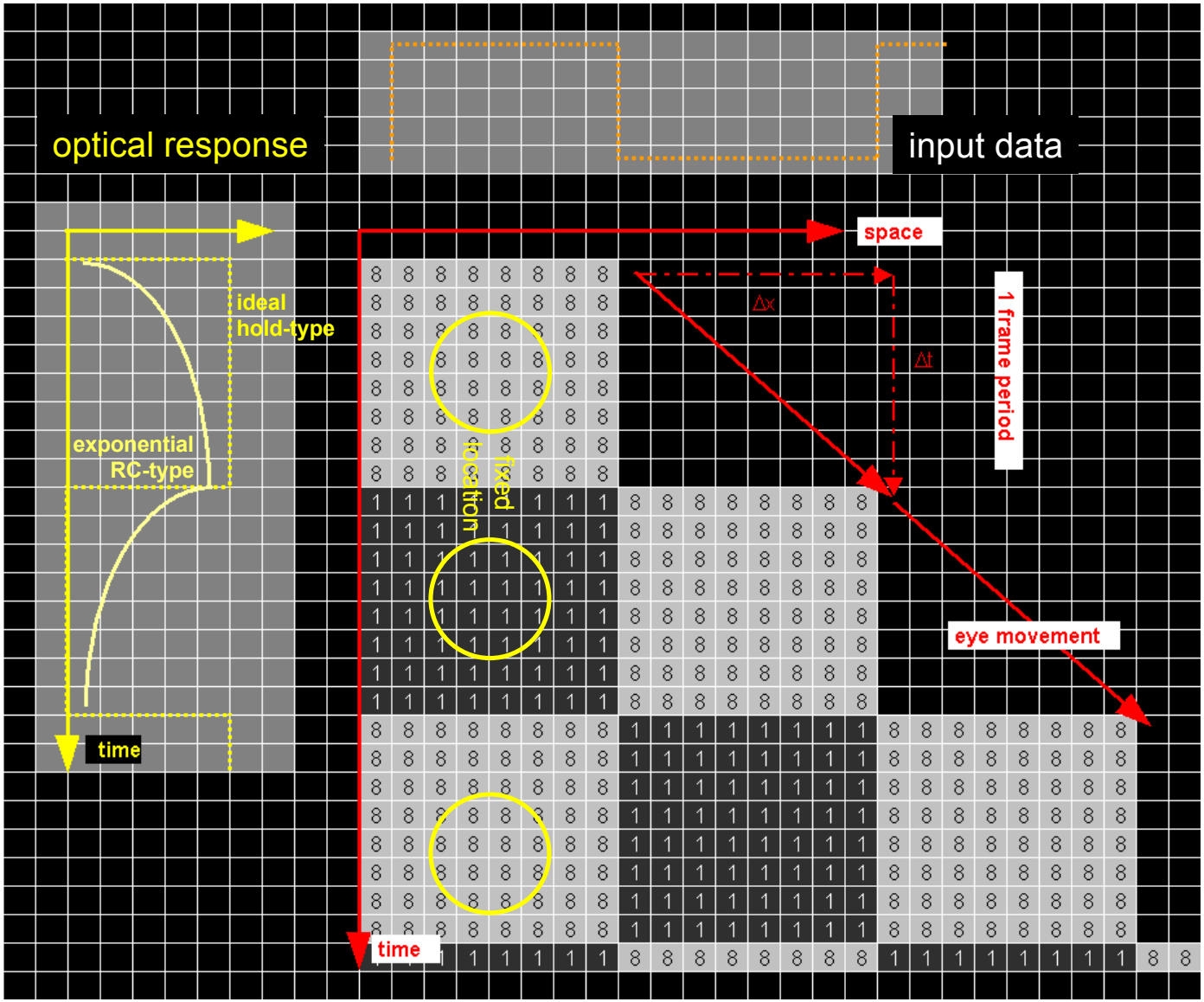
??????????

IMPULSE:
fastest event that can be shown on an electronic display; ON or OFF for 1 frame period only.

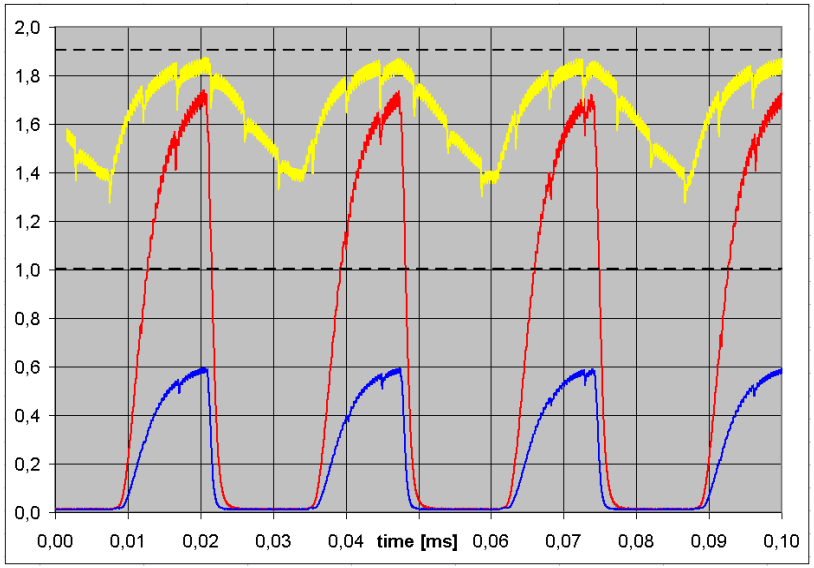
Moving Grating

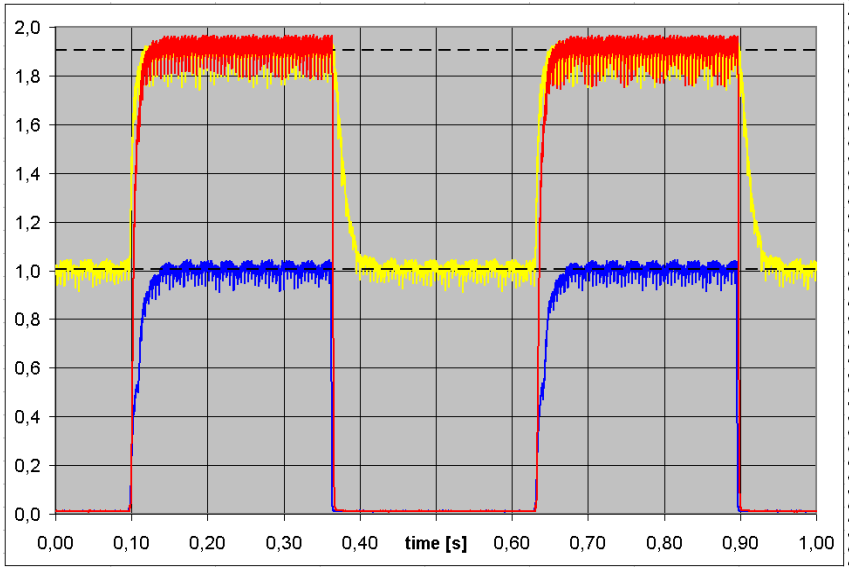


Moving Grating



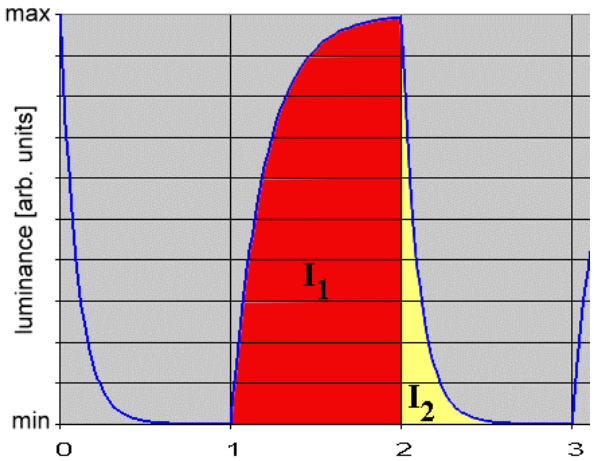
Periodic Responses





1 frame period hold-time: impulse responses

20 frame periods: step responses



Frame-integrated dynamic contrast

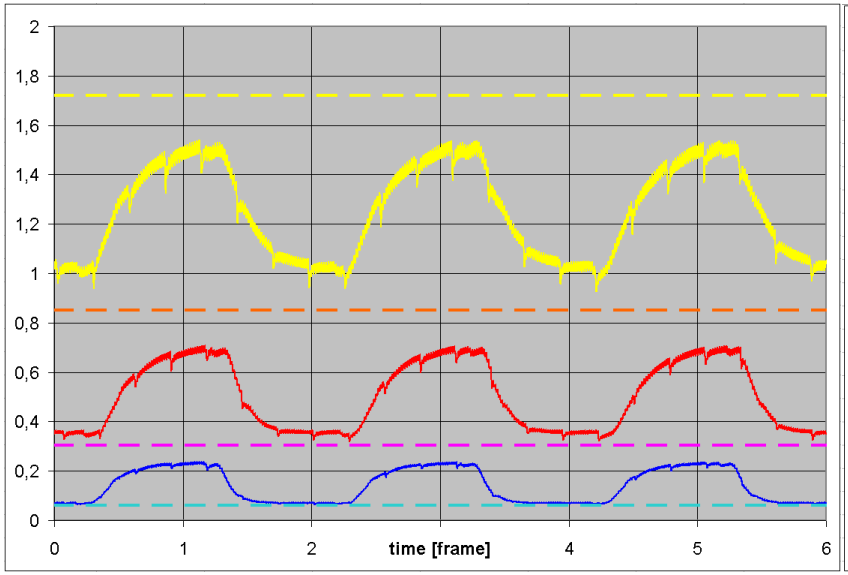
$$C_{dyn} = \frac{L_{min} + I_1 \cdot (L_{max} - L_{min})}{L_{min} + I_2 \cdot (L_{max} - L_{min})}$$

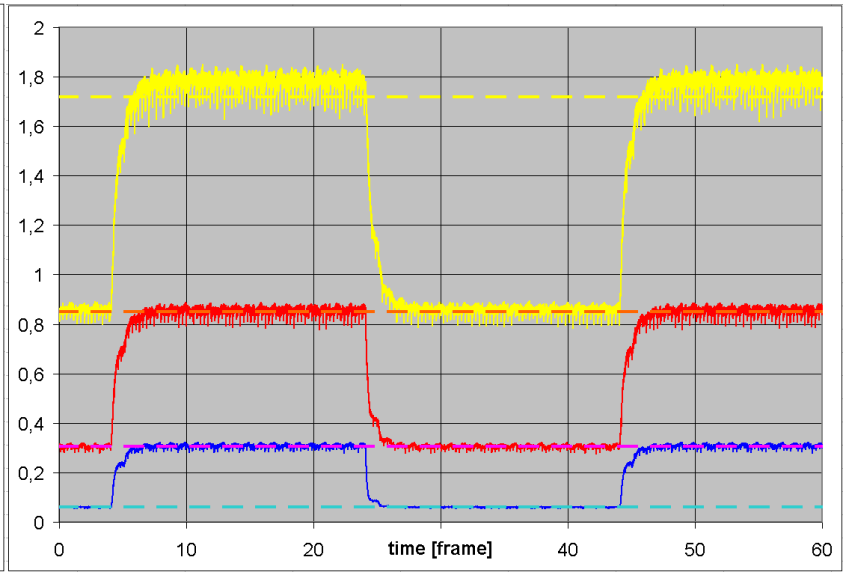
ideal hold-type:
$I_1 = 1$, $I_2 = 0$

$$C_{stat} = \frac{L_{max}}{L_{min}}$$

➲ not easy to determine frame limits (phase)

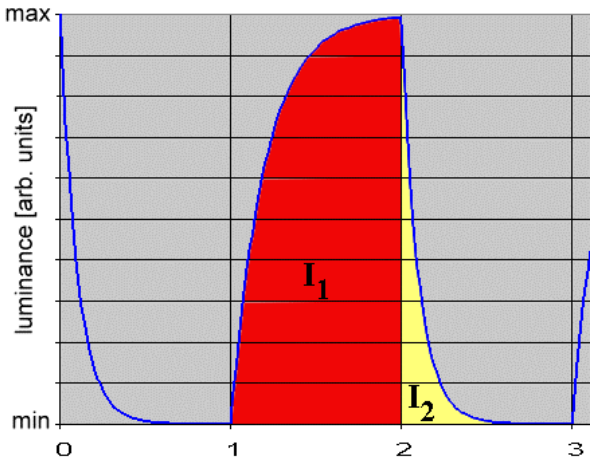
Periodic Responses





1 frame period hold-time: impulse responses

20 frame periods: step responses



Frame-integrated dynamic contrast

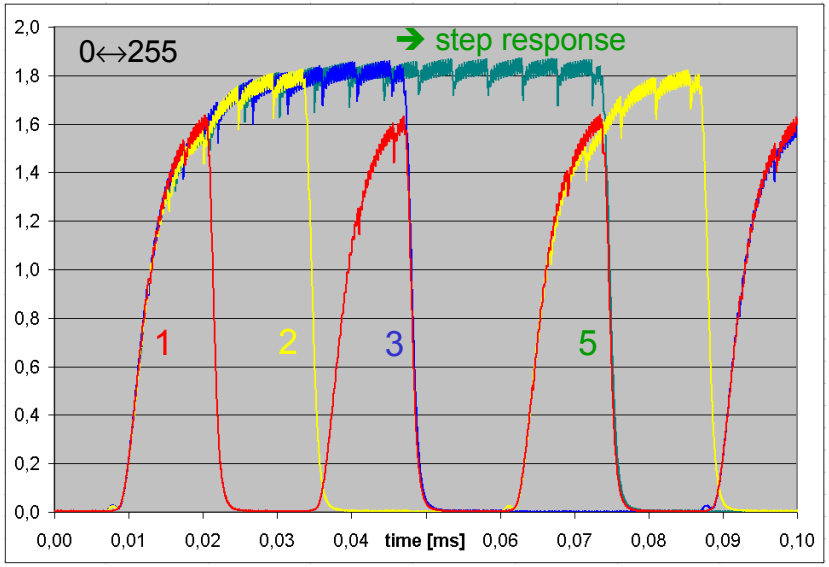
$$C_{dyn} = \frac{L_{min} + I_1 \cdot (L_{max} - L_{min})}{L_{min} + I_2 \cdot (L_{max} - L_{min})}$$

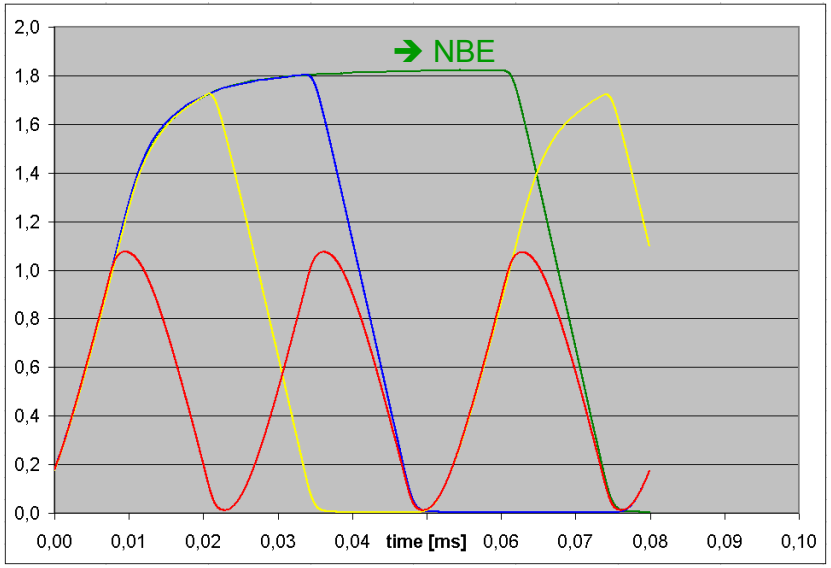
ideal hold-type:
$I_1 = 1$, $I_2 = 0$

$$C_{stat} = \frac{L_{max}}{L_{min}}$$

➲ not easy to determine frame limits (phase)

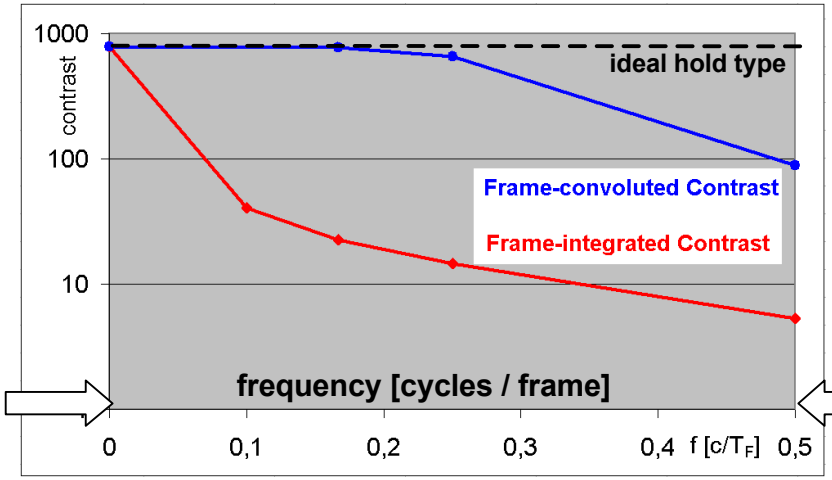
Periodic Responses

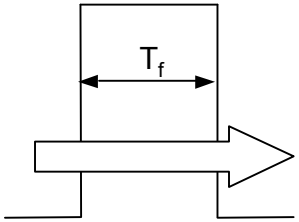




periodic responses - 1, 2, 3, 5 frame periods hold-time

frame period **convolution**

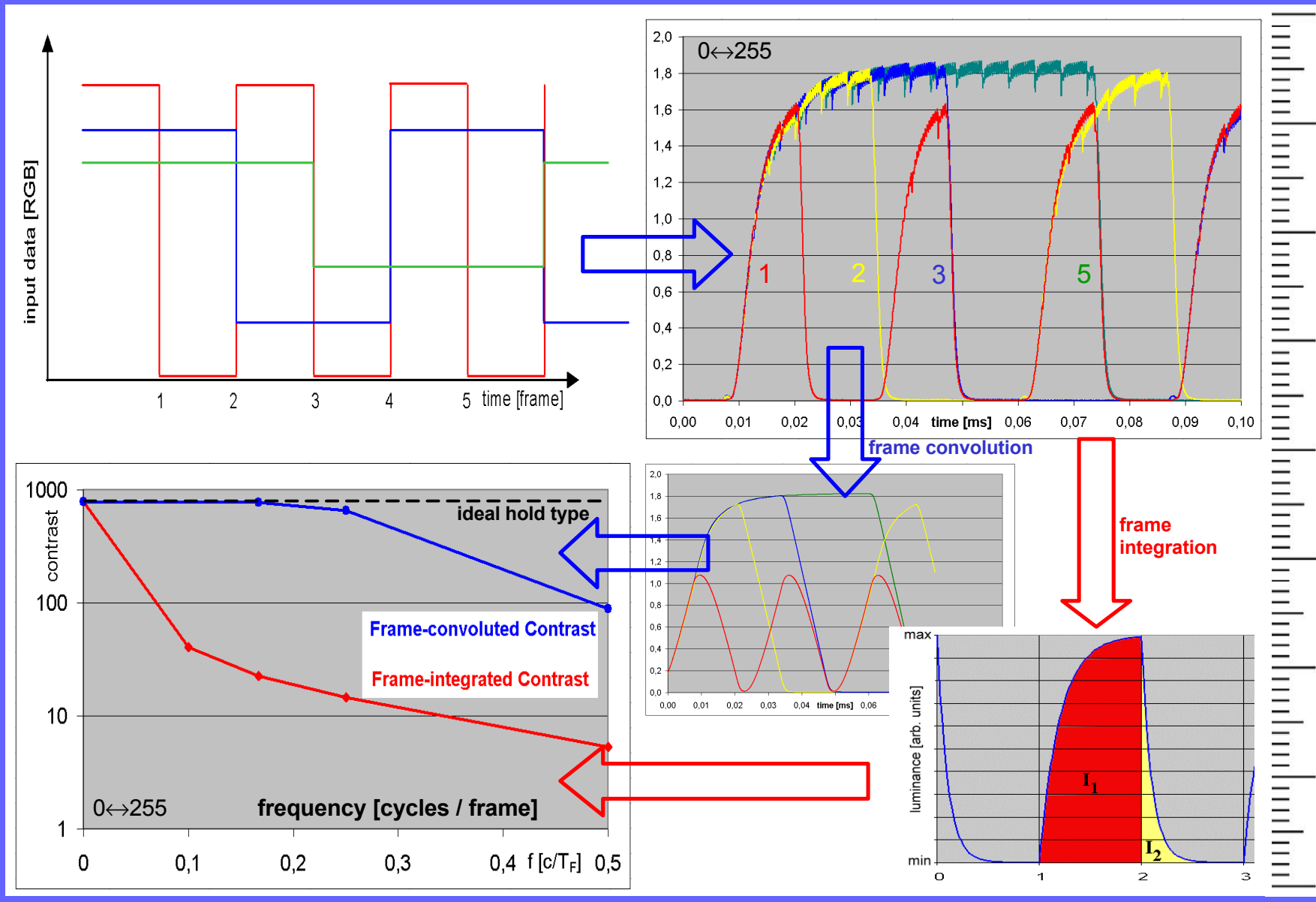




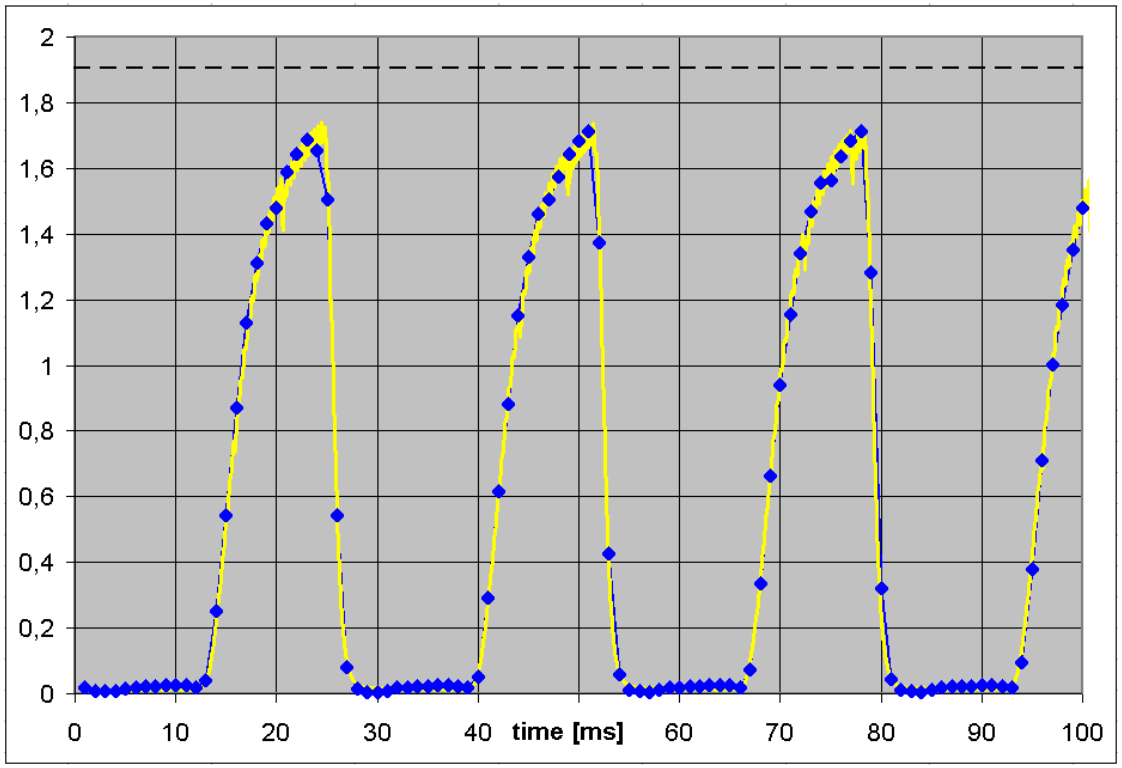
step response
static contrast

impulse response
dynamic contrast

Variable Hold-Time Periodic Response



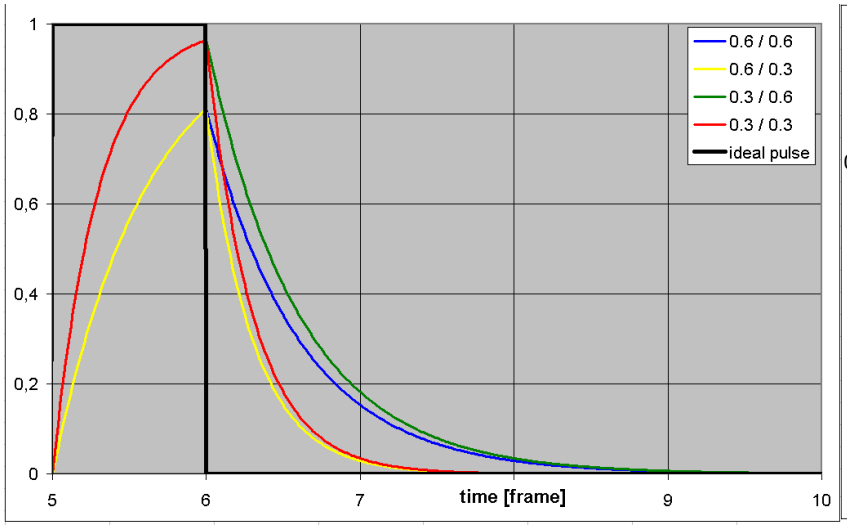
Periodic Impulse Response



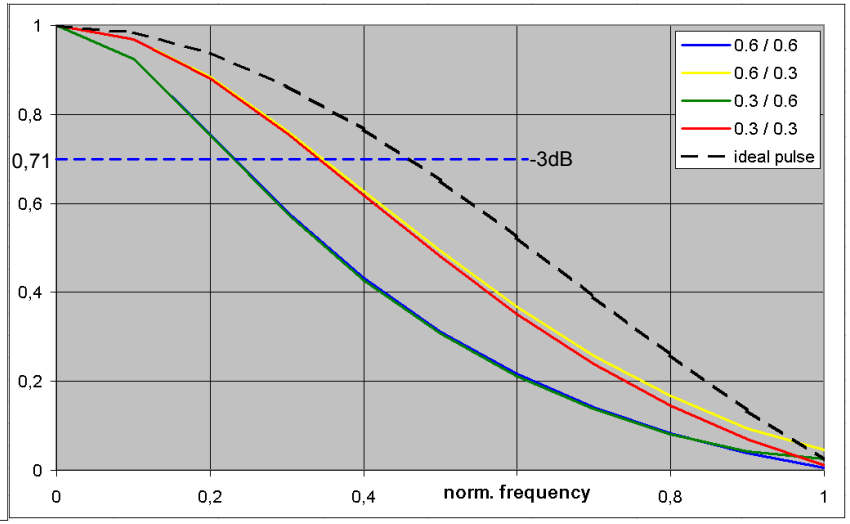
Comparison of periodic impulse response measured with

- high-speed camera (oversampling, T_x = 1ms),
- optical transient recording (at fixed location).

Impulse Response Evaluations



Exponential single-shot impulse responses calculated for 4 combinations of time constants of 0.3 and 0.6 T_F for rising and falling edge respectively.



The –3 dB bandwidths of red and yellow pulse and their MTFs are much alike, but dynamical contrast is not.

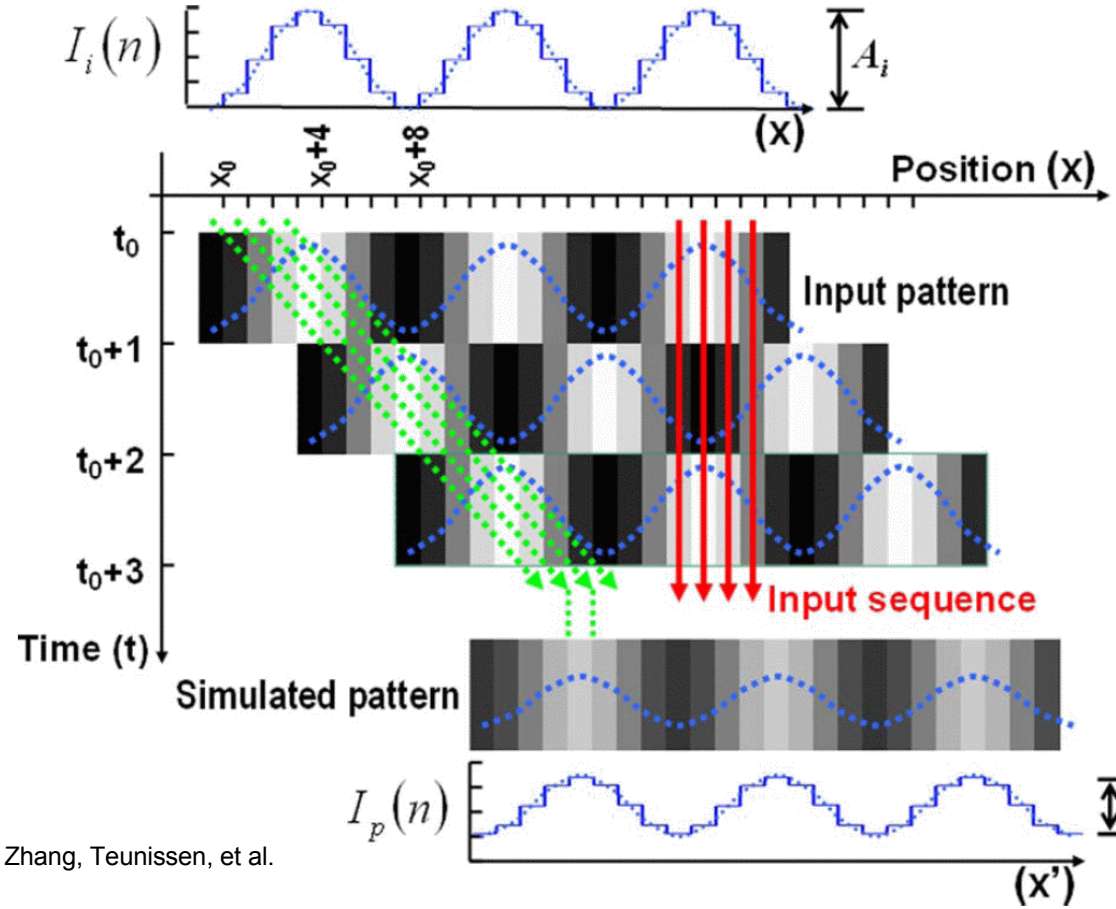
MTF evaluations provide basis for comparison of DUTs but no information about contrast.

Single-shot impulse response is not characteristic for visual characteristics of LCD dynamics.

dynamic contrast (frame integrated):	0,509/0,239=2,13	0,706/0,284=2,49
dynamic contrast (frame convoluted):	6,037	5,662

Analysis of dynamic properties of displays based on the (idealized single-shot) impulse response by M. A. Klompenhouwer, e.g. SID'05 Digest, pp. 1578- 1581, SID'06 Digest, pp. 1700-1703

Dynamic Modulation Transfer Function



sine-pattern
(step-approximation)

effect of both
- display dynamics,
- frame convolution.

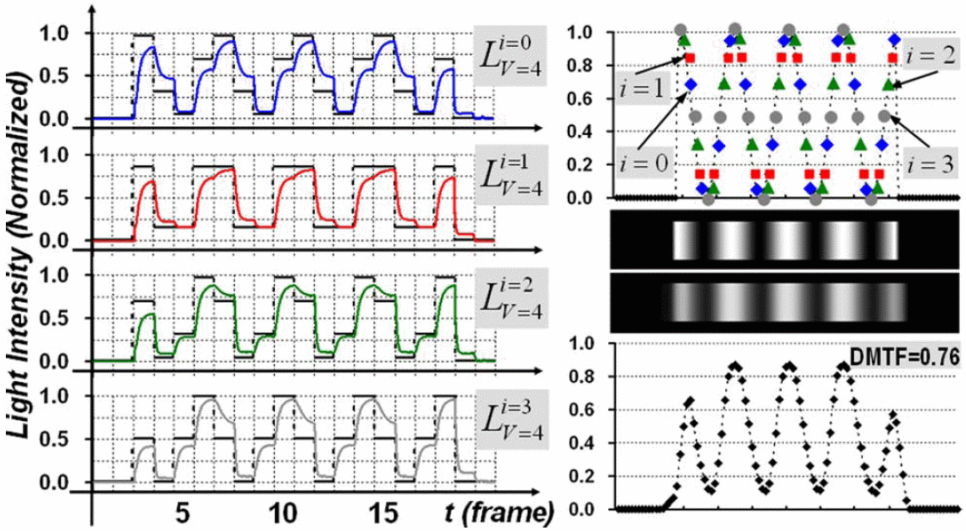
$$\mathrm{DMTF}(V,f) = \frac{A_p(V,f)}{A_i},$$

Zhang, Teunissen, et al.

Taiichiro Kurita, Asako Saitoh, Ichiro Yuyama, *Consideration on Perceived MTF of Hold Type Display for Moving Images*, IDW'98 Digest, pp. 823-826

Yuning Zhang, Kees Teunissen, Wen Song,and Xiaohua Li, *Dynamic modulation transfer function: a method to characterize the temporal performance of liquid-crystal displays*, Optics Letters 33, 6(2008), pp. 533-535

Dynamic Modulation Transfer Function



DUT driving (columns)

sine-pattern as displayed,

sine-pattern on retina of observer (SPET),

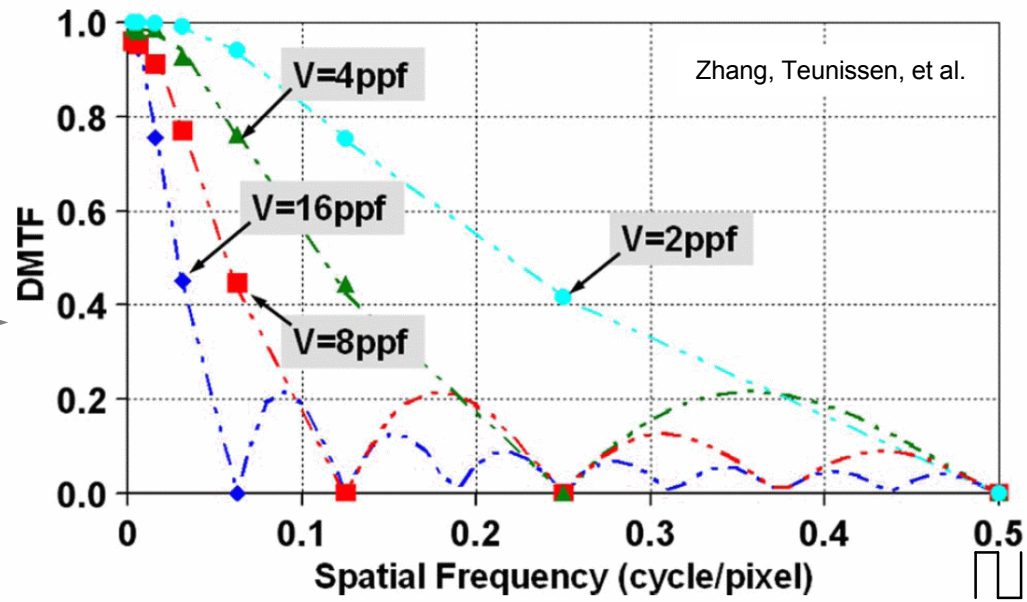
DMTF

$$\mathrm{DMTF}(V,f) = \frac{A_p(V,f)}{A_i},$$

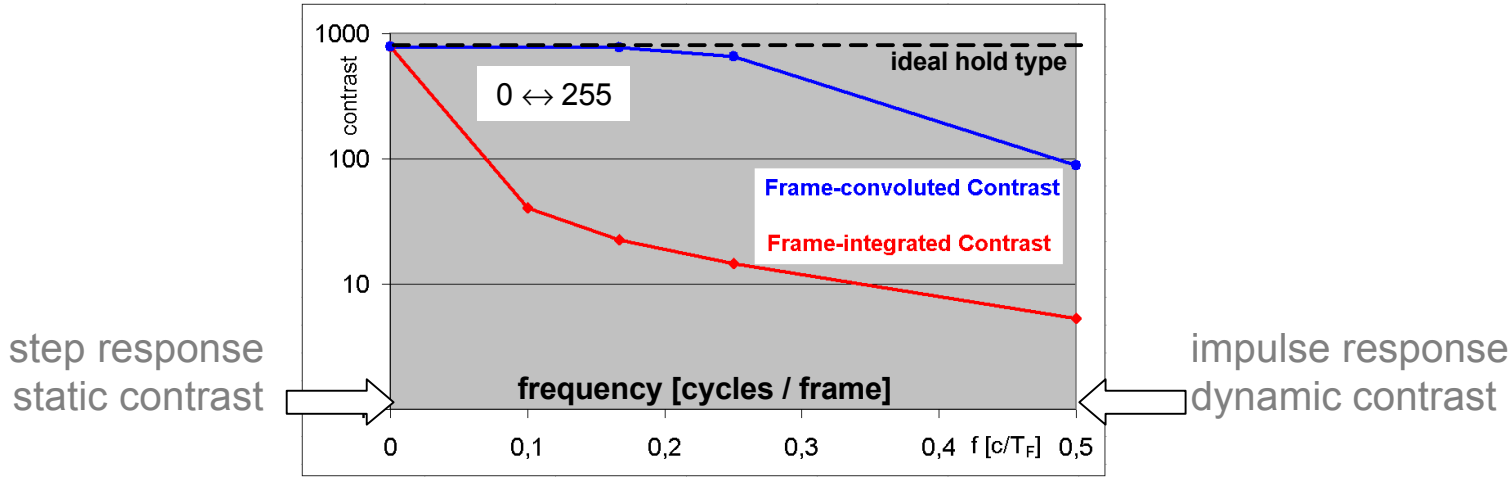
Zhang, Teunissen, et al.

Comprises a variety of gray-level transitions.

Zeros of DMTF due to frame period convolution of moving pattern.

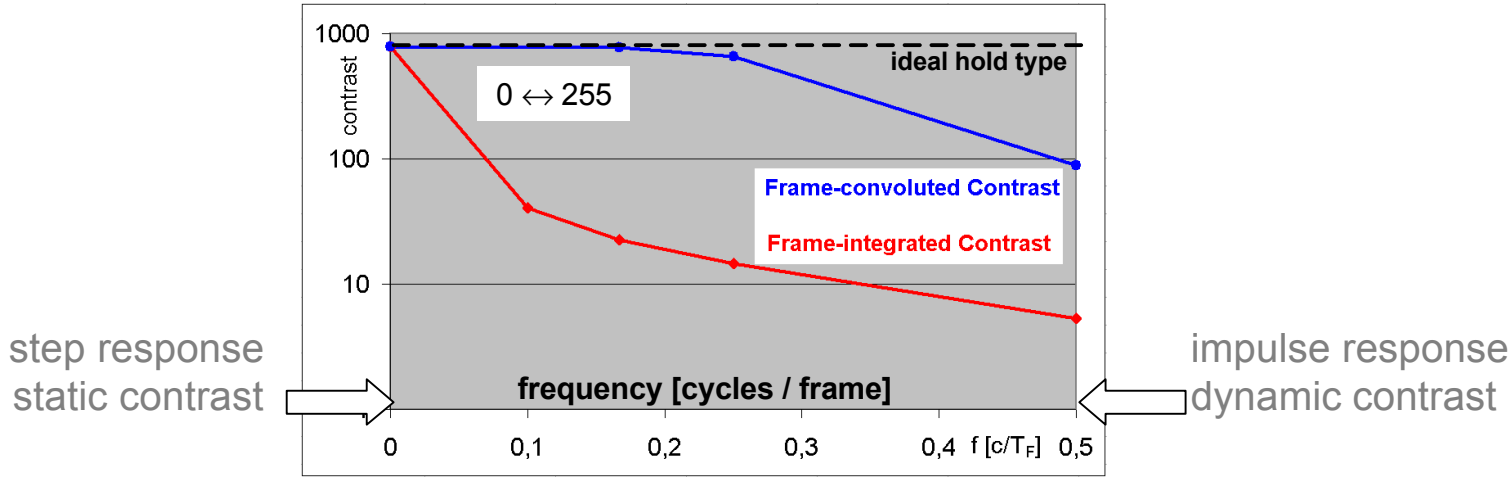


Comparison of Approaches



Approach	Type	Instrumental Efforts	Remark
Grille (burst) in motion Kawahara, et al., IDW'07 Digest	metrological	**high** tracking camera with high magnification	
DMTF T. Kurita, et. al., IDW'98 Zhang, et al., OptLett 33, 6(2008)	visual	**moderate** all results obtained from temporal luminance variations at fixed location , special DUT driving circuitry required	
Dynamic Contrast		**low** all results obtained from temporal luminance variations, DUT driving is easy	highest possible temporal frequencies included, NBE included in results.
frame convoluted	visual		results in terms of contrast complete range of timings from impulse to step response included.
frame integrated	metrological		data processing required

Comparison of Approaches



Approach	Type	Instrumental Efforts	Remark
Grille (burst) in motion Kawahara, et al., IDW'07 Digest	metrological	**high** tracking camera with high magnification	
DMTF T. Kurita, et. al., IDW'98 Zhang, et al., OptLett 33, 6(2008)	visual	**moderate** all results obtained from temporal luminance variations at fixed location , special DUT driving circuitry required	
Dynamic Contrast		**low** all results obtained from temporal luminance variations, DUT driving is easy	highest possible temporal frequencies included, NBE included in results.
frame convoluted	visual		results in terms of contrast complete range of timings from impulse to step response included.
frame integrated	metrological		data processing required

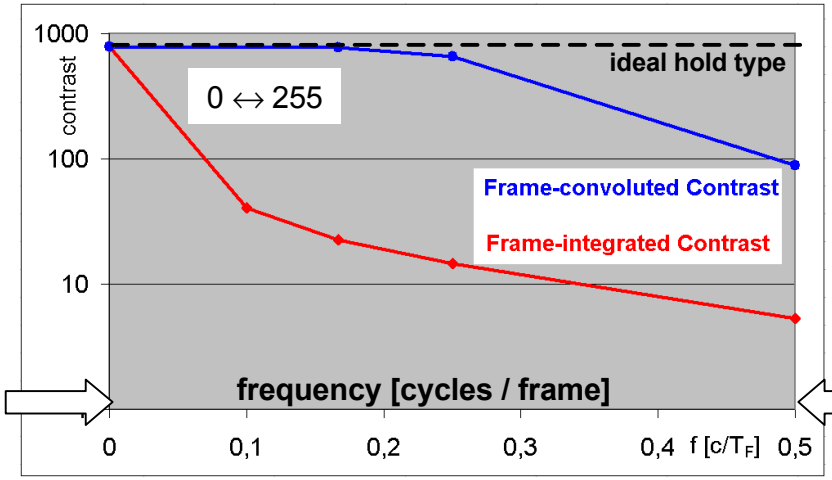
Conclusion

- frame synchronized driving of DUT (extended area), with hold time as variable,
- recording of luminance vs. time (at fixed location),
- **frame convolution** of optical response to reproduce SPET, or
- **frame integration** of optical response,
- evaluation of contrast of moving pattern (on retina),

➲ dynamic contrast vs. hold time (impulse to step response),

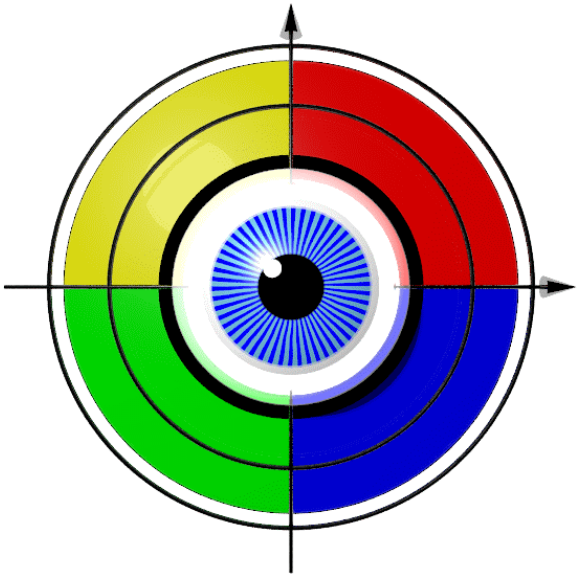
➲ complete characterization of DUT dynamics in terms of contrast.

step response
static contrast



impulse response
dynamic contrast

Thank you very much for your attention



DM&S - we measure what your eyes see ...