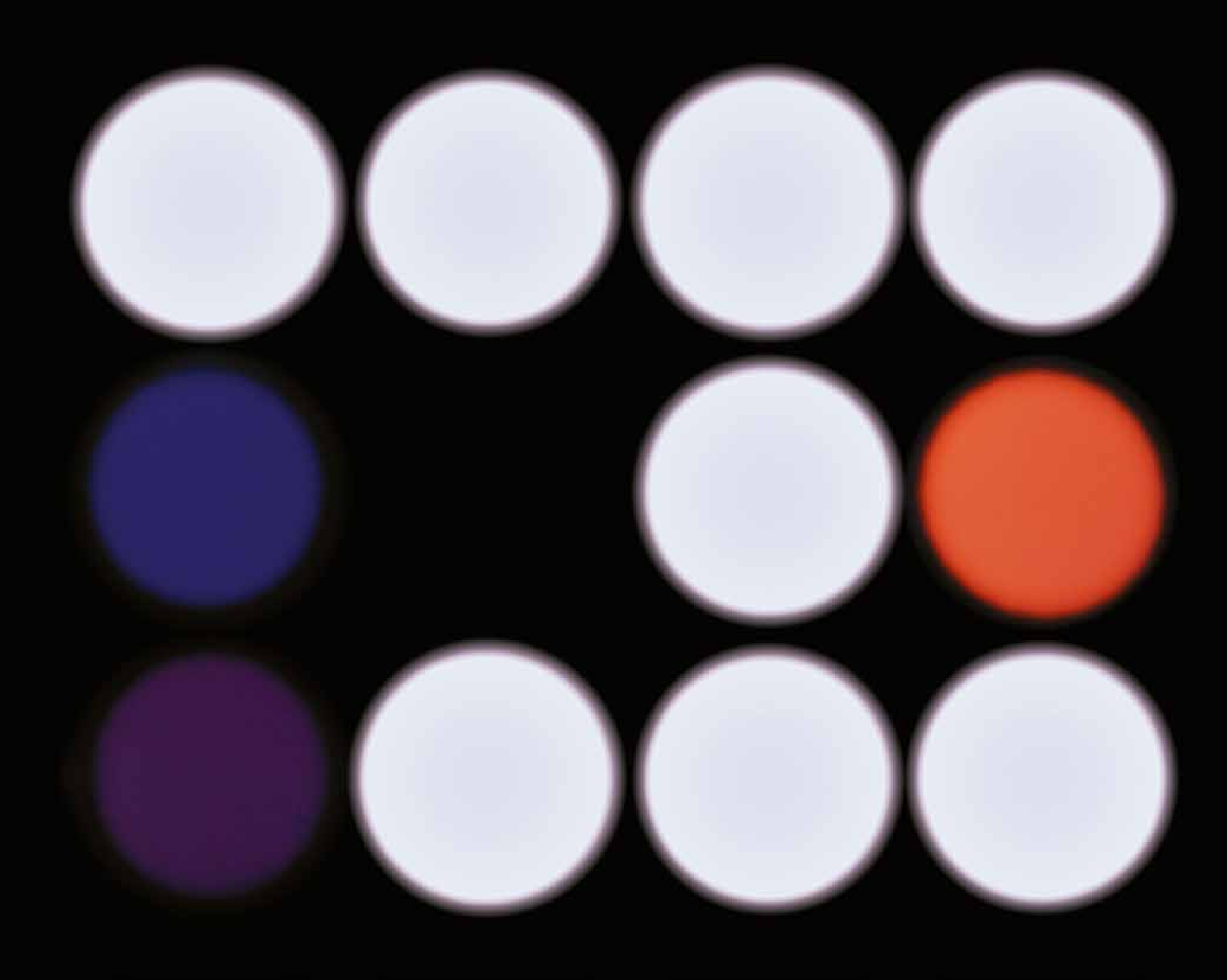


The Royal Danish Academy of Fine Arts,
Schools of Architecture, Design and Conservation

KADK
IBD

Pixel eksperimenter / Pixel Experiments

Authors: Christina Augustesen & Kjell Yngve Petersen & Karin Søndergaard

Print: Eks-Skolens Trykkeri Aps

Layout: Vibeke Hjortskov Knudsen

Published by: The Royal Danish Academy of Fine Arts
Schools of Architecture, Design and Conservation

Partner: IT – University of Copenhagen

IT UNIVERSITY OF COPENHAGEN

Published 2015

ISBN: 978-87-7830-358-5

Pixel eksperimenter
Pixel Experiments

Architect and Lighting designer, MSc, Christina Augustesen, Grontmij, DK
Associate professor Kjell Yngve Petersen, IT-University
Associate professor Karin Søndergaard, KADK

The Royal Danish Academy of Fine Arts,
Schools of Architecture, Design and Conservation

IT UNIVERSITY OF COPENHAGEN

Pixel eksperimenter / Pixel Experiments

Tekst / Text Christina Augustesen & Kjell Yngve Petersen & Karin Søndergaard

Forsknings team / Research Team Christina Augustesen, Kjell Yngve Petersen, Ole Kristensen, Karin Søndergaard

Fotos / Photos Christina Augustesen

Video journalisme / Video Journalism Rina de Place Bjørn

video: www.itu.dk/pixelexperiments

Oversættelse / Translation Courtney D. Coyne-Jensen

Layout / Layout Vibeke Hjortskov Knudsen

Organisation og administrativ ledelse / Management Karin Søndergaard, Jens Overby, Kjell Yngve Petersen

Indhold Contents

Forord

Denne bog er en af fire bøger udgivet i forbindelse med forskningsprojektet *LEDlys; Interdiciplinær LED lysforskning*. Forskningsprojektet har været et treårigt samarbejde mellem Det kgl. Danske Kunstakademis skoler for Arkitektur, Design og Konservering, og IT-Universitetet i København.

Med LED-lyskilden (Light Emitting Diode) er der introduceret afgørende nye betingelser for belysningsområdet. Hvor lyskilder tidligere var konstante størrelser med fast definerede lysfarver og lysintensiteter, lancerer LED teknologien helt nye potentialer, hvor det er muligt at operere med komplekse forandringer af farvekvaliteter og lysintensiteter. LED er desuden konvertibel til digitale styringssystemer, hvilket betyder, at en betydelig del af designudviklingen i fremtiden vil foregå som software-design, og at kunstlyset fremover vil være potentielt dynamisk, intelligent og adaptivt. På grund af LEDens meget lille størrelse er der mange muligheder for integrering af lyskilder i materialer, bygningstrukturer og byrum. Alle disse forhold har stor indflydelse på udformningen af fremtidens design, arkitektur og IT infrastruktur. Der er derfor et udstrakt behov for nyudvikling af begrebslige defineringer, udvikling af planlægnings-strategier, og der er i høj grad brug for en udforskning og identifisering af nye æstetiske og kvalitative parametre i relation til LED. Projektet inddrager disse komplekse sammenhænge ud fra en særlig fokus på perceptuelle oplevelses parametre som organiserende designprincip.

Preface

This book is one of four books that is published in connection with the research project entitled *LED Lighting; Interdisciplinary LED Lighting Research*. The research project has been a three-year collaboration between The Royal Danish Academy of Fine Arts Schools of Architecture, Design and Conservation and The IT University of Copenhagen.

The LED (Light Emitting Diode) light source has introduced new, crucial conditions to the field of lighting design. Where light sources have previously been of uniform sizes with predefined colour temperatures and luminous intensities, LED technology brings forth totally new potentials, where it is possible to operate with complex changes in colourations and luminous intensities. LEDs are moreover convertible to digital control systems, which mean that a significant part of design developments in the future will occur in the form of software design, and that artificial lighting will continue to be potentially dynamic, intelligent, and adaptive. Because LEDs have a very small size, there are many opportunities for their integration into materials, building structures, as well as urban spaces. All these factors exert major influences on the shaping of future design, architecture, and IT infrastructure. Therefore, there exists an extensive need for new developments in conceptual delineations, the development of planning strategies, and – to an especially high degree – an exploration and identification of new aesthetic and qualitative parameters related to LEDs. This project engages these complex contexts and concerns via a specific focus on perceptual experiential parameters as an organising design principle.

Forskningsprojektet er opdelt i følgende tre skala områder:

Mikro skala, – hvor LEDen er forstået og undersøgt som del af et pixel system. Projektet udforsker hvilke kvaliteter LEDen potentielt tilfører belysningsapplikationer i arkitektonisk kontekst. Publikationen *Pixel Eksperimenter*, beskriver udførte eksperimenter og hvordan erfaringer fra disse test-opstillinger danner mulige strategier for design af belysningsapplikationer med LED.

Medium skala, – med en fokus på det arkitektoniske rum som lysarmatur. Disse praksis-baserede undersøgelser er opdelt i to foki. Den ene handler om integrering af dagslys og dynamisk kunstlys, som udfoldes i bogen *Integration af dagslys og dynamisk kunstlys undersøgt gennem et iagttagelsesinstrument*. Den anden – handler om undersøgelsen af rummet som lysende armatur og adaptive lyssituationer i test installationer. Undersøgelserne analyseres og diskuteres i bogen *Adaptivt lys*.

Makro skala, – med LEDlys som ny belysningskomponent i byrummet. Projektet arbejder med en mapping metode, hvormed byens oplevede belysning anskueliggøres i relation til den overordnede planlægning af gadebelysning. Projektet anvender København som case. Metoden belyses i bogen *På tværs af Københavns Gadebelysning 2014*.

I denne bog interesserer vi os for at identificere, hvordan LEDens kvaliteter kan anvendes i belysningsapplikationer. Med erfaring fra planlægning og implementering af arkitektonisk belysningsdesign i praksis, opleves et uudnyttet potentiale af LEDteknologiens kvaliteter. Der er gennemført spekulative undersøgelser med LEDens egenskaber i arkitektonisk kontekst, med ambitionen om at erfare nye strategier for brugen af LEDlys. De opstillede spekulative eksperimenter tydeliggør variabler, der kan benyttes som parametre i design af belysningsapplikationer, herunder f.eks. strukturering og styring. Eksperimenterne tydeliggør og eksemplificerer tillige allerede velkendte problematikker i forhold til oplevelsen af vertikal og horisontal belysning. *Pixel eksperimenterne* danner en synergi mellem spekulative test-opstillinger og lysdesign i praksis.

Karin Søndergaard

The research project is divided into the following three areas of scale:

Microscale, wherein LEDs are understood and studied as part of a pixel system. This project explores the qualities that LEDs can potentially add to lighting applications in architectural contexts. This publication, *Pixel Experiments*, describes executed experiments and how the lessons learned from these test setups form possible strategies for the design of lighting applications using LED.

Mezzo scale, with a focus on architectural space as a luminaire. These practice-based studies are divided into two foci. One concerns the integration of dynamic artificial lighting and daylight, which is unfolded is in the book called *An Exploration Into Integrating Daylight and Artificial Light via an Observational Instrument*. The second is about an inquiry of space as a luminous luminaire, as well as adaptive lighting situations in test installations. The studies are analysed and discussed in the book entitled *Adaptive Lighting*.

Macro scale, with LED lighting as a new lighting component in urban spaces. This project works with a mapping method in which the lighting experienced in the city is visualised in relation to the overall planning of the street lighting. The project uses Copenhagen as a case study. The method is illustrated in the book *Into a Mapping of Copenhagen Street Lighting 2014*.

In this book our interest has been in identifying how the qualities of LEDs can be used in lighting applications. With experiences in the planning and implementation of architectural lighting design in practice, one quickly experiences and realises that there are untapped potentials in the attributes of LED technology. In this research, speculative studies have been made working with the attributes of LEDs in architectural contexts, with the ambition to ascertain new strategies for using LED lighting in lighting design practice. The speculative experiments that have been set-up have aimed to clarify the variables that can be used as parameters in the design of lighting applications; including, for example, the structuring and software control of light. The experiments also elucidate and exemplify already well-known problems in relation to the experience of vertical and horizontal lighting. *Pixel Experiments* exist as a synergy between speculative test setups and lighting design in practice.

Karin Søndergaard

Fra pixel systemer til belysningsapplikationer med LED

Pixel
Pixel begrebet defineres traditionelt som en enhed ud af en større sammenhæng. Den har sin egen form, og er den mindste enhed – set i en større kontekst.
I arbejdet med LEDteknologiens potentiale er det interessant at bruge LEDen som det fysiske svar på en pixel. Med andre ord – at danne pixel konstellationer, hvor LEDen (eller en repræsentation af denne) fungerer som pixel-enhed, med dens kvaliteter og potentiale. Med en pixel-enhed der har LEDens egenskaber, opstår muligheden for at arbejde med en enkelt lysende enhed – én pixel, og ligeledes en pixel organisering – en konstellation af flere LEDer til en sammensætning af armaturer og lysende flader. Pixelen kan kendetegnes ved at have LEDens egenskaber. LEDens variable egenskaber muliggør dannelse af forskellige visuelle formationer, og der kan på denne måde tales om billeddannende kvaliteter.

Billeddannelse
Billeddannelse defineres i denne sammenhæng som en visuel repræsentation eller reproduktion af et objekts form eller dynamik. I forhold til arbejdet med LEDer som pixel enheder, er det netop pixel konstellationen af LEDer, der bestemmer, hvornår og hvordan en billeddannelse opstår. Pixel konstellationen definerer hvor relativ få og hvilke type pixels, der skal til for at opnå billeddannelse. I undersøgelserne er der fokus på hvilke af pixelens variable egenskaber, der virker billeddannende, og hvordan denne billeddannelse kan inspirere til design af belysningsapplikationer med LED.

Belysningsapplikationer
I designet af belysningsapplikationer viser de gennemførte eksperimenter, at struktureringen af pixels, deres belysningskarakteristik og styring, er afgørende for, hvordan belysningen opleves i en arkitektonisk kontekst. Publikationen illustrerer og beskriver udførte eksperimenter, og hvordan erfaringer fra disse test-opstillinger identificerer, skitserer og udvikler designstrategier til brug for belysningsapplikationer med LED. De visuelle eksperimenter er overordnede og har fokus på belysningsapplikationer i simple ruminstallationer. Applikationerne har sit fokus på belysning af vertikale flader (vægge) og horisontale flader (gulv). Der er naturligvis potentiale for at udføre eksperimenter, der belyser andre flader samt fritstående objekter, i andre mere komplekse kontekstuelle sammenhænge.

From Pixel Systems to Lighting Applications Using LEDs

Pixel

The term *pixel* is traditionally defined as any of the minute elements that together constitute a larger context or image. A pixel has its own form and is the smallest unit seen within a larger structure. In working with the potentials of LED technology in architectural lighting design it became relevant to investigate the use of LEDs as the physical equivalent of a pixel as a design approach. In other words, to form pixels constellations where a singular LED (or a representation thereof) serves as a pixel unit with all its qualities and potentials. Using a pixel unit that has the properties and potentials of an LED, the opportunities then arise to work with a single light emitting unit – one pixel – and also with an organisation of pixels, which can be seen as a constellation of multiple LEDs into a composition of luminaires and light emitting surfaces. The pixel in this investigation is thus characterised as having the attributes of an LED, where the variable properties enable the creation of different visual formations – and in this regard we can also speak of image forming qualities and potentials.

Image Formation

Image formation is defined in this context as a visual representation or reproduction of an object's form or dynamics. Compared to working with LEDs as individual pixel units, it is precisely an LED pixel constellation that determines when and how an image formation occurs. A pixel constellation defines how relatively few pixel structures and types promote image formations. In these investigations there is a focus on understanding which of the pixel's variable properties influence image formation and how this visual structuring can inspire the design of future lighting applications using LEDs.

Lighting Applications

In the design of lighting applications, the conducted experiments demonstrate that the structuring of pixels as well as their lighting characteristics and control are decisive to how lighting is experienced in architectural contexts. This publication illustrates and describes the experiments that were performed, and how the lessons learned from the test setups aid in identifying, outlining and developing design strategies for use in LED lighting applications. The visual experiments are general and focus on lighting applications in simple spatial installations. The applications concentrate on illuminating vertical surfaces (walls) and horizontal surfaces (the floor). There are obviously potentials to perform experiments that illuminate other surfaces and free-standing objects, and in other more complex contextual relations, but that lies outside the scope defining this project.

Pixel eksperimenter

Med baggrund i beskrevet indgangsvinkel til projektet, undersøges pixel-egenskaber som størrelse, indbyrdes afstand (pitch), intensitet, diffusitet og farvetemperatur. Det er pixel egenskaber og konstellationer, der danner basis for pixel eksperimenterne, men der drages samtidig en parallel mellem pixels - og belysningsarmaturer. Variable som strukturering, karakteristik, dimensionering og styring gælder således for pixels såvel som for belysningsarmaturer i arkitektonisk kontekst.

Disse egenskaber holdes op imod hinanden i komparative opstillinger opdelt i følgende variable:

• strukturering af pixels armaturer (grid/non-grid)
• belysningskarakteristik i form af pixel skarphed (skarp/uskarp) / armaturets belysningskarakteristik
• pixel armatur dimensionering (small/medium/large) og indbyrdes afstand (small/medium/large)
• software styring af pixel armaturer (statiske og dynamiske belysningssituationer)

Udvalgte motiver transformeret gennem et *undersøgelsesinstrument,* – en projektspecifik udviklet software vist på LCD skærme, repræsenterer og simulerer LED lys vist i pixel form. Softwaren gør det muligt at justere og teste ovenstående variabler, og hermed udforske hvordan strukturering af belysningslayout, belysningskarakteristika og dimensionering samt lysstyring, påvirker dannelsen af *lysaftegninger*, *lysvolumener* og *belysningsatmosfære*. Eksperimenterne er med til at tydeliggøre hvilke belysningsvariabler og dynamiske variationer, der har potentialer ved iscenesættelse af en arkitektonisk kontekst.

Pixel Experiments

Based on the aforementioned approach to this project, pixel properties such as size, spacing (pitch), intensity, diffusion, and colour temperature have been examined. The pixels' properties and constellations create a basis for the pixel experiments, but simultaneously a parallel is drawn between pixels and luminaries. Variables such as structuring, characteristics, sizing and control therefore apply not only to pixels but also to luminaries in architectural contexts as well.

Properties have been compared with one another in comparative setups, divided into the following variables:

• structuring of the pixels luminaires (grid/non-grid)
• lighting characteristics, pixel sharpness (sharper/blurrier) / the characteristics of the luminaires
• pixel luminaire sizing and spacing (both in terms of small/medium/large)
• software control of pixels luminaires (static and dynamic lighting situations)

Selected motifs have been transformed through the use of an *investigative instrument* – software was specifically developed for the project and displayed on LCD screens, representing and simulating LED illumination presented in pixel form. The software made it possible to adjust and test the above mentioned variables, and thus also to explore how the structuring of the lighting layouts, lighting characteristics, sizing, and lighting control, affect the formation of *lighting delineations*, *lighting volumes* and *lighting atmospheres*. The experiments are important in that they help clarify the lighting variables and dynamic variations that hold potentials in the staging of architectural contexts.

Lysaftegning, lysvolumen og belysningsatmosfære

Når der i denne publikation tales om iscenesættelse af arkitektonisk kontekst med belysning, er det med baggrund i følgende begrebsdefinition, som bruges til at præcisere redskaber og koncepter for arbejdet med arkitektonisk belysning: *lysaftegning, lysvolumener* og *belysningsatmosfære* (*fig.1*).

Lysaftegning forstås her som aftegning af belysning på en flade (der hvor lyset kommer til syne). *Lysaftegningen* kan opleves på vertikale og horisontale flader og kan således bekrives som vertikal belysning af f.eks. vægflader og horisontal belysning af f.eks. gulv flader. *Lysvolumener* forstås her som den volumen af lys, der skabes ved et eller flere armaturer, og som accentuerer en fysisk rumlighed. *Lysvolumenet* opleves som belysning af flere flader, objekter og mennesker og som en belysningsformation der opleves som en rumlighed. *Lysvolumenet* består dels af det direkte lys fra lyskilden/armaturet, dels af det reflekterede lys der opstår, når lyset rammer en flade og reflekteres. *Lysaftegning* og *lysvolumener* er en nuancering af begrebet *lysrum* (Madsen 2002), der beskrives som rumlige grupperinger af belysningsvariabler, der er væsentlige for oplevelsen af rummet. Belysningsvariabler forstås her som lysets formgivende karakteristika som; belysningsintensitet, retning, distribution og farve.

Lighting Delineations, Lighting Volumes and Lighting Atmospheres

When the writings and images in this publication speak about the staging of an architectural context using lighting, it is done with the following conceptual definitions noted below as a basis: *Lighting Delineations, Lighting Volumes* and *Lighting Atmospheres* (*Fig.1*). These have been used to specify the tools and concepts for working with architectural lighting.

Lighting delineations are understood here as a trace of light on a surface; there, where light comes into visibility A *lighting delineation* can be experienced on vertical or horizontal surfaces, and can thus be accordingly described as vertical lighting (e.g. on wall surfaces) and horizontal lighting (e.g. on floor surfaces). *Lighting volumes* are understood here as the volumetric formations of light that are generated by one or more luminaires, which accentuate a physical spatiality in a given space. A *lighting volume* can be experienced as the illumination of multiple surfaces, objects and/or people at the same time – and as a lighting formation experienced as a spatial presence. A *lighting volume* consists of the direct light from the light source/luminaire, as well as reflected light. *Lighting delineations* and *lighting volumes* can be understood to nuance the concept of *light-zone* (Madsen 2002); zones which are described as spatial groupings of lighting variables that are essential to the experience of a given space. Here, lighting variables are understood as light shaping character; as lighting's intensity, directionality, distribution, and colour.

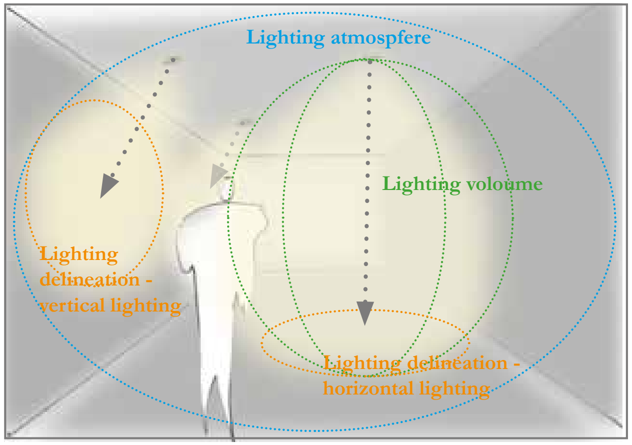


Fig. 1

Lysaftegninger og *lysvolumener* er med til at skabe en såkaldt *belysningsatmosfære*. Karakteren af en atmosfære er den måde, hvorpå den kommunikerer en følelse for os som deltagende subjekter (Böhme 2013). *Belysningsatmosfæren* forstås således her som måden hvorpå belysningsaftegninger og volumener er med til at sætte en stemning hos beskueren der opholder og bevæger sig i en arkitektonisk kontekst.

Den arkitektoniske belysning kan både opleves i statiske og dynamiske situationer.

- Statiske situationer, hvor beskueren opholder sig i en rumlighed med en statisk belysning.
- Dynamiske/statiske situationer, hvor beskueren bevæger sig, og hvor lyset er statisk.
- Dynamiske situationer, hvor lyset er dynamisk og hvor beskueren bevæger sig gennem *lysvolumener* mod andre og nye *lysaftegninger* og *lysvolumener,* der ligeledes kan have en statisk eller dynamisk belysningskarakter (*fig. 2*).

Lighting delineations and *lighting volumes* contribute to the creation of a so-called *lighting atmospheres*. The nature of an atmosphere (Böhme 2013) may be seen as the way that a space/place communicates a feeling to us as participating subjects. *Lighting atmospheres*, in the setting of this project, have been defined and understood as the way(s) that lighting's delineations and volumes help set a mood for the person(s) situated in and moving about a given architectural context (*Fig. 1*).

Architectural lighting is experienced in both static and dynamic situations alike. These can be described as followed:

• Static situations are when a person is situated statically in a spatiality with static lighting.
• Dynamic/static situations are when the person is moving, and the light is static.
• Dynamic situations are when the lighting is dynamic and the person also moves dynamically through *lighting volumes* towards others, and towards new *lighting delineations* and *lighting volumes* which also have a static or dynamic lighting character themselves (*Fig. 2*).

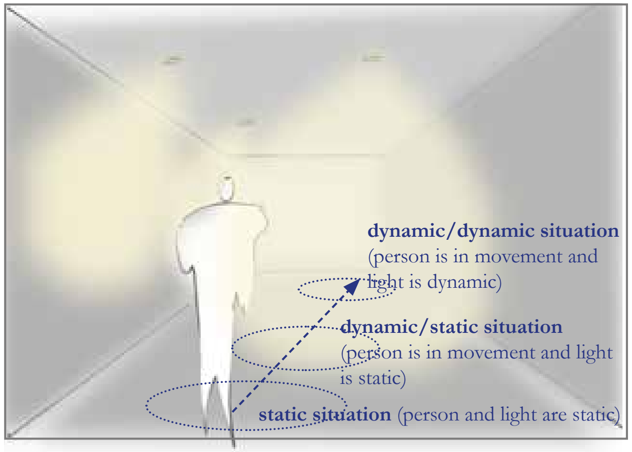


Fig. 2

Undersøgelsesinstrument

Til undersøgelsen af pixelformer og pixelorganisering benyttes et visuelt instrument. Det består af to identiske opsætninger med 55 tommer tv skærme på højkant, hvorpå der vises pixelformationer (*fig. 3*). For at kunne afprøve variationer i parallelle forløb af indstillinger, og således løbende kunne sammenligne oplevelsen af forskellige konfigurationer, arbejdes der med to opsætninger.

Skærmene er tilsluttet hver sin computer med specialdesignet software, som muliggør detaljerede indstillinger af pixelformationerne (*fig. 4*). De enkelte pixel og pixelfordelingen formes af følgende variable:

• dotSpacing indstiller afstanden mellem pixel
• dotRadius indstiller størrelsen af de enkelte pixel
• dotPositionNoiseScale indstiller graden af dis-organisering af pixels
• dotPositionNoiseAmount indstiller variationer af pixel konstellationer
• dotBrightnessFactor indstiller lysheden af de enkelte pixel
• blurStrength indstiller graden af sløring i pixelkanten
• blurGain indstiller hvor stort et område af pixelkanten der sløres

Investigative Instrument

A visual instrument was employed for the investigation of the forms and organisations of pixels . It consists of two identical setups, each using 55 inch television screens that are mounted vertically and which display the various pixel formations (*Fig. 3*). Two setups were used in order to be able to test out variations in parallel sequences of settings, and thus to be able to continually compare the experiences of the different configurations.

The screens were coupled to each computer using specially designed software that allowed detailed settings of the pixel formations (*Fig. 4*). The pixels and their distribution were shaped using the following variables:

• dotSpacing, which sets the distance between pixels
• dotRadius, which sets the size of each pixel
• dotPositionNoiseScale, which sets the degree of the disorganisation of the pixels
• dotPositionNoiseAmount, which sets the variations of pixel constellations
• dotBrightnessFactor , which sets the brightness of each pixel
• blurStrength, which sets the degree of blurring of the pixel edge
• blurGain, which sets how large an area of the pixel edge is blurred

Fig. 3

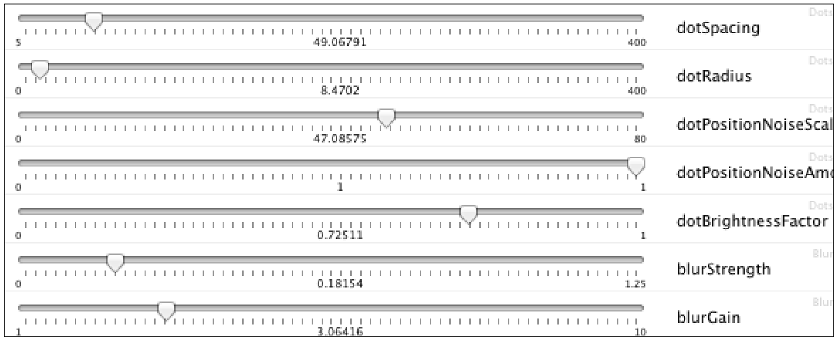


Fig. 4

Dis-organiseringen af pixelformationerne er genereret ved hjælp af Perlin Noise algoritmen (Perlin 1997), som er specielt designet til at udforme en tekstuel spredning i computergrafik, der er sammenlignelig med naturligt forekommende materialevariationer. Algoritmen giver adgang til at foretage graduerede indstillinger af pixelorganiseringen, hvor der samtidig bibeholdes en tekstuel fornemmelse af sammenhæng.

Det visuelle instrument er et skitseværktøj, hvor man intuitivt kan afprøve oplevelsen af forskellige pixelformer og pixelorganiseringer. Variationsmulighederne af pixelformationerne er designet ud fra oplevelseskvaliteter og holder sig således inden for en ramme af kvalitative skalaer, der er afstemt ud fra undersøgelsens formål om at undersøge distributionen af lyskilder i arkitektoniske rum.

Indholdet af lysfarver og lysintensiteter er styret af et bagvedliggende motiv (for eksempel et æble) eller en bagvedliggende video, live eller pre-recorded (for eksempel et gående menneske), som giver mulighed for at afprøve pixelorganiseringens indflydelse på forskellige lys og billeddannelser (*fig.5*).

The disorganisation of the pixels was generated by a Perlin Noise algorithm (Perlin 1997) that was specifically designed to develop a textual proliferation comparable to naturally occurring material variations in computer graphics. The algorithm allows one to perform graduated settings of the pixel organisations, where a textual sense of the context can be maintained at the same time.

The visual instrument can therefore be seen as a sketching tool with which one can intuitively test-out the experience of different pixel forms and pixel organisations.. The variations of the pixel formations consequently keep within a framework of qualitative scales and is designed based on experiential qualities, that are aligned with the inquiry's aim of investigating the distribution of light sources in architectural spaces.

In the instrument, the content of the colours of light and light intensities have been controlled by an underlying design (e.g. an apple), or an underlying video that was either pre-recorded or live-feed (e.g. a walking person), which in turn made it possible to test the influences of an organisation of pixels in different light and image formations (*Fig. 5*).

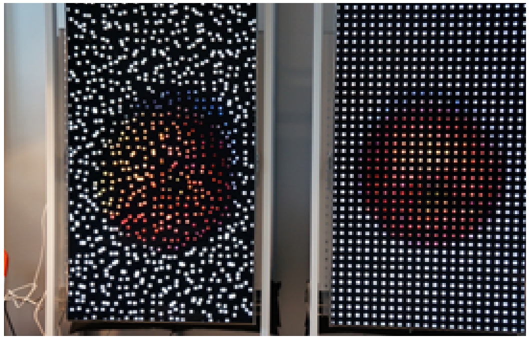


Fig. 5

Pixel eksperimenter - strukturering

Strukturering af lysende pixels/armaturer har betydning for, hvordan flader med integrerede armaturer opleves. Struktureringen af de lysende pixels/armaturer bør derfor indtænkes som designmæssige overvejelser i forhold til hvor og hvordan en flade belyses. I *pixel eksperimenterne* er det undersøgt, hvordan struktureringen af pixels/armaturer har indflydelse på oplevelsen af *lysaftegninger*, *lysvolumener* og *belysningsatmosfære*. Dette testes ved en iagttagelse af, hvornår der opstår forskellige lys/billeddannelser.

Der er anvendt komparative testopstillinger, som varierer i struktureringen af pixels i henholdsvis *grid* (kvadratisk grid med samme afstand mellem pixels i højde og bredde) og *non-grid* (dannet ud fra Perlin Noise allogoritmen). De komparative tests med grid/non-grid gengives i 3 variationer – hver med forskellige pixel dimensioner (small/medium/large). De lysende pixels er genereret ud fra et billede af en gående person.

Det opleves, at der ved en non-grid strukturering af de lysende pixels opstår en relativ naturtro billededannelse, med en tydeligere form/skygge tegning af motivet og en mere tre dimensional fremtoning (*fig. 7, 9, 11*) til sammenligning med samme motiv struktureret i et grid (*fig. 6, 8 10*). Ligeledes opnås der ved en non-grid strukturering flere farvenuancer og en graduering mellem forskellige farver/farvetemperaturer. I non-grid struktureringen opleves en mere uhomogen baggrundsstruktur og mere afvekslende og kontrastfulde luminansspring mellem lys og mørke (*fig. 7, 9, 11*). Man oplever tilsvarende i alle tre variationer af pixel størrelser.

Pixel Experiments - Structuring

The structuring of illuminating pixels/luminaires affects how surfaces with integrated luminaires are experienced. The structuring of illuminating pixels/luminaires should therefore be included as design considerations in relation to where and how a surface is illuminated. In these *Pixel Experiments*, we have investigated the ways that the structuring of illuminating pixels/luminaires impacts the experience of *lighting delineations*, *lighting volumes* and *lighting atmospheres*. This has been tested by observing and analysing when different lighting and image formations emerge.

Comparative test setups have been used, which differ in their structuring of the pixels; differing between *grid* (a square grid having the same distance between the pixels in height and width), and *non-grid* (formed by using the Perlin Noise algorithm). The comparative tests using grid/non-grid structurings were conducted in three variations, with each using different pixel sizes (small/medium/large). And the illuminating pixels were generated from an image of a person walking.

Using a non-grid structuring of illuminating pixels, one experiences a rather lifelike image formation that is characterised by a sharper form, clearer shading of the subject and also a more three dimensional appearance (*Fig. 7, 9, 11*) in comparison to the same motif using a grid structuring (*Fig. 6, 8, 10*). Likewise, using a non-grid structuring several colour shades and a gradation between colours and colour temperatures are achieved. In a non-grid structuring, one experiences a more heterogeneous background structure, as well as a more varying and contrasting spring in luminance between light and dark (F*ig. 7, 9, 11*). Moreover, one experiences similarities in all three pixel size variations.

Fig. 6

Fig. 7

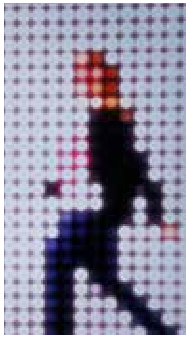


Fig. 8

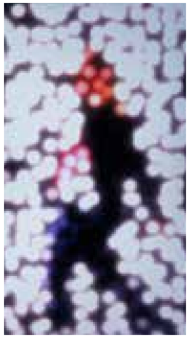


Fig. 9

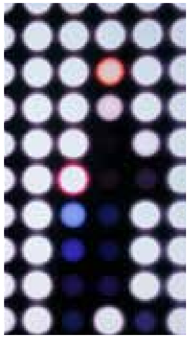


Fig. 10

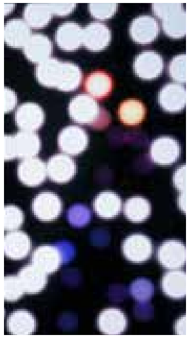


Fig. 11

Fig. 6

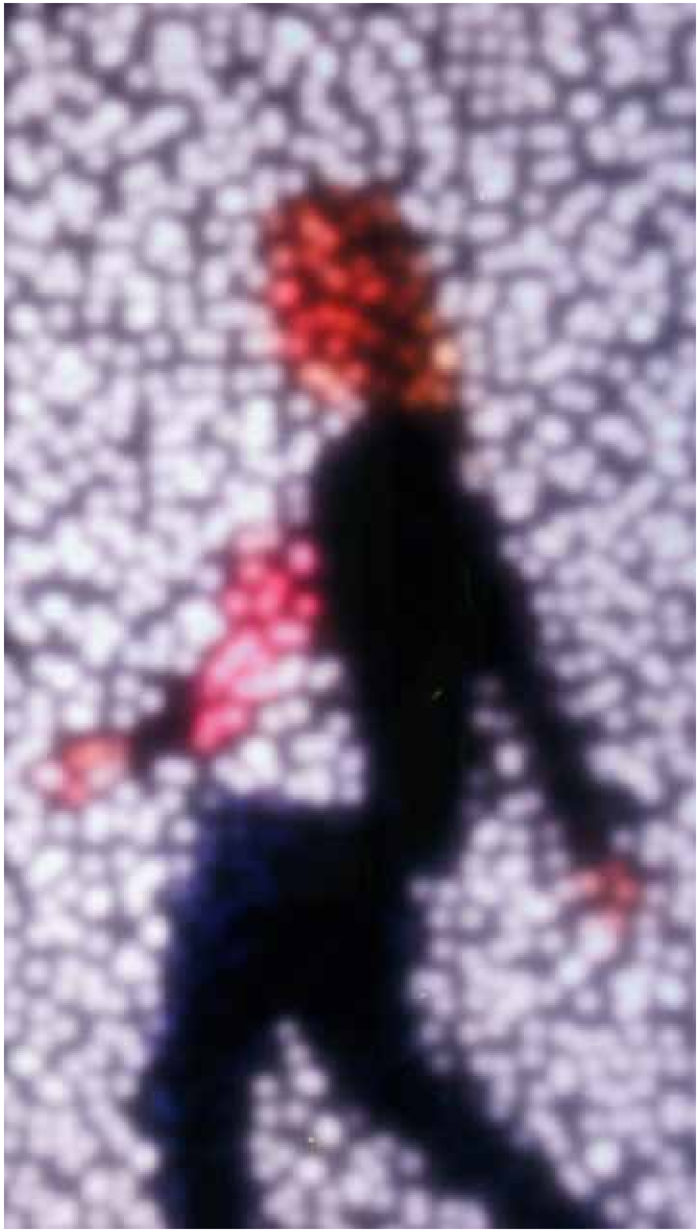


Fig. 7

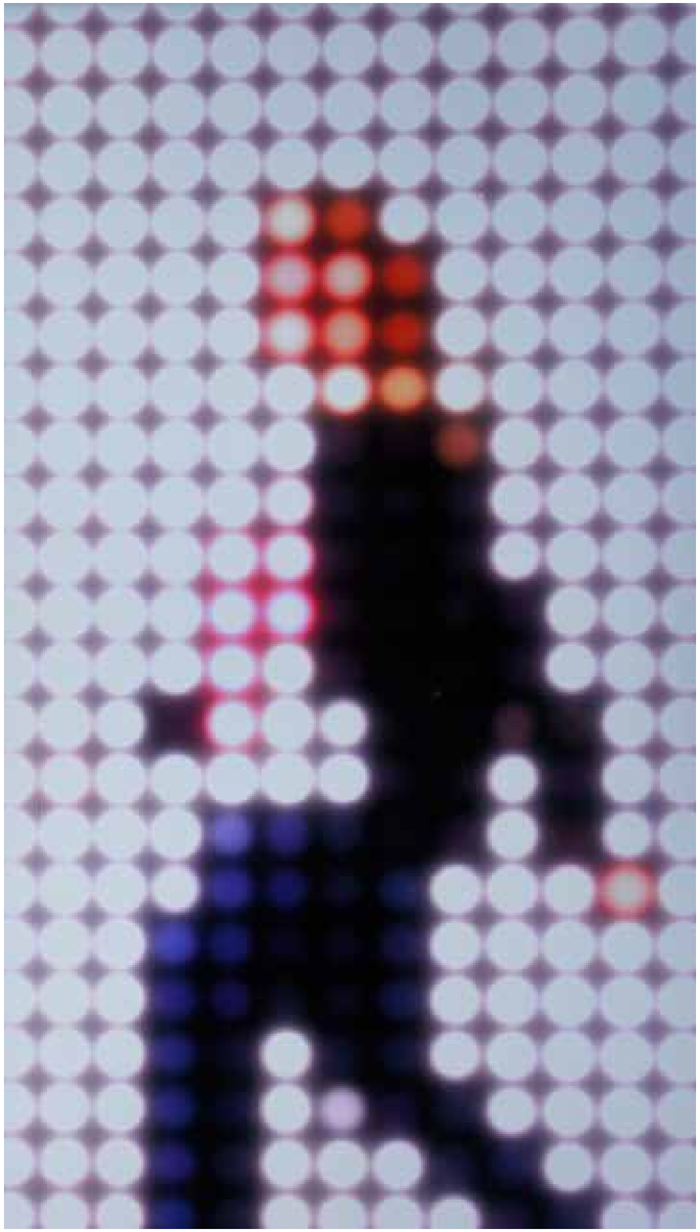


Fig. 8

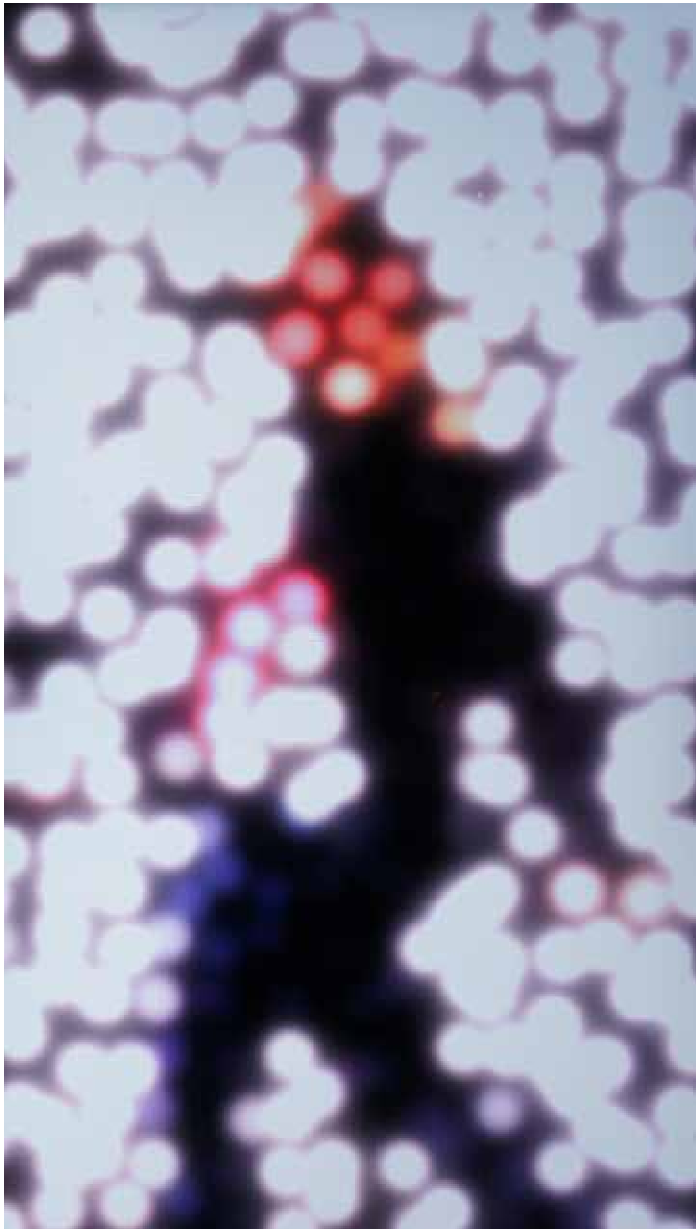


Fig. 9

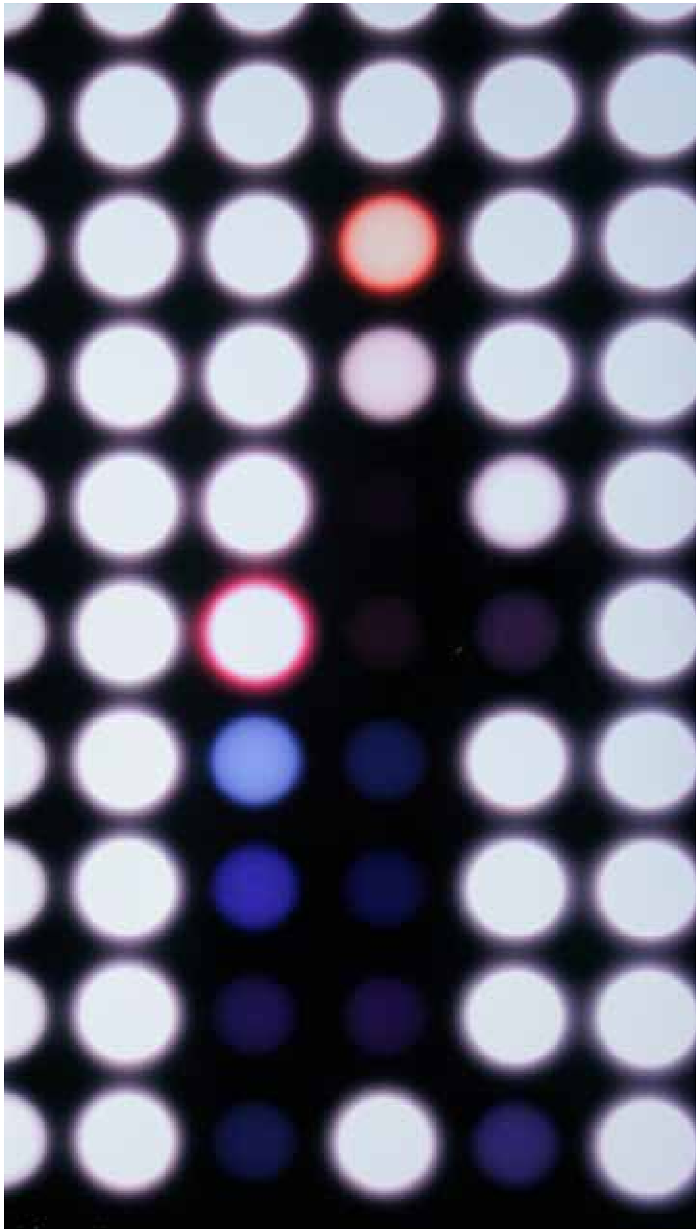


Fig. 10

Fig. 11

Pixel eksperimenter - belysningskarakteristik

Lysets fordelingskarakteristik har betydning for, hvordan lyset kommer til syne på en flade og i et rum. I *pixel eksperimenterne* er det identificeret, skitseret og udviklet hvordan belysningskarakteristika som rettet og diffust lys har indflydelse på oplevelsen af *lysaftegninger* og *lysvolumener*. Dette er undersøgt ved en iagttagelse af, hvornår der opstår forskellige lys og billededannelser ved henholdsvis skarpe og uskarpe lysende pixels. De komparative tests med skarpe/uskarpe lysende pixels gengives i 2 variationer – begge i en høj pixel opløsning, med henholdsvis en grid og en non-grid struktur og med graduering i lyset fra rettet til diffust lys (skarp/uskarp). De lysende pixels er genereret ud fra et billede af en gående person.

Det diffuse lys skaber *lysaftegninger* med en uskarp kant, hvormed de enkelte *lysaftegninger* forenes til en samlende lysende flade og i visse tilfælde producerer en billededannelse (*fig.16, 21*).

I en applikation med rettet lys skabes en klar aftegning af lysets kegle, og lyset producerer enkeltstående *lysaftegninger* – som fragmenter i en større sammenhæng (*fig. 12, 17*).

Diffust lys i en grid struktur producerer en mere jævn belysning sammenlignet med diffust lys i en non-grid struktur. Når dette princip anvendes som belysning på vertikale flader, dannes der en homogen iscenesættelse af en flade, som rumligt betragtet skaber perspektiv (*fig. 16*).

Anvendes diffust lys i en non-grid struktur på horisontale flader (f.eks. gulv), skabes en variation hen over fladen og dermed opleves en variation i lyset, når en beskuer bevæger sig gennem rummet.

Pixels Experiments - Lighting Characteristics

Lighting's distribution characteristics affect how light appears on surfaces and in space. The *Pixel Experiments* have identified, sketched and developed the ways that lighting characteristics, such as directed and diffuse light, influence one's experiences of *lighting delineations* and *lighting volumes*. This has been probed by observing when different light and image formations emerge in a spectrum between sharper and blurrier illuminating pixels. The comparative tests using sharper/blurrier illuminating pixels were devised in two variations using a high pixel resolution in one grid structuring and one non-grid structuring, and having an illumination gradation from directed to diffuse light. As noted prior, the illuminating pixels were generated from an image of a person walking.

The diffuse light creates *lighting delineations* with blurry edges, in which each individual *lighting delineation* is unified into a collective luminous surface and which in some cases also produces an image formation (*Fig. 16, 21*).

In an application using directed light, a clear delineation of the light beam and the illumination can be seen to produce singular *lighting delineations* – as fragments within a larger field (*Fig. 12, 17*).

Diffuse light in a grid structuring can be seen to produce a more even illumination compared to diffuse light in a non-grid structuring. When this principle is used as lighting on vertical surfaces a homogeneous staging of a surface is formed, which – seen spatially – establishes perspectival depth (*Fig. 16*).

When diffuse light is employed in a non-grid structuring on horizontal surfaces (e.g. a floor), it creates a variation over the surface and hence also a variation in the light when a viewing person moves through the space.

Pixel konstellation i grid struktur, i relativ høj opløsning, med graduering i lyset fra rettet til diffust lys (skarp/uskarp)

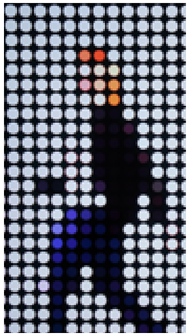


Fig. 12

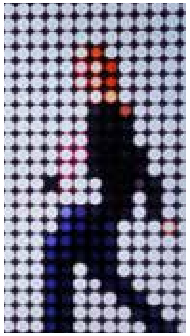


Fig. 13

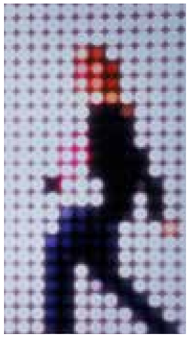


Fig. 14

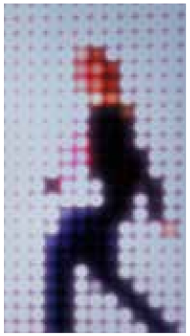


Fig. 15

Fig. 16

Pixel constellation in a non-grid structure, with a relative high resolution, graduating from directed to diffuse light (sharp/blurry)

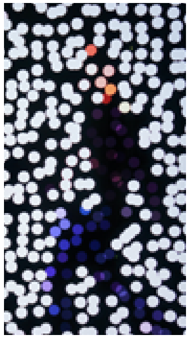


Fig. 17

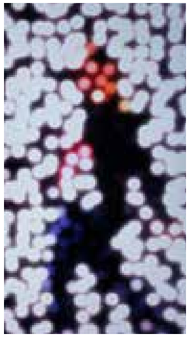


Fig. 18

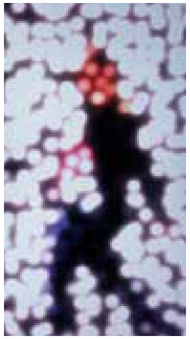


Fig. 19

Fig. 20

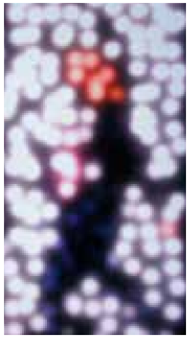


Fig. 21

Fig. 12

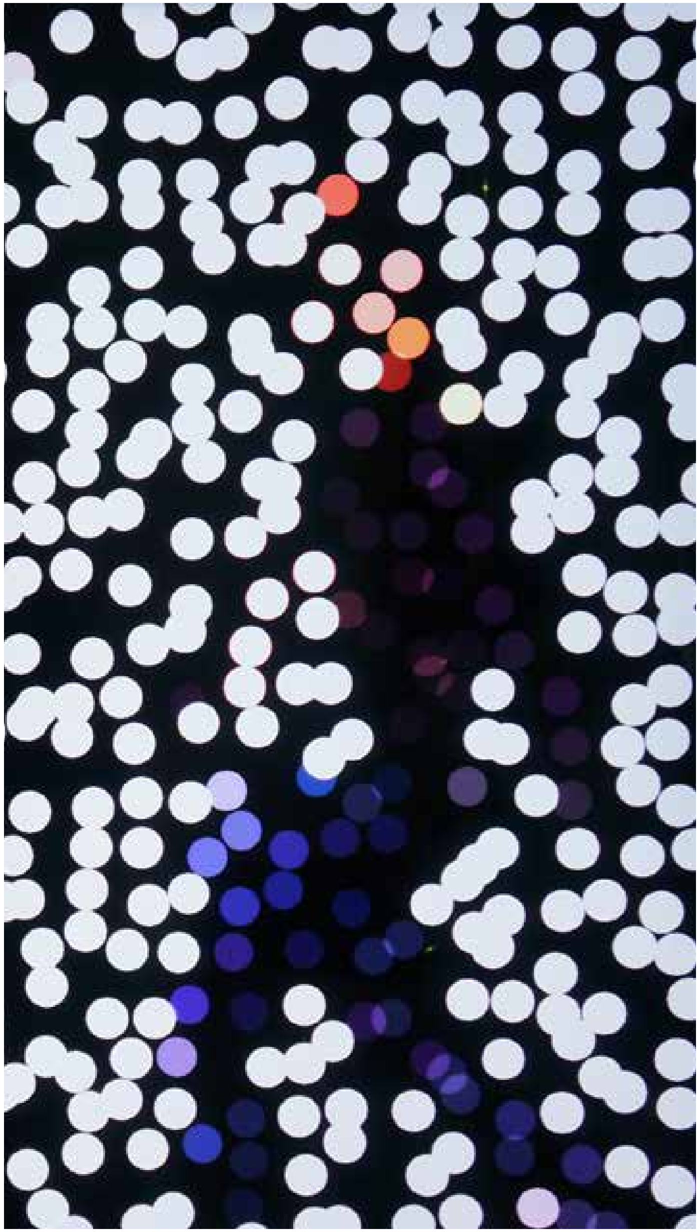


Fig. 17

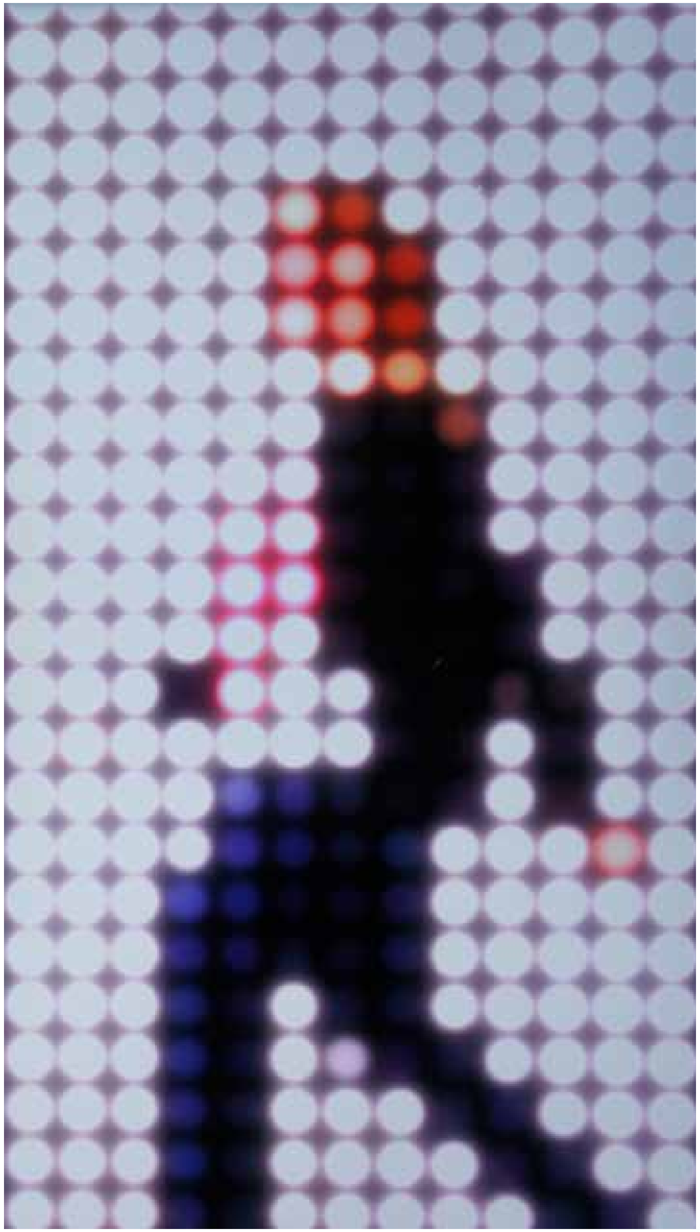


Fig. 14

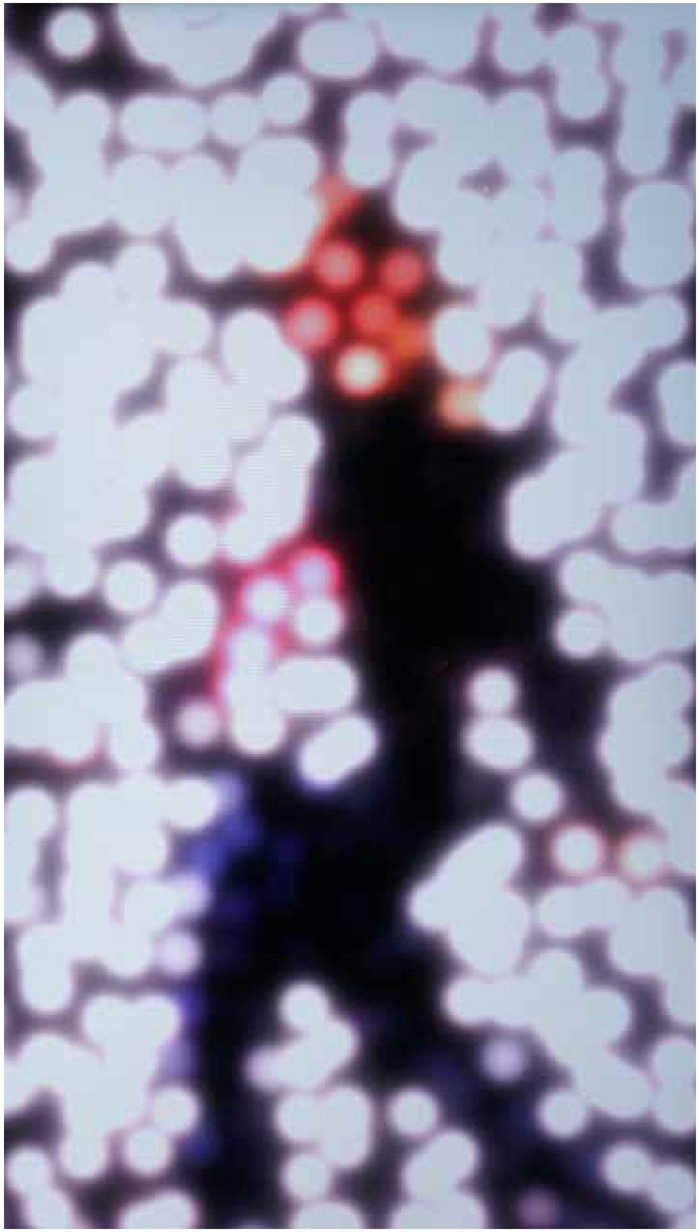


Fig. 19

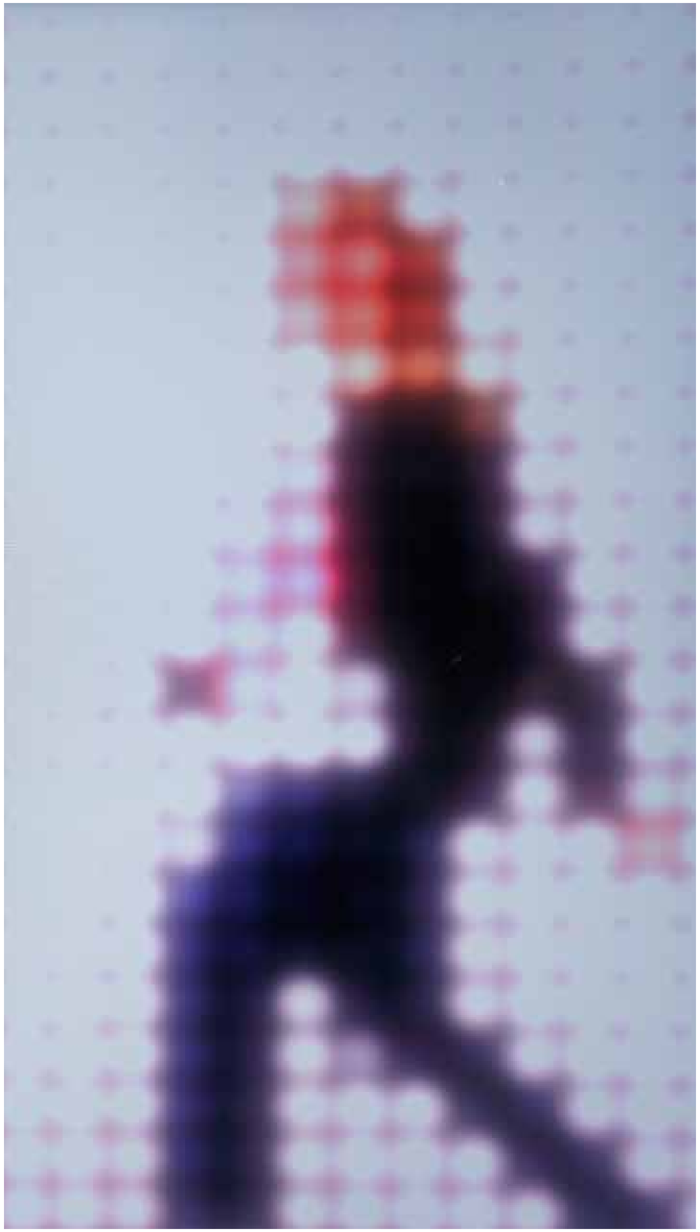


Fig. 16

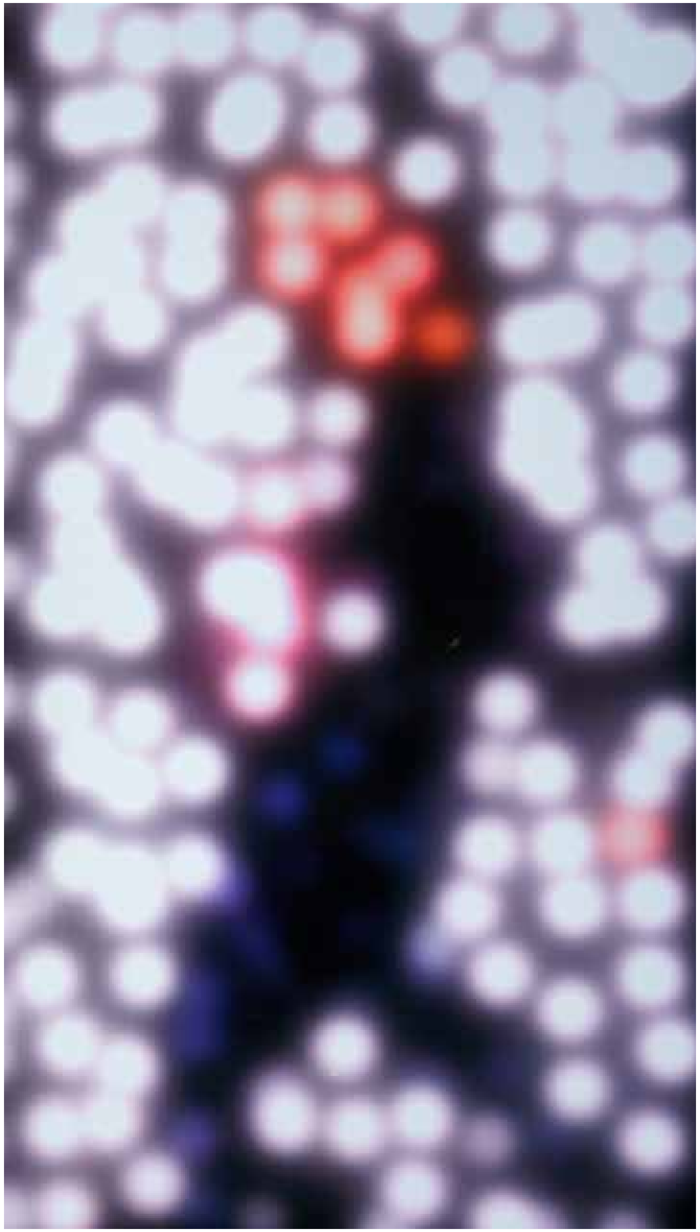


Fig. 21

Pixel eksperimenter - dimensionering

Dimensionering af lysende pixels/armaturer og deres indbyrdes afstand har betydning for om belysningen opleves som fragmenter eller som en lysende helhed. Dette er testet ved at iagttage, hvornår der opstår forskellige lys/billededannelser ved henholdsvis store/mellem/små størrelse pixels, gengivet henholdsvis i skarpe/uskarpe lysende pixels, struktureret i henholdsvis grid/non-grid. De lysende pixels er genereret ud fra et billede af en gående person.

De uskarpe lysende pixels smelter nemmere sammen til en lysende flade uafhængigt af pixel størrelse i sammenligning med lysende pixels med skarp *lysaftegning*. Lysende pixels med skarp *lysaftegning* smelter sammen til en lysende enhed, når de er små, og der er relativt mange af dem.

Højopløste formationer opstår i applikationer med mange små pixels placeret relativt tæt, hvor disse visuelt forenes til en lysende helhed (*fig. 25*). I applikationer med større pixels vil disse opleves som selvstændige lysende aftegninger (*fig. 27*). Opfattelsen af pixel størrelse og billedopløsning hænger ligeledes sammen med beskuerens afstand til den lysende flade. Jo større afstand fra beskuer til lysende flade, jo mindre opleves de lysende pixels som enkelte punkter, og jo højere opløst virker billeddannelsen.

Pixel Experiments - Sizing

The sizing of illuminating pixels, such as luminaires, and their spacings are relevant to determining if the lighting will be experienced as fragments or as a luminous whole. This has been tested by observing when different light and image formations emerge; respectively by large/medium/small sized pixels, and reiterated in sharper/blurrier illuminating pixels, structured as grid/non-grid respectively. As mentioned before, the illuminating pixels are generated from an image of a walking person.

In comparison to illuminating pixel that have sharper *lighting delineations*, blurrier illuminating pixels visually appear to more easily melt into a luminous surface, independent of pixel size. Furthermore, illuminating pixels with sharper *lighting delineations* appear to merge into a luminous totality when they are small and when there are relatively many of them.

Highly indistinct image formations arise in lighting applications using many small pixels of light that are located fairly closely to one another, in which these pixels then become visually united into a luminous whole (*Fig.25*). In applications using large illuminating pixel, these pixels will be perceived as independent lighting delineations (*Fig. 27*). The perception of pixel size and image resolution is also related to the distance between a person and the illuminating surface: the greater the distance is between the two, the less the illuminating pixels are experienced as individual pixels and the image formation will appear more indistinct.

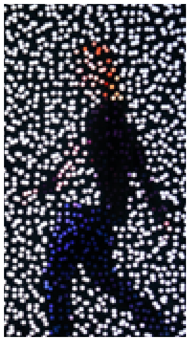


Fig. 22

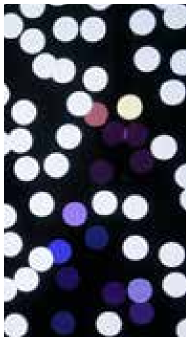


Fig. 23

Fig. 24

Fig. 25

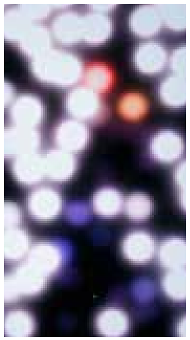


Fig. 26

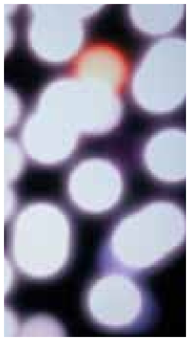
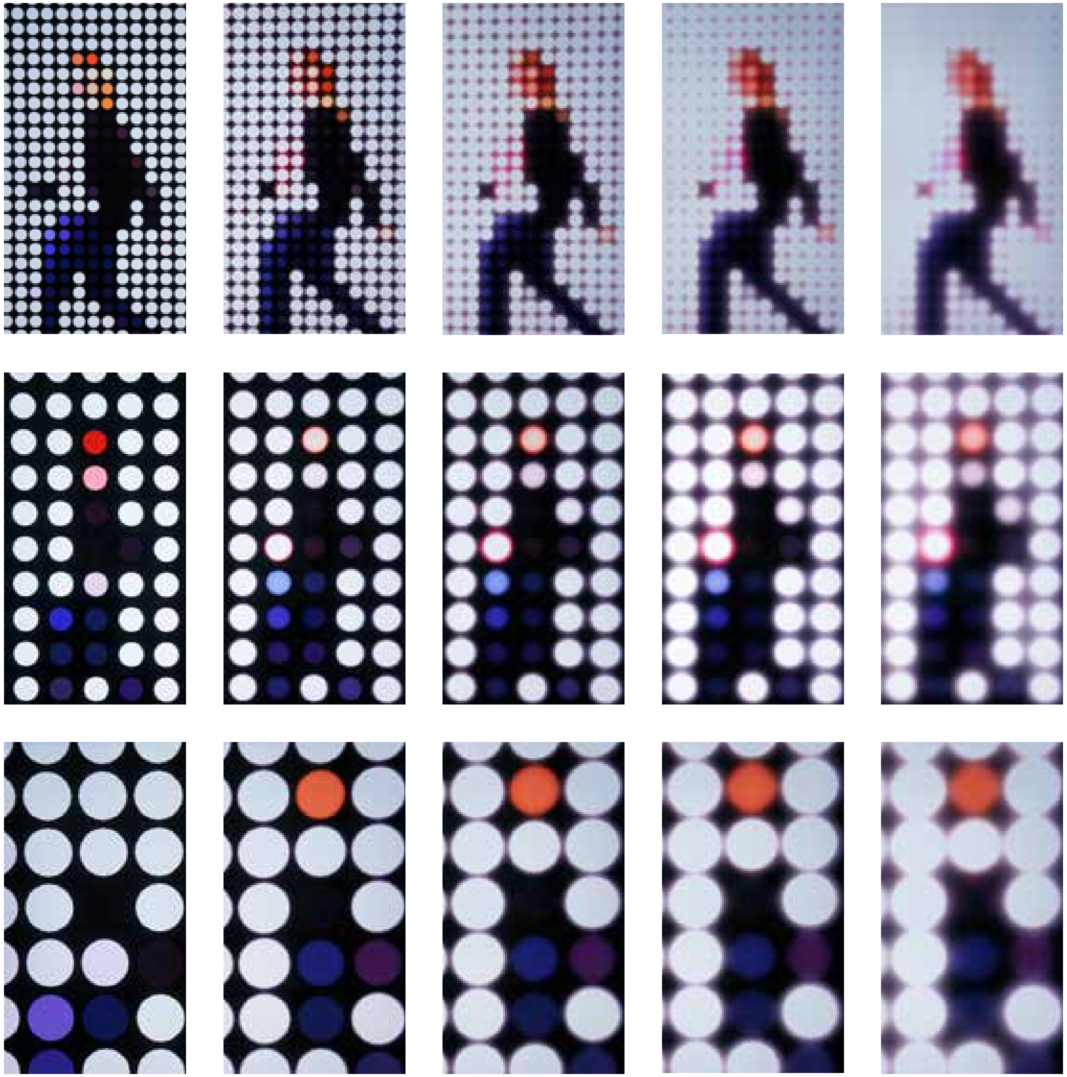
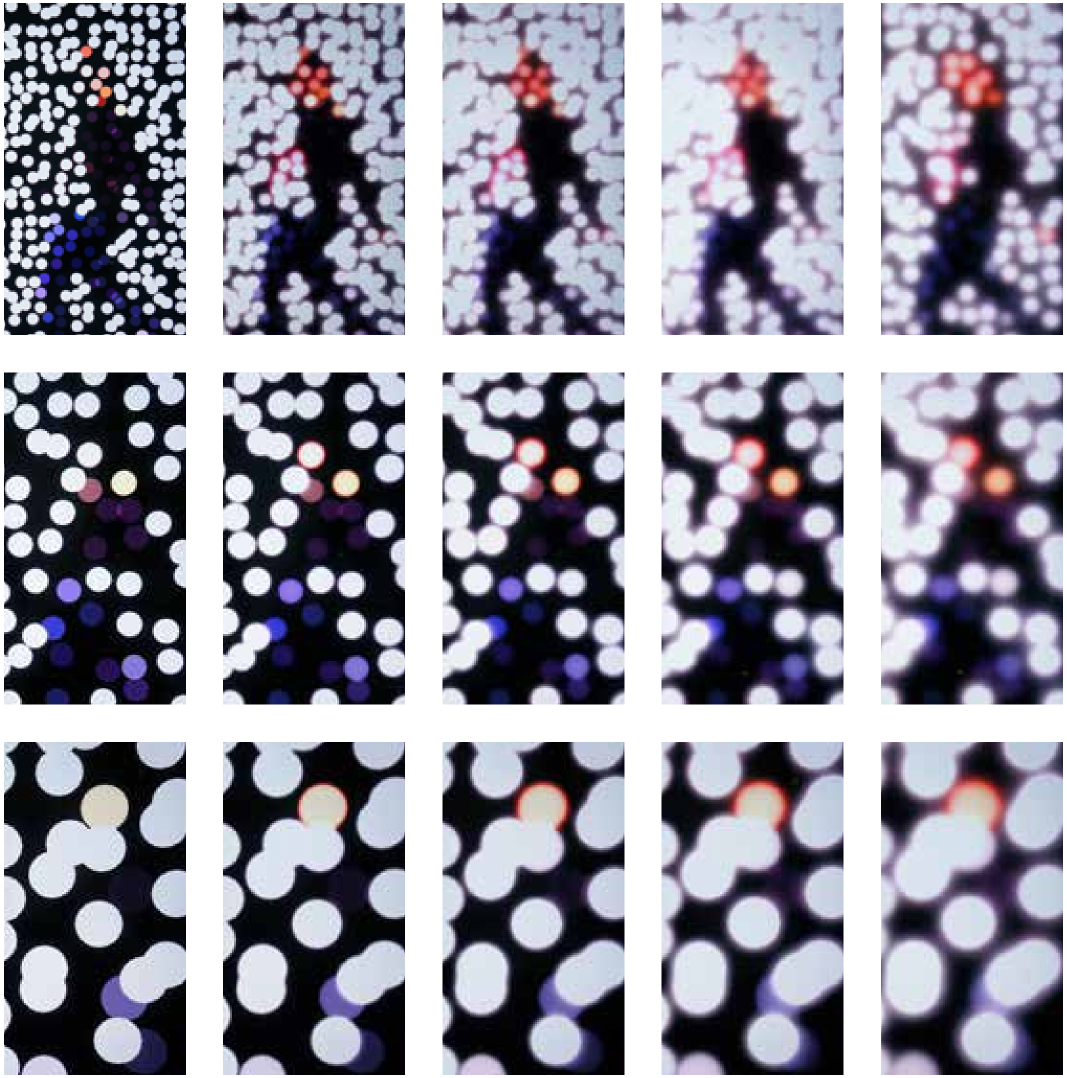


Fig. 27

Eksperimentet tydeliggør, at uskarpe lysende pixels opleves mere lysende til sammenligning med skarpt aftegnede lysende pixels. Dette betyder, at man i en belysnings applikation vil opleve uskarpe lysende pixels påvirke den visuelle komfort negativt, til sammenligning med skarpt aftegnede pixels, som fremstår mindre kontrastfulde. Ligeledes vil lysende pixels fremstå tydeligere i en konstellation, hvor der er færre lysende pixels og dermed en mere mørk baggrund, da der her opstår en større luminanskontrast. For optimal visuel komfort er det relevant at finde den rette balance og det rette hierarki for hver enkelt belysningsapplikation i relation til luminans og kontrast forhold, belysningskarakteristik som diffust/rettet lys, lysfarver og kombinationer af vertikal og horisontal belysning.

This experiment may be seen to expound the fact that blurry illuminating pixel appear brighter when likened to sharply defined illuminating pixels. This means that in a lighting application one will experience that blurry illuminating pixels have a negative effect on visual comfort, comparative to sharply-defined illuminating pixels that appear with less contrast. Similarly, illuminating pixels will appear clearer in a constellation consisting of fewer illuminating pixels and thus also having a darker background, because in such an application a greater luminance contrast arises. For optimum visual comfort, it is essential to find the proper balance and the correct hierarchy for each lighting application in relation to the luminance and contrast ratio, the lighting characteristics for diffuse and directed light, the colours of light, and the combinations of vertical and horizontal lighting.





Pixel eksperimenter - styring

Styringen af belysningsapplikationer muliggør en fleksibilitet og variation af belysningen tilpasset funktionelle, æstetiske og visuelle behov. Variabler som belysnings-intensitet, farve og retning, samt disses *lysaftegninger* på vertikale og horisontale flader, og dannelse af *lysvolumener* kan styres og koordineres gennem styringssoftware.

I *pixel eksperimenterne* undersøges lyset respektivt i en statisk og en dynamisk situation. De statiske situationer genereres af bagved liggende billeder. De dynamiske situationer genereres fra videoklip eller live-feed fra kamera. De illustrerede eksperimenter viser 3 x 2 momenter fra videoklip med pixel konstellationer i bevægelse i henholdsvis en grid og non-grid struktur, hvor der i begge udsnit slukkes 2 pixels (se markering på *fig. 28, 29, 30, 31*). Ligeledes vises samme pixelkonstellation i henholdsvis skarp og uskarp tilstand.

Pixel Experiments - Control

The control of lighting applications enables flexibility and variation in lighting adaptations related to function, aesthetics, and visual requirements alike. Variables such as the lighting's intensity, colour and directionality – as well as the *lighting delineations* on the vertical and horizontal surfaces and the creation of *lighting volumes* – can be managed and coordinated through control software.

In the *Pixel Experiments*, illumination has been studied in both static and dynamic situations. The static situations were generated using underlying images. And the dynamic situations were generated from video clips and as live-feed from a video camera. The illustrated experiments depict 3 x 2 moments from video clips using pixel constellations set in motion in grid and non-grid structurings respectively, where in both sections two pixels were switched off. (See the highlighted area in *Fig. 28, 29, 30, 31*). Also shown are the same pixel constellations, seen as blurry and sharp correspondingly.

Ved belysningsstyring af en non-grid struktureret belysningsapplikation (*fig. 28, 29*) vil skiftet i lysintensitet og antal pixels opleves mindre tydeligt end ved en grid struktureret applikation (*fig. 30, 31*).

I en non-grid applikation er det muligt at styre belysningen af flere lysende pixels på samme tid, uden at der opleves en stor kontrast, da der i forvejen opleves en variation i de eksisterende lysdannelser (*fig. 28, 29*).

I en grid struktur vil en ændring af en lysende pixel opfattes tydeligere, da der opleves en forandring i en allerede registreret orden og ligeledes en ændring i kontrastforhold. Den mørkere baggrund vil træde tydeligere frem i en gridstruktur, og lysstyringen vil opleves tydeligere (*fig. 30, 31*).

Applikationens belysningskarakter har ligeledes betydning for hvordan styringen af lyset opleves. Styringen af det rettede lys vil opleves tydeligere end styring af diffust lys, kva en lavere kontrast-overgang mellem et diffust lys og en mørk bagrund – sammenlignet med et rettet lys og en mørk baggrund (*fig. 32, 33*).

For lighting control of a lighting application using a non-grid structuring (*Fig. 28, 29*), the changes in the light intensity and the number of pixels will be perceived less clearly than in an application using a grid structuring (*Fig. 30, 31*).

In a non-grid application it is possible to control the lighting of several illuminating pixel at the same time without experiencing high contrast, since one already experiences variation in the existing light formations (*Fig. 28, 29*).

In a grid structuring, a change in an illuminating pixel will be perceived more clearly because one experiences a transformation in an already registered order and also change in the contrast ratio. A darker background becomes more apparent in a grid structuring, and the control of the light is perceived more distinctly (*Fig. 30, 31*).

An application's lighting characteristics also affects how the control of the light will be experienced. The control of directed light will be more clearly perceived than the control of diffuse light due to a lower contrast transition between diffuse light and a dark background – comparative to directed light and a dark background. (*Fig. 32, 33*).

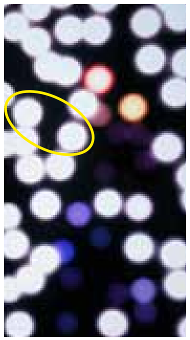


Fig. 28

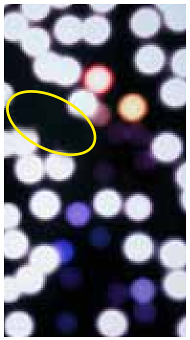


Fig. 29

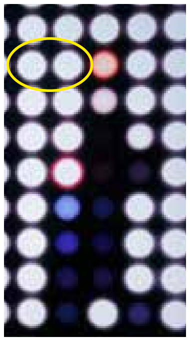


Fig. 30

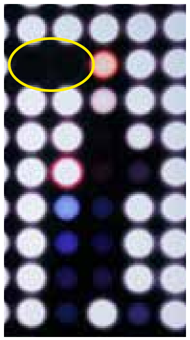


Fig. 31

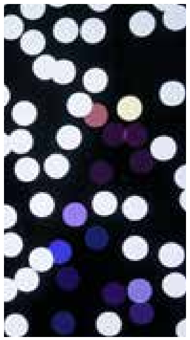


Fig. 32

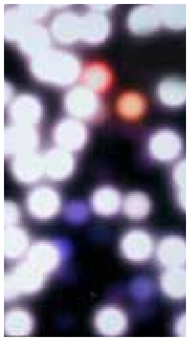


Fig. 33

Fig. 28

Fig. 29

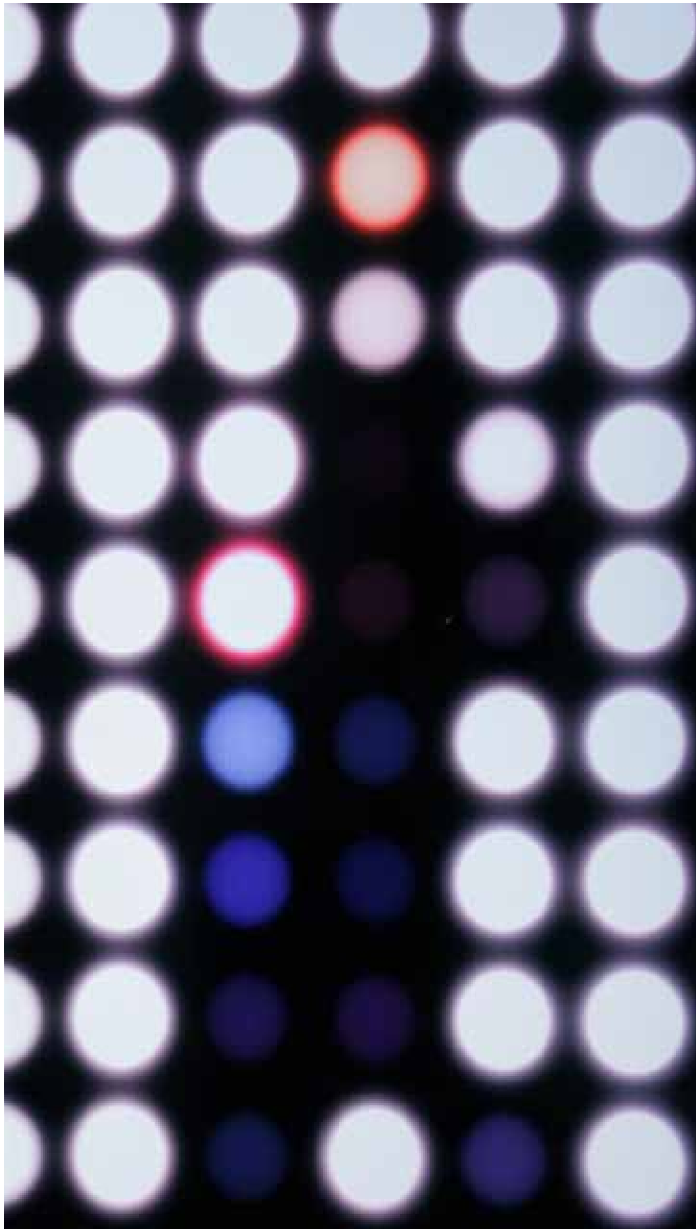


Fig. 30

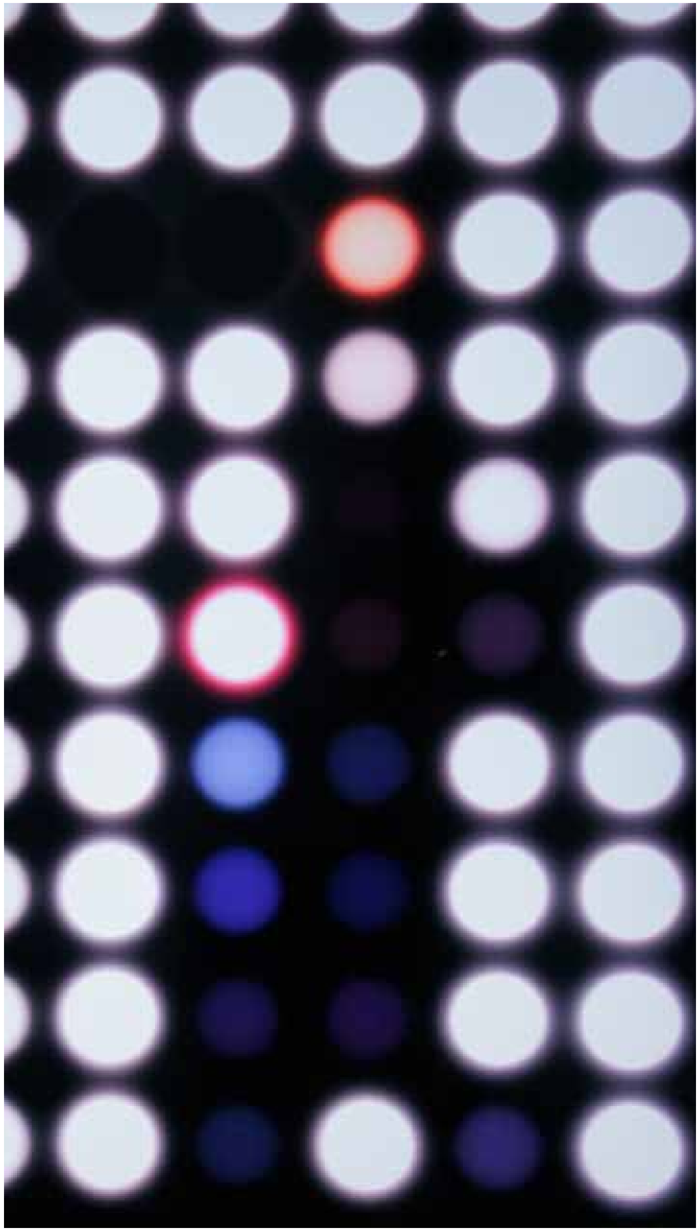


Fig. 31

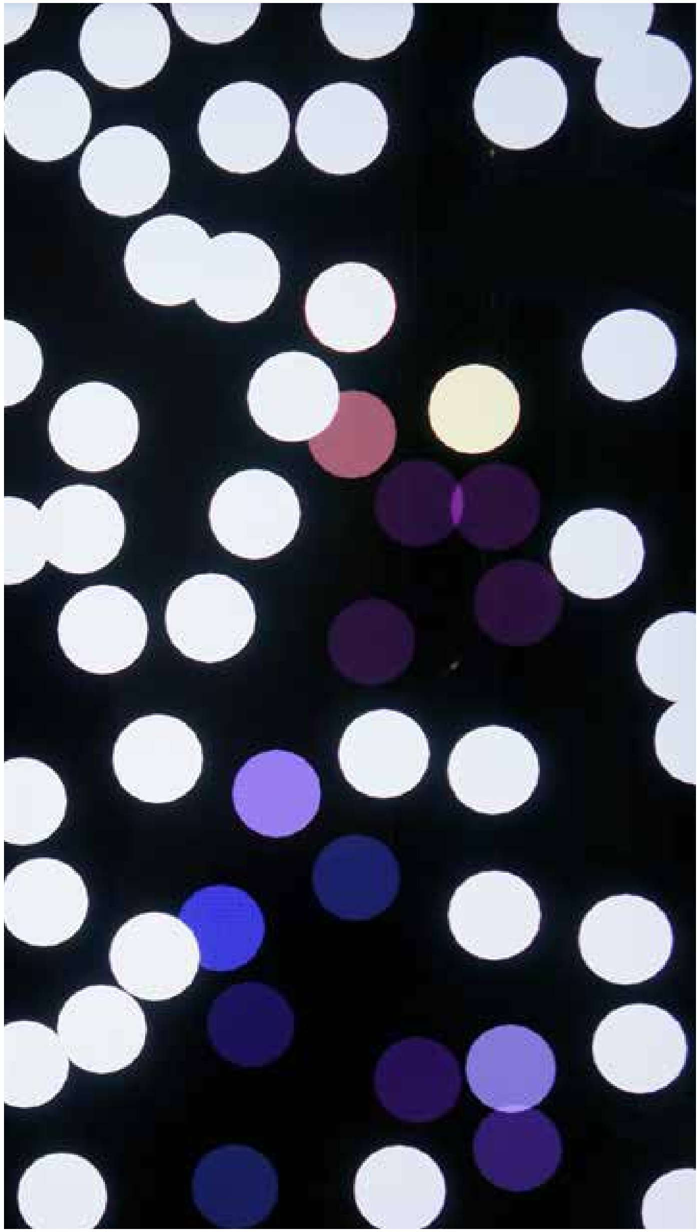


Fig. 32

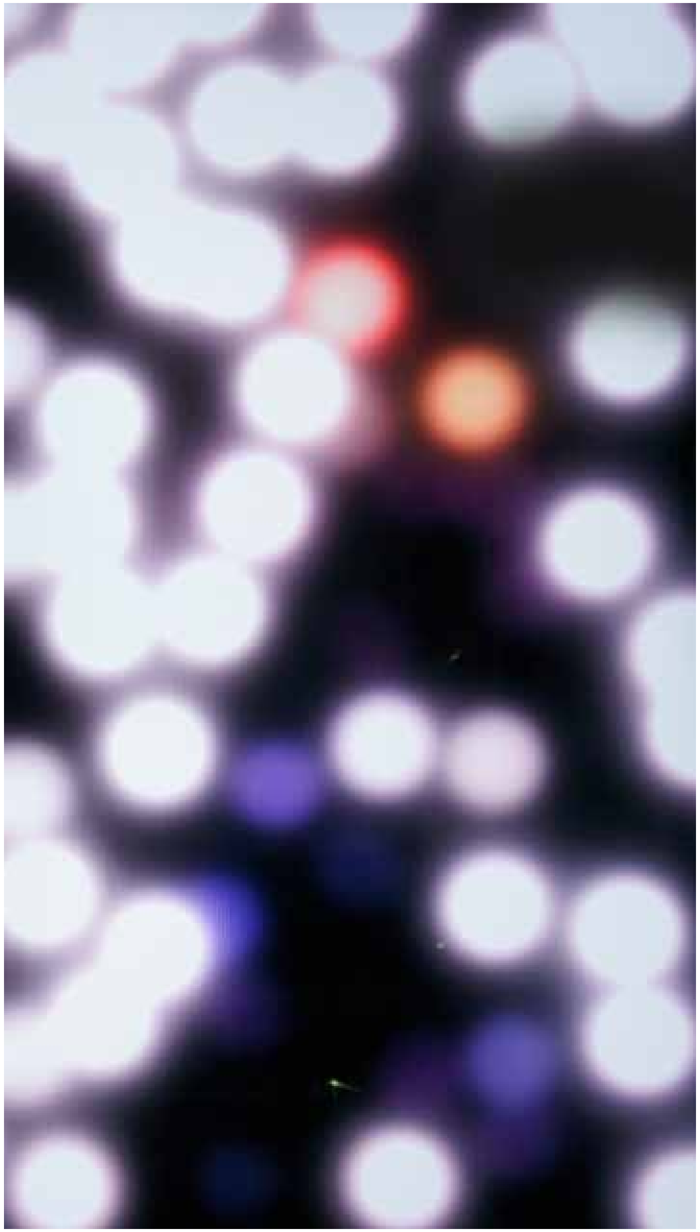


Fig. 33

I *pixel eksperimentet* testes video, transformeret til pixel konstellation på to skærme. Fig. 35 viser forskellige momenter fra video af en person i bevægelse, og fig. 34 viser et statisk billede af samme person. Alle billederne er fotograferet fra samme position, 2 meter fra skærm. Eksperimenterne undersøger, hvordan der sker en billeddannelse ved brug af færre pixels ved en dynamisk pixel konstellation, hvor pixel intensitet og placering ændrer sig (som i en video) sammenlignet med en stationær pixel konstellation.

Pixel eksperimenterne anskueliggør, at form og formens reference er afgørende for, hvordan billeddannelse opstår, lige som antallet af pixels er afgørende for billeddannelsen. Ydermere tydeliggør eksperimenterne, at billeddannelse opstår afhængig af om billedformationerne er statiske, dynamiske eller statiske/dynamiske. Ligeledes kan det konstateres, at hvis formen (i dette tilfælde en gående person) gengives fra en vinkel, hvor den er let genkendelig, kan billededannelse opstå ved brug af færre pixels. Endvidere ses det, at billededannelsen forsvinder ved en meget lav pixelopløsning, da pixels begynder at fremstå som enheder, – modsat ved højere opløsning, hvor pixels opfattes som dele af en helhed.

As noted previously, the *Pixel Experiments* transformed videos into pixel constellation on two screens. Fig. 35 shows different moments from the video of a person in motion, whilst Fig. 34 shows a static image of the same person. All images are photographed from the same position: a two meter distance from the screens. These experiments have investigated the ways that image formations emerge when using fewer pixels in a dynamic pixel constellation wherein the pixels' intensities and positions change (as in a video), comparative to a stationary pixel constellation.

The *Pixel Experiments* show how forms and its references are decisive to determining when image formations will emerge, as well as to when they will emerge in relation to a set number of pixels. The experiments similarly clarify when image formations will emerge depending on whether they are static, dynamic, or static/dynamic. This project also shows that if a form (in this case, a person walking) is reproduced from an angle where the form is easily recognisable then image formation can occur when using fewer pixels. Furthermore, one can see that image formations disappears with very low pixel resolution because the pixels start to appear as units opposite a higher resolution in which pixels are perceived as parts of a whole.

Fig. 34

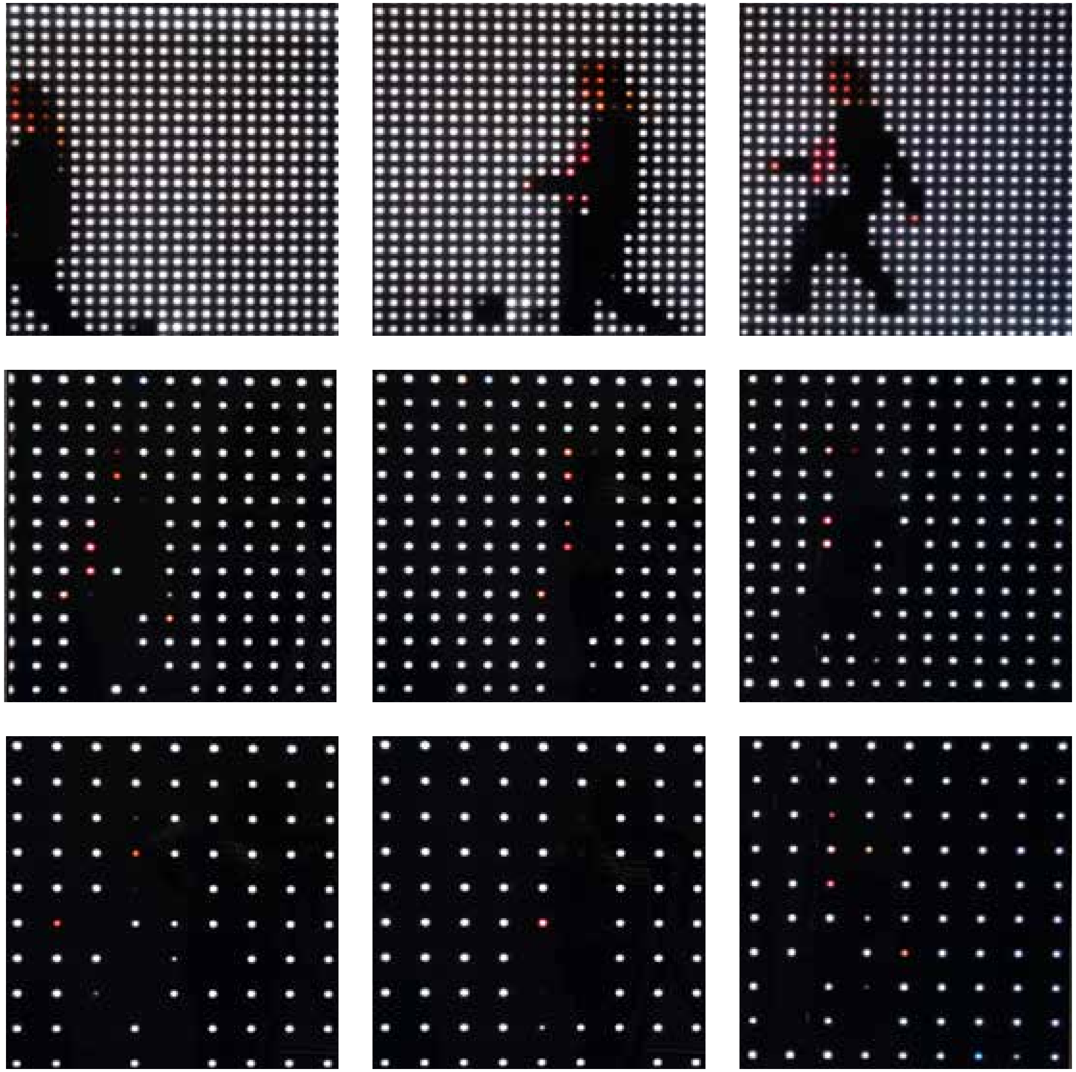


Fig. 35

Belysningsapplikationer

Erfaringerne fra pixel eksperimenterne har dannet grundlag for refleksioner vedrørende brugen af LED lyskilder og armaturer i arkitektonisk kontekst. I dette afsnit illustreres erfaringer fra professionel lysdesignpraksis i rumlige skitser med udgangspunkt i belysning af vertikale og horisontale flader. Illustrationerne repræsenterer 4 overordnede belysningsscenarier, med 2 scenarier for horisontal belysning og 2 scenarier for vertikal belysning.

Illustrationerne repræsenterer belysningsapplikationer, hvor armaturerne er placeret henholdsvis i et grid og et non-grid i loft eller væg. Armaturerne er rettet, så de lyser henholdsvis lodret og mellem 20 og 30 grader (fra lodret). Lysets karakter er henholdsvis rettet (smalstrålende lyskegle) og diffust lys (bredstrålende lyskegle). Lyset belyser henholdsvis væg (vertikale flader) og gulv (horisontale flader).

Illustrationerne forsøger med reference til lysdesign praksis, at svare på problematikker vedrørende rumlige tilstande i forhold til placering af armaturer og oplevelsen af lyset i rummet. Illustrationerne er tænkt som skitser for forskellige kombinationer af belysningsvariabler. Ved konkrete lysdesign opgaver er det altid afgørende at tage afsæt i den enkelte konteksts rumlighed og materialer, samt brugernes fysiske og æstetiske behov, når belysningsapplikationer planlægges.

Lighting Applications

Experiences from the *Pixel Experiments* have provided a basis for reflecting on the use of LED light sources and luminaires in architectural contexts. In this section, the experience of professional lighting design practice will be illustrated in spatial sketches based on the illumination of vertical and horizontal surfaces. The illustrations represent four lighting scenarios overall; with two scenarios testing horizontal lighting and two scenarios testing vertical lighting.

The illustrations represent lighting applications where the luminaires are located in a grid and non-grid ceiling or on a wall. The luminaires are directed so that they illuminate vertically between 20 and 30 degrees (from vertical). The character of the lighting is directed and diffuse light (i.e. a narrow beam of light and a wide beam of light). The light illuminates the walls (vertical surfaces) and floor (horizontal surface) respectively.

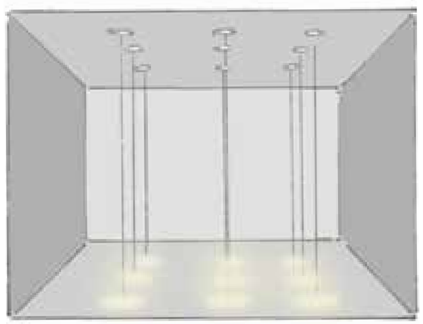
With reference to lighting design practice, the illustrations embody an attempt to respond to issues relating to spatial conditions in relation to the location of luminaires and the experience of light in a space. The illustrations are intended as sketches for various combinations of lighting variables. For specific lighting design tasks when lighting applications are being planned, it is always essential to take one's point of departure in the spatiality and materiality of the concrete context, and to consider the functional and aesthetic needs of the people in the particular individual situation.

Scenarie 1A, 1B, 1C, 1D - Belysning af horisontale flader med rettet lys

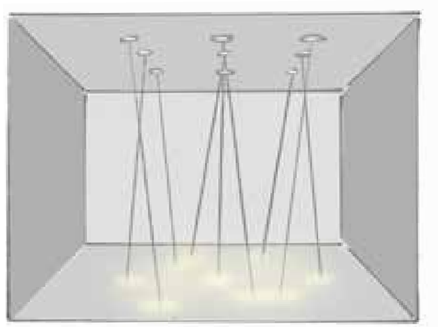
Armaturerne er placeret henholdsvis i et grid (1A og 1B) og i et non-grid (1C og 1D) i loft. Armaturerne er vinklet lodret i scenarie 1A og 1D og vinklet mellem 20 og 30 grader i scenarie 1B og 1C. Armaturet udsender et rettet lys (smalstrålende lyskegle).

I scenarie 1A og 1C skaber armaturerne et grid af lysende zoner, med høj luminans i midten, der aftager udefter. Rummet fremstår således med en relativ jævn belysning på gulv. I scenarie 1A og 1C vil de jævnt fordelte lysende pletter visuelt smelte sammen til en lysende flade, dog med et struktureret grid af luminans peaks på steder, hvor det rettede lys har sit centrale luminans maksimum.

Rummet i scenarie 1B og 1D fremstår med variationer i luminansforhold – hvilket er med til at skabe et varieret belysningsmiljø og flere forskellige *lysvolumener* i det eksisterende rum.



Scenarie / Scenario 1A



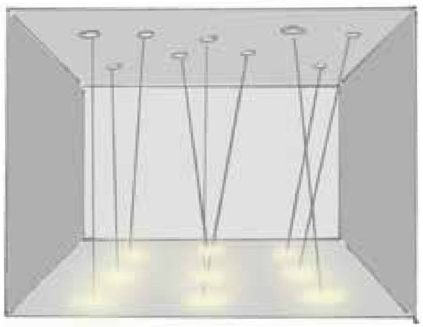
Scenarie / Scenario 1B

Scenarios 1A, 1B, 1C, 1D - Lighting of Horizontal Surfaces Using Directed Light

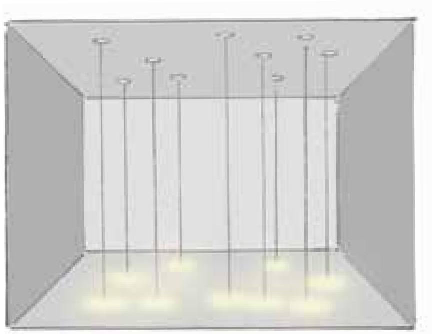
The luminaires are correspondingly located in a grid (1A and 1B) and non-grid (1C and 1D) in the ceiling. The luminaires are angled vertically in scenarios 1A and 1D, and angled between 20 and 30 degrees in scenarios 1B and 1C. Each luminaire emits directed light (i.e. a narrow beam of light).

In scenarios 1A and 1C, the luminaires create a grid of luminous zones that have high luminance in the middle and which then taper outward. Thus, the space appears with a relatively evenly distributed lighting of the floor. In scenarios 1A and 1C, the evenly-spaced illuminating pixels merge visually into a luminous surface – however with a structured grid of luminance peaks in places where the directed light has its central luminance maximum.

The space in scenarios 1B and 1D appears with variations in the luminance conditions, which helps to create a diversified lighting environment and several *lighting volumes* within the existing space.



Scenarie / Scenario 1C



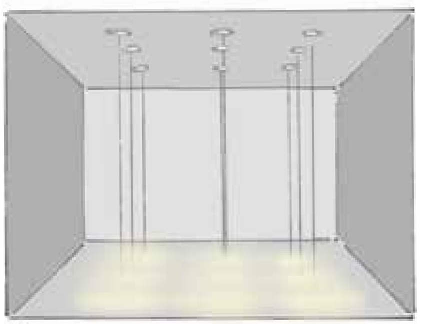
Scenarie / Scenario 1D

Scenarie 2A, 2B, 2C, 2D - Belysning af horisontale flader med diffust lys

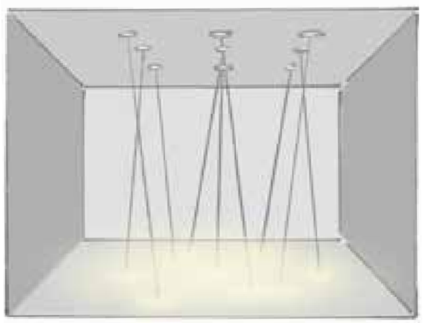
Armaturer er placeret henholdsvis i et grid (2A og 2C) og i et non-grid (2C og 2D) i loft. Armaturerne er vinklet lodret i scenarie 2A og 2D og vinklet mellem 20 og 30 grader i scenarie 2B og 2C. Armaturet udsender et diffust lys (bredstrålende lyskegle).

Forskellen på disse 4 scenarier og de 4 foregående scenarier er armaturernes lystekniske karakteristik. Armaturerne i scenario 2 lyser med en bredstrålende lyskegle og vil erfaringsmæssigt skabe et jævnt lys med mindre luminans forskelle.

I scenarie 2A og 2C skaber armaturerne en meget jævn belysning af gulvet og med meget små *luminansovergange*. De jævnt fordelte lysaftegninger smelter visuelt sammen til en lysende flade. Rummet i scenarie 2B og 2D fremstår med et relativt jævnt lys, dog stadig med variationer i luminansforhold, hvilke er med til at skabe et varieret belysningsmiljø og flere forskellige *lysvolumener* i det eksisterende rum.



Scenarie / Scenario 2A



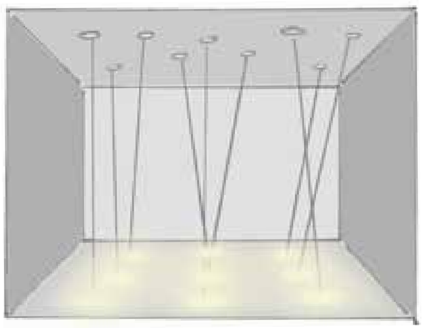
Scenarie / Scenario 2B

Scenarios 2A, 2B, 2C, 2D - Lighting of Horizontal Surfaces Using Diffuse Light

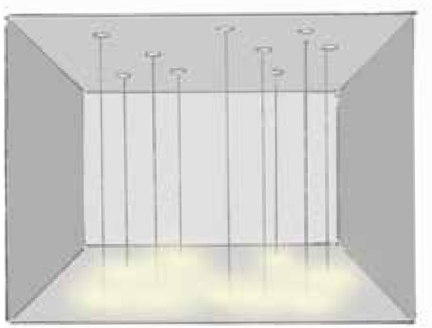
The luminaires are correspondingly located in a grid (2A and 2C) and non-grid (2C and 2D) in the ceiling. The luminaires are angled vertically in scenarios 2A and 2D, and angled between 20 and 30 degrees in scenarios 2B and 2C. Each luminaire emits diffuse light (i.e. a wide beam of light).

The difference between these four scenarios and the four preceding scenarios are the luminaires' photometric characteristics. The luminaires used in this scenario have a wide light beam, and thus create an evenly distributed light with fewer luminance variations.

In scenarios 2A and 2C, the luminaires create a very even illumination of the floor, having very little luminance. The evenly spaced *lighting delineations* can be seen to blend visually into a luminous surface. The space in scenarios 2B and 2D appears with a relatively evenly distributed light – though still having variations in luminance – which helps to establish a varied lighting environment with several *lighting volumes* in the existing space.



Scenarie / Scenario 2C



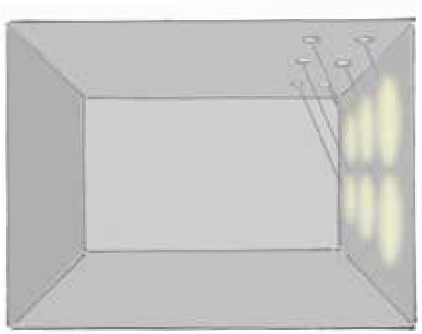
Scenarie / Scenario 2D

Scenarie 3A, 3B, 3C, 3D - Belysning af vertikale flader med rettet lys

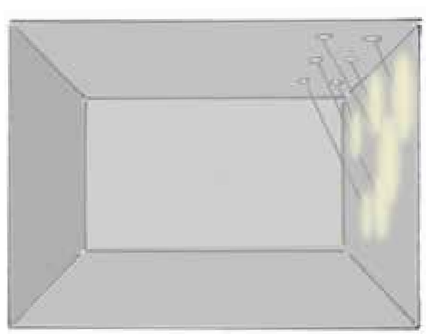
Armaturerne er placeret henholdsvis i et grid (3A og 3B) og i et non-grid (3C og 3D) i loft. Armaturerne er vinklet mellem 20 og 30 grader (målt lodret mod væg). I scenarie 3B og 3C er armaturerne rettet mod væggen men også til siden. Armaturet udsender et direkte lys (smalstrålende lyskegle).

I scenarie 3A og 3C skaber armaturerne et grid af lysende zoner med høj luminans i midten, der aftager udefter. De jævnt fordelte lysende pletter smelter visuelt sammen til en lysende flade, dog med et struktureret grid af luminans peaks der hvor det rettede lys har sit centrale luminans maksimum. Rummet i disse scenarier fremstår således med en vertikal flade, hvor der visuelt opleves luminans peaks i en grid struktur. Denne grid orden skaber dog visuelt en rolig belysning af den vertikale flade.

I scenarie 3B og 3D skaber armaturerne en ujævn belysning af vægfladen, og således en større luminanskontrast mellem lys og mørke. Den ujævne belysning af den vertikale flade skaber en uro visuelt betragtet.



Scenarie / Scenario 3A



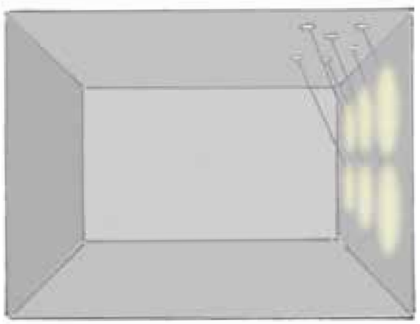
Scenarie / Scenario 3B

Scenarios 3A, 3B, 3C, 3D - Lighting of Vertical Surfaces Using Directed Light

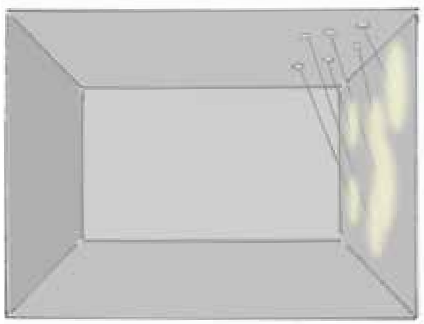
The luminaires are correspondingly located in a grid (3A and 3B) and non-grid (3C and 3D) in the ceiling. The luminaires are angled between 20 and 30 degrees (measured vertically against the wall). In scenario 3B and 3C the luminaires are directed towards the wall, but also to the side. Each luminaire emits directed light (i.e. a narrow beam of light).

In scenario 3A and 3C, the luminaires create a grid of luminous zones that have high luminance in the middle, which then tapers outward. The evenly spaced illuminating pixels appear to visually melt into a luminous surface, with a structured grid of luminance peaks, where the directional light has its central luminance maximum. Thus, the space in these scenarios is comparable to a vertical surface where luminance peaks in a grid structuring are visually perceived. This grid structuring, however, creates a visually calm illumination of the vertical surface.

In scenario 3B and 3D, the luminaires create an uneven illumination of the wall surface, and consequently a higher luminance contrast between light and dark. The uneven illumination of the vertical surfaces may be seen to produce visual unrest.



Scenarie / Scenario 3C



Scenarie / Scenario 3D

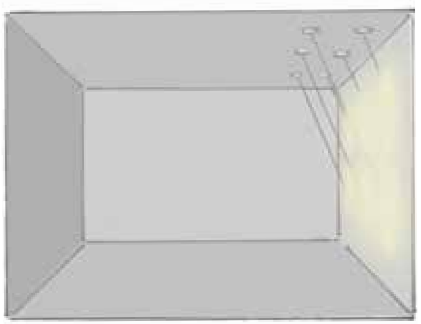
Scenarie 4A, 4B, 4C, 4D - Belysning af vertikale flader med diffust lys

Armaturerne er placeret henholdsvis i et grid (4A og 4B) og i et non-grid (4C og 4D) i loft. Armaturerne er vinklet mellem 20 og 30 grader (målt lodret mod væg). I scenarie 4B og 4C er armaturerne rettet mod væggen men også til siden. Armaturet udsender et diffust lys (bred strålende lyskegle).

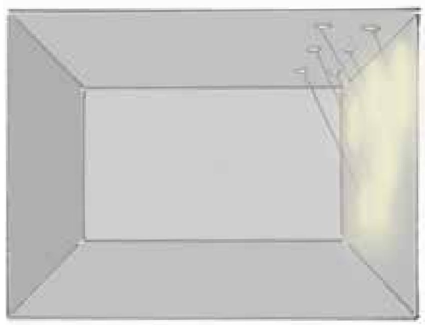
Forskellen mellem scenarie 3 og 4 er således en forskel i lysfordelingen, hvor scenarie 4 arbejder med bredstrålende lyskegler, der skaber et diffust lys i stedet for det rettede lys i scenarie 3.

For scenarie 4A og 4C fremstår væggen med en endnu mere jævn belysning kva armaturernes brede lysfordeling til sammenligning med scenarie 3A og 3C. De jævnt fordelte lysende pletter smelter visuelt sammen til en homogen lysende flade, uden luminans peaks. Rummet i disse scenarier fremstår således med en vertikal flade, der er relativt jævnt belyst. Den jævnt belyste vertikale flade er med til at skabe et rumligt perspektiv.

For scenaire 4B og 4D opleves en lavere luminans kontrast mellem lys og mørke, sammenlignet med scenariet med det rettede lys. Der opleves dog stadig en uhomogen belysning idet de lysende felter ikke er jævnt fordelt over den vertikale flade.



Scenarie / Scenario 4A



Scenarie / Scenario 4B

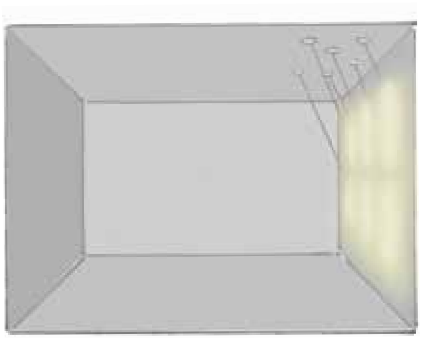
Scenario 4A, 4B, 4C, 4D - Lighting of Vertical Surfaces Using Diffuse Light

The luminaires are correspondingly located in a grid (4A and 4B) and non-grid (4C and 4D) in the ceiling. The luminaires are angled between 20 and 30 degrees (measured vertically against the wall). In scenario 4B and 4C, the luminaires are directed towards the wall, but also to the side. Each luminaire emits diffuse light (i.e. a wide beam of light).

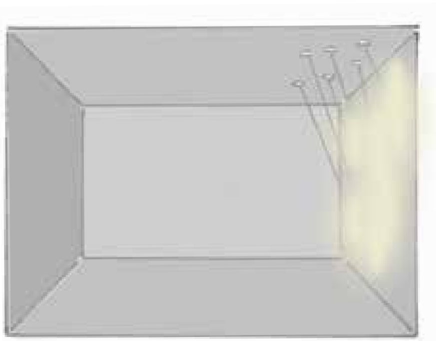
The difference between scenarios 3 and 4 is therefore a difference in the distribution of the light, wherein scenario 4 uses wide beam of light that creates diffuse light, instead of the directed (narrow beam) light of scenario 3.

In scenarios 4A and 4C, the wall appears with an even, more uniform lighting due to the luminaires' wide distribution of light, in comparison to scenarios 3A and 3C. The evenly spaced illuminating pixels may be seen to visually fuse into a homogeneous luminous surface without any luminance peaks. Thus, the space in these scenarios is comparable to a vertical surface that is illuminated relatively evenly. An evenly illuminated vertical surface helps create spatial perspective.

In scenarios 4B and 4D, one experiences a lower luminance contrast between light and dark, comparative to the scenario using directed light. However, one still experiences heterogeneous lighting in the luminous fields that are not evenly distributed across the vertical surface.



Scenarie / Scenario 4C



Scenarie / Scenario 4D

Belysningsscenarier i arkitektonisk kontekst

Belysningsscenarierne skildrer belysningsstrategier for placering af lyskilder/armaturer, indstilling af lysets retning, brugen af lysets spredning, og den deraf genererede belysningskvalitet i rummet. Scenarierne viser, at det er afgørende for oplevelsen af lyset, hvordan lyset aftegnes på en flade og i disse tilfælde, mindre afgørende hvordan armaturerne er placeret i loft, så længe det er muligt at indstille lysretningen.

Scenarierne har ligeledes demonstreret at lysfordelingen og jævnheden af en belyst flade opleves forskelligt, alt efter om det er en vertikal eller horisontal belyst flade. Ved en uhomogen belysning af en horisontal flade opleves variation i belysningen på gulvfladen, og variationer i *lysvolumener* opstår i det større fysiske rum. Omvendt vil der ved en uhomogen belysning af vertikale flader, med variationer i luminansforhold hen over en vægflade, opleves en urolig flade, kva den ujævne luminansfordeling.

Tilmed tydeliggøres fordele og ulemper ved henholdsvis rettet og diffust lys. Det diffuse lys skaber en jævn belysning, der kan være at foretrække ved især vertikal belysning af flader. Når enkeltstående objekter eller områder på en flade ønskes fremhævet, kan dette skabes med et rettet lys. Det rettede lys kan bruges selvstændigt eller i kombination med det diffuse lys ved belysning af horisontale flader som gulvflader. Alt efter funktionelle og æstetiske behov kan der, med en variation i lysfordeling og indjustering af armaturer, skabes variationer i luminans kontraster og hermed variationer i *lysvolumener*.

Pixel eksperimenterne og de illustrerede belysningsscenarier kvalificerer, hvordan belysningsvariabler og dynamiske variationer har potentialer i forhold til lysdesign i praksis. Netop belysningsvariabler og struktureringen af disse har en indflydelse på *lysaftegninger*, skabelsen af *lysvolumener* og *belysningsatmosfære* i den arkitektoniske kontekst. Ligeledes er softwarestyringen afgørende for oplevelsen af dels statiske og dels dynamiske belysningssituationer.

Lighting Scenarios in Architectural Contexts

The lighting scenarios depicted in this book address lighting strategies for: the placement of light sources/luminaires; the positioning of the directionality of light; the uses of light's distribution; and the subsequently generated lighting qualities of a given space. The scenarios describe how light delineated on surfaces is essential to the experience of light – and how luminaires are positioned in a ceiling is of less importance, as long as it is possible to adjust the directionality of the light being emitted from the luminaires.

The scenarios have also demonstrated that the distribution of the light and the evenness of an illuminated surface are experienced differently depending upon whether a surface is vertically or horizontally illuminated. In the heterogeneous illumination of a horizontal surface, one will experience variations in the illumination of the floor surface and variations in the *lighting volumes* occurring within the greater physical space. Conversely, using a heterogeneous illumination of vertical surfaces with variations in luminance conditions across a wall surface, one will experience an irregular surface due to the uneven luminance distribution.

Additionally, this practice-based research has clarified the pros and cons of using directed and diffuse light. Diffuse light creates an even lighting that may be particularly preferred in the vertical illumination of surfaces, and when individual objects or areas of a surface need to be accentuated this can be achieved using directed light. Directed light can be used independently or in combination with diffuse light in the illumination of horizontal surfaces such as a floor. Depending on the functional and aesthetic requirements, a variation in the light's distribution and the positioning of the luminaires can be used to create variations in luminance contrasts and thus also variations in *lighting volumes*.

These *Pixel Experiments* and the illustrated lighting scenarios in this publication qualify how lighting variables and dynamic variations offer rich potentials for lighting design in practice. It is precisely the lighting variables and their structuring that influence *lighting delineations*, the creation of *lighting volumes* and *lighting atmospheres* in architectural contexts. Likewise, software control must be seen as being decisive to the experiences of static and dynamic lighting situations alike.

Referencer / References

Applin, Jo (2012). *Yayoi Kusama; Infinity Mirror Room – Phalli's Field*. Massachusetts and London, MIT Press.

Böhme, Germot (2013). The art of the stage set as a paradigm for an aesthetics of atmosphere. In *Ambiences* http://ambiances.revues.org/315 (Visited December 18, 2014).

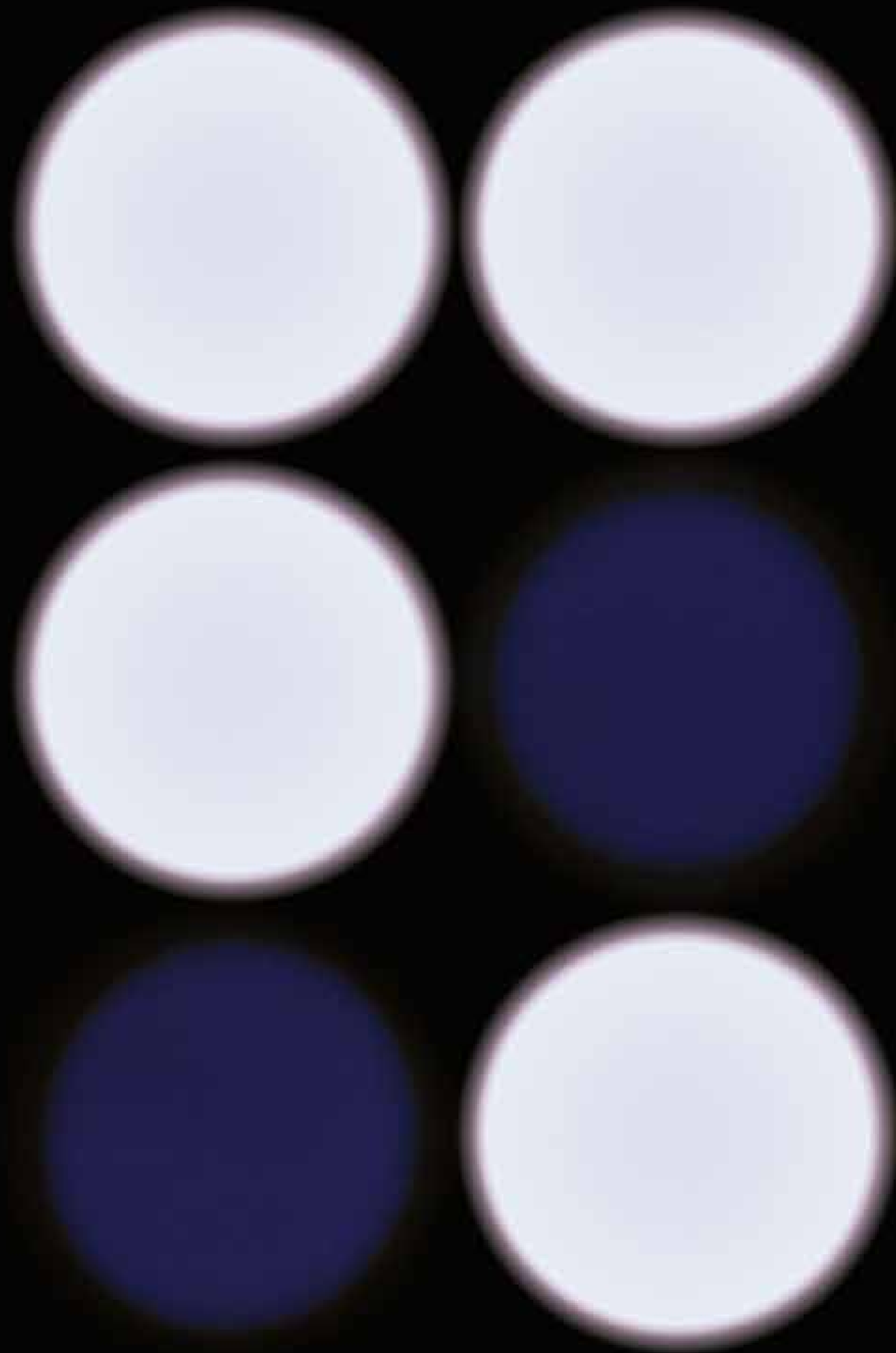
Cuttle, Christoffer (2008) (second edition). *Lighting by Design*. Amsterdam, Architectural Press Elsvier, Butterworth-Heinemann.

Madsen, Merete (2002). *Lysrum – som begreb og redskab*. Ph.d. afhandling. København, Kunstakademiets Arkitektskole.

Grusin, Richard (2010). *Jim Campbell; Material Light*, New York, Hatje Cantz

Perlin, Ken: Reference to Ken Perlin's webpage on Perlin Noise:
http://mrl.nyu.edu/~perlin/doc/oscar.html (Visited December 18, 2014).

Tregenza, Peter & Loe, David (2014) (second edition). *The Design of Lighting*. New York, E & FN Spon, Routledge.



The Royal Danish Academy of Fine Arts,
Schools of Architecture, Design and Conservation