MIDDLA makerspace dynamics in lighting          Master’s Thesis
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Architectural Lighting Design
School of Architecture and the Built Environment KTH
Master's Thesis AF270X
May 2019 // Stockholm, Sweden
KEYWORDS

dynamics - dynamic lighting - biophilia - daylight - circadian rhythms - sustainability - Luminous diversity - emotional effects of light - projections

ABSTRACT

This thesis report deals with the meaning of dynamics in lighting in context of the current state of lighting technology and how certain aspects of those can be applied to a specific space.

Former studies discovered that biophilic aspects in design can create great benefits for the users of a space. Natural elements is what we humans most affiliate to. Based on those findings I implemented aspects of dynamics in lighting into my design proposal assuming to be able to give the users of the MIDDLA space benefit by recreating some degree of ‘virtual biophilia’.

MIDDLA is the laboratory of the Media Technology and Interaction Design department of KTH. Characteristics of these facilities are unique as it is located in the attic floor of the oldest building on campus which is rather restricted in terms of daylighting and room clearance. Focus is put on the corridor to evolve into an extension of the laboratory itself as a study area.

Future post-occupancy research could be worthwhile of being conducted in combination with further development of the lighting design.

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The sun has always been and still is our main natural source of light that enlightens our surrounding. On the one hand trivial but on the other a fact not to be underestimated. Daylight therefore is probably our most important time giver (Boyce, 2014, p. 93).

In built environments however daylight is excluded up to a certain amount which is defined by the architecture and its surrounding as well as its location on our planet. The closer to the equator we live the more in tune with equal time of presence and absence of light we are - the further away the more distorted day and night gets in terms of their occurrence and length.

Stockholm is an example of a city where people have to live with daylight occurrence which is varying a lot throughout the year [Fig 5.1]. When it comes to study environment in dependence to the academic calendar the study period of a year is actually not beneficial to our circadian rhythms. A great amount of the study time is taking place within the time of year when nights are longer than days. Moreover most of the daytime is usually spend indoors. Daylight hours are falling short especially during the winter.

[Fig 5.1] Sun graph for Stockholm
// beginning and end-date of the academic year are marked by the cyan bars
// equinoxes are marked by green bars
Spaces that do not have much visual connection to the outside world intensify the conflict between time of day and presence or absence of daylight (Panda, 2019, lecture). Historical architecture sometimes do not provide sufficient openings due to the lack of technical window solutions at the time of construction. Within KTH’s main campus building examples of this phenomenon can be found. Especially in areas that originally were not intended to be used as spaces for longer stays such as studying the lack of daylight is immense and cannot easily be fixed by construction measures.

This is where lighting design can potentially improve architectural challenges. To bring back a hint of daylight by a glance of simulated daylight-effects - this is my personal challenge and motivation for this project.

MIDDLA makerspace is a laboratory facility of the MID (Media Technology and Interaction Design) department located in the main KTH campus building. It has been undergone some re-equipment recently in which lighting was included partly. Especially the change of use of the corridor from a pure transition zone into a study and exhibition zone asks for improvement of the lighting situation.

MIDDLA derives from att middla [²midːlar]: to construct or create from a diverse range of things specifically in the context of physical interaction design.
MAIN RESEARCH QUESTION
BACKGROUND // INTRODUCTION

How to recreate dynamic daylight effects as part of a lighting design in a specific study environment?

[Fig 7.1] Sunlight patterns in a corridor
Daylight defines itself by its very unique characteristics. In the following I take a closer look on a few characteristics and contrast them with those of current electric lighting solutions:

**DAYLIGHT**

**COLOUR TEMPERATURE**

// Throughout a day the colour temperature of daylight changes a lot. Mainly because of the position of the sun in dependence to the earth and the resulting difference in the path of the sun’s light rays through the atmosphere. Local occurrences such as higher or lower amount of particles in the air change the resulting colour temperature as well.

**ELECTRIC LIGHT**

// Current LED technology is able to emit white light of colour rendering capability higher 90 in correlated colour temperatures ranging from around 1500 to 6500 Kelvin. Light controllability is crucial for implementing ergonomic design solutions though.

**LUMINOUS INTENSITY**

// The illuminance at a certain point on earth depends mostly on the specific constellation between sun and earth. Furthermore climate changes the result as different layers of weather phenomena such as clouds block light and therefore shield the earth’s surface from the sun.

**ELECTRIC LIGHT**

// Luminous intensities of electric light sources are extremely low compared to the sun but as the distance between those and the surface to be illuminated is close similar levels of illuminance can be achieved. Dynamic in intensity throughout the day is technologically possible and of great potential.

**DIRECTIONALITY**

// The characteristic of constantly changing directionality is also mainly dependant on the constellation of sun and earth. It is defined by the location on earth as well as the time of the year and day. Additionally direct sunlight will get reflected at objects in between which change directionality partly.

**ELECTRIC LIGHT**

// Usually electric lighting solutions in living, working or studying environments are not designed with elements of dynamic in terms of changing light directionality. Due to recent findings in research and the further development of lighting technology this might be a beneficial addition.
Rhythms, repeating occurrences, surround us at all times. Some repetitions might be obvious whereas others happen subconsciously. Natural dynamics can be rhythms without apparent triggers.

**DAYLIGHT**

// Depending on the climatic conditions the sun’s light can either be clear and unobstructed or diffused in various intensities which affects the appearance of shadows.

**CLARITY / DIFFUSION**

// Lighting designs using electric lighting can create all combination of clear or diffuse light and its resulting shadows but has rarely been done yet in a dynamic manner.

**CONSISTENCY / DYNAMIC**

// Climate conditions but also obstructions between the sun and the observer take influence on the consistency of daylight. A combination of climate influence and obstructions such as a tree that gets moved by wind can create dynamic light patterns that hit a surface.

// Dynamic light patterns can be realised by the use of narrow beam lenses (projector optics) in combination with gobo filters for example. Those can be static but also dynamic like a moving head. Another option would be the use of luminous surfaces, see 'projects / technology'.

**EPHEMERALITY**

// All of the effects described above can be of almost any duration. Sometimes regularly repeating sometimes irregular and changing over time.

// This might be the most challenging aspect when creating dynamics in lighting. Either a schedule of predefined actions needs to be programmed which is kind of contradictory to the definition of ephemerality itself or a sensor based content creator programme can take care of that job. Self learning systems of artificial intelligence will take the creation of nature-like rhythms a big step further in the future as far as my own estimation goes.
Biophilia according to the psychologist, psychoanalyst, sociologist and philosopher Erich Fromm can be used to describe a healthy individual who is attracted to live (human and non-human) as opposed to death (Fromm, 1964). Later the biologist, theorist, naturalist and author Edward O. Wilson defined the term biophilia as an innate human tendency to affiliate with life and lifelike processes (Wilson, 1984, p.85).

Various case studies were conducted that further investigated on that matter. Natural environments were prioritised over built environments. Built environments with water, trees and other vegetation over those without such features (Kaplan and Kaplan, 1989).

Peter H. Kahn, Jr. Professor of the Department of Psychology and Director of the Human Interaction With Nature and Technological Systems (HINTS) Lab of the University of Washington concludes in his book ‘Technological Nature - Adaption and the future of human life’ by stating ‘If through evolution certain natural landscapes have promoted human survival and reproductive success, then it would seem likely that such landscapes nurture people physically and psychologically’ (Kahn, 2011, p. 13).

These biophilic phenomena were observed in all kinds of research. Contact with animals showed the promotion of psychological and physical health (Katcher and Wilkins, 1993; Melson 2001; Myers 2007). An other study dealt with the recovery phase of patients after a surgery which showed that after different measures such as self-reports, nurses’ reports, amounts of pain medication used, and length of stay patients with a view towards nature did recover better compared to patients who looked towards a brick wall (Ulrich, 1984).

Yannick Joye (Free University of Brussels) describes in his paper ‘Architectural Lessons from Environmental Psychology: The Case of Biophilic Architecture’ (2007, p. 324) two ways of how biophilia can be achieved in the built environment: By either bringing elements of nature into the built environment or by mimicking those properties in the building.
According to Kahn’s (2011) interpretations of Kellert’s, Heerwagen’s and Mador’s publication ‘Biophilic Design’ (2008) the first option to bring elements of nature into the design ‘...can be achieved, for example, through the use of natural lighting and the presence of water and vegetation’. Based on those descriptions of biophilia a possible contribution could also be done by lighting design I assume. An example that represents a modest and unobtrusive approach towards mimicking elements of nature in a built environment is a small lounge area of Terminal 5 at Arlanda airport. Even if the layer of electric lighting is of a static non dynamic character the effect of it contributes greatly to the overall impression of natural elements and the welcoming feel to it in my eyes.

My personal approach would include the aspect of dynamics as a potential reaction or interaction with a living being. Biophilia supported by lighting design. In order to achieve this the relationship between human factors - our needs - perception - technology - architecture and lighting design needs to be kept in focus during the design process. Inconspicuous elements of lighting design to support our humans’ longing for biophilia and to create an atmosphere of harmony - these aspects therefore are going to play a major role in my lighting design proposal for MIDDLA.
dynamics in light

how to recreate dynamic daylight effects as part of a lighting design in a specific study environment?

literature

research

- characteristics of daylight
- light and health
- technological approaches
- biophilia
- projects

translating

project

space analysis

- daylight
- electrical lighting
- potentials
- user interviews
- personal analysis

adaptation

lighting

design

- design development
- testing
- matching design brief
- realisable design

[Fig 12.1] methodology table
METHODOLOGICAL DISCUSSION

METHODS

quantitative analysis of the space

daylight factor - horizontal illuminance - luminance - personal project analysis - CAD 3D drawings - daylight analysis - areas - zones - material's reflectance analysis - perception - light typology

personal qualitative analysis

A thorough perceptual investigation dealing with the topics of daylight conditions, electric lighting setup, materiality and users of the space.

unstructured interviews

Through unstructured interviews users' needs are evaluated. Possible lacks of the current lighting system can be discovered by that method.

midterm presentation

As a follow-up meeting this presentation was meant to update all parties involved about the development of the project and to address questions or concerns.

My contribution was the presentation of my analysis' results and an outlook on my mood and vision for the space. After some feedback we discussed about possible technical solutions to realise our vision. As an assurance of acceptance of the direction that my approach was going towards the reunion was helpful for both sides - for the ‘client’ and for me as the designer.

literature research

By researching specific literature previous findings concerning my main question are considered as part of my methodology and applied in my design proposal. Moreover the chapter about the background and also the discussion are supported and validated by this method.

limitations

Due to the specifics of the spaces’ use some limitations apply

// my research and design will concentrate on the emotional effects of light

// possible biological effects will rather not be considered
METHODOLOGICAL DISCUSSION

METHODS

**design process**
A detailed analysis of the space alongside with talks to the users of the space form the base for my design process. Site observations shape that impression and let my mind imagine the space in variations of light and moods. A mood board visualises those scenarios. Visions show up once the moods get applied to the space. 3D-CAD drawings document the technical development of the space.

**on-site testing**
Ideas developed in a computer aided design process are still theoretical and virtual no matter how realistic they might look. Therefore the testing on site with close to ready fixtures is one of my methods. Contact with manufacturers to be able to test the design ideas is essential in this step.

**design development**
Ideas are drawn in CAD and partly tested on site. Calculations and visualisations go along with the design development.

**project research**
To get an overview about the current state of technology and design a project research is one of my methods. A visit of the Prolight + Sound fair in Frankfurt is part of that.
Backlit surfaces create big vertical or horizontal elements in the space. Those LED arrays can be controlled in such ways to implement an momentum of dynamic and unexpected.
In aviation dynamic lighting design can potentially influence travellers’ circadian rhythms and well-being. Spacial limitations get optically dissolved and the impression of the space changes.

**luminous intensity**

// high enough in bright spaces

**fixtures size**

// architectural integrable solutions

**dynamic**

// video / pixel-mapping

DLP or LCD projectors can be used to project dynamic structures as moving images of high contrast onto any surfaces within a space. After testing however I found that luminous flux of small projectors is not sufficient to create a contrast of light that is visible in daytime lighting scenarios. Therefore this technology is probably rather useful for night-time conditions when ambient lighting is at a lower level.
moving profile lighting

luminous intensity
// potentially high enough in bright spaces

fixtures size
// medium / tendency of smaller fixtures due to the use of LED technology

dynamic
// 360° rotational fixture / rotational gobo / zoom / framing shutter and dimming functionality / video projecting possibility (projector)
rotating glass projection

[Fig 18.1-3] glass rotating projector by Zumtobel

luminous intensity
// potentially high enough for bright spaces
fixture size
// medium
dynamic
// pattern / speed / colour

moving array lighting

[Fig 18.4-5] moving lights ©GLP

luminous intensity
// potentially high enough for bright spaces
fixture size
// medium/ tendency of smaller fixtures due to the use of LED technology
dynamic
// rotation / bit-mapping / pixel-mapping / video content representation / zooming / beam shaping
the laboratory has seven skylight roof windows

the two corridor windows are located below the glass roof of the inner courtyard
Situated in the top floor of the KTH’s oldest campus the Media Technology and Interaction Design department - MID - operates MIDDLA makerspace. The facilities are almost north-south oriented with a slight tilt of around 30 degrees clockwise. There are trees eastwards the building which however not reach the top of the building and therefore not shadow the roof windows. As recognisable from the aerial photographs a glass roof covers the inner courtyard. The north-west facing windows of the corridor are located underneath that cover.
Towards the end of March (20/21) and the end of September (22/23) daytime and nighttime are of about equal lengths.

This is why I choose this specific sun path for my daylight analysis.

The Sun path shows the path that the Sun appears to follow across the sky as the Earth rotates. The red arc highlights the sun's path at equinox. The orange arcs show the sun's paths at the two solstices throughout the year - June and December.

Furthermore the chart also shows the sun's declination throughout the year.
My personal method of analysing a space is structured along a derivation of the MAK-method which analyses lighting regarding:

// daylight conditions
// electric lighting conditions in the space
// relations of light and materiality
// relations of people and space

The results show a snapshot in time of the overall impact of light in the space from any light source. With growing experience these findings may be scalable to other times or dates throughout a year for that specific space.

[Fig 23.1] personal analysing method
larger version available as an appendix
Two main areas are recognisable looking closer at the MIDDLA facilities. The corridor as one area connecting the main circulation with the laboratory and other facilities connected. And the laboratory itself as another area.
According to my analysis the space can be divided into at least six zones.

The corridor shows potential for additional usage besides its main function as a transition space between different rooms/areas. Its middle part has just been redecorated with four tables and chairs to create space for working. A sofa provides some opportunity for recreation. I call this middle part of the corridor Development II.

For the laboratory I dedicated three zones - Think Tank, Development I and Making. The zone Think Tank offers furniture and equipment for idea brainstorming. The zone Development I is a space ideal for team meetings and presentations. The biggest zone Making is the location of all tools and machines necessary to actually produce what was born as an idea in the zone Think Tank and developed in the zones Development I and II.
The two corridor windows provide a small amount of daylight to enter the space. The visual connection with the sky (no-sky-line) is however almost non existent due to the courtyard situation and also the low positioning of the windows and the depth of its embrasure.

The orientation of the two openings is towards north-west which is why there is hardly any direct sunlight impact into the corridor.
There are two types of luminaires in the corridor. A linear wall washing light (S1) in the main part and a downlight flood (R2) in the northern end.

Both fixtures making use of fluorescent light source technology.
Seven skylight windows are integrated into the roof’s slope. Visual connection with the sky enable indication of the time of day and year.

The windows are tiltable and are equipped with inside shading devices in the form of curtains which store at the upper part of the window.

Due to furniture partly in front of the openings and curtains blocking the upper part of it, view and thereby also light intake is impaired a bit.

Orientation of the openings is East-southeast. Hence direct sunlight impact occurs.
The general lighting in the laboratory is realised by ceiling integrated panel downlights (R1). Those are providing decent lux levels on almost all working surfaces. Those surfaces that do not receive sufficient light are equipped with additional task lights.

There is one area in the lab however which suffers from horizontal illuminance which is pointed out on the illuminance map [Fig 32.1].
ELECTRIC LIGHTING LAYOUT
PROJECT ANALYSIS // METHODS

Fig 30.1 lighting plan - current design
// panel downlights in the laboratory
// linear downlights in the corridor
// downlight floods in one end of the corridor
[Fig 31.1] lighting section - current design
// downlight in the laboratory -> mainly direct lighting
// wallwash in the corridor (downlight in one end) -> mainly indirect lighting

[Fig 31.2] plan
Levels of horizontal illuminance vary in the spaces. In the corridor illuminance levels are generally in accordance with standards of a minimum requirement of 100 lux horizontal according to DIN EN 12464-1 for the use scenario of transition zones/corridor. There are two exceptions however - the area towards the south end and towards the north end. Towards south the downlights might be undersized. Towards north the existing luminaires are not working due to a technical failure presumably.

The points measured on the tables do not yet fulfil the requirements necessary for a study environment that is intended to be introduced inside the corridor. Potential for improvement is seen here. Horizontal lux levels in the laboratory are fully complying with the standards of DIN EN 12464-1 Light and Lighting - Lighting of work places - Part 1: Indoor work places requiring 500 lux on desk level. Except one small area in the very south of the room between the laser cutter and the soldering work space shows too low values (100 lux) on floor level in contrast to the adjacent work desk (670 lux).
The amount of daylight (lux) reaching specific spots in a room in relation to the measured lux level outside at an unobstructed place with full coverage of the overcast sky at the exact same time.

Results in the corridor are extremely low - below 0.1 - as expected due to the lack of openings - only two small windows.

Measured spots in the laboratory however are rather low as well - not reaching a minimum level of one percent despite the seven roof windows.
[Fig 34.1-2] laboratory view from north
photograph and luminance false colour calculation (electric lighting solely)
[Fig 35.1-2] Laboratory view from south
photograph and luminance false colour calculation (electric lighting solely)
LUMINANCE CORRIDOR
PROJECT ANALYSIS // METHODS

[Fig 36.1-2] corridor view from north photograph and luminance false colour calculation (electric lighting solely)
LUMINANCE CORRIDOR
PROJECT ANALYSIS // METHODS

[Fig 3.1-2] corridor view from south photograph and luminance false colour calculation (electric lighting solely)
MATERIAL REFLECTANCE (vertical surfaces)

PROJECT ANALYSIS // METHODS

[Fig 38.1-4] reflectance of vertical surfaces (estimated values)

~80%  ~60%  ~80%  ~10%
Figure 39.1-8: Reflectance of horizontal surfaces (estimated values)

- ~80%
- ~70%
- ~30%
- ~80%
- ~40%
- ~10%
- ~10%
- ~10%

[Fig 39.1-8] Reflectance of horizontal surfaces (estimated values)
MATERIAL REFLECTANCE (ceiling)

PROJECT ANALYSIS // METHODS

~85% ~65%

[Fig 40.1-2] reflectance of ceiling panels (estimated values)
comparison of clean (simulated) and current status of ceiling panels
As a part of my project analysis I conducted unstructured short interviews with several students working in the laboratory’s facilities. My main interest using this method was to find out whether there are any weak spots in the current lighting layout.

Through this feedback I found out that all reported issues are matching with two other methods used which are the measurements and also with my personal analysis/observations of the space.

The main concerns are:
// A lack of light in the south end of the laboratory (soldering work space)
// A lack of light in the corridor in general
// Impractical task lamps
In order to find the best compromise for a lighting design solution I defined my top ten design goals and ranked them by my priority:

1. Improving the impression of spaciousness in the corridor
2. Adding a layer of the unexpected / dynamic
3. Keeping it realisable (in terms of costs, constructional details and timeframe)
4. Improving the colour rendering characteristics of the electric lighting
5. Keeping in mind sustainability
6. Ensure flexibility in lighting design in regard to a change of use / research requirements / preferences of the individual user
7. Fulfilling design brief
8. Fulfilling standards for educative environments
9. Upgrading the lighting technology
10. Reducing energy consumption
PROJECT ANALYSIS

The project analysis can be summarised as follows:

// MIDDLA facilities compose of two main areas which consist of six zones of activity [Fig 24.1 + Fig 25.1].

// Orientation in regards to the sun path favours the laboratory whereas the corridor is at a disadvantage. Openings underpin this tendency as they are plenty in the laboratory but only few in the corridor. [Fig 33.1]

// Daylight factor is too low in the whole facilities of MIDDLA but especially in the corridor if it is to be considered as a permanent working space, see [Fig 33.1].

// Reflectance values of materials used for vertical surfaces are mostly high. Some materials however used for horizontal surfaces in the laboratory show potential for improvement. Those are the floor and the ceiling, see [Fig 39.1-8 + Fig 40.1-2]

// In order to improve the daylight factor in the laboratory all ceiling panels must be cleaned or changed due to discolouration to raise reflectance of the ceiling's surface, see [Fig 40.1-2].

// Levels of horizontal illuminance [Fig 32.1] are sufficient with the exception of a few areas pointed out in [Fig 46.1 + Fig 47.1].

// Photographic luminance calculations show that there is no risk of glare caused by the fixtures currently installed, see [Fig 34-37.2].

OBJECTIVES of METHODS

// Overall I conclude my project analysis that the current lighting system fulfils its purpose from a functional point of view but lacks in any form of lighting dynamics.

// By interviewing users of the space lighting flaws could be uncovered quickly.

// My personal analysis focussing on perceptual aspects of the space revealed the space's qualities and challenges.

// Literature research about daylight characteristics and biophilia and formed a base for my concept.

// Project research about dynamic lighting technology was necessary to get up to date about tools.
Contraposition of my personal impression of the space today and my future vision for it.

Impression today // A pretty dark path without a clear end or goals in between. A place to leave as soon as possible. Dark surfaces create the impression of narrowness and discomfort to me. The dark lets the space feel static.

Future vision // A light and open atmosphere that invites for staying. Areas clearly marked by light. Elements of dynamic and adaption.
MOOD & VISION
LIGHTING DESIGN PROPOSAL // RESULTS

[Fig 45.1] vision - sunlight patterns in a corridor
There are mainly three areas of potential for improvement in the laboratory as of my analysis.

One area is defined by the windows. Another one is marked by the work desks towards the wall and the third one is the space between the laser cutter and the work desk for soldering.

The windows offer the highest quality of light in the space. Furthermore the daylight factor is highly dependent on the clearance of the glass surfaces. Therefore the view outside and hence light intake is important not to be obstructed by objects such as the movable curtains or obstacles on the racks in front of the windows.

The work desks currently are equipped with adjustable desk lamps which operate with fluorescent light sources. My recommendation would be to gradually phase out those and replace them by LED solutions with higher CRI to enable more accurate colour distinction and also reduce energy use.

The area between the laser cutter and the soldering workspace shows extremely low horizontal illuminance which is due to two factors: The blocking of windows by the laser cutter and a missing downlight. A quick fix here would be to add a ceiling integrated LED panel as defined in my lighting layout plan.
In the corridor I found five different partly overlapping areas of potential for improvement regarding the lighting. One of those is the newly defined area for (co-)working which consists of the four table setup. Two others are the north and the south ends of the corridor. One more is the windows. And finally the overall space as another area of potential.

By numbers increase of illuminance is necessary in either ends of the corridor as well as on the tables.

The work desks could be improved in usability by adding task lights which allow individual control. This would enable studying according to the personal preferences and makes sure of matching standards at the same time. Due to the limitation of height and also in order to not compromise space on the table I recommend ceiling mounted fixtures here.

Especially as the windows are rather small and the embrasure is very deep it is truly important to keep them clear of any obstacles. Simple but effective to maintain the daylight factor.

Illuminance levels at both ends of the corridor can be addressed by my overall new lighting design which replaces the current solution consisting of wall-mounted downlights that wash the walls in the main part of the corridor and some recessed downlights in the northern end. The new design not only fixes the numbers but also implements my vision of a light and dynamic space into the
**DESIGN LIMITATIONS**

**LIGHTING DESIGN PROPOSAL // RESULTS**

**corridor**

After my analysis of the spaces and discussions with people using the area I realised that there are certain aspects to be addressed and others to be compromised.

Most obvious is the very limited height of the corridor. Due to a clearance of only two meters in height this space by itself completely lacks in supporting to create the feeling of spaciousness for the user.

Spaciousness supporting solutions such as the illumination of ceiling and walls seemed to be the solution to reach my vision. Nevertheless the space turned out to be a challenge to even implement any luminaires without compromising other aspects. Different setups showed different weaknesses and strengths regarding glare risk due to only narrow mounting possibilities and light distribution. A compromise can only be properly evaluated through on-site testing.

Furthermore the ceiling supposedly does not support the installation of recessed luminaires. Therefore surface mounted solutions must be considered in this already ‘cramped’ space. Pendant or conventionally surface mounted luminaires on the ceiling were excluded as general lighting options by me right away as those options would further reduce the impression of spaciousness.

**laboratory**

The laboratory shows a pretty decent lighting design already according to my analysis. The few existing flaws can be fixed with rather simple solutions fortunately.
A collective meeting with Charles Windlin, Nadia Campo Woytuk, Federico Favero and all of us students interested in dealing with the project was held in order to discuss requirements and guidelines. The following was agreed upon:

// to transform the corridor into a space for meeting and working
  // ideally individually modifiable
  // by controlling / programming / experimenting
>> two main functions
  // work setting and individual settings

// budget SEK 100.000.- (lighting) / SEK 50.000.- (furniture)
// the project needs to be ready for realisation within this year of 2019
CONCEPT
LIGHTING DESIGN PROPOSAL // RESULTS

current lighting
electric
// wall wash
// indirect lighting
daylight
// two small daylight openings

future lighting
electric
// wall wash
// ceiling wash
// activation of the ceiling as a canvas for light
// task lighting
// indirect and direct lighting
daylight
// two small daylight openings

[Fig 50.1] layers of light current lighting

[Fig 50.2] layers of light future lighting
**dynamic lighting 1**
// activation of the wall as a canvas for dynamic lighting

>> rhythm by dynamic lighting layer

![Fig 51.1] dynamic lighting 1

**dynamic lighting 2**
// activation of the wall as a canvas for dynamic lighting
// activation of the ceiling as a canvas for dynamic lighting

>> rhythm by dynamic lighting layer

![Fig 51.2] dynamic lighting 2
Several variants have been theoretically evaluated throughout my CAD development. Furthermore matching fixtures which offer the light distribution required are gradually integrated in the later stages. On-site testing is required after this theoretical design development to get more realistic results and make further adaptations to the design.
Derived from my findings of the space analysis (zones of activity) I developed a simple but effective solutions for the light concept of the laboratory. It is realised by making use of the same typology of light which remains large-scale downlights. Ceiling integrated LED panels capable of adapting the colour temperature of white light emitted.

The area most north of the laboratory - defined by me as ‘Think Tank’ - is going to be illuminated by warm white light in order to create an atmosphere of togetherness in the sense of supporting a team spirit. The middle area ‘Development I’ is lit up by neutral white light as a transition zone towards the area in the south ‘Making’ which is going to be closest to daylight by colour. This ensures to stay awake and concentrated on detailed work.

This preset should be individually controllable however in order to enable alternative settings.
LIGHTING PLAN
LIGHTING DESIGN PROPOSAL // RESULTS

[Fig 54.1] lighting plan

<table>
<thead>
<tr>
<th>Location</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1.1</td>
<td>wall / cove-mounted</td>
</tr>
<tr>
<td></td>
<td>wallwash / linear</td>
</tr>
<tr>
<td>C2.1</td>
<td>wall / cove-mounted</td>
</tr>
<tr>
<td></td>
<td>ceilingwash / linear</td>
</tr>
<tr>
<td>C3.1</td>
<td>wall / cove-mounted</td>
</tr>
<tr>
<td></td>
<td>variable beam angle /</td>
</tr>
<tr>
<td></td>
<td>projector</td>
</tr>
<tr>
<td>R1.1</td>
<td>ceiling / recessed-mounted</td>
</tr>
<tr>
<td></td>
<td>flood / 62x62cm panel</td>
</tr>
<tr>
<td></td>
<td>(existing)</td>
</tr>
<tr>
<td>R3.1</td>
<td>ceiling / recessed-mounted</td>
</tr>
<tr>
<td></td>
<td>flood / 62x62cm panel</td>
</tr>
<tr>
<td>R4.1</td>
<td>ceiling / recessed-mounted</td>
</tr>
<tr>
<td></td>
<td>flood</td>
</tr>
<tr>
<td>S2.1</td>
<td>ceiling / surface-mounted</td>
</tr>
<tr>
<td></td>
<td>track flood / task</td>
</tr>
<tr>
<td></td>
<td>light</td>
</tr>
<tr>
<td>E1.1</td>
<td>ceiling / surface-mounted</td>
</tr>
<tr>
<td></td>
<td>emergency lighting</td>
</tr>
<tr>
<td></td>
<td>(existing)</td>
</tr>
</tbody>
</table>
LIGHTING SECTIONS CORRIDOR
LIGHTING DESIGN PROPOSAL // RESULTS

[Fig 55.1] plan + [Fig 55.2] lighting section corridor 1/2

[Fig 55.3] lighting section corridor 2/2 + [Fig 55.4] plan
Taking up the current lighting design of washing the vertical and consequently yet logically extending it by ceiling washing light.

The illuminated ceiling is supposed to open up the narrow ceiling and create an improved impression of height and overall spaciousness.
Dynamic is created through patches of light emitted by projectors.
TESTING
LIGHTING DESIGN PROPOSAL // RESULTS

Ceiling grazing

// hotspot in the corner
// patch of light at the opposite wall
// sharp edge of light

>> light distribution not as intended
// wall wash reflector needed
// more distance to ceiling needed

Wall grazing + wash

// pretty even wall wash effect
// no sharp edge of light visible
// no hotspots visible

>> light distribution as intended

Wall and ceiling grazing/wash

// light patch on wall opposite light source eliminated

>> light effect on wall as intended
>> light effect on ceiling to be improved
fixture tested

LED LINEAR XOOLUM™ R HYDRA White IP67

4.300 Kelvin / CRI 85

65° rotational symmetric beam angle

10W/m / 840lm/m / 103 lm/W

made in Germany

results

// The light distribution curve of the fixture tested is not ideal for the ceiling wash as it does not provide a homogeneous intensity throughout the ceiling. A wall wash characteristic would be a better solution for this scenario. Additionally, more distance between ceiling and fixture would probably be necessary.

// On the wall, a pretty even wash is achieved, however, with this fixture's characteristics.

// Further testing is necessary in order to select the perfect version of luminaire for the space.
VISUALISATIONS
LIGHTING DESIGN PROPOSAL // RESULTS

[Fig 60.1-2 + Fig 61.1] lighting simulations corridor
ray tracing (photon shooting) visualisation of the lighting calculation + artwork
VISUALISATIONS
LIGHTING DESIGN PROPOSAL // RESULTS
[Fig 62.1-3] horizontal illuminance corridor
false colour visualisation with lux value indicating isolines
LIGHTING CALCULATIONS
LIGHTING DESIGN PROPOSAL // RESULTS

Fig 63.1 horizontal illuminance work desks
false colour visualisation with lux value indicating isolines
**Scenarios**

**ABSENCE**

Laboratory & Corridor

// All lights switch off after detection of absence of people.

**PRESENCE**

Laboratory

// The layer of general lighting is dimmed up to 100% in dependence of the daylight.
// CCT is reset to standard design according to programming and can be overdriven manually.

Corridor

// The layer of general lighting is dimmed up to 100% in dependence of the daylight.
// The layer of task lighting switches on if someone is present at or in a close distance to the desks (e.g. walks past).

**DYNAMIC**

Corridor

// The layer of dynamic lighting can be controlled individually and is therefore an open scenario.
**Sensors**

// presence sensors make sure light switches off after all users have left the space
// daylight sensor send their lux level signal to the controllers in order to dim up luminaires as much as necessary or in other words dim them down as much as possible
// wall switches and dimmers enable adaptations by the users at all times

**Control System**

In order to enable all control abilities necessary a DALI control system/gateway is required. On top of DALI the mesh network technology Casambi based on the Bluetooth Low Energy protocol takes care of wireless controllability.

**Automatic control**

Presence sensors are the main sensing aspect responsible for engaging the different scenarios. An astronomical clock is the second factor.

**Manual controllability**

The users of the space will always have the opportunity to overdrive any automatic sensor driven light scenario. In order to control all functions of the spaces three manual sensors are necessary: // Colour temperature // Intensity // Dynamics. The aspects of colour temperature and intensity need the ability of linear scaling or dimming whereas the aspect of dynamic simply needs the on/off functionality.
DETAILS
LIGHTING DESIGN PROPOSAL // RESULTS

Fig 66.1 cove lighting solution

Fig 66.2 cove lighting solution with integrated projector
Regarding the area of the laboratory itself not much intervention in terms of electric lighting solutions is necessary to my eyes. All three layers of light analysed according to Richard Kelly - focal glow, ambient luminescence and play of brilliants - light to guide the view, light to see and light to look at are recognisable within the space. Although more oriented towards the pragmatic aspect of providing sufficient lux levels on the working surfaces also elements of focal glow and brilliants are represented.

There are a few measures however that I would suggest for the laboratory’s lighting:

// Addition of one ceiling-integrated panel downlight, see [Fig 54.1 lighting plan]
// upgrade of task lamps to LED technology with high CRI characteristics (90+) and better ergonomics
// rearrangement of 3d-printers and other materials which currently are blocking out daylight
// replacement of all ceiling tiles due to their discoloured condition and therefore low reflectance in order to achieve higher daylight factors through increased reflectance of new tiles
// upgrade of LED-panel downlights to CRI 90+

In the corridor bigger interventions are necessary moving from a one layer general lighting setup to a three layers of light scenario. Ambient luminescence is achieved by indirect lighting activating the ceiling and one wall as reflectors. Task lighting is realised by a flexible mini-track system. Dynamics are created by projections of light onto the wall.
'Daylight is a dynamic source of illumination in architectural space, creating diverse and ephemeral configurations of light and shadow within the built environment' (Rockcastle, Andersen, 2013, p.V).

In the specific scenario I was dealing with a north-northwest facing narrow corridor with just two small windows in the Nordic latitude of 59.2° where those diverse and ephemeral configurations of light and shadow created by daylight hardly appear. Therefore I took into consideration a technical solution to simulate those dynamic effects for my lighting design.

Electric lighting in its essence has always been a recreation of daylight in a way but aspects of dynamics only became realisable recently due to the latest technological and design developments. From a pure functional aspect of extending working hours by the use of electric lighting today more and more awareness is rising about how the use of artificially created light might interfere with our biological system. Light not only triggers our visual system but also our non-image forming system. (Peter R. Boyce, 2014, p.48)

Taking into consideration our current knowledge about how our non-visual system interacts with light and from the perspective of using electric lighting to our favour my lighting design offers improvement for the users of the space.

High values of vertical and horizontal luminance which once the emitted light gets received through certain angles are most effective in triggering areas of highest concentration of melatonin repressing ganglion cells in our eyes’ retinas (Panda, 2019, lecture KTH).

Vertical and horizontal upper surfaces show much higher than average values of luminance from diagonally above which similar to skylight enables light to enter our eyes from the upper half space of a dome. The corresponding areas of our retinas (lower half space) are equipped with ganglion cells of highest sensitivity which are responsible to suppress the release of the sleep hormone melatonin (licht.wissen 19, 2014, p.20).
Dynamics occur as natural phenomena - they basically define all natural processes. Static behaviour is often connected to something lifeless whereas dynamic phenomena appear more lively. That might be one of the reasons for the affiliation which nature evokes in many of us (Wilson, 1984, p.85).

During my lighting design development I found though that in certain scenarios dynamic lighting effects might not necessarily be beneficial for the users. This applies for the area of the laboratory itself. Especially as the ratio of openings is quite high in this room dynamics created by natural daylight can take effect pretty easily. Therefore a more static lighting design is applied here.

To conclude whether artificial dynamics make sense to be implemented I suggest to thoroughly analyse the space and its use first in order to be able to evaluate if natural dynamics are sufficient and to decide thereafter.
Due to ongoing chronobiological research and further technological development of electric lighting systems almost infinite lighting design opportunities occur to be realised in the future. As of today we as professionals are all experimenting in the field and try to understand the outcomes of our designs.

Awareness about potential influence of certain lighting solutions partly triggered by manufacturers pushing their innovations on the market but on the same time independent research is making progress.

It remains a challenge for lighting designers how to best deal with spaces that for various reasons are not sufficiently sun-drenched. Reasons for that lack of daylight can for example be noticed during a change of use of the space in historic buildings as in the case of my project or also be planned for functional areas in modern architecture.

Innovative lighting systems can help to improve sojourn quality in such spaces. A lighting solution that simulates daylight in a static way has been evaluated as satisfying by the majority of test subjects in a comparing study to a room with natural daylight (sun research TH OWL, 2017).

The addition of dynamics in electric lighting solutions might be beneficial for a wide range of spaces not as an alternative for daylight but as an improvement of spaces that are not sufficiently impacted by it.

The aspect of dynamics in lighting establish potentials which are not yet investigated sufficiently and therefore worth doing further research on. My lighting design proposal offers the flexibility to use the space in different preset scenarios but also to adapt it in the future by creating new dynamics. Inspired by the research being conducted concerning biophilia the phenomenon of dynamics in lighting could be useful addition.
To sum up I see great potential in the field of lighting design by the integration of dynamics in lighting. Further research would be necessary to confirm possible benefits for the users.

Technology-wise products originating from the professional field of highly dynamic stage lighting get more and more miniaturised and therefore become valid options to be integrated into architectural contexts.

It is important to continue investigating in this topic by evaluating two main issues concerning dynamics in lighting:

1) Does the user benefit by any element of dynamic at all?
2) Post occupant: How are different elements and intensities of dynamics in lighting perceived?

Once realised those studies can be carried out in the facilities of MIDDLA.

Interesting questions could be whether dynamics create awareness or attention and how it correlates with performance or well being.

Dynamics in electric lighting is of great potential in future lighting designs I conclude.

[Fig 71.1] project timeline
SPACE ANALYSIS TABLE

APPENDIX

[Fig 72.1] personal analysing method
inspired by the MAK method
## Fixtures Table

### 282
**LED Linear GmbH - XOBULM-R HYDRA LD10 W835**
- **Lichtausstritt**: 1
- **Bestückung**: 1x
- **Betriebswirkungsgrad**: 100%
- **Lampenlichtstrom**: 136 lm
- **Leuchtenlichtstrom**: 136 lm
- **Leistung**: 1.3 W
- **Lichtausbeute**: 108.7 lm/W
- **Farbmetrische Angaben**: 1x: CCT 3000 K, CRI 100

### 4
**Reggiani Spa Illuminazione - CN61H-HQ-31° EVO 48V**
- **Lichtausstritt**: 1
- **Bestückung**: 1xCN61H-HQ-31°
- **Betriebswirkungsgrad**: 100%
- **Lampenlichtstrom**: 142 lm
- **Leuchtenlichtstrom**: 142 lm
- **Leistung**: 4.0 W
- **Lichtausbeute**: 35.5 lm/W
- **Farbmetrische Angaben**: 1x: CCT 3000 K, CRI 100

### 4
**ZUMTOBEL - 60818506 P-INF R150L LED1800-927-65**
- **Lichtausstritt**: 1
- **Bestückung**: 1xLED_P-INF_1850_927 23W
- **Betriebswirkungsgrad**: 100%
- **Lampenlichtstrom**: 1850 lm
- **Leuchtenlichtstrom**: 1850 lm
- **Leistung**: 23.0 W
- **Lichtausbeute**: 80.4 lm/W
- **Farbmetrische Angaben**: 1xLED_P-INF_1850_927 23W: CCT 2700 K, CRI 90

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Gesamtlampenlichtstrom: 43600 lm, Gesamtleuchtenlichtstrom: 43600 lm, Gesamtleistung: 448.6 W, Lichtausbeute: 97.2 lm/W
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[Fig 5.1] Time and Date AS

[Fig 15.1] Philips Large Luminous Surfaces

[Fig 16.4-7] VEX Caustics by animatrix

[Fig 16.8] Panasonic Corporation

[Fig 17.1-2] Robe Lighting S.R.O.

[Fig 17.3] Rosco Laboratories

[Fig 18.4-5] GLP German Light Products GmbH

[Fig 19.1] onesmallstich

[Fig 20.1-2] apple maps

[Fig 21.1] google maps

[Fig 22.1] andrewmarsh.com (sun path map) + Wikimedia maps/OpenStreetMap

[Fig 34-37.2] visual calculation by Lupin for iPhone app by ENDO Lighting Corp.

[Fig 59.1-5] LED-Linear GmbH

[Fig 73.1] DIALux

created by author Jonas Becker
Das Fräulein stand am Meere

Das Fräulein stand am Meere
Und seufzte lang und bang,
Es rührte sie so sehre
Der Sonnenuntergang.

Mein Fräulein! sein Sie munter,
Das ist ein altes Stück;
Hier vorne geht sie unter
Und kehrt von hinten zurück.

Das Fräulein stand am Meere
The girl was standing on the shore,
Und seufzte lang und bang,
Deep were her sighs, tears filled her eyes,
Es rührte sie so sehre
For she was moved to the very core
Der Sonnenuntergang.
By the glory of that sunset.

‘There, young lady, don’t you mind,
That’s an old stunt you will find;
Hier vorne geht sie unter
The sun you see go down in front,
Und kehrt von hinten zurück.
Comes up again, behind!’

Heinrich Heine