Building Simulation

Seventh International IBPSA Conference
Rio de Janeiro, Brazil
August 13-15, 2001

LIGHTSHELVES AND FINS - CARRYING ON WHERE THE TROPICAL MODERNISM LEFT OFF

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ABSTRACT

When modernist architecture in the tropics started in the 30´of the 20th century, air-conditioning systems and special glazing were not yet available. To realize modernist architecture in the tropics a tropical approach was necessary so as to adapt modernist design with the climatic reality of the tropics: the fins were introduced.

Due to handling and maintenance problems, poor daylighting conditions and a new aesthetic in form of curtain wall facades, the fins were widely abandoned by architects and engineers.

But due to the high solar radiation even new glazing technologies couldn't resolve a mayor problem in tropical office buildings: the extremely uneven daylighting distribution, causing glare problems close to the façade and creating spots without sufficient daylighting just a couple of meters away from the façade.

Radiance therefore was used to improve and develop a three-dimensional fixed system, a combination of light shelves and fins, specifying new materials to ensure the demands of daylighting in modern office buildings. The results are quite promising.

INTRODUCTION

Generally the technical best solution to adapt a façade to the always changing sky situations, from clear sky and sun to overcast sky is a combination between a highly flexible sun protection system and a relatively low depth of the room. This solution is confronted many times with three mayor problems:

1. The initial costs of a highly sophisticated sun protection system are very high, especially compared with the relatively low construction costs in a tropical country like Brazil
2. The necessary maintenance for the electrical and mechanical parts of the system is generally not guaranteed
3. Whenever an appropriate depth for workspace, ensuring proper daylighting even under clouded conditions, is not enforced by law, the investors will try to use to a maximum the possibility to construct sellable space, creating deep office spaces without proper daylighting.

This facts may not be exclusive arguments for firms, which build there own administration building. Their cost calculation are more projected into the future. For all the others it is important to offer a solution, which brings together a simple sun protection system to counter point 1 and 2 and a daylighting system to bring daylight deep into office spaces and so counter point three.

METHODOLOGY

Rio de Janeiro can be considered as one of the most interesting tropical cities with modernist architecture. Therefore it has been chosen to deliver the daylight parameters for the simulations. The maximum value as measured with a class 2 illuminance meter by the author at midday for CIE clear sky and sun were of 114000 Lux for the 21st of December and 60.000 Lux for the 21st of June, which were used in the Radiance - simulations. The values or CIE intermediate sky & sun were approximately measured for intermediate sky without sun. This distortion is due to the generally higher illuminance in tropical countries. The daylighting situation was checked for three times a day: 9 am, 12 am and 4 pm, which can be considered as core office hours. As the deepest room penetration by sunlight takes place on June, 21st, causing glare close to the façade while at the same time showing the lowest illumination level, this paper will limit its report on that date.

CIE clear sky sun	9 am	12 am	4 pm
21.06.	34045 lx	60201 lx	21344 lx
21.12.	64358 lx	114007 lx	50017 lx
CIE intermediate with sun	9 am	12 am	4 pm
21.06.	13086 lx	21201 lx	8588 lx
21.12.	21880 lx	25582 lx	18594 lx

Table 1: Illumination Values on different Day Times at Solar Max. and Min. Dates; confirmed through handheld class 2 measurements by the author (variation < 5%)

The horizon is supposed to be free of any obstruction. The standard room is 8 m deep, 5 m wide and 3 m high (see also figure 1). The geometry was chosen to reflect a typical situation in office spaces in Rio de Janeiro – deep rooms with bad daylight situation.
The degree of reflection of the walls and the ceiling is 0.85, of the floor 0.54. The reflectance of the working place is 0.8 (Radiance material "plastic").

The external lightshelf reflects 87 %, the internal light shelf 85 % (Radiance material "plastic"). The fins have a reflectance of 85 % ("plastic").
For the Radiance-simulations a ambient value 0.1 was chosen (considering all layers), 4 reflections were calculated.

The depth of the external lightshelf is 1.20 m with an inclination of 25°. The depth of the internal lightshelf is 2.09 m, with an inclination of 6°. The fins are 1.30 m deep and fixed in a 90° angle to the façade, on a regular axis of 1.25 m. That means 5 fins on the 5 m part of the façade.
To protect the room from low incoming solar radiation, a blind of 0.76 m was fixed 0.33 m from the outside boundary of the fin.
With this combination of light shelf, fins and blind, a direct penetration of daylight can be completely avoided.

The illuminance level is calculated for a work place altitude of 0.72 m. The points of the calculation grid are every 1.0 m in the depth of the room and every 1.5 m in the width, with a distance of the grid of 0.25 m from the walls.

In order to compare the performance of the lightshelf and the fins, two standard glazing where simulated within the same scenery: a single pane clear glazing with a transparency of 85 % and a single pane reflective/absorptive glazing with a transparency of 54 %. As a fourth possibility the application of a lightshelf without fins was simulated.

As sole orientation of the facades North was considered. South wasn't considered because of the very low importance of sun protection in this orientation. (see figure 2). For daylighting, other systems might be more appropriated. The East and West orientation were not considered due to the low incoming solar beams, which does not favour a fixed system. Openings in East and west facades should generally be avoided, or be equipped with a flexible system.

Observation: the thermal aspect of the results as well as the luminance aspect are part of the study and are under preparation for publishing.

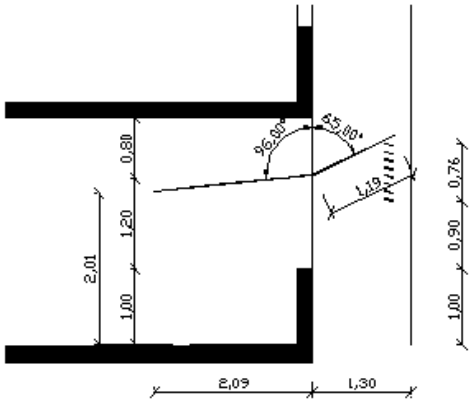

Figure 1: section of type room with light shelves, fins and glare protection

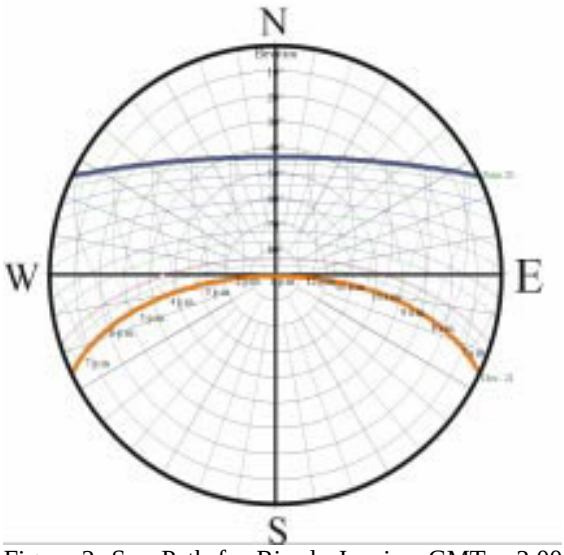

Figure 2: Sun Path for Rio de Janeiro, GMT – 2.00 (summertime)

RESULTS

The demonstration of the results has to be split due to the wide range of illumination values created by the different types of façades. The first part of the tables shows the full range, while the second part concentrates on the comfort range between 0 and 3000 lux, therefore zooming this part of the full

range figure. The Brazilian norm NBR 5413 for illumination foresees 500 lux as minimum for the general illumination of office spaces, recommends up to 2000 lux in class B (general illumination for working space) and promotes 2000 to 20000 lux (the highest value for surgical operations) as additional illumination for difficult visual tasks.
The results concentrate on maximum values obtained by the simulation, due to the special situation in the tropics: the problem is an offer of very high illumination values, causing glare and thermal discomfort. The minimum values in the back of the room were fairly distributed and are therefore not separately shown (example fig. 4c).

A) CIE Clear sky and sun

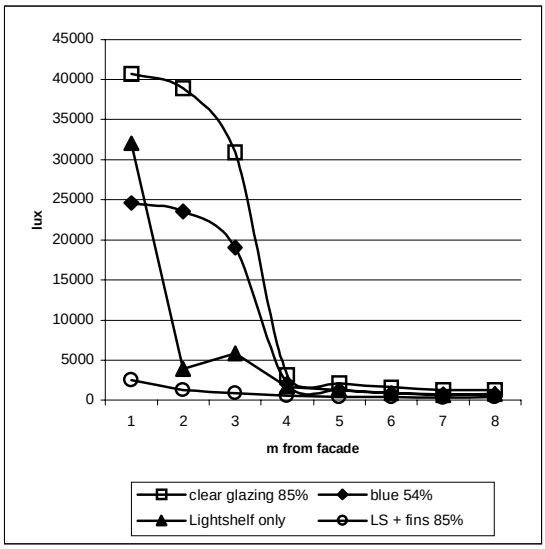

Figure 3a: Analysis of Full Range, 21st of June, 9 am, CIE clear sky sun

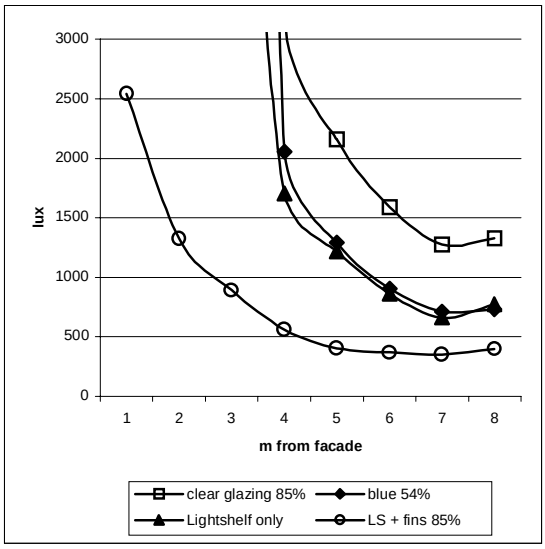

Figure 3b: Analysis of Comfort Level, 21st of June, 9 am, CIE clear sky sun

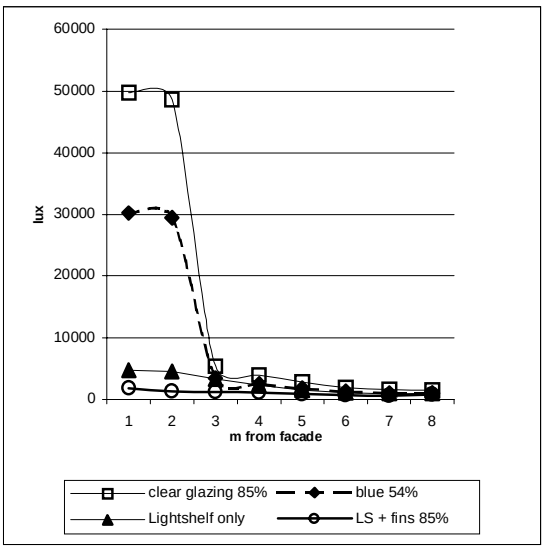

Figure 4a: Analysis of Full Range, 21st of June, 12 am, CIE clear sky sun

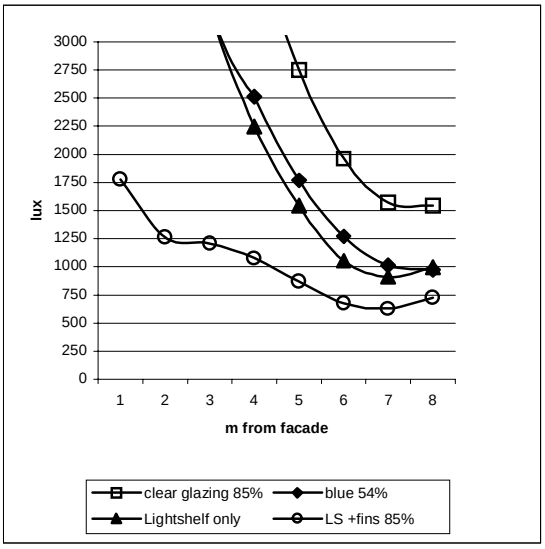

Figure 4b: Analysis of Comfort Level, 21st of June, 12 am, CIE clear sky sun

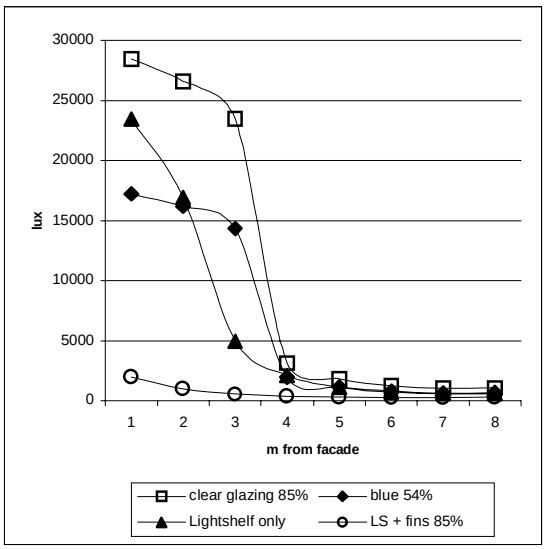

Figure 5a: Analysis of Full Range, 21st of June, 4 pm, CIE clear sky sun

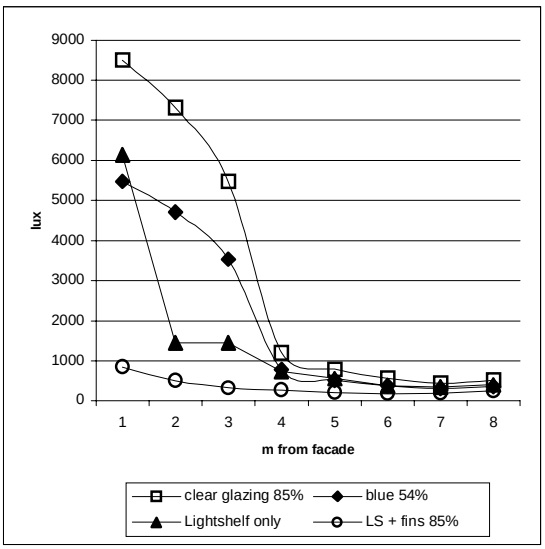

Figure 6a: Analysis of Full Range, 21st of June, 9 am, CIE intermediate & sun

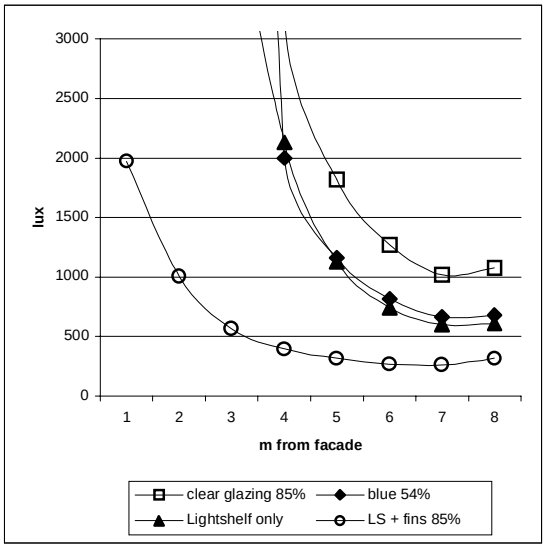

Figure 5b: Analysis of Comfort Level, 21st of June, 4 pm, CIE clear sky sun

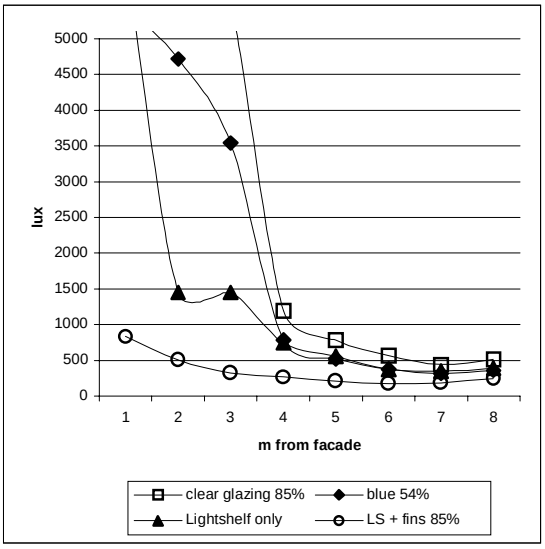

Figure 6b: Analysis of Comfort Level, 21st of June, 9 am, CIE intermediate & sun

The combination of lightshelf and fins results in an excellent daylighting distribution. Even in the depth of the room the available daylight situation is quite good.
The "lightshelf only" solution performs reasonably well at 12 am and from 1 m on at 9 am, but suffers from a lack of lateral protection.
All other possibilities are suffering from a very high illuminance in the first 3 to 4 m from the façade, which, in an office situation. Even the reflective glazing with a transmittance of 54% can not avoid the high illuminance rate close to the façade.

B) CIE Intermediate sky and sun

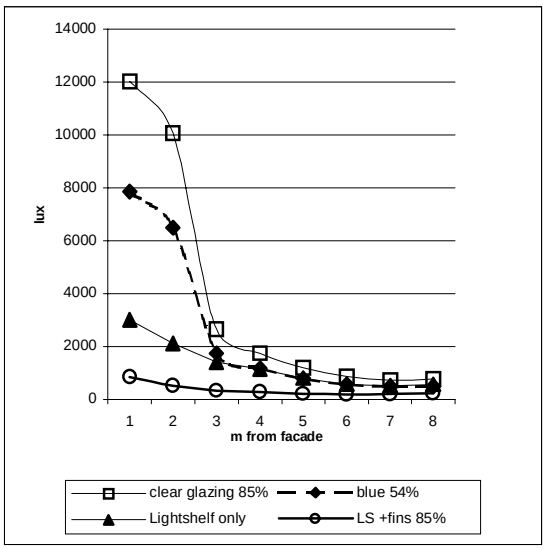

Figure 7a: Analysis of Full Range, 21st of June, 12 am, CIE intermediate & sun

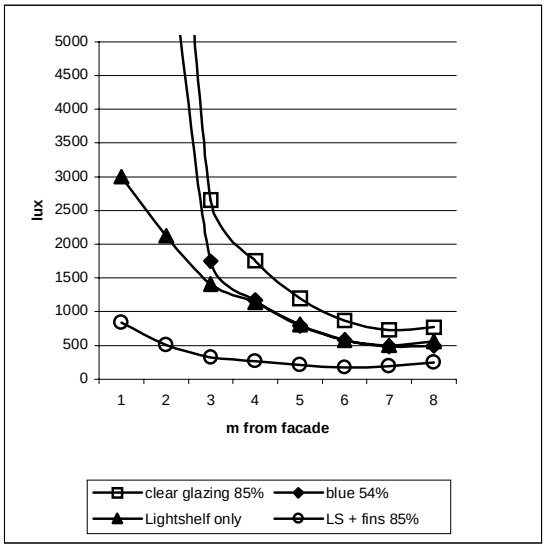

Figure 7b: Analysis of Comfort Level, 21st of June, 12 am, CIE intermediate & sun

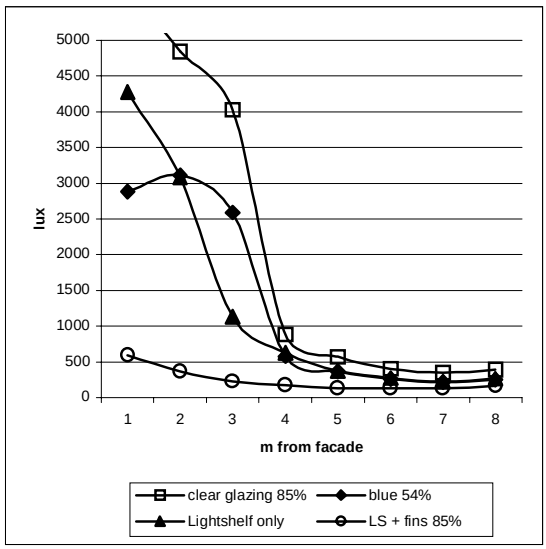

Figure 8: Analysis of Comfort Level, 21st of June, 4 pm, CIE intermediate & sun

Under CIE intermediate sky and sun conditions, the daylight distribution with the combination of lightshelf and fins is quite even, but this time suffers from a low illuminance level in the depth of the room.
All other solutions suffer, despite a much lower external illuminance level, from a too high illuminance level close to the facade.

CONCLUSION

In a typical weather situation for Rio de Janeiro – clear sky and sun – the combination of lightshelf and a semi-transparent fins can improve significantly the necessary combination between sun protection and daylight distribution. The maximum illuminance close to the façade is reduced to less than 3000 lx, while even in the morning and the afternoon the illuminance in the back of the room still is around 500 lx (fig. 3b & 5b). Beside the advantages in glare reduction and daylight distribution must be emphasised the visual comfort of very light fins, reducing the obstruction of the view perpendicular to the façade to almost zero.

Clear glazing without additive sun protecting devices is definitely not possible, and, even with these devices will only provide reasonable natural illumination close to the façade.

Reflective or absorptive glazing reduces solar radiation, but still can't provide a reasonable daylight distribution. Too high illuminance close to the façade and a sharp drop of daylight in the back of the room are the result.

A lightshelf-only solution does not work very well, too, due to direct solar radiation penetrating the room from the side in the morning and in the afternoon.

Considering the results of Radiance, the efficiency of the combination of lightshelf & fins loses its advantages when there is few or no direct solar radiation. But there should be taken into account two facts:

1. a recent evaluation of Radiance showed too low values for diffuse daylight in the back of the room[1], so some better depth performance can be expected in a real application;

2. the CIE descriptions for intermediate and overcast sky are not very useful for the tropics, because the diffuse radiation in the tropics can be extremely powerful, which is not considered in the CIE descriptions[2] and

3. Rio de Janeiro is a sunny city (1750 kWh/m² year [3]), and even when partially overcast there is still plenty of direct radiation available.

Anyway, even with a powerful and evaluated (day-)lighting design tool like Radiance it is always advisable to cross check results in some other way, preferably in a 1:1-test unit.

REFERENCES

[1] Adeline Newsletter Nr.8, 7.Jahrgang, Fraunhofer-In stitut für Bauphysik, Stuttgart 10/1999, Germany, p. 1f

[2] Roy, G., Ruck, N., Reid, G., Winkelmann, F., Julian, W. [1995] The Developement of Modelling Strategies for Whole Sky Spectrums under Real Conditions for International Use. University of Sydney, Murdoch University/Australia, p. 83

[3] Corbella, Oscar [1995] Reconstrução e analise de dados de radiação solar e horas de brilho solar para a cidade de Rio de Janeiro. Anais do III Encontro Nacional/Iencontro Latino-Americano de Conforto no Ambiente Construído. Gramado/Brazil, p. 170

NOMENCLATURE

CIE: Commission Internationale de l'Éclairage

Annotation: Radiance simulations create photo-realistic images and false color picture, which are both quite helpful for the development of (day-)lighting solutions. Due to well known quality problems in monochrome reproduction on normal paper and in small scale, this images are not included in this paper. They might be shown as slides at the conference.

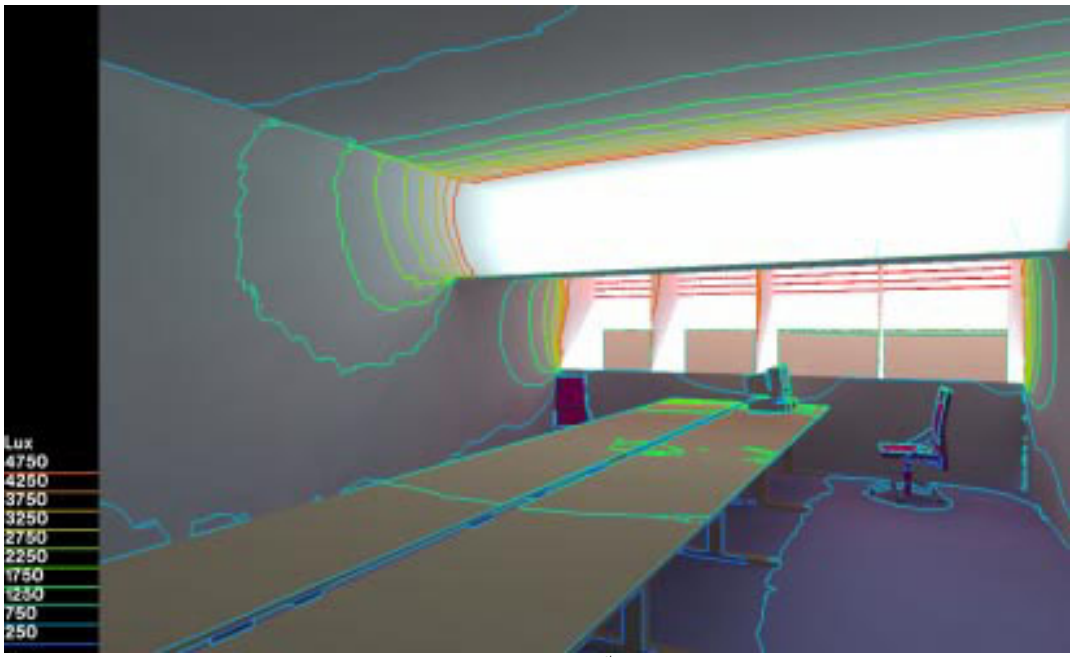

Figure 4c: False color image for light shelf with fins, 21st of June, CIE clear sky sun