(e) Provide daylight filters

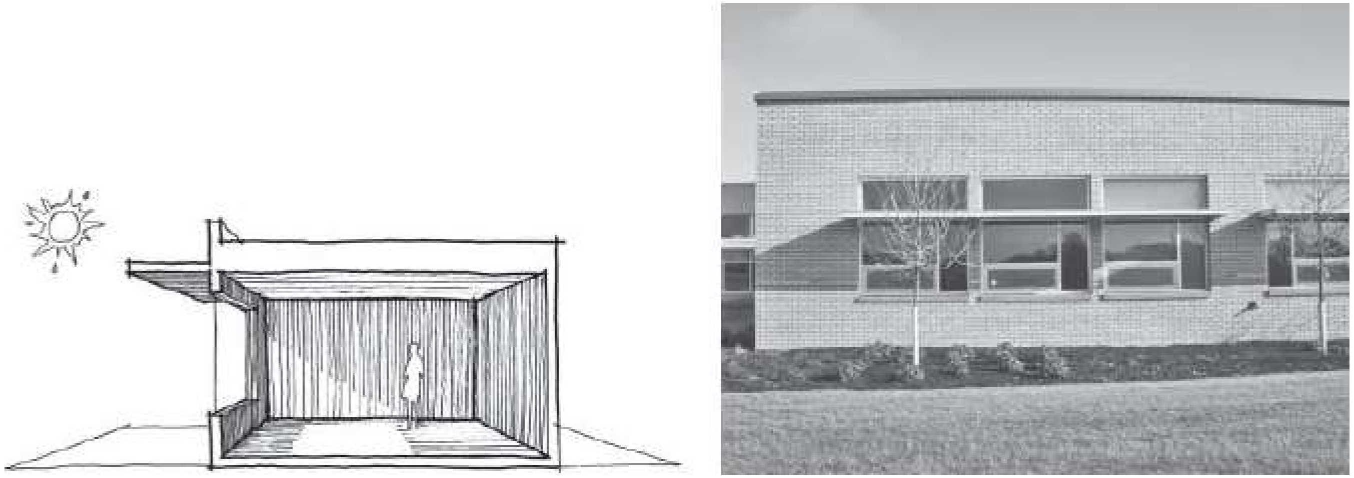
- To modify, block, diffuse daylight
- Elements: trees, vines, trellises (격자구조물) (Fig.10.11(a)) (exterior), blinds, drapes, etc. (interior)

(a) (b)

Fig. 10.11 (a) Trellis at Westcave Environmental Center, Round Mountain, Texas. (b) Several layers (trees, shading, curtains) at a window can filter light and provide shade. (a: © Walter Grondzik; all rights reserved; b: photo by Nathan Majeski.)

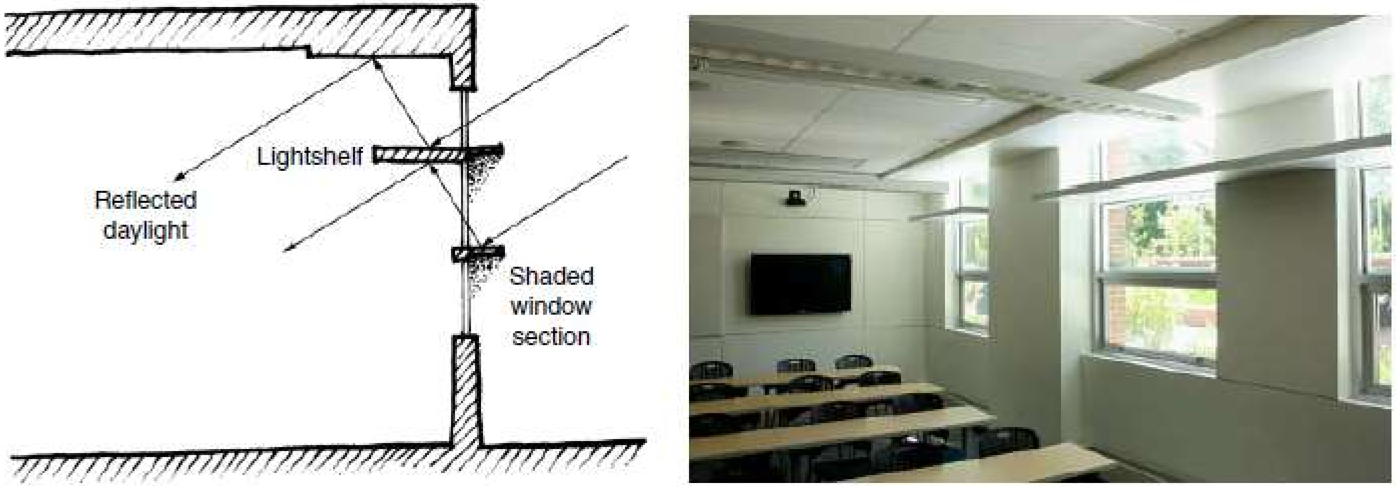
(f) Provide summer shading

- Why? Direct sunlight should be blocked before it enters a space.
- Exterior lovers (horizontal, vertical), overhangs, trellises, trees, light shelves



(a) (b)

Fig. 10.12 *(a) Horizontal overhangs block light but also act as a reflector for light from the ground plane. (b) Horizontal shading devices at Ash Creek Intermediate School, Monmouth, Oregon. (Drawing by Erik Winter; photo by Alison Kwok; © Alison Kwok; all rights reserved.)*



(a) (b)

Fig. 10.13 *(a) Lightshelf reduces the daylight factor near a window and increases it at greater depths. Shelf material (opaque, translucent) and angle of installation (horizontal, sloped up) markedly affect performance. (b) Classroom lightshelf, Allen Hall School of Journalism, Eugene, Oregon. (© Karen Tse; used with permission.)*

Fig. 10.14 *Fixed horizontal louvers on the south façade at the Phoenix Public Library, Phoenix, Arizona. (© Walter Grondzik; all rights reserved.)*

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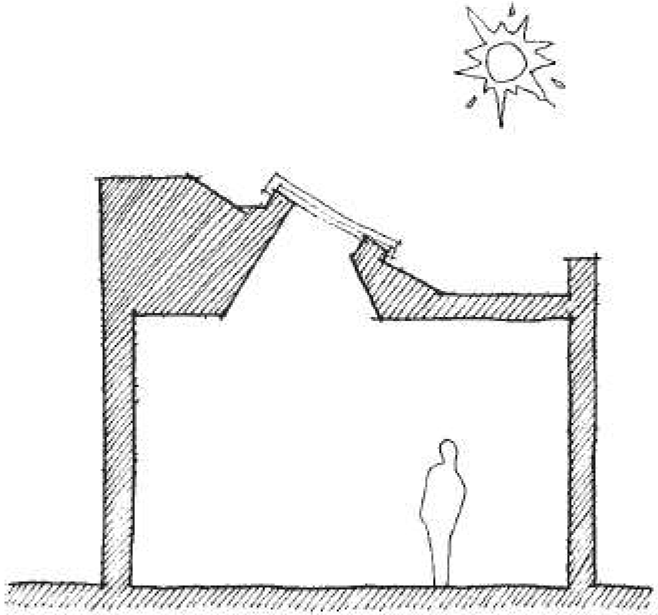
desgined by Dominique Perrault

Aperture strategies: toplighting

- Elements: skylights, roof monitors, clerestories (고측창), particularly for interior locations of large floors that are far from perimeter windows
- Top lighting components should be away from the offending zone (areas with a direct view from an occupant) or use a baffle or interior reflector to diffuse or control daylight.

(a) Splay the wall of an aperture

- To reduce the glare (because light washes along a larger surface area)

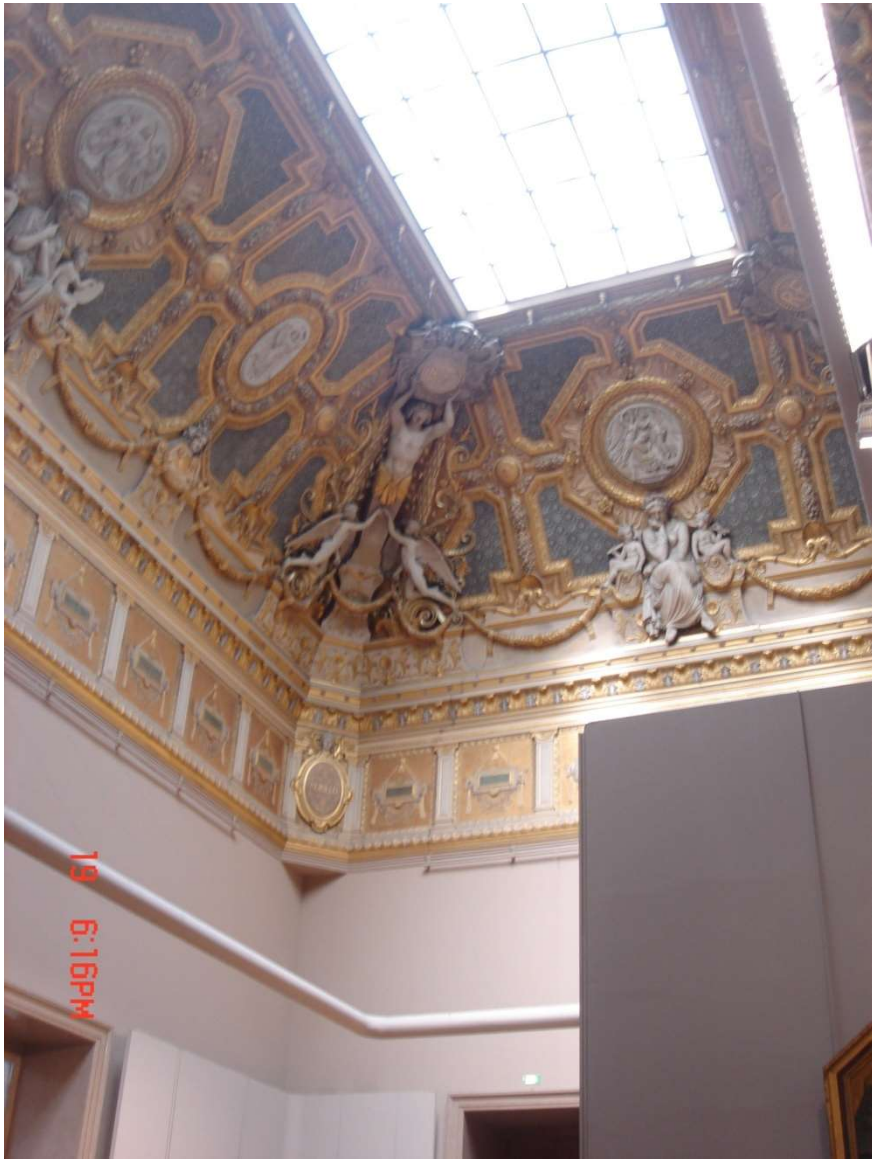


(a)

(b)

Fig. 10.15 *(a) Splayed surfaces of a skylight provide areas for diffusely reflected light. (b) Conical skylights at Millesgården Museum and Sculpture Garden, Lidingö, Sweden (Everet Milles). (Drawing by Erik Winter; photo © Karen Tse; used with permission.)*

Getty museum, LA

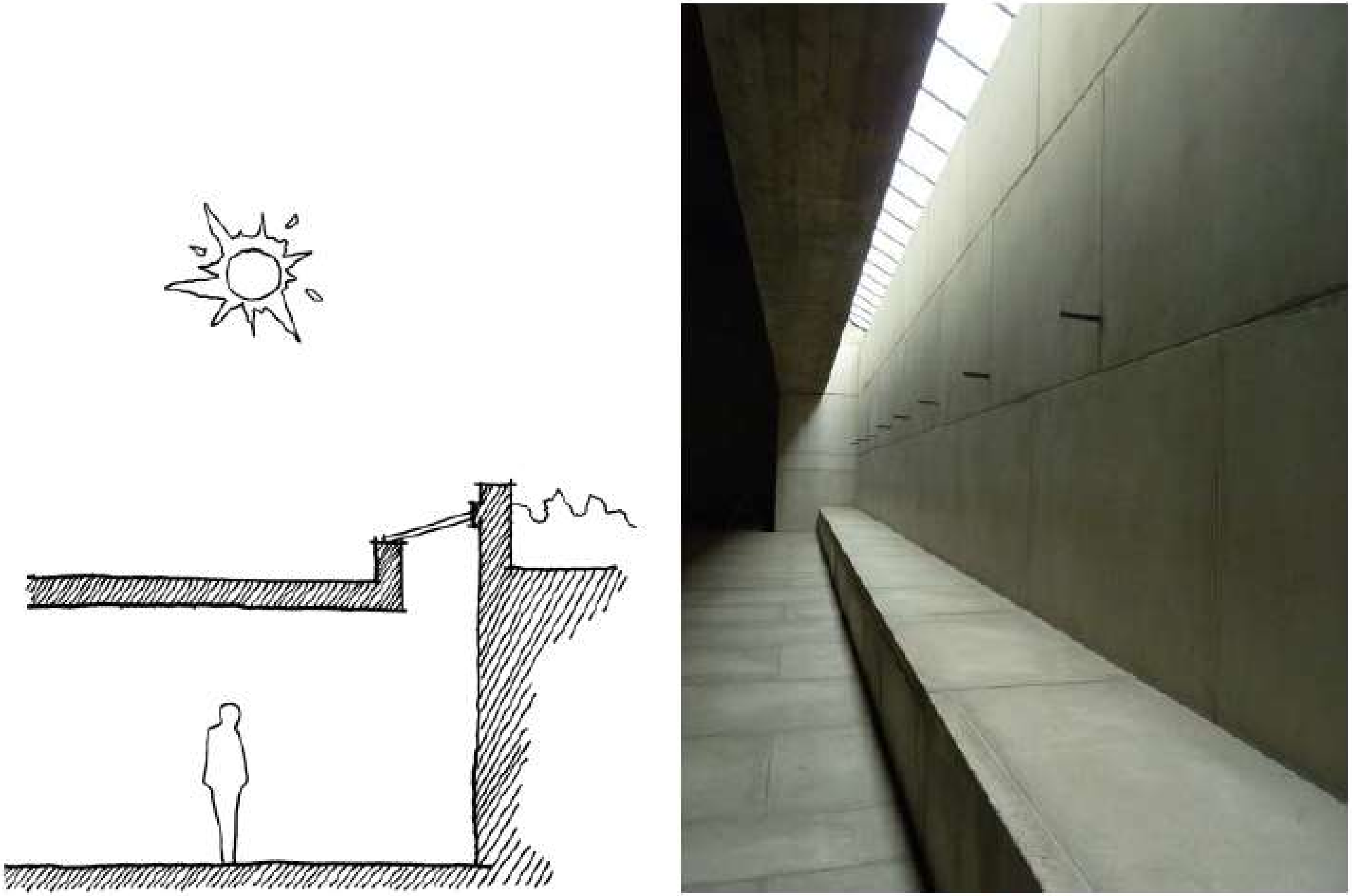


Louvre, Paris, France

Louvre, Paris, France

(b) Place toplights high in the space

- Allowing more surface to diffuse light



(a) (b)

Fig. 10.16 *(a) A skylight near a north wall provides reflecting surfaces for uniform light distribution and reduces the potential for glare. (b) The linear toplight enables light to wash an interior concrete wall at the Chapel of the Holy Cross, Turku, Finland (Pekka Pitkänen). (Drawing by Erik Winter; photo © Karen Tse; used with permission.)*

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The Orlando Int'l airport (2010.01)

The Orlando Int'l airport (2010.01)

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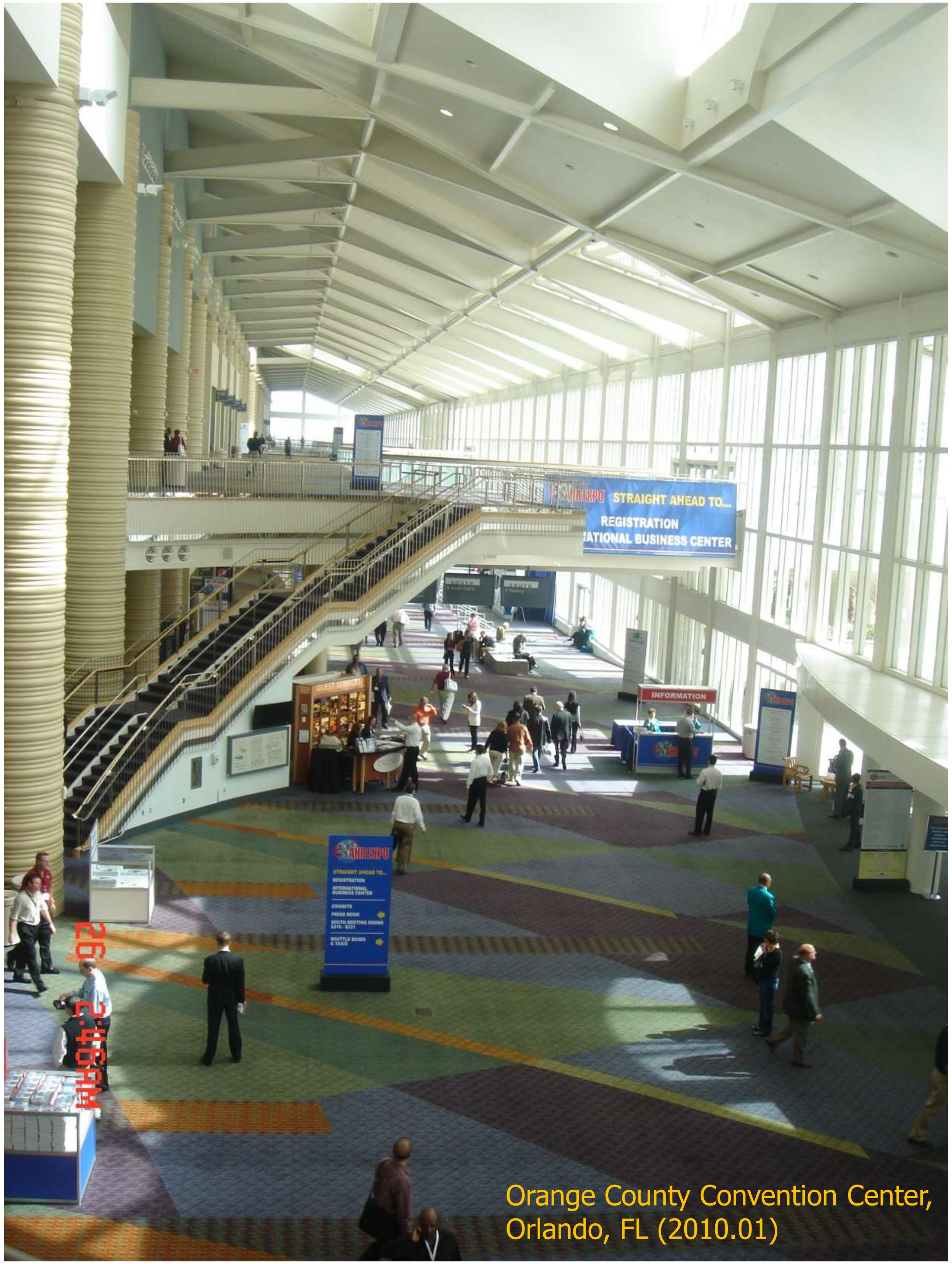
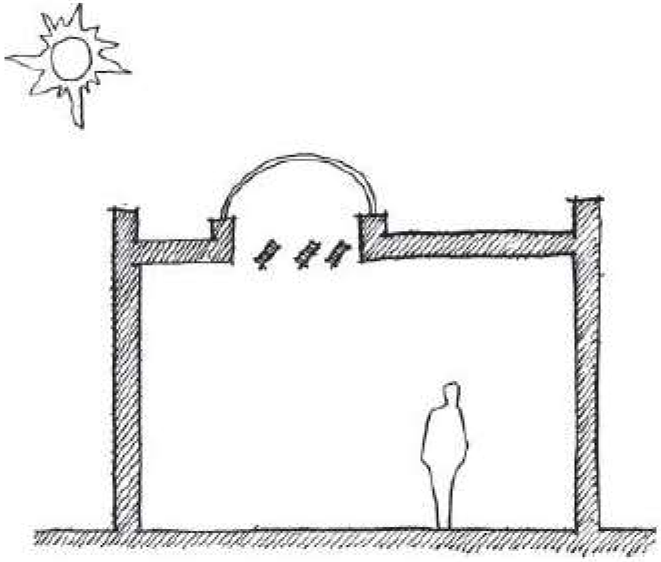


Orange County Convention Center,
Orlando, FL (2010.01)

(c) Use interior devices to block, baffle, or diffuse light

- To diffuse the light onto another surface within the space

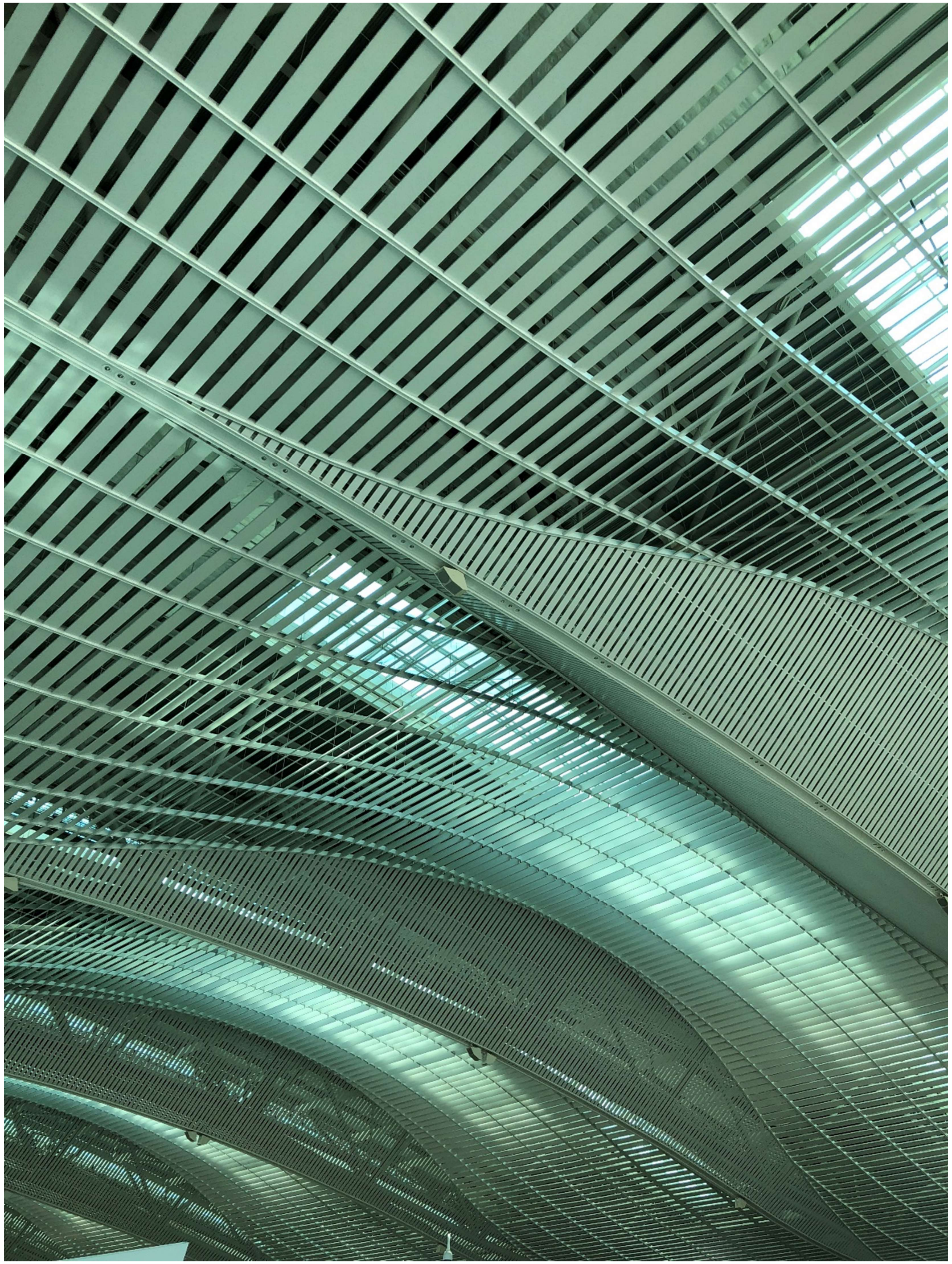


(a)

(b)

Fig. 10.17 *(a) Skylight with baffles that block direct solar radiation. (b) Baffled skylight daylighting design at Mt. Airy Public Library, Mt. Airy, North Carolina (Edward Mazria). (Drawing by Erik Winter; photo by Fuller Moore; © 2004 The Society of Building Science Educators; used with permission.)*

Fig. 10.18 *Clerestory skylights with louvers at the U.S. Holocaust Memorial Museum in Washington, DC (Pei, Cobb, Freed & Partners). (© Alison Kwok; all rights reserved.)*

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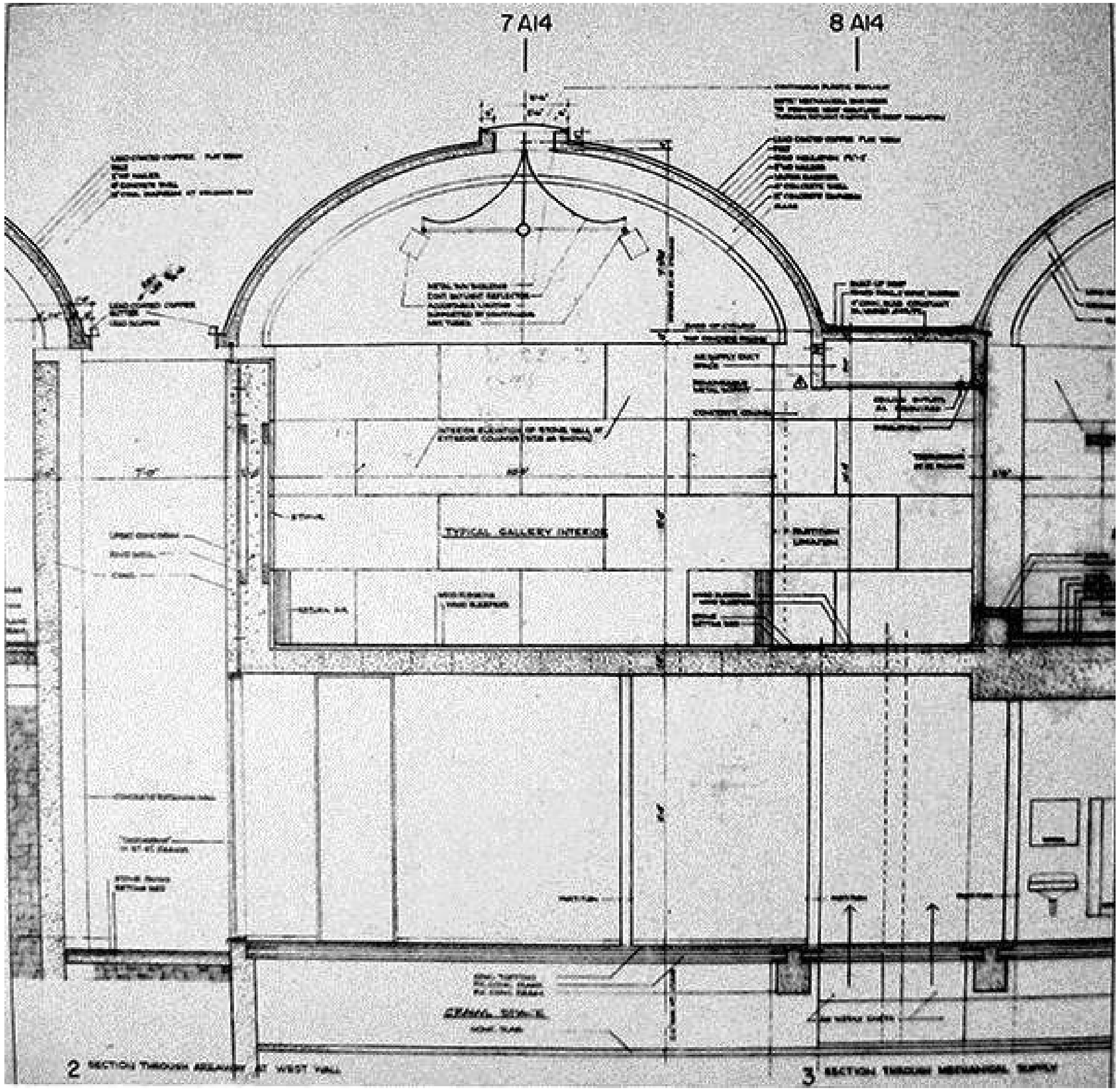
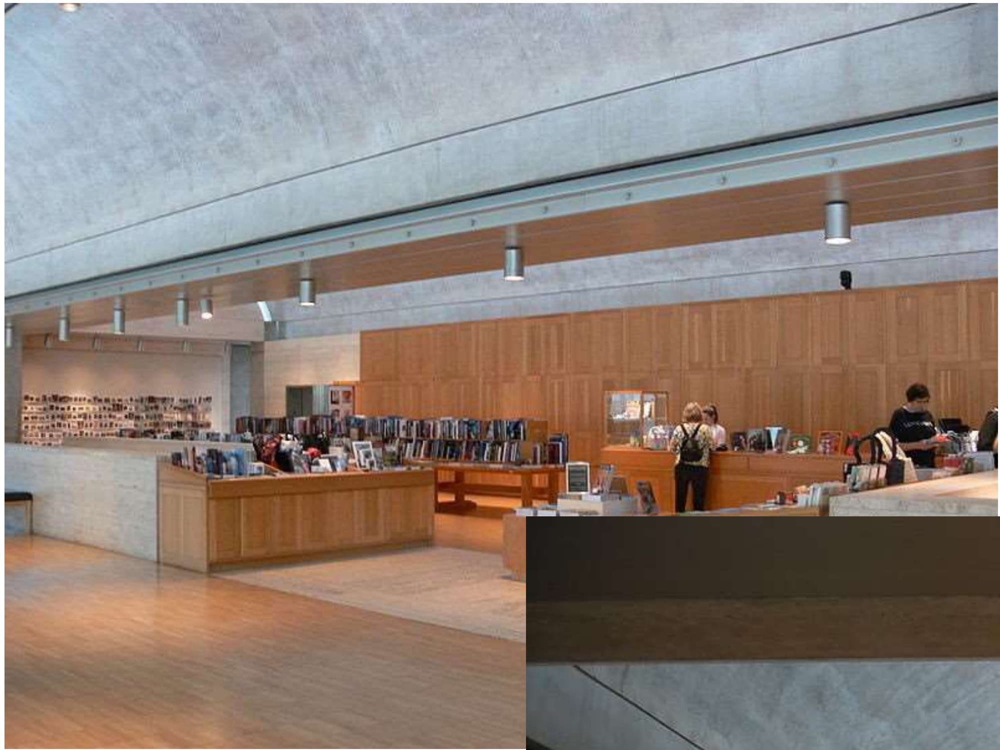
Louis Khan:Kimbell Art Museum





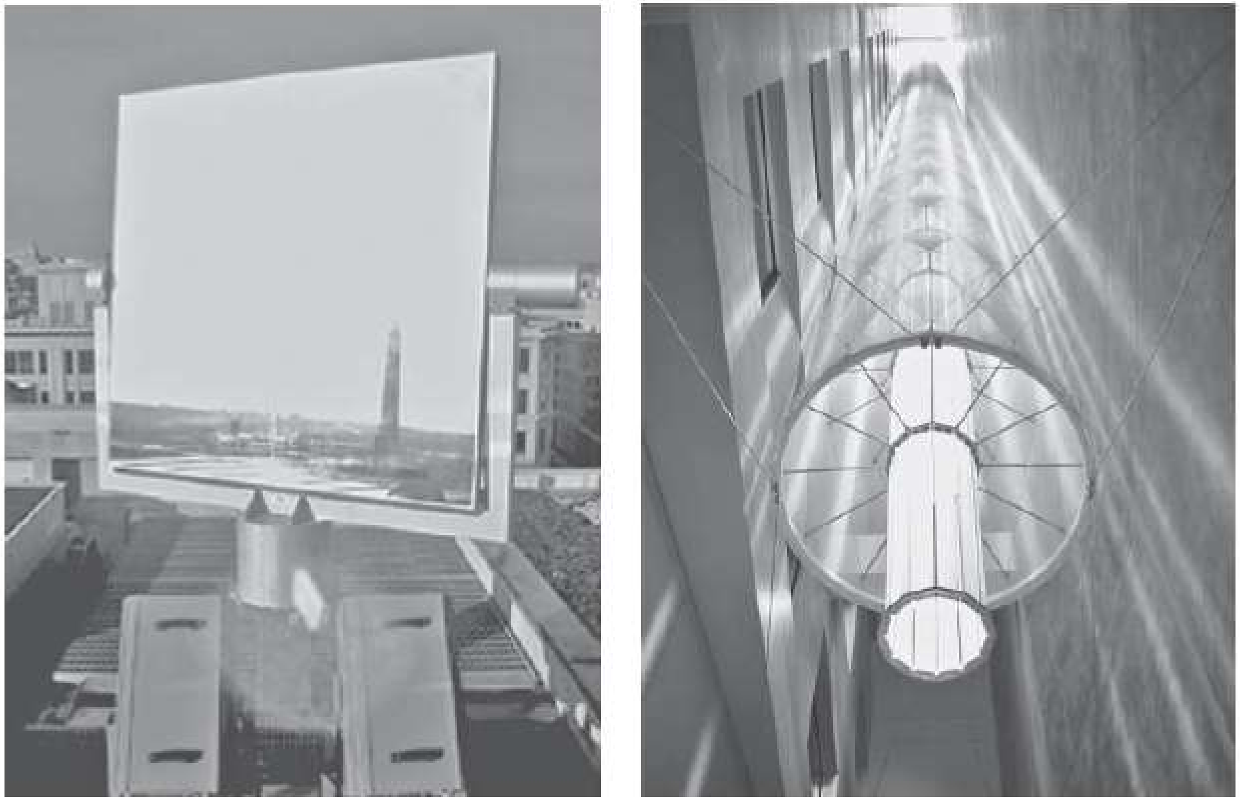

Exhibition Tickets


18 6:59PM

Musée de l'Orangerie

Specialized daylighting strategies

- Light pipes: daylight pipes, fiber optic pipes (See Fig.10.19)
  - Low Energy Building at Tsinghua Univ.
- Tubular skylights (See Fig.10.20)



(a) (b)

Fig. 10.19 *(a) Heliostat on the rooftop of a building tracks the sun and directs light into an 8-ft (2.4-m) wide atrium and down 14 floors. (b) The heliostatic light tube is a 120-ft (37-m) long, 6-ft (1.8-m) diameter, 12-sided steel-and-aluminum frame—enclosing laminated glass panels and surrounded by fabric—within the atrium at the Morgan Lewis building in Washington, DC. (© Carpenter Norris Consulting; used with permission.)*

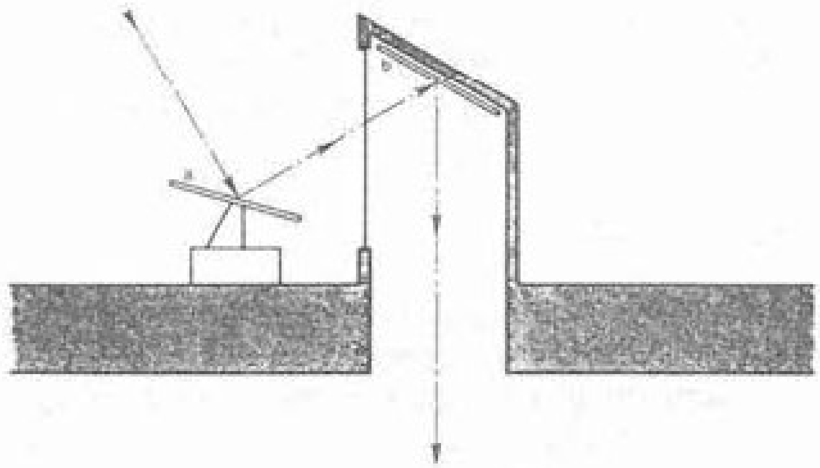


Fig.8.3 A simple heliostat with plane mirrors

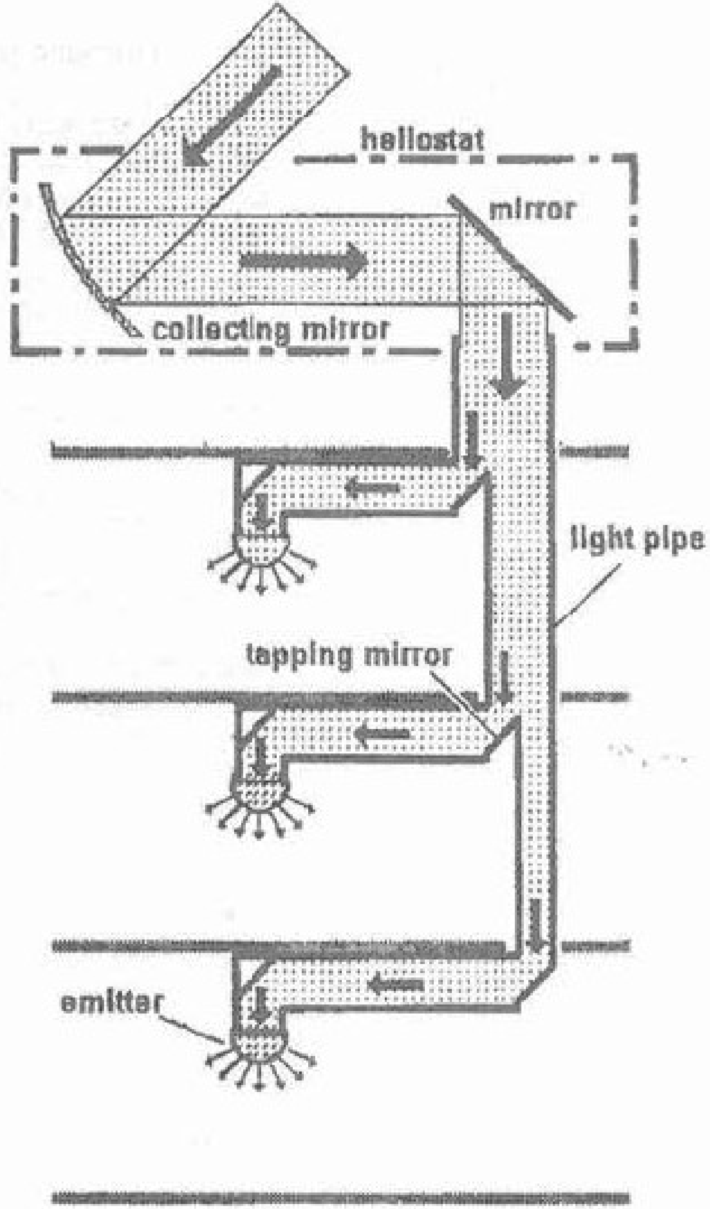
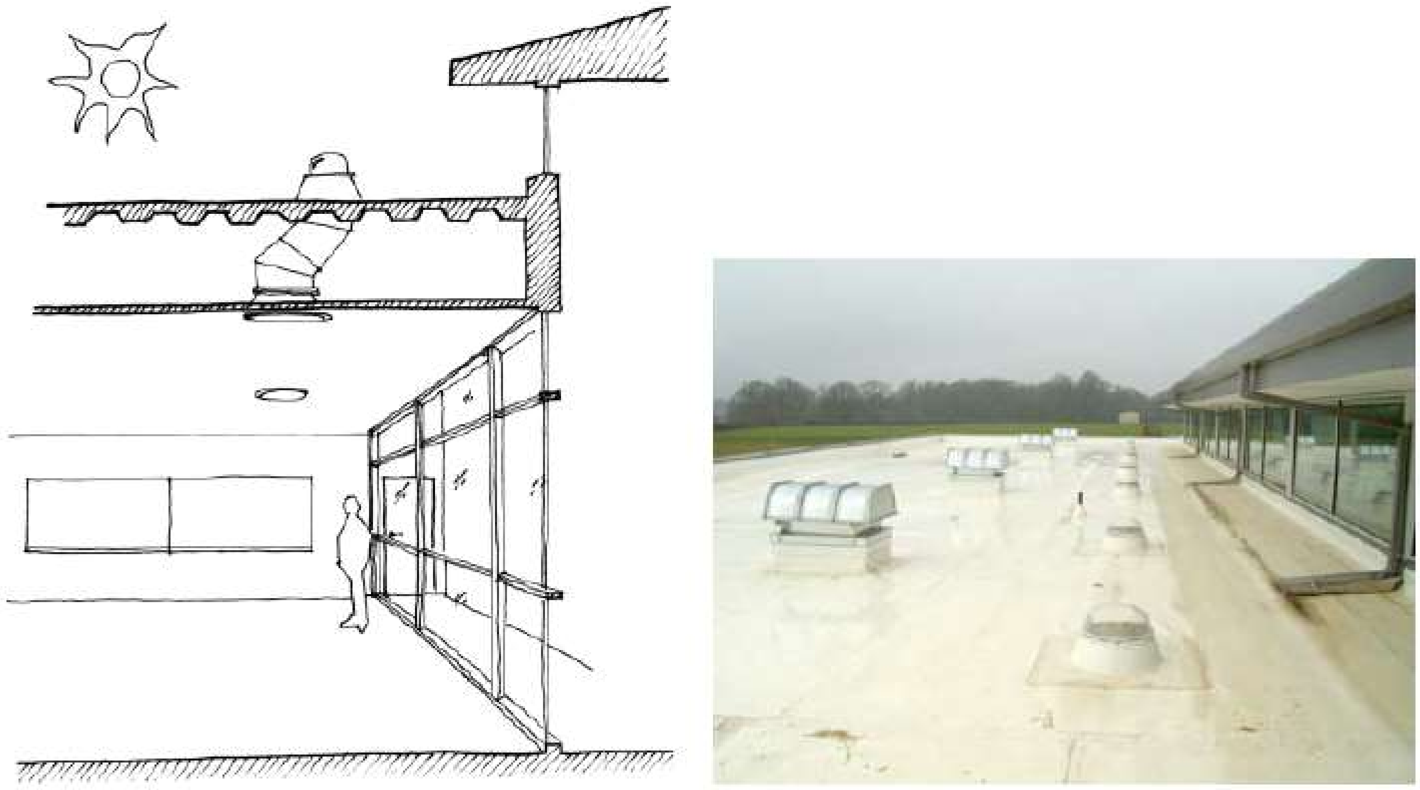


Fig.8.4 A multi-point light pipe system

Image source: PLEA lecture note 4



(*a*) (*b*)

Fig. 10.20 *(a) Skylight through a roof structure. (b) Top of Solatube® skylights on the roof at Ash Creek Intermediate School in Monmouth, Oregon (Bora Architects). (Drawn by Karen Tse; photo © Alison Kwok; all rights reserved.)*

Hollow light guides

Architectural applications


Beijing 2008
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BANK OF CHINA
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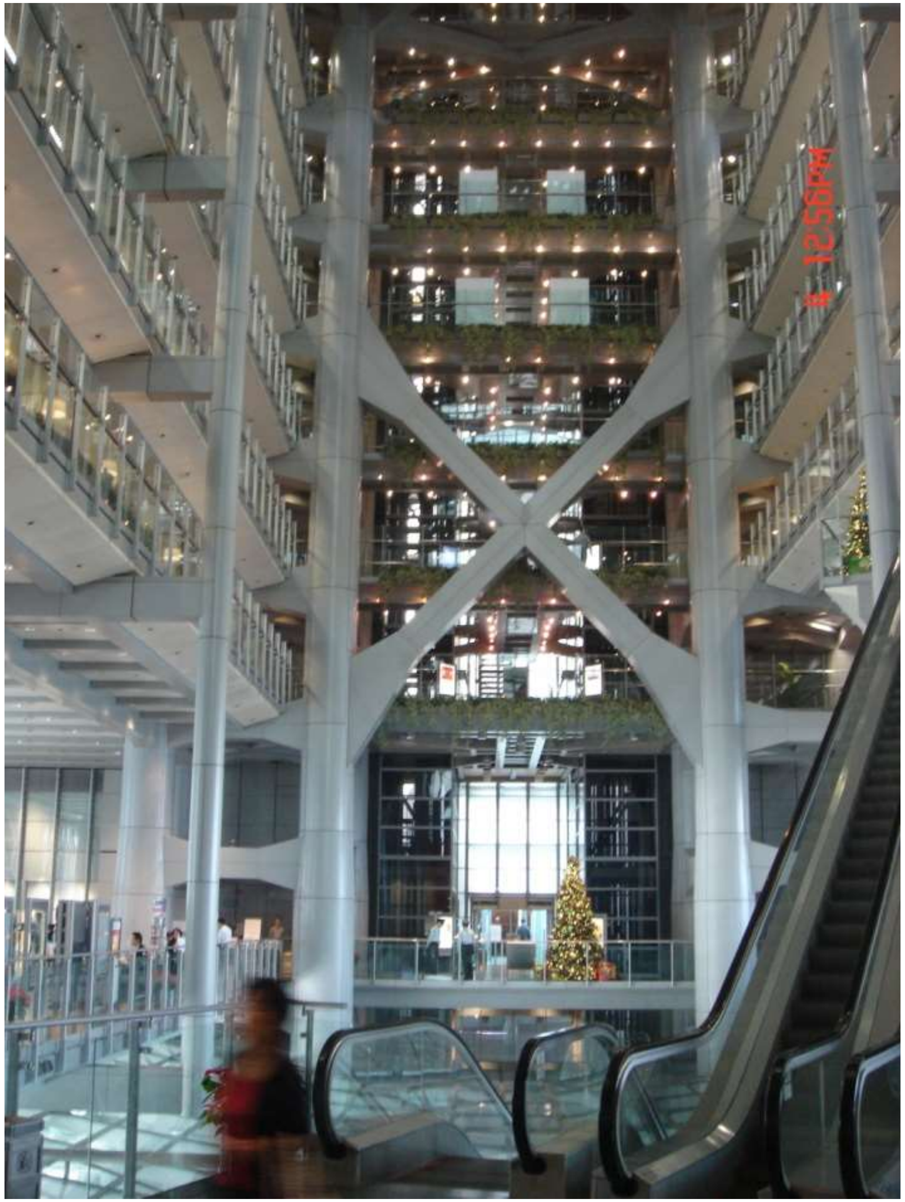
HSBC




Dior
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WOMEN EMPOWERMENT

Case studies: daylighting and shadings

Disney concert hall

Pompidou

Louvre

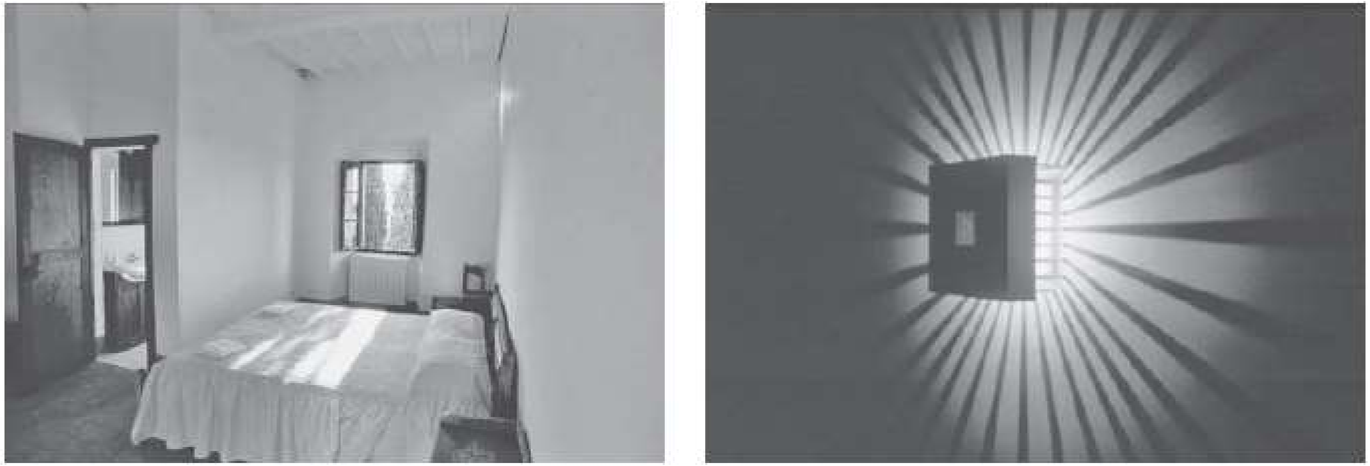
Institute Arabe

Bibliotheque Nationale de France

Musée d'Orsay

Musée de l'Orangerie

Two light sources



(a) (b)

Fig. 10.21 *(a) A daylit space; sunlight streams through a window at the Santa Anna Monastery in Santa Anna, Italy. (b) An electrically lit space—a wall sconce at the Westin Peachtree Plaza hotel in Atlanta, GA. (© Alison Kwok; all rights reserved.)*

Basic characteristics of light sources

- Two light sources: daylight and electric light sources
- Daylight sources:
  - Direct: sunlight, diffuse skylight
  - Indirect: reflected or modified from its primary source
- Electric light sources (chapter 15)
  - Incandescent lamps: incandescent, tungsten-halogen types
  - Gaseous discharge lamps: fluorescent, mercury vapor, metal halide, high pressure and low pressure sodium lamps, induction lamps

Efficacy

- The efficiency of a light source: lumen/watt (must include ballast losses)
- Incandescent lamp: 7% light + 93% released as heat out of total electrical energy.
- Electrical lighting in US nonresidential buildings consumes 25% to 60% of the electric energy.
- The most desirable form of lighting: daylight

TABLE 10.1 Efficacy of Various Light Sources

Source	Efficacy (Lm/W)
Candle	0.1
Oil lamp	0.3
Original Edison lamp	1.4
1910 Edison lamp	4.5
Incandescent lamp (15–500 W)	8–22
Tungsten–halogen lamp (50–1500 W)	18–22
Fluorescent lamp (15–215 W)[a]	35–80
Compact fluorescent lamp[b]	55–75
Mercury-vapor lamp (40–1000 W)[a]	32–63
Metal-halide lamp (70–1500 W)[a]	80–125
High-pressure sodium lamp (35–100 W)[a]	55–115
Induction lamp[c]	48–70
Sulfur lamp[c]	90–100
Direct sun (low altitude = 7.5°)	90
Direct sun (high altitude > 25°)	117
Direct sun (mean altitude)	100
Sky (clear)	150
Sky (average)	125
Global (average)	115
Maximum source efficacy predicted (in the year 2010)	150
Maximum theoretical limit of source efficacy	250 (approximate)

[a]Includes ballast losses (with electronic ballasts, lumens per watt become much higher). Losses vary between ballasts and manufacturers.

[b]With electronic ballasts.

[c]With a power supply.

Characteristics of daylight

- Source of daylight: Sun
- Three factors
  - Solar position
    - [solar altitude, azimuth] = f(latitude, date, time of day)
    - Absolutely predictable
  - Weather conditions (cloud cover, smog)
    - Only statistically predictable
  - Effects of local terrain (natural or man-made obstructions and reflections)
    - case-by-case approach

Sky conditions

- Solid overcast sky
- Clear sky
  - without sun (in the field of view)
  - with sun
- Partly cloudy sky

Standard overcast sky

- Northerly climates such as England, Scandinavia, and the Pacific Northwest
- CIE overcast sky
- Luminance ratio: 3:1
- Illuminance ratio: 2.5:1

$$L_A = L_Z \frac{1 + 2\sin A}{3} \qquad (10.1)$$

where

L_A = luminance at $A°$ above the horizon (in any direction)
L_Z = luminance at the zenith

Thus at the horizon, where $A = 0°$,

$$L_A = \frac{L_Z}{3}$$

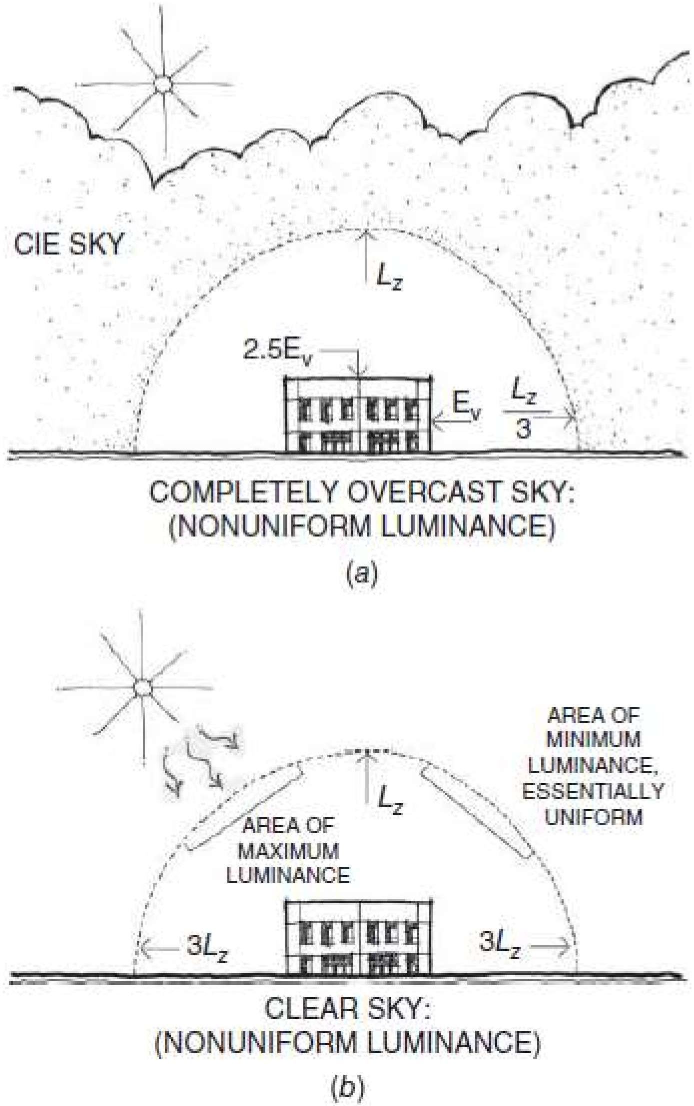


Fig. 10.22 *(a) The completely overcast sky has a zenith luminance L_Z, which is 3 times the horizon luminance. With such a sky, illuminance on unobstructed exterior horizontal surfaces (E_H) is about $2\frac{1}{2}$ times that on similar vertical surfaces (E_V). (b) The clear sky has the area of brightest luminance around the sun. The area opposite the sun is darkest and can be considered as essentially uniform at approximately 3500 cd/m² (1000 fL). (Redrawn by Erik Winter.)*

CIE (COMMISSION INTERNATIONALE DE L'ECLAIRAGE: International Commission on Illumination)

Approach I: Illuminance from overcast sky

- Use Eq.(10.2) by Krochman (1963)
  - There is agreement among all sources that with an overcast sky, exterior horizontal illuminance varies directly with the sun's altitude, irrespective of azimuth.

$$E_H = 300 + 21{,}000 \sin A \qquad (10.2)$$

where

E_H is exterior horizontal illuminance (lux) and A is the solar altitude, in degrees.

Solar altitude (and azimuth) for various times of day can be obtained from Table D.1. Figure 10.23 is a plot of year-round averages for both vertical and horizontal illuminance from an overcast sky as a function of solar altitude, based on U.S. Weather Service observations.

Approach II: Illuminance from overcast sky

- Observation-based data (Fig.10.23)

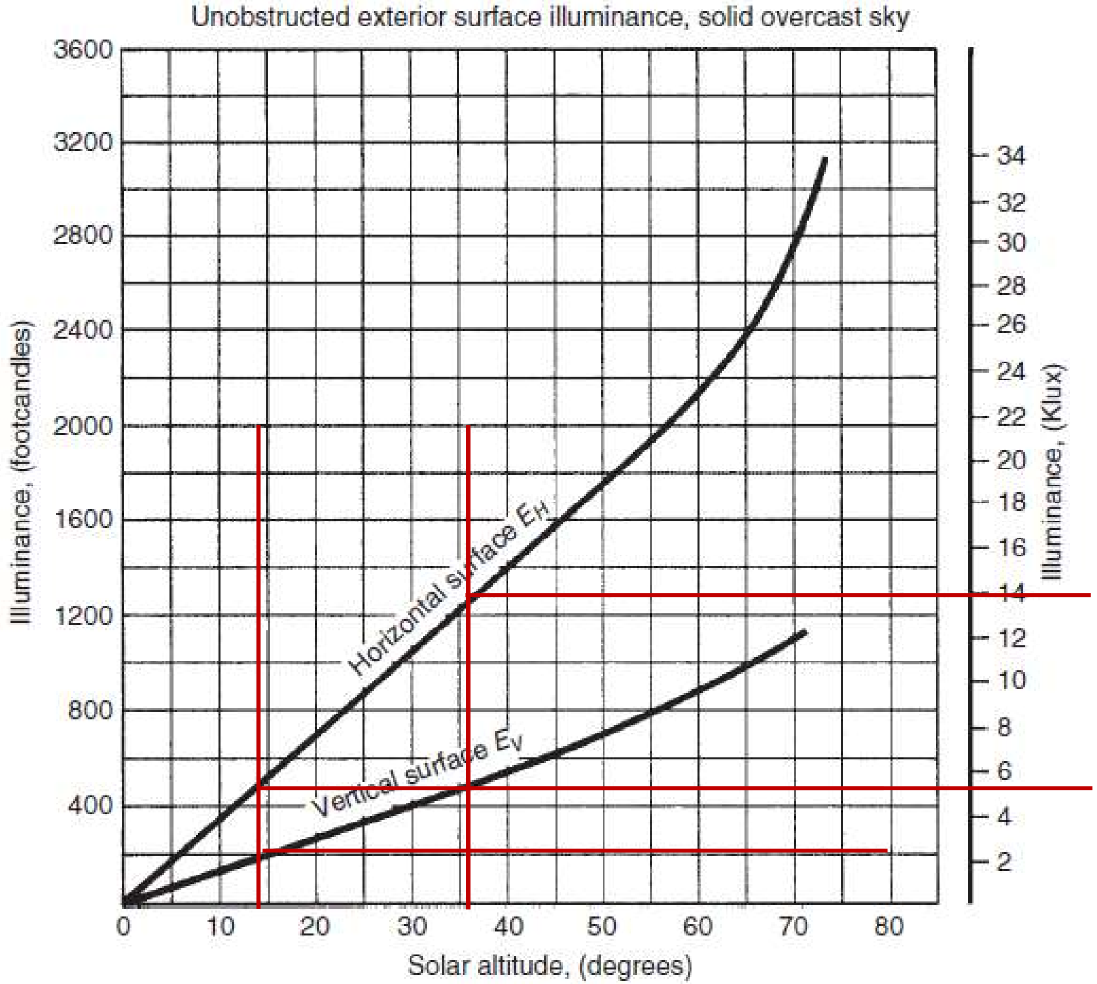


Fig. 10.23 *Curves giving unobstructed exterior surface illuminance directly from an overcast sky. (Data based on U.S. Weather Service observations; courtesy of Libbey-Owens-Ford.)*

Comparison between two approaches

- The degree of agreement is generally satisfactory, and either source will yield suitable results.

Latitude: 38°
Solar Time: 10:00 A.M.
Dates: Dec. 21, March/Sept. 21, June 21

	Eq. 10.2	Fig. 10.23
Dec 21	8500 lux (790 fc)	8608 lux (800 fc)
Mar/Sept 21	14,623 lux (1359 fc)	15,923 lux (1480 fc)
June 21	18,669 lux (1735 fc)	23,134 lux (2150 fc)

Clear sky: Horizontal illuminance

- Two sources of exterior horizontal illuminance: diffuse from the entire sky and plus much larger component of direct sunlight
- Figure 10.24 gives values for both components of exterior horizontal illuminance based upon observations.
- The sky only values are used to determine shaded skylight illuminance or daylong ground illuminance outside a shaded window - that is, a north-facing window, or an east/west window when the sun is on the opposite side of the building.

E_H=direct sun + diffuse sky

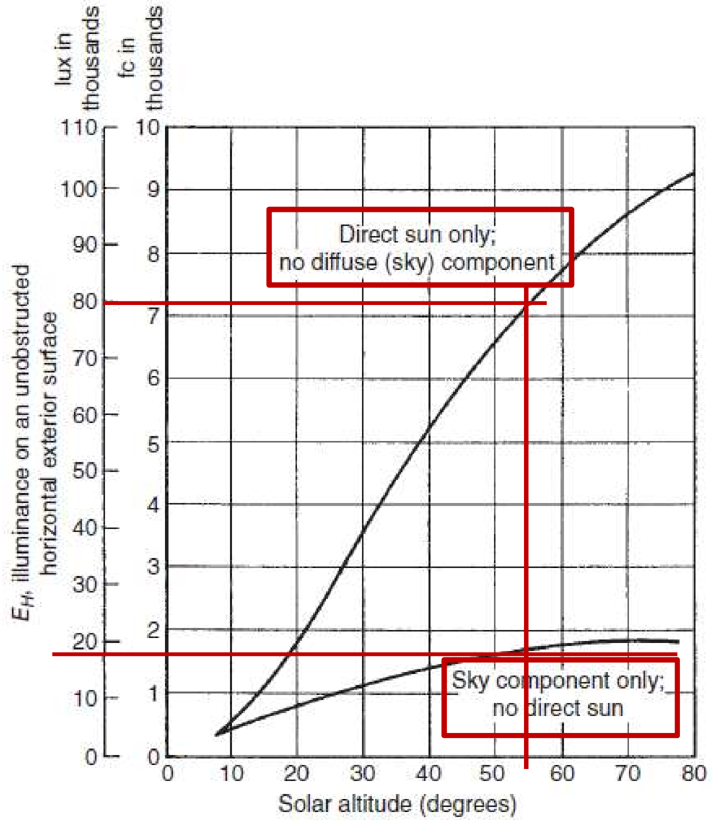


Fig. 10.24 Components of the exterior horizontal illuminance on an unobstructed surface, from a clear sky, as a function of solar altitude. Total illuminance E_H is the sum of the two components. (From data in Rennhackkamp, 1967.)

Fig.10.24 exterior horizontal illuminance from a clear sky