UNEP-*lites.asia* Laboratory Training Workshop

Beijing, China

22-24 April 2015

UNEP Collaborating Centre for Energy Efficient Lighting

Gonio-photometry

XIN Hongzheng

UNEP Collaborating Centre for Energy Efficient Lighting

Content

- Basic knowledge
- Gonio-Photometer
- Operation
- Standards

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge

- Introduction: Lighting, light
- Radiometry, Photometry
- Colorimetry
- Integrating-sphere photometry
- Gonio-photometry
- Mathimatics

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： introduction

Lighting，

UNEP Collaborating Centre for Energy Efficient Lighting

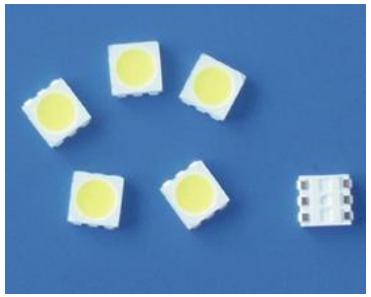
Part1: Basic knowledge： introduction

Appratus —light sources，lamps





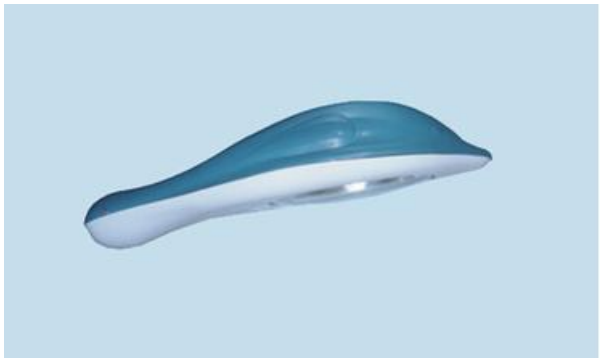


UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： introduction

Appratus -luminaire

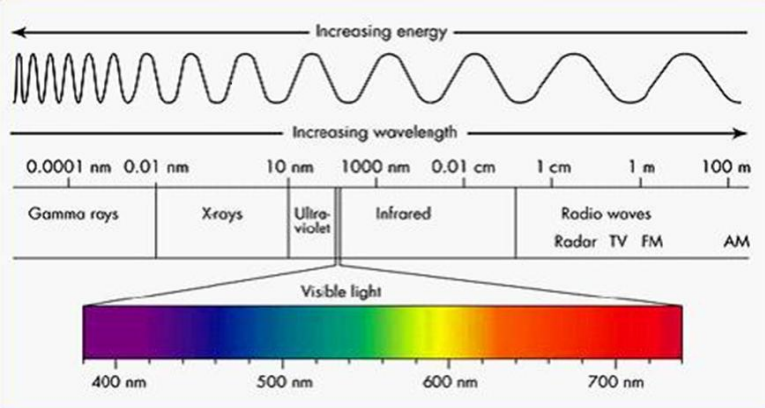


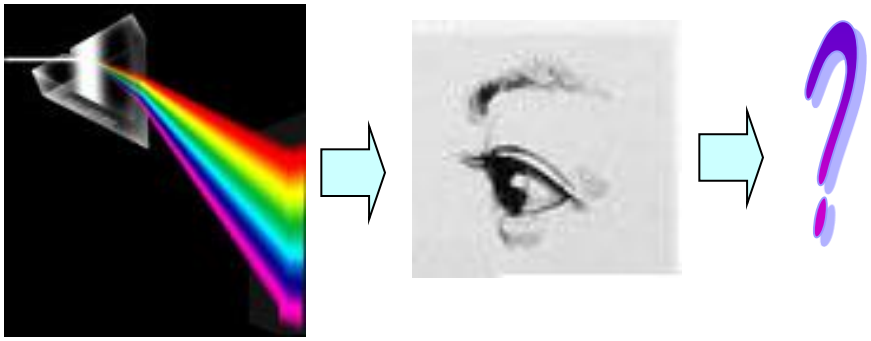
=》 what do we get from the lamps and luminaires?

=》 Having lamps, why we still need the luminaires?

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： radiometry and photometry





Radiation
-Energy transferring.

$$Q = h\nu$$

unit： J

Part1: Basic knowledge： radiometry and photometry

Radiant flux

$$\Phi_e = \frac{dQ_e}{dt}$$

unit： W or J/s

Also called radiation power。

Special appratus, so called radiation meter to measure.
Based on this quantity, all the others are derived.

Part1: Basic knowledge： radiometry and photometry

Radiant intensity

$$I_e = \frac{d\Phi_e}{d\Omega}$$ unit： W/sr

Character of ideal radiation source：

$$\Phi_e = I_e \Omega$$

$$\Phi_e = 4\pi I_e$$

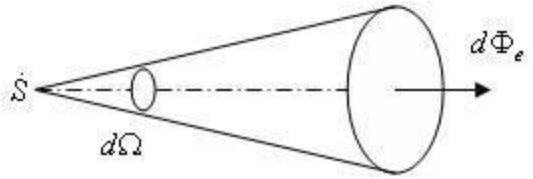


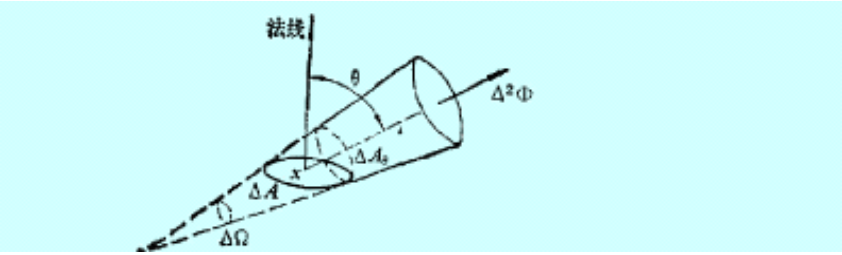
图 1—2　点辐射源的辐射强度

Part1: Basic knowledge： radiometry and photometry

Radiance

$$L_e = \frac{dI_e}{dA\cos\theta} = \frac{d^2\Phi_e}{d\Omega dA\cos\theta}$$

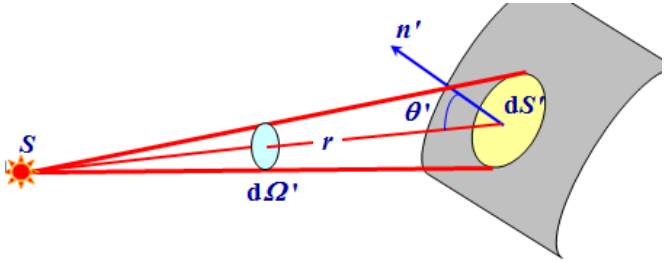
unit： W /(sr·m^2)



Part1: Basic knowledge： radiometry and photometry

Irradiance:

$$E_e = \frac{d\Phi_e}{ds}$$ unit： W /m²

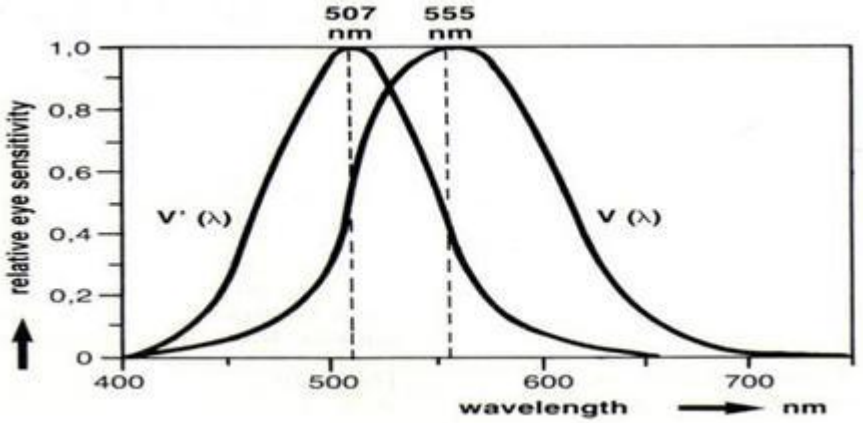


$$\frac{\Phi_e}{ds'} = \frac{\Phi_e}{\frac{d\Omega' \cdot r^2}{\cos\theta'}} = \frac{I_e \cos\theta'}{r^2}$$

$$d\Omega' = \frac{dS' \cdot \cos\theta'}{r^2}$$

Part1: Basic knowledge： radiometry and photometry

The sensitive function for human eyes to radiation: V(λ)



V(λ) function to radiation, ==>photometric quantity

$$\frac{X_V}{X_e} = \frac{K_m \int_0^\infty S_t(\lambda) V(\lambda) d\lambda}{\int_0^\infty S_t(\lambda) d\lambda}$$

Part1: Basic knowledge： radiometry and photometry

Candela is :

the luminous intensity
in a given direction
of a source
that emits monochromatic radiation of $540*10^{12}$ hertz and that has a radiant intensity in that direction of (1/683) watt per steradian.

1 cd=1/683 W/sr
(1 lm=1/683 W) at 555.00nm

Part1: Basic knowledge： radiometry and photometry

Photometric :

$$\Phi_v = \Phi_e \cdot V(\lambda)$$ unit：lm

$$I_v = I_e \cdot V(\lambda) = \frac{d\Phi_v}{d\Omega}$$ unit：cd

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： radiometry and photometry

Comparison sheet

Radiometric quantity	symbal	units	units	symbal	Photometric quantity
Radiant energy	Q_e	J	lm·s	Q_v	Luminous energy
Radiant flux （power）	Φ_e,P_e	W	lm	Φ_v	Luminous flux
Irradiance	E_e	W/m^2	lm/m^2	E_v	Illuminance
Radiance	L_e	$W/(m^2\ sr)$	cd/m^2	L_v	Luminance
Radiant intensity	I_e	W/sr	cd	I_v	luminous intensity

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： radiometry and photometry

	Parameters	Conception
Photometry	Luminous flux	Amount of the light emitted
	Luminous efficacy	Efficiency for turning electricity to light
	Intensity	Amount of light in the designated direction
	Illuminance	Amount of light on surface that being illuminated
	Luminance	Brightness

UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： summary

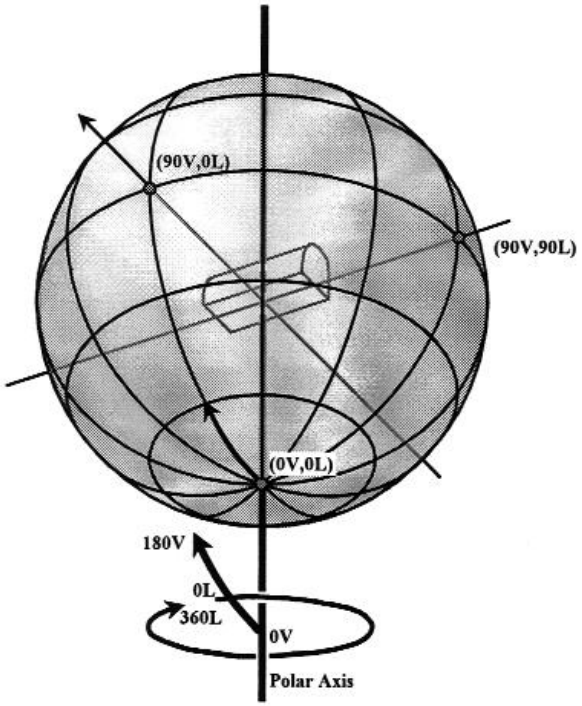
Photometry is based on radiometry.

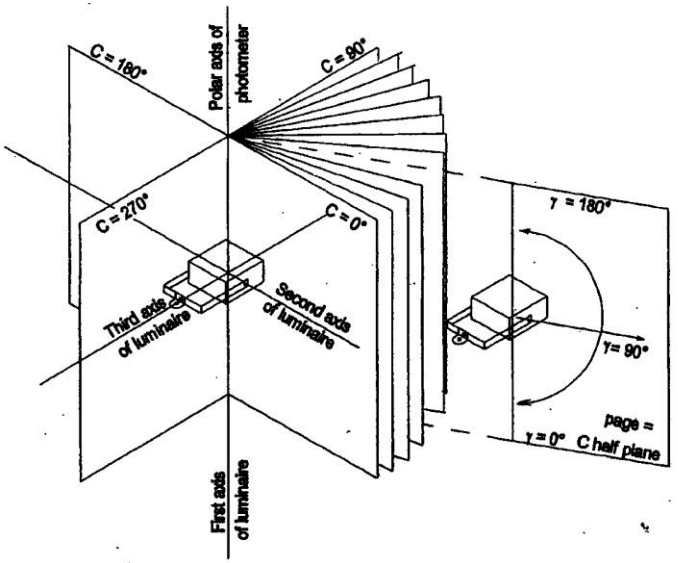
Related transferring, such as reflectance or transmitting are all based on radiometry .

UNEP Collaborating Centre for Energy Efficient Lighting

Spacial integrating

Co-ordinates: C

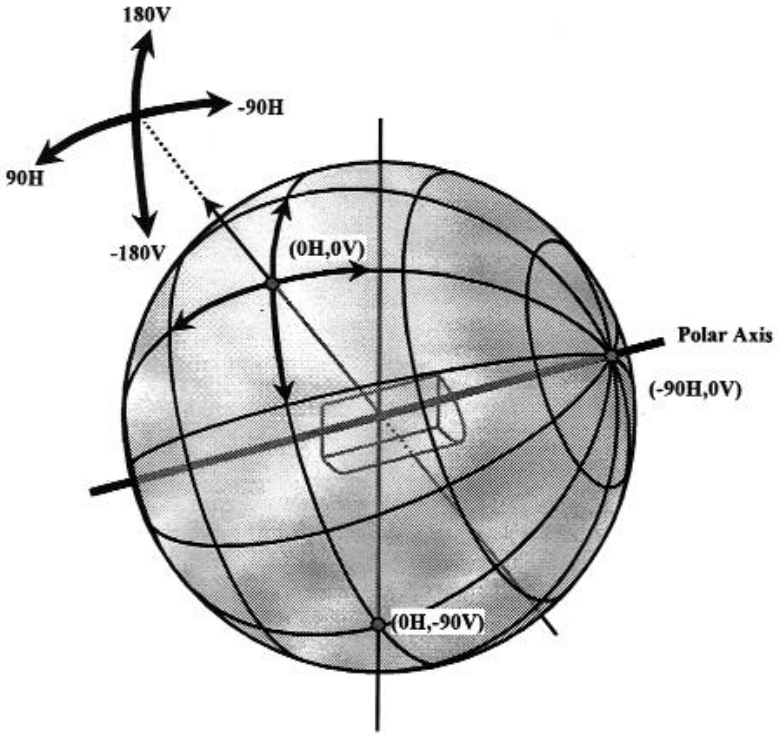


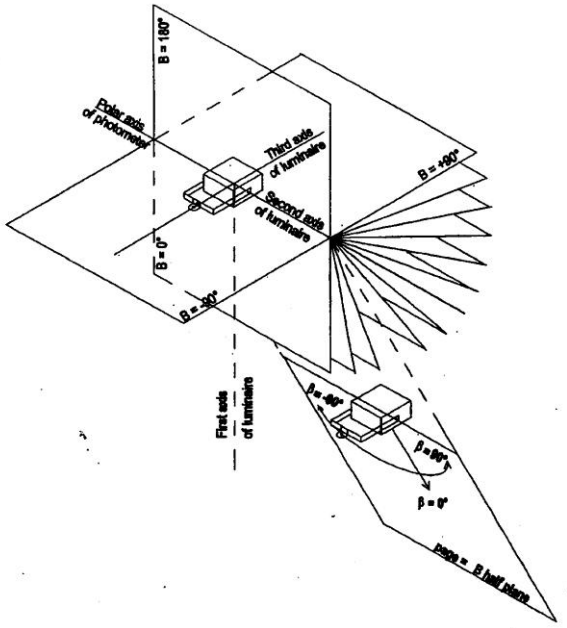


UNEP Collaborating Centre for Energy Efficient Lighting

Spacial integrating

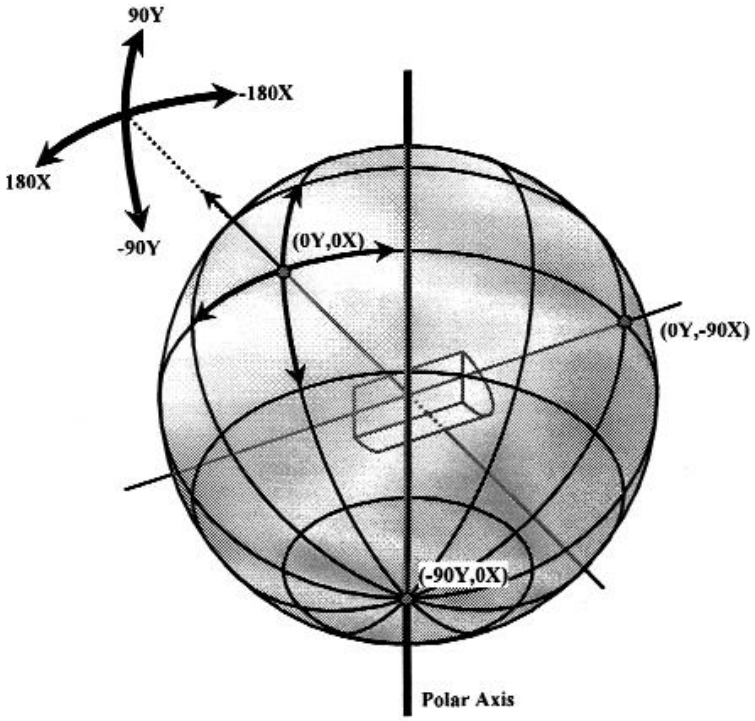
Co-ordinates: B

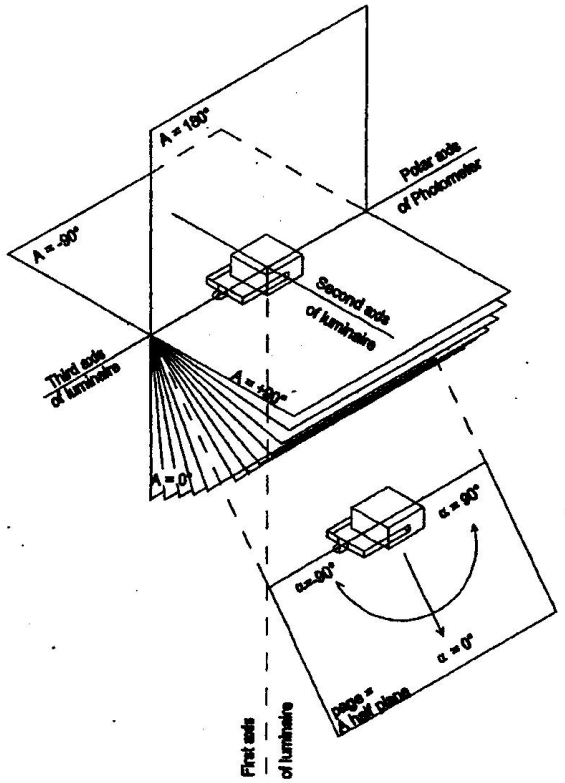




UNEP Collaborating Centre for Energy Efficient Lighting

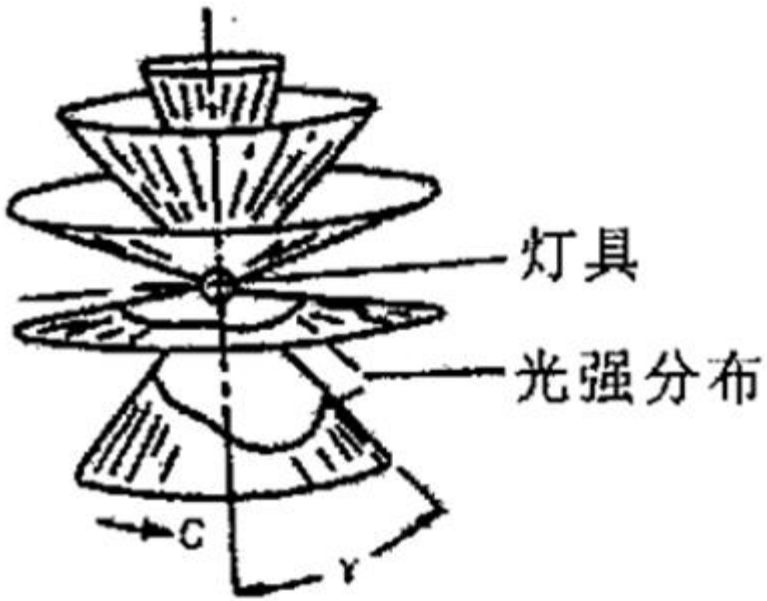
Part1: Basic knowledge： gonio-photometry





UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： gonio-photometry



UNEP Collaborating Centre for Energy Efficient Lighting

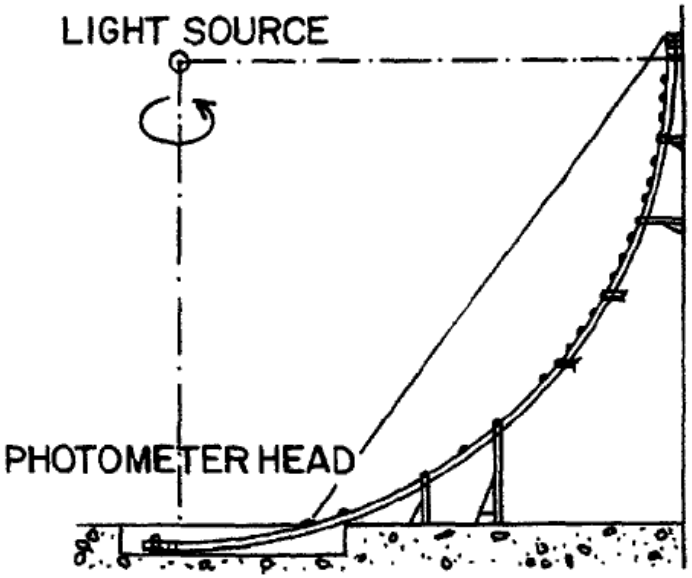
Part1: Basic knowledge： gonio-photometry

SYS	Angle in plane	Tilt angle of the plane
A-plane	α	A
B-plane	β	B
C-plane	γ	C
conical	C	γ

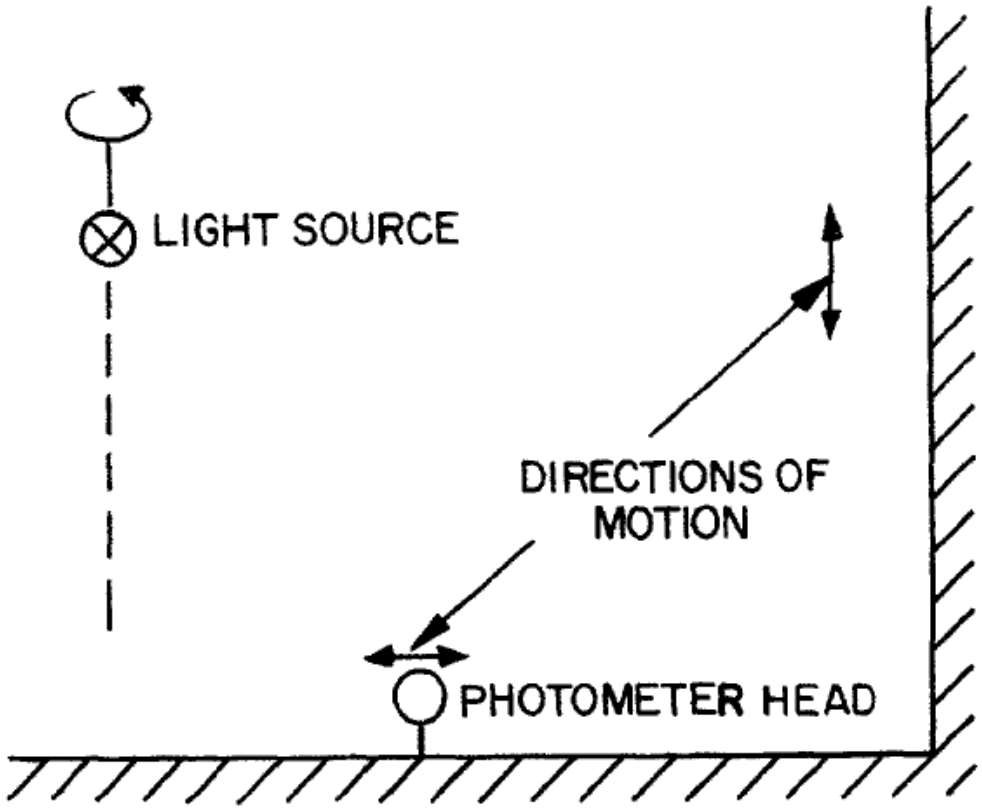
direction	Angle in plane	Tilt angle of the plane
known	Un-known	
A ,α	B ,β	tanB=tanα/cosA
A, α	C ,γ	tanC=tanα/sinA
B, β	A ,α	tanA=tanβ/cosB
B ,β	C ,γ	tanC=sinB/tanβ
C ,γ	A, α	tanA=cosC*tanγ
C, γ	B ,β	tanB=sinC*tanγ

Part1: Basic knowledge： gonio-photometry

Prototype of gonio-sys



Part1: Basic knowledge： gonio-photometry



UNEP Collaborating Centre for Energy Efficient Lighting

Part1: Basic knowledge： gonio-photometry

Basic assumption for measurement:
-ideal point source
-ideal illumiance
-ideal intensity

UNEP Collaborating Centre for Energy Efficient Lighting

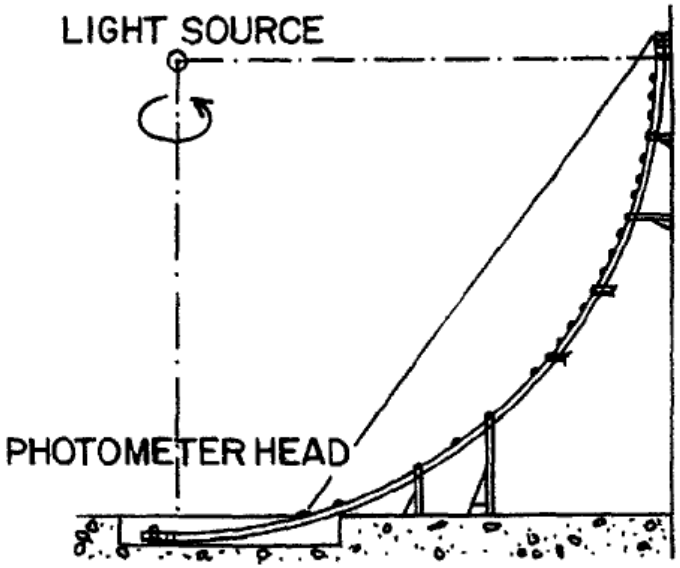
Part2: Gonio-photometer

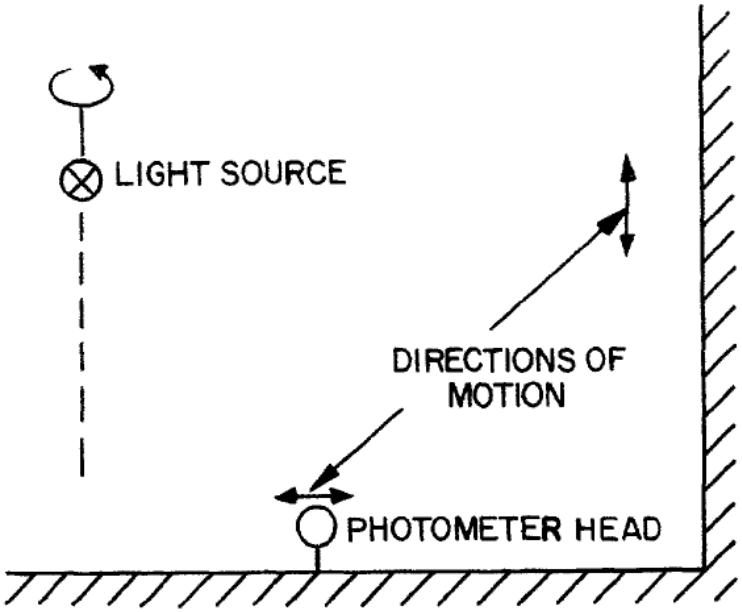
- Types and theroy
- Key components
- Related parameters

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer: types and theory

- prototype





UNEP Collaborating Centre for Energy Efficient Lighting

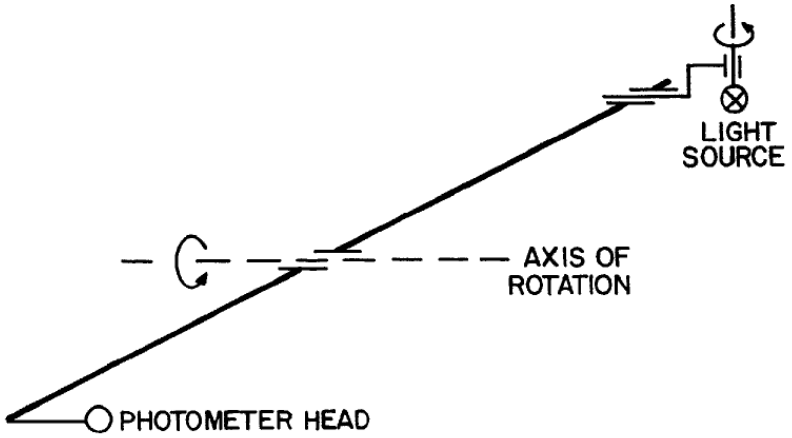
Part2: Gonio-photometer： types and theory

UNEP Collaborating Centre for Energy Efficient Lighting

Part2：Gonio-photometer：types and theory

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： types and theory



UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： types and theory

UNEP Collaborating Centre for Energy Efficient Lighting

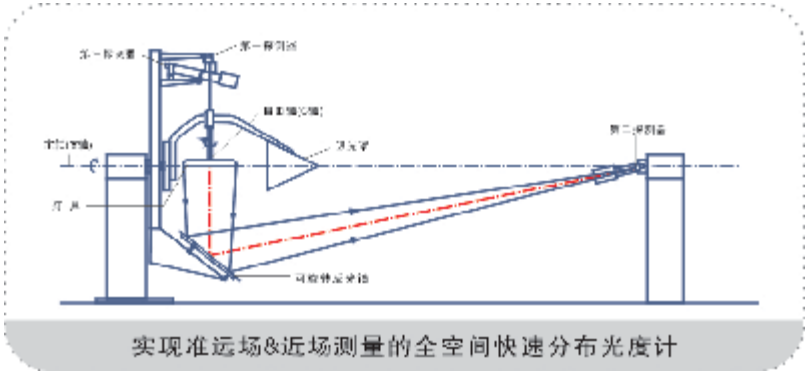
Part2：Gonio-photometer： types and theory

-

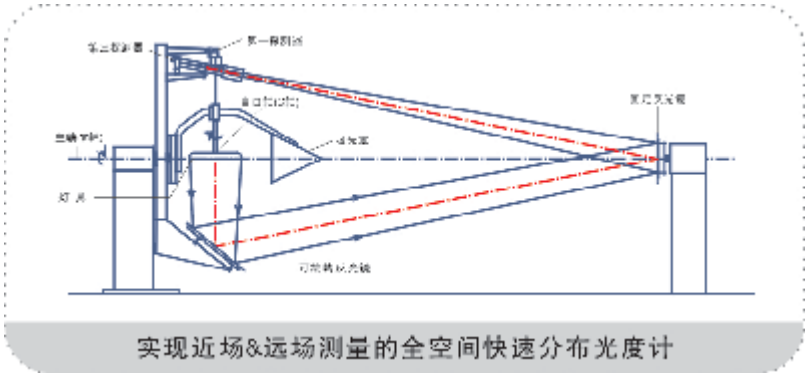
UNEP Collaborating Centre for Energy Efficient Lighting

Part2：Gonio-photometer： types and theory

- 



实现准远场&近场测量的全空间快速分布光度计



实现近场&远场测量的全空间快速分布光度计

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer: types and theory

china.makepolo.com

UNEP Collaborating Centre for Energy Efficient Lighting

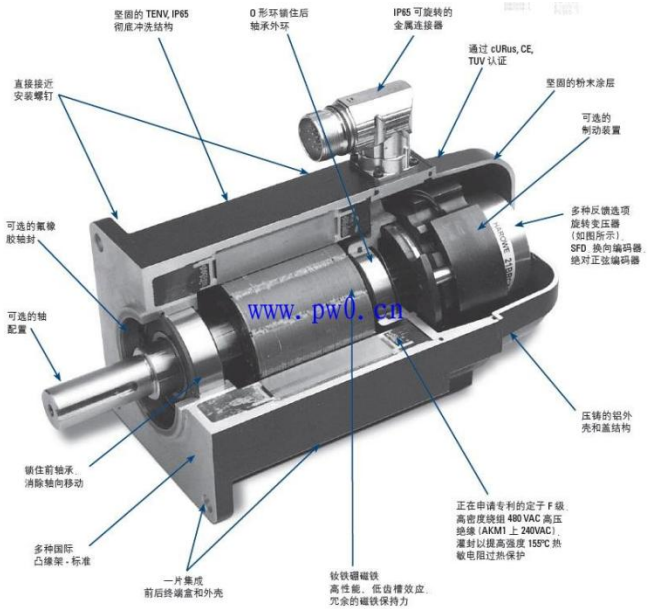
Part2: Gonio-photometer： types and theory

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： types and theory

UNEP Collaborating Centre for Energy Efficient Lighting

Part2：Gonio-photometer： types and theory

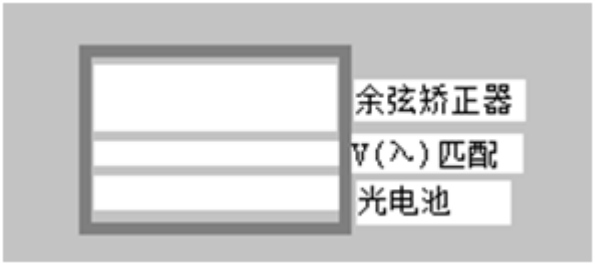


Part2: Gonio-photometer: types and theory

- detect device

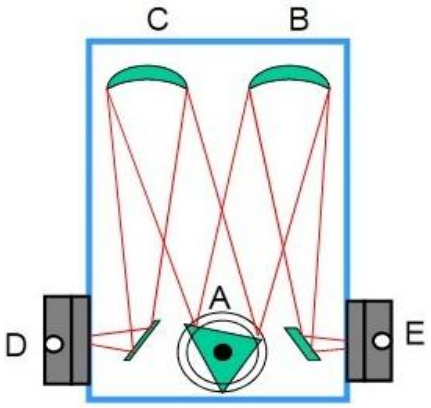
Part2：Gonio-photometer： key parts

- photometer: lux-meter



UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： key parts



A : Grating turret
B : Collimation Mirror
C : Focus Mirror
D : side exit Slit
E : side entrance Slit

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： key parts

- motion controller

- cloed-loop control， prefered

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： key parts

- power source

china.makepolo.com

UNEP Collaborating Centre for Energy Efficient Lighting

Part2: Gonio-photometer： key parts

- electric measurement appratus

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation

- Tracing
- Photometric centre of samples
- Sample orientation
- Step interval setting
- Preheating and tranferring
- Circuiting and powering
- Surrounding
- Test reporting

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: tracing

- Absolute photometer（lux-meter）+distance

$$\Phi = \int_A E dA$$

$$\Phi = r^2 \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} E(\theta,\phi) \sin\theta d\theta d\phi$$

- for non-mirror systems

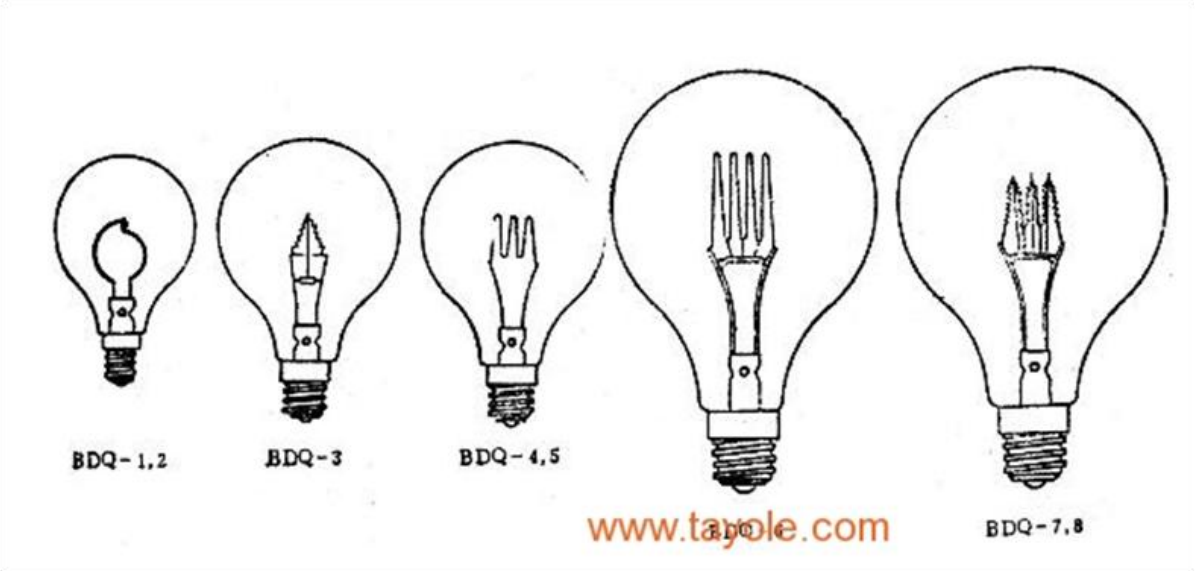
$$\Delta\Phi = r^2 2\pi(\cos\theta_1 - \cos\theta_2)E_\theta$$

$$\Delta\Phi = r^2(\phi_2 - \phi_1)(\cos\theta_1 - \cos\theta_2)E_\theta$$

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: tracing

- intensity standard lamp+photometer (not absolute)



UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: tracing

- total luminous flux standard lamp+photometer (not absolute)
- BDT-standard lamp for flux
- BDP-standard lamp for general use
- working substitute

UNEP Collaborating Centre for Energy Efficient Lighting

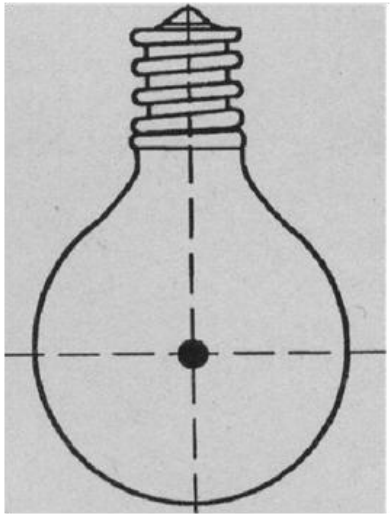
Part3: Operation: tracing

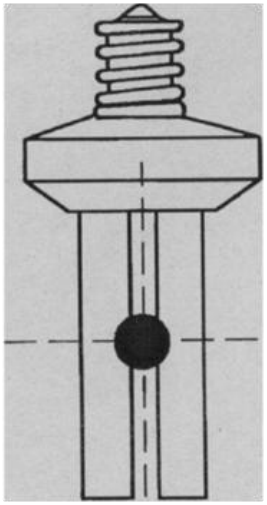
- difference of the length of the tracing line
- GONIO-system could be used to create flux standard lamp

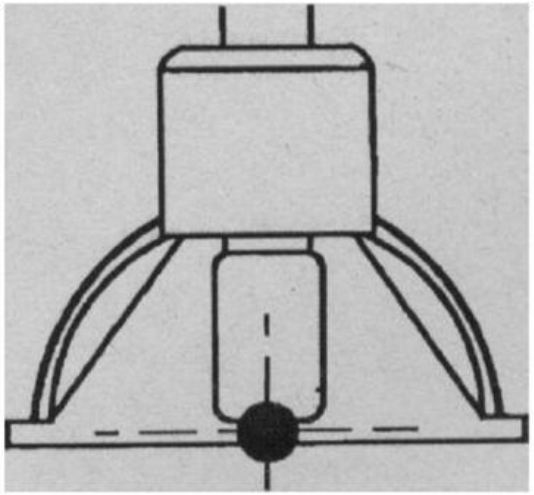
UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: photometric centre of the sample

- photometric centre of lamps





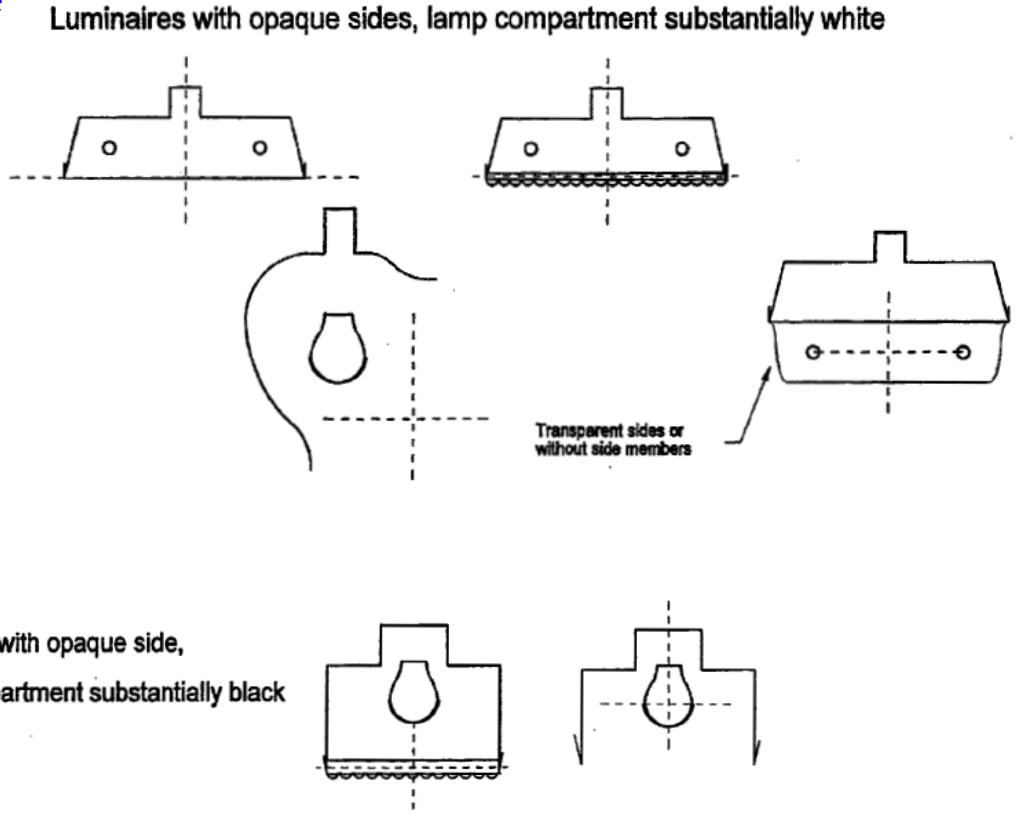


- A
- B
- C
- D

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: photometric centre of the sample

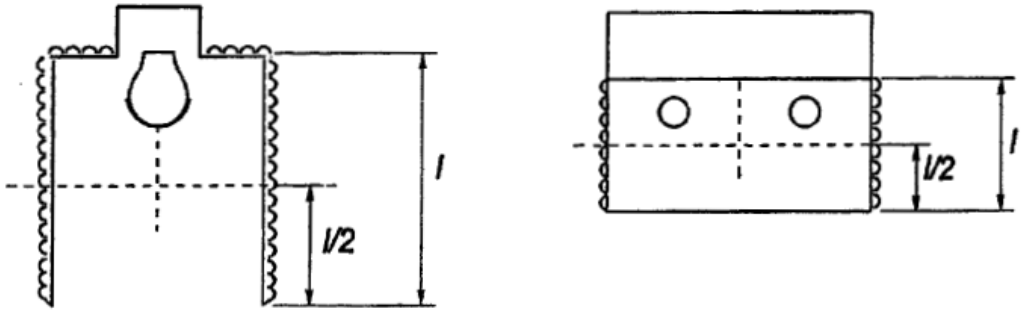
- photome



Part3: Operation: photometric centre of the sample

- photometric centre of luminaires

Luminaires with diffusing/prismatic sides



Luminaires with transparent sides or without side members:
all at lamp photometric centre

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: orientation

- angle 1—type C,γ

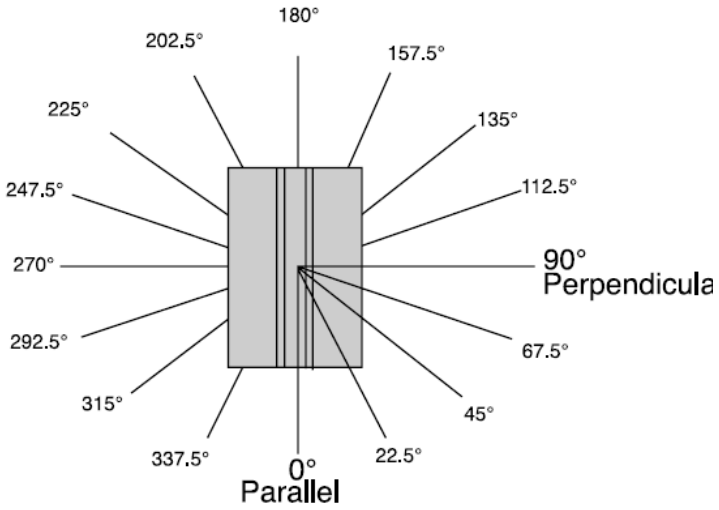
- nadir
- how to confirm?

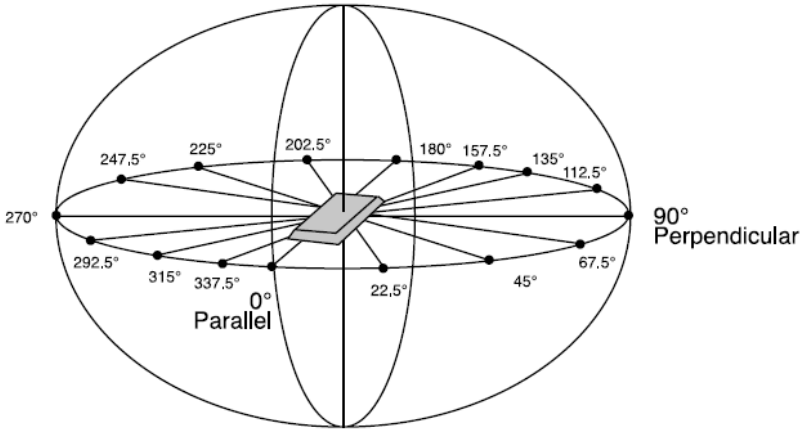
- horizental
- how?

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: orientation

- angle 2-C

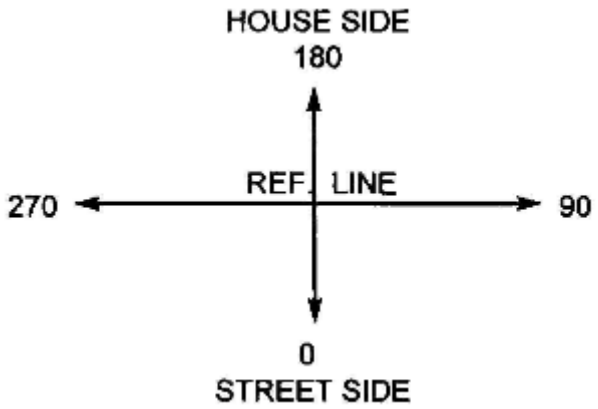




UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: orientation

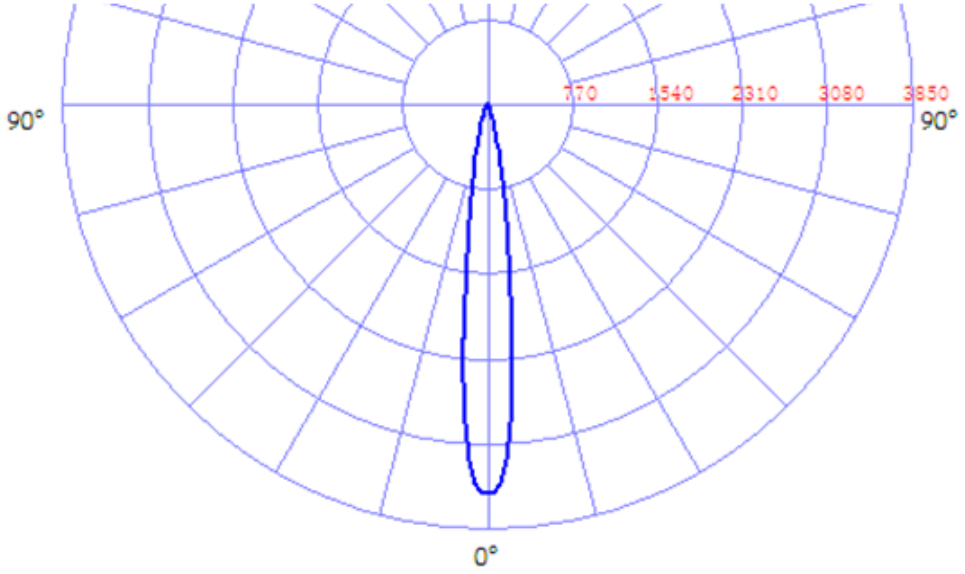
- angle 2

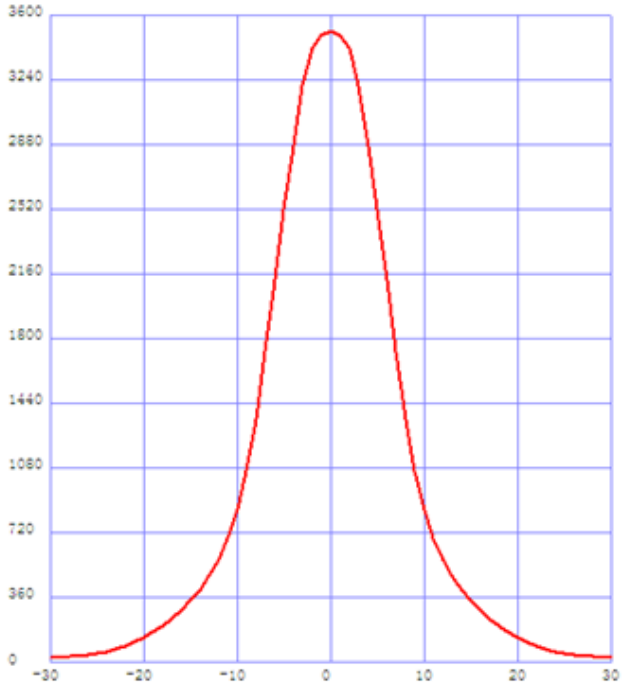


UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: step interval

- angle1： narrow beamed

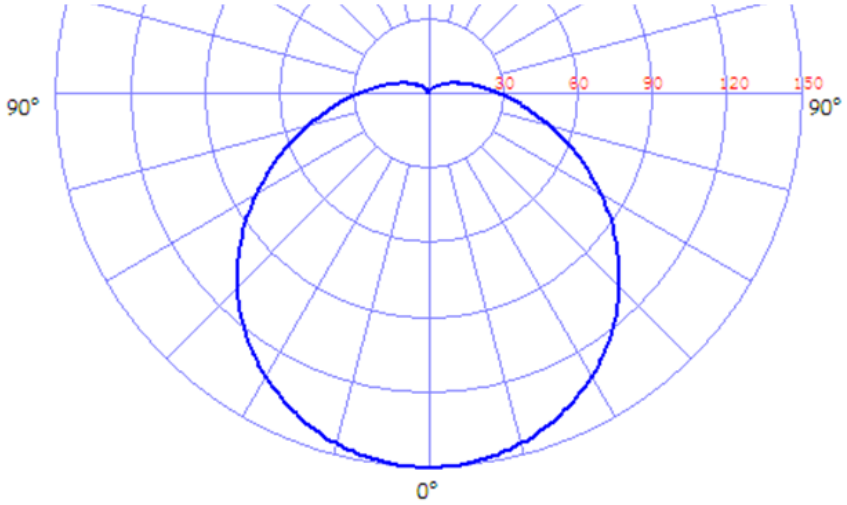


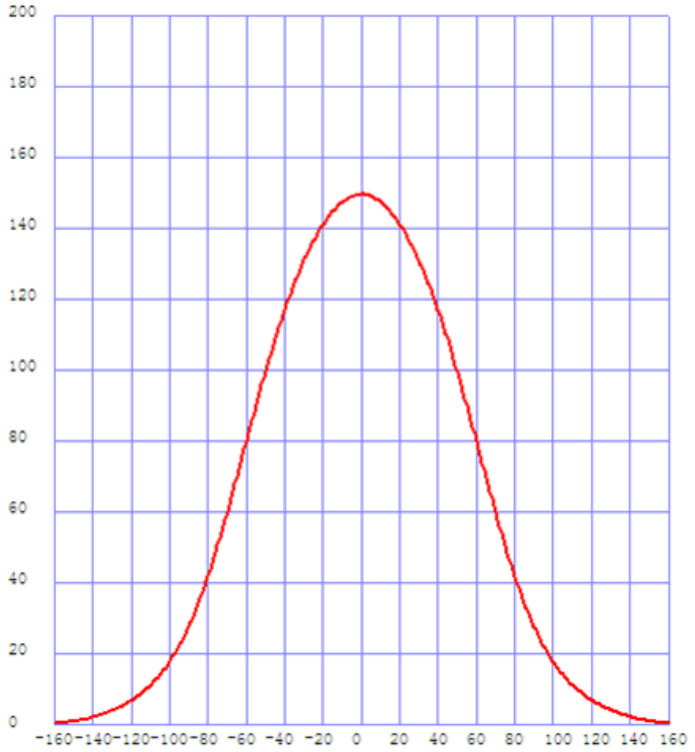


UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: step interval

- angle1：spread beamed

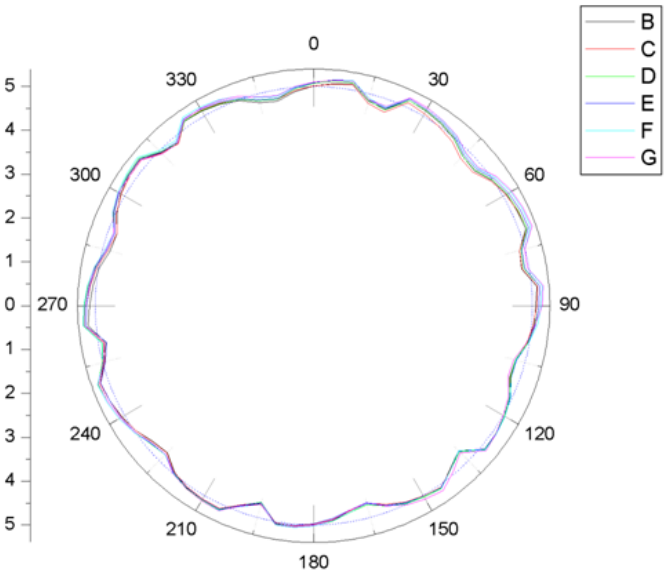


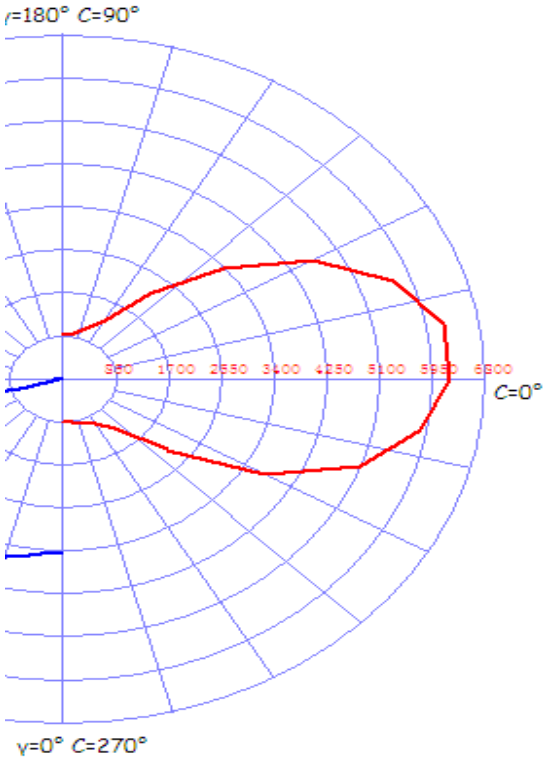


UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: step interval

- angle2





UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: transferring

- types1-sensitive
- HID
- FL WITH COLD SPOT

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: transferring

- types2

- FILAMENT,partly
- LED

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: preheating

- types1- quickly
- FILAMENT

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: preheating

- types2
- FL
- HID
- LED

UNEP Collaborating Centre for Energy Efficient Lighting

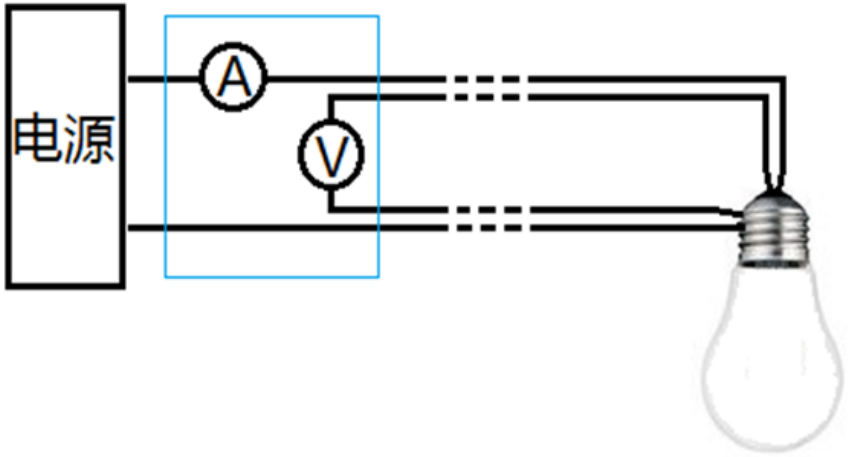
Part3: Operation: preheating

- stationary monitoring and determination
- INTERVAL AND PERIOD
- ACCEPT deviation
- FLICKER

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: circuiting

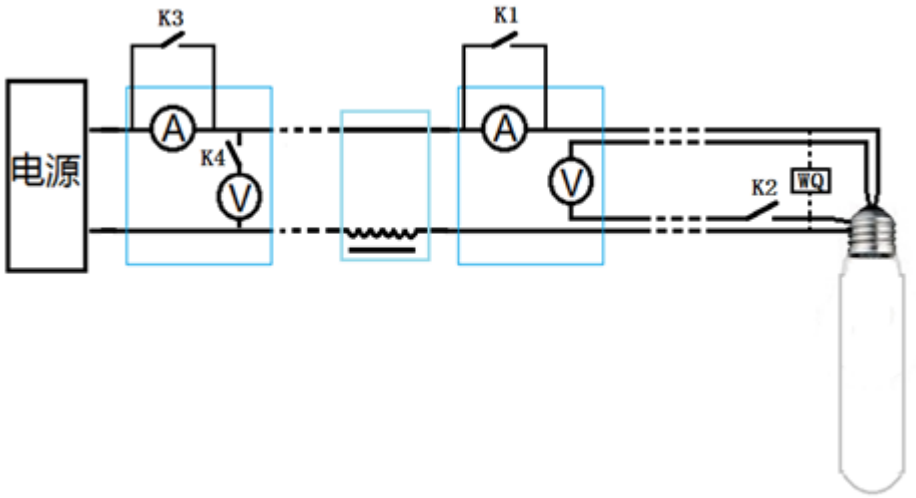
- type1



UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: circuiting

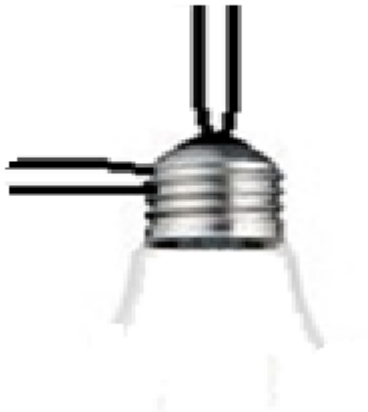
- type2



UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: circuiting

- four-terminal(4-pole) method



UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: environment

- temperature
- environment->sample and instrument
- sensitive sample : FL, LED

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: environment

- relative humidity
- environment-> instrument

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: environment

- air movement
- heat loss-> temperature->...

UNEP Collaborating Centre for Energy Efficient Lighting

Part3: Operation: environment

- stray light
- -source,not limited to other sources than the device under test
- -path, not limited to other paths than the main path for test

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- CIE-70, CIE-121,CIE S 025
- LM-10, LM-31,LM-35, LM-41, LM-46,LM-79-2008
- LM-63-2002， CIE 102-1993
- GB/T 9468-2008, GB/T 7002-2008

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- CIE-70, CIE-121
- BASE for all

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- LM-79-2008
- special for SSL
- not limited to gonio-sys
- color in different direction involved

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- CIE S 025
- detailed requirement, UNCERTAINTY INCLUDED
- SSL products
- not limited to gonio-system

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- LM-10, LM-31,LM-35, LM-41, LM-46， etc
- detailed for application.
-

UNEP Collaborating Centre for Energy Efficient Lighting

Part4: Standards

- LM-63-2002， CIE 102-1993
- VERY USEFUL
- all information
- lighting design- software reading
- "-1" for absolute data

UNEP Collaborating Centre for Energy Efficient Lighting

Thanks

- Reference
- standards or publications：
- CIE-70, CIE-121,CIE-S 025
- LM-10, LM-31,LM-35, LM-41, LM-46,LM-79-2008
- LM-63-2002， CIE 102-1993
- GB/T 9468-2008, GB/T 7002-2008

- other material：
- example pictures from web

UNEP GELC Global Efficient Lighting Centre

UNEP Collaborating Centre for Energy Efficient Lighting

Thanks for your attention