

Repetitorium for “Illumination System Design”:

- What are the units of photometric and radiometric flux?
 - Lumen, Watt
- How can you convert between radiometric and photometric units?
 - Spectral weighting curve, 683 lm/Watt at 555nm
- How is efficiency of light source defined? What is more efficient an incandescent bulb lamp or a fluorescence lamp?
 - Photometric flux per input electrical power
 - Fluorescent lamp is better since more light in visible range
- What are the main radiometric/photometric quantities? How are they defined, and what are their units?
 - Irradiance, intensity and radiance
 - Definition see script
 - Units: Lux, Candela, and Candela/m²
- What is the difference between solid angle and projected solid angle? How much is
 - Projected solid angle is solid angle times projection-cosine
 - Hemisphere is 2pi (solid angle) and pi (proj. solid angle)
- What is the relation between NA (numerical aperture) and projected solid angle?
 - $\pi \cdot \text{NA}^2$
- How does the radiance and intensity distribution of a lambertian source look like?
 - Radiance is constant, intensity shows cos-behavior
- What is Etendue? How is it related to radiance?
 - Etendue is area x proj. solid angle
 - Radiance is flux per Etendue
- Sketch and explain the chromaticity diagram?
 - Tristimulus values X,Y,Z – normalized to x,y (z).
x,y-values define position in diagram.
- What does color temperature mean?
 - Corresponding spectrum of a black-body radiator at this temperature.
- What is the basis law of radiation transfer?
 - Transferred flux is integral over radiance x area x proj. solid angle
- What is a form factor?
 - Radiation transfer ratio for lambertian source, only depending on geometry.
- What is the irradiance distribution of a point source / small lambertian segment on a screen far away?
 - Point source $\cos^3$
 - Lambert $\cos^4$
- What is shown in a phase space diagram? How can you get irradiance and intensity?
 - Phase space diagram is ray-position versus angle.
Distribution corresponds to radiance. Projection corresponds to intensity and irradiance.

- How can you calculate the phase space transformation in paraxial optics? What transformation does free propagation correspond to?
 - ABCD-matrix
 - Shear
- What mirror shapes / lens shapes are typically used for high NA sources?
 - Elliptical mirrors
 - Aspheres / Fresnel lens
- What a typical optical elements to mix radiation? Explain operation principle? Draw principle for array plus integrator lens?
 - Homogenizer rod, array
 - Overlay of different parts of the input (angle for rod, channels for array)
 - Array sketch: all channels overlay at focal plane of integrator lens.
- Explain difference temporal and spatial coherence of laser radiation?
 - Temporal related to spectrum
 - Spatial coherence describes interference-ability for double-slit-experiment and is related to divergence.
- What is a Gaussian laser beam? What are the characteristics and how does it propagate?
 - Gaussian intensity distribution
 - Beam waist (raighley-range), Wavefront radius, Divergence (diagrams)
- What is the beam parameter product and how large is it for a perfect singel-mode laser beam and a multi-mode beam?
 - Divergence x beam waist = $M^2 \times \lambda / \pi$
 - For mono-mode $M^2=1$
- Which optical systems are used for laser beam expansion?
 - Kepler or Gallilean telescope, prism expander
- What happens to beam divergence if the beam is expanded twice – why?
 - Divergence is reduced by factor 2, due to etendue conservation
- What does partial coherent illumination in optical lithography mean, why is it used?
 - Illumination pupil is not full filled, but has some shape (dipole, quadrupole, etc.).
 - Partial coherent illumination can increase contrast and depth of focus.
- What does BRDF mean, and how is it defined? How can you calculate the scattered radiance distribution?
 - BRDF describes scattering. BRDF = scattered flux per proj. solid angel per input flux.
 - $L(\text{scattered}) = \text{integral over BRDF} \times \text{input radiance over proj. solid angle.}$
- How is the BRDF measured?
 - Laser light source under some angle, detector in a known distance is moved over hemisphere.