

# 05 Shading and Frames

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**CS5625** Spring 2018

# Light reflection physics

# Radiometry redux

## **Power**

**Intensity** power per unit solid angle

**Irradiance** power per unit area

**Radiance** power per unit (solid angle  $\times$  area)

# Sources of light

## **Point sources**

- intensity
- can be directionally varying—spotlights

## **Area sources**

- radiance
- can be spatially varying

## **Directional sources**

- irradiance (normal irradiance)

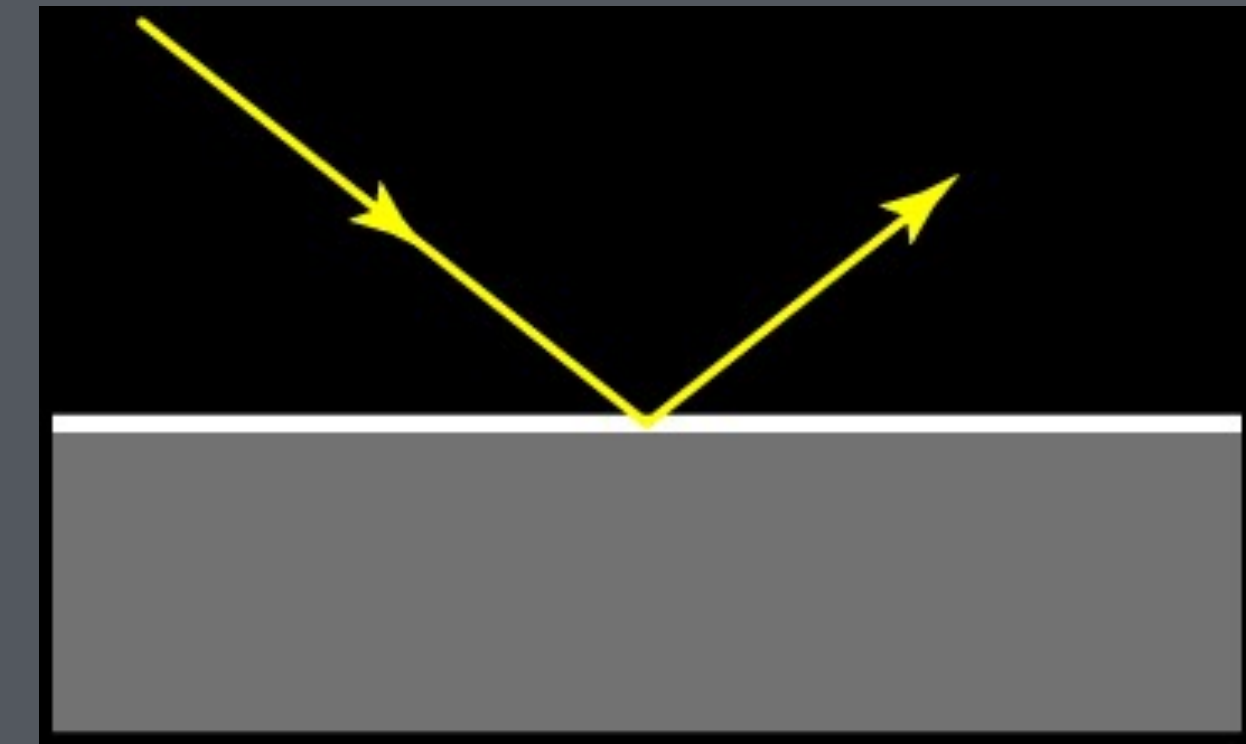
## **Environment lighting**

- radiance (usually spatially varying)
- sun-sky models

# Simple kinds of scattering

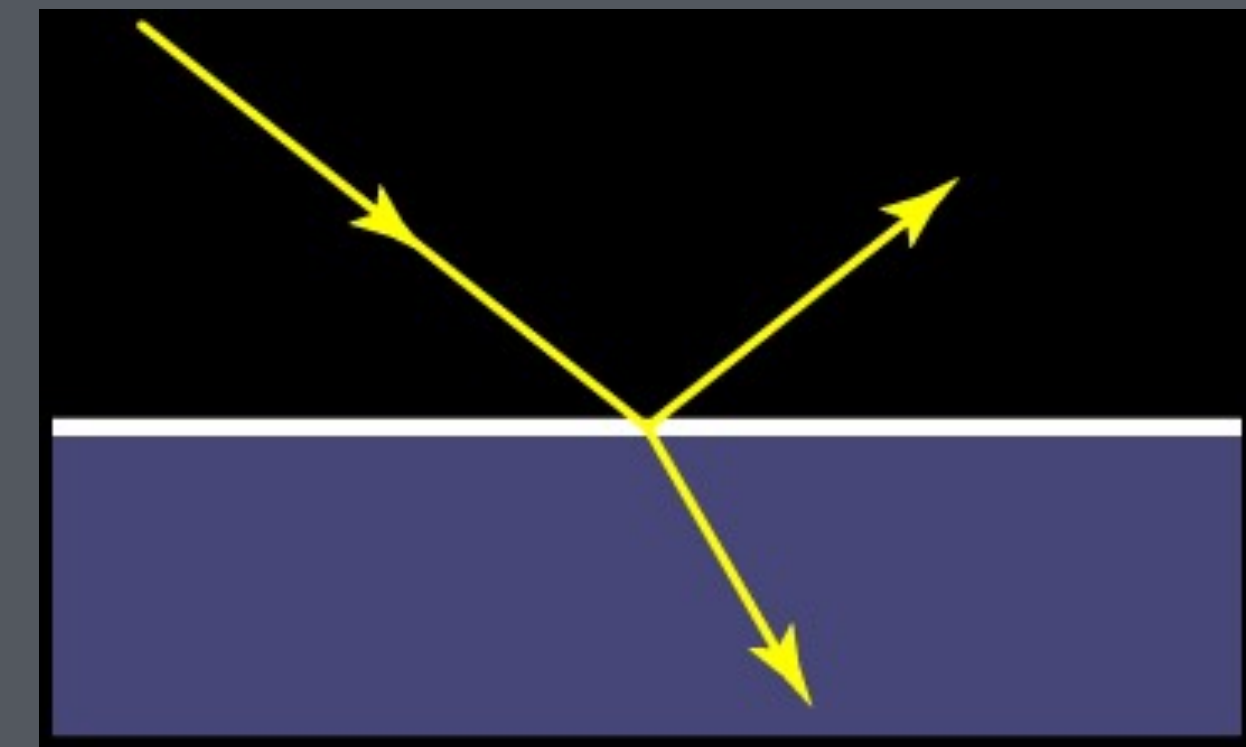
## Ideal specular reflection

- incoming ray reflected to a single direction
- mirror-like behavior
- arises at smooth surfaces



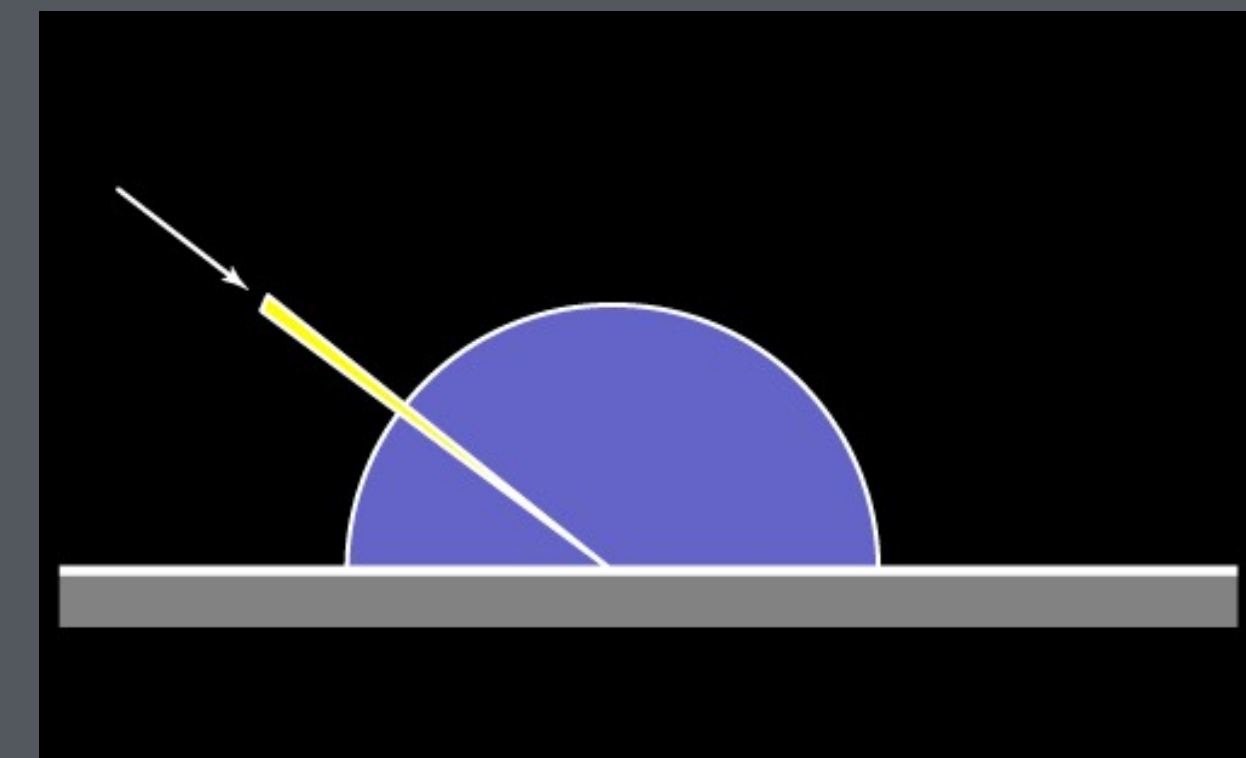
## Ideal specular transmission

- incoming ray refracted to a single direction
- glass-like behavior
- arises at smooth dielectric (nonmetal) surfaces



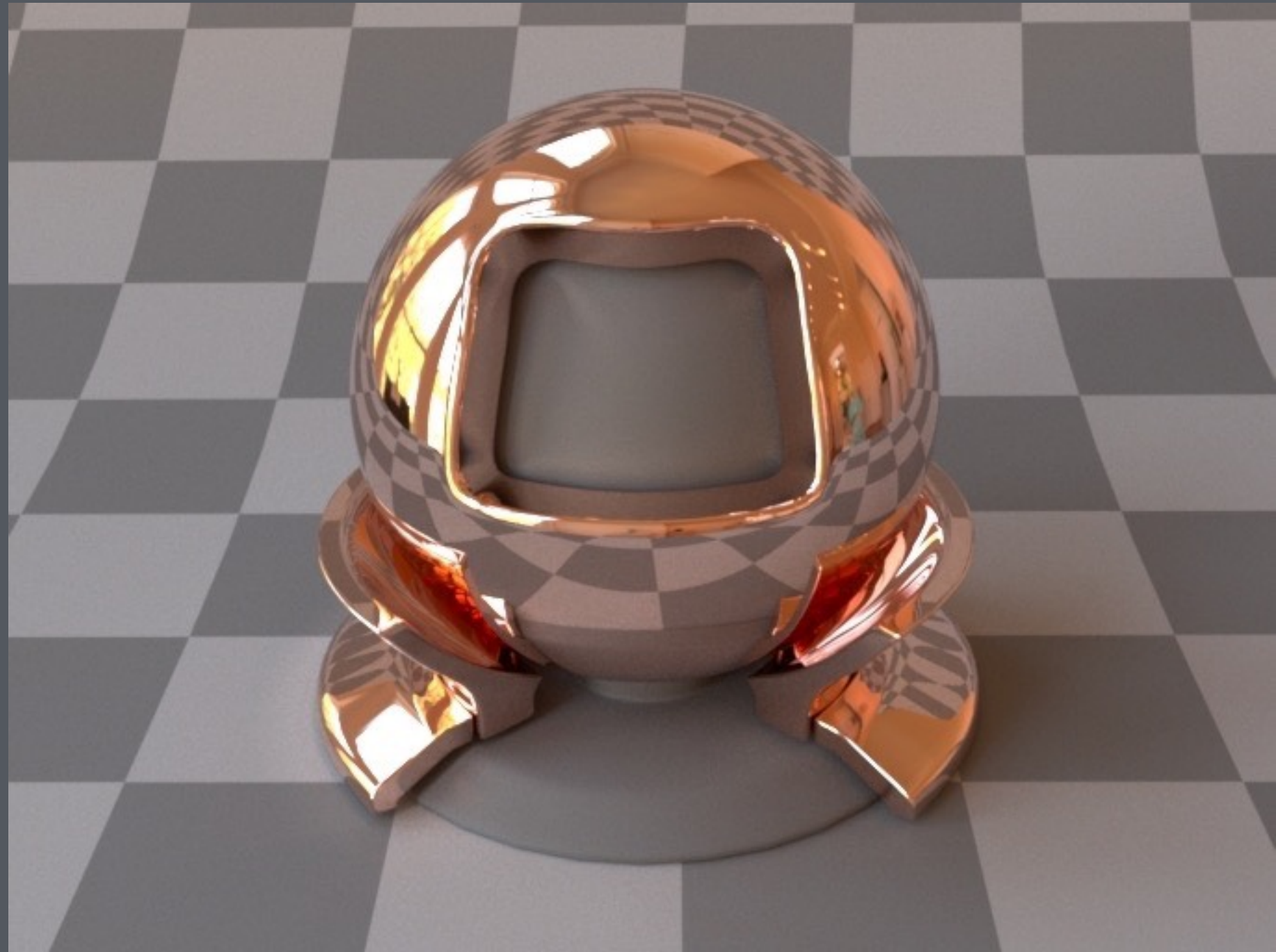
## Ideal diffuse reflection or transmission

- outgoing radiance independent of direction
- arises from subsurface multiple scattering

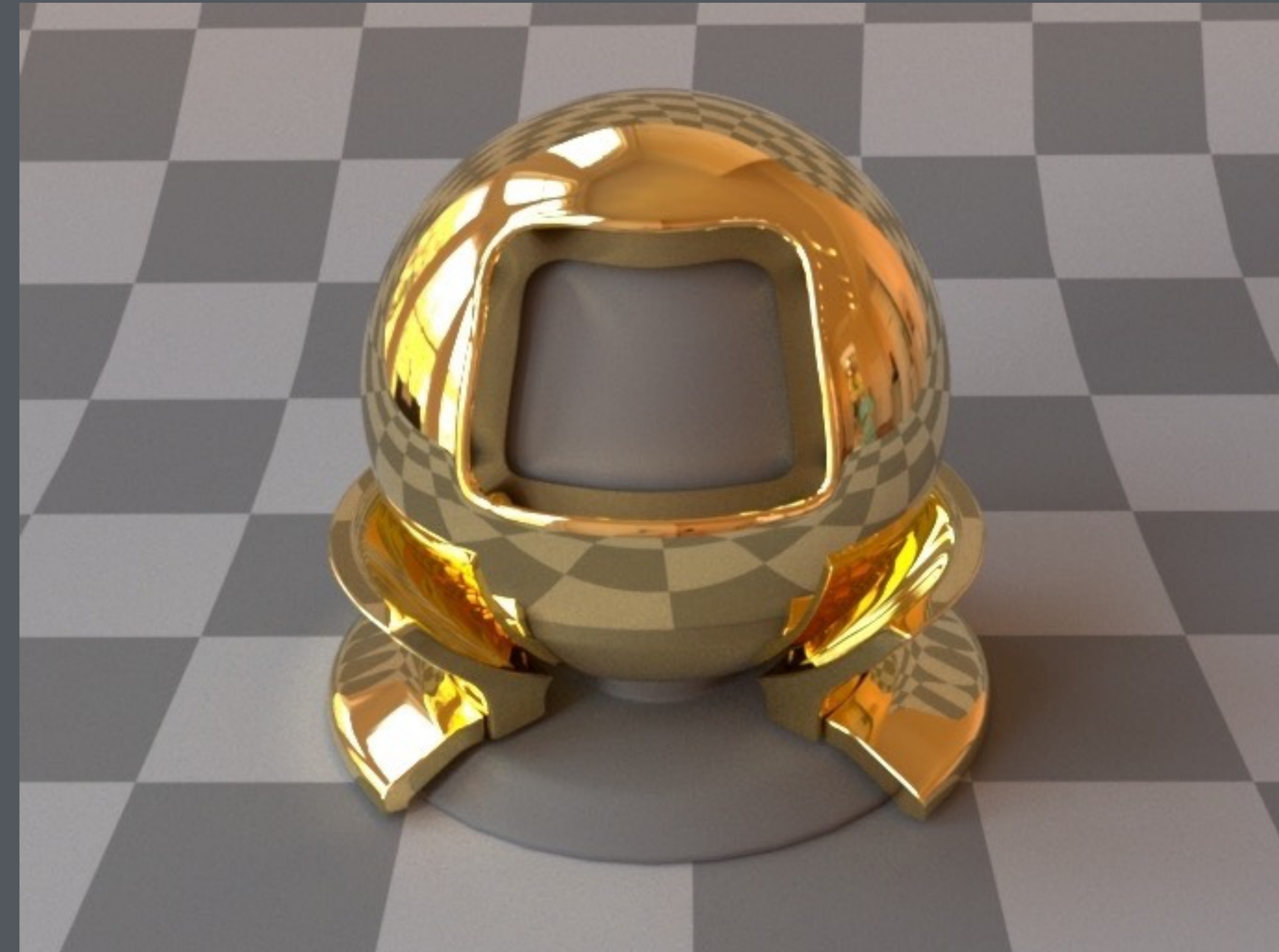




# Ideal specular reflection from metals



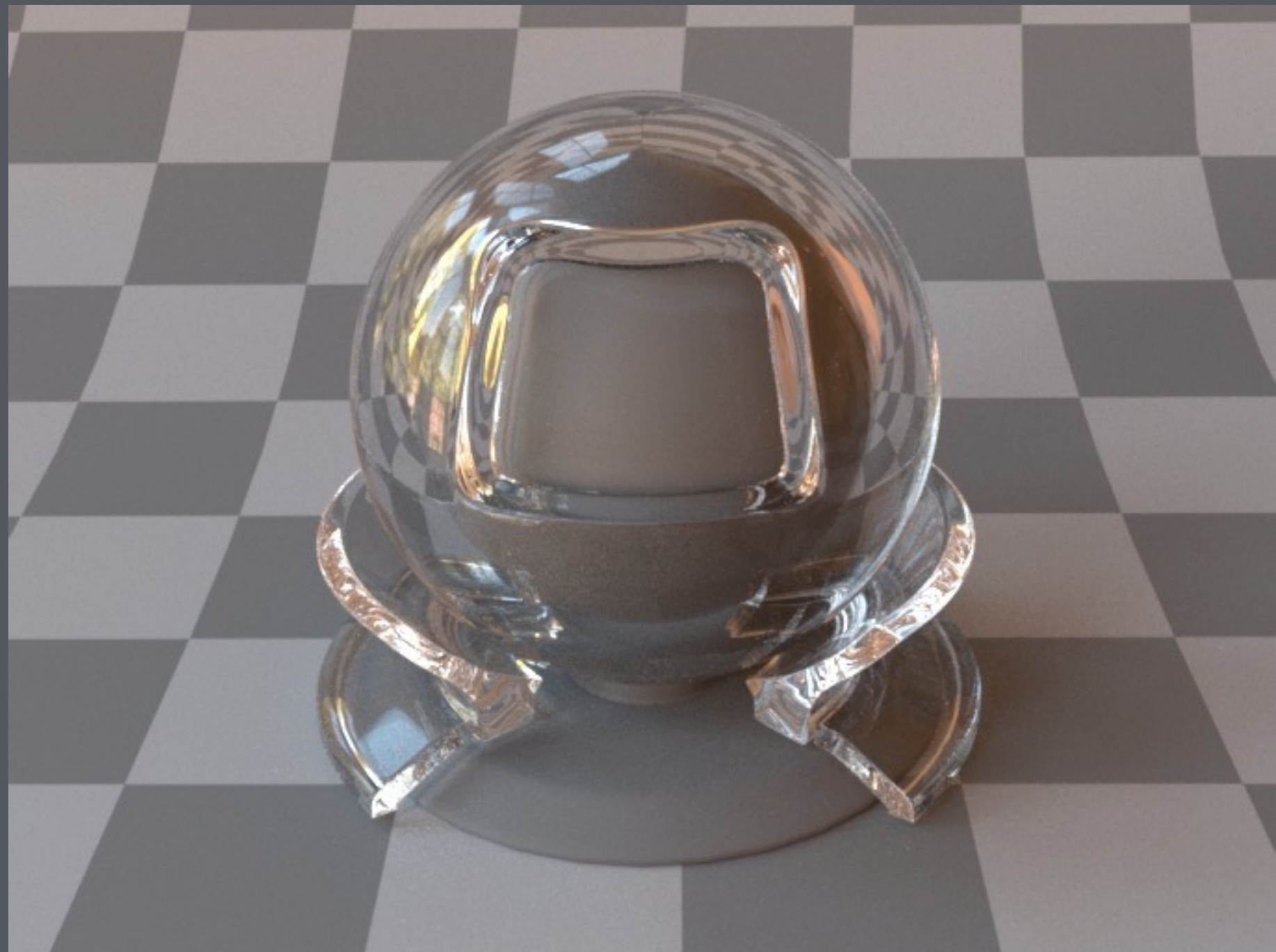
Cu



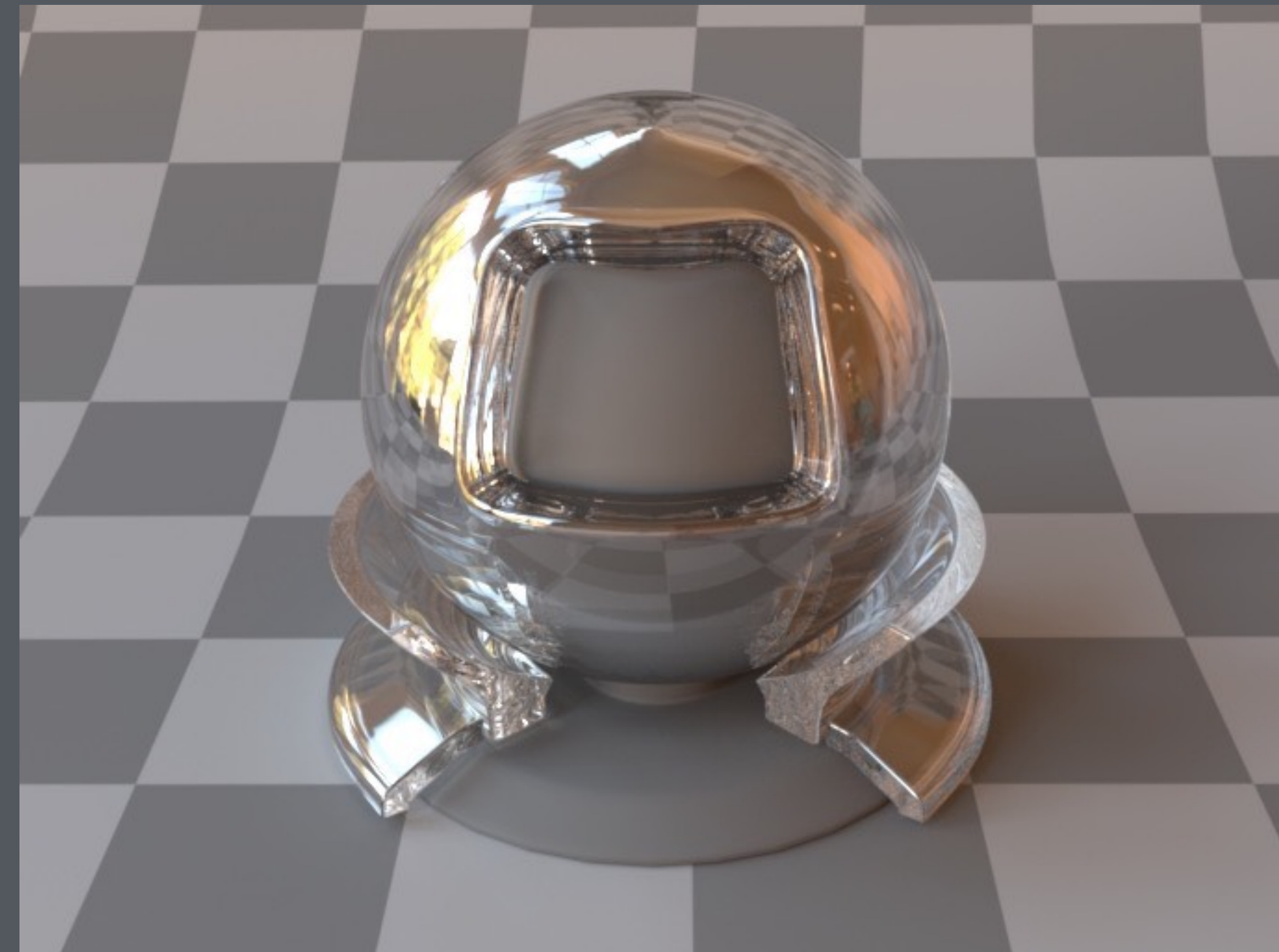
Au



# Ideal reflection and transmission from smooth dielectrics



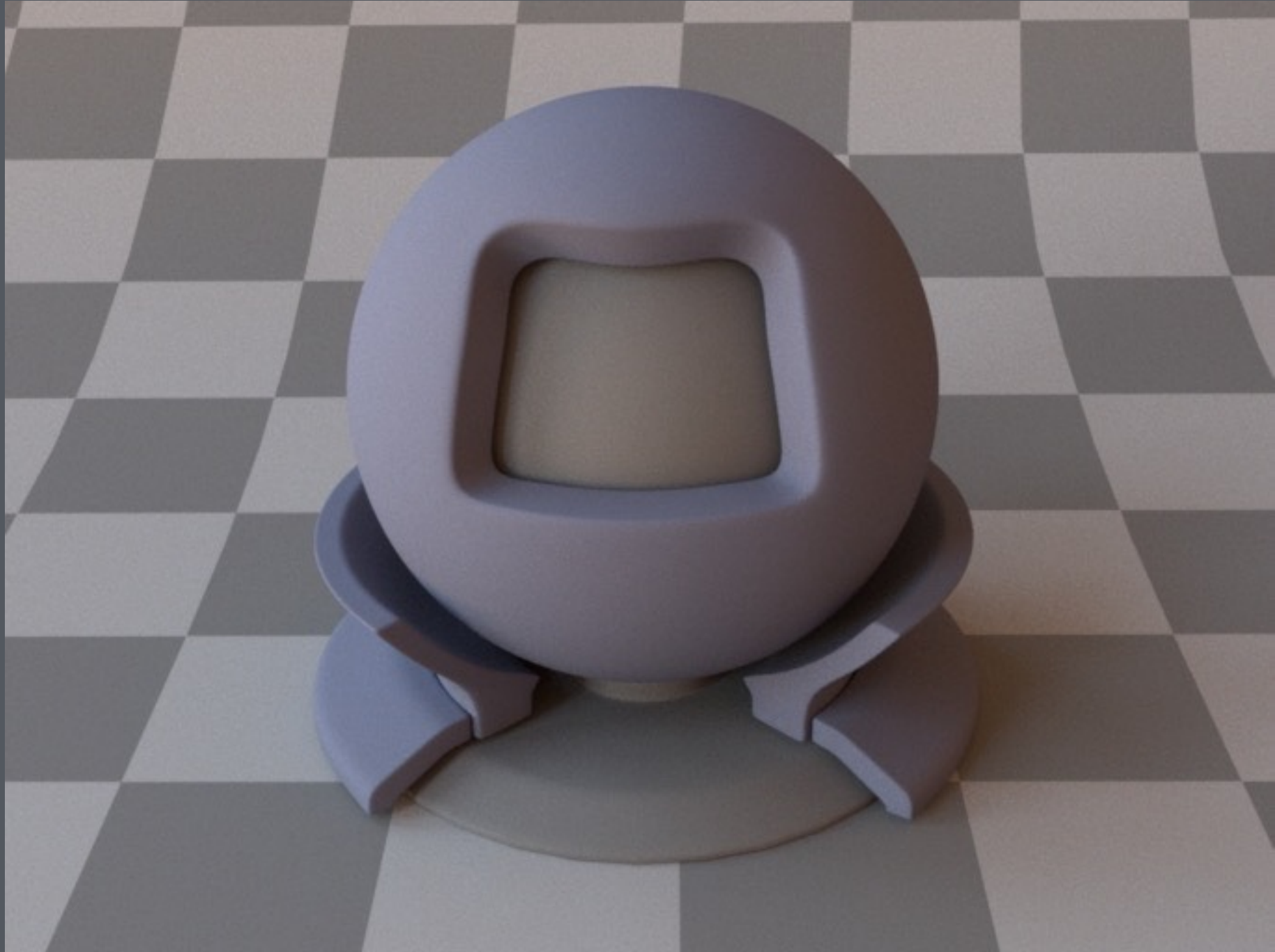
Water (ior = 1.33)



Diamond (ior = 2.4)



# Two diffuse surfaces

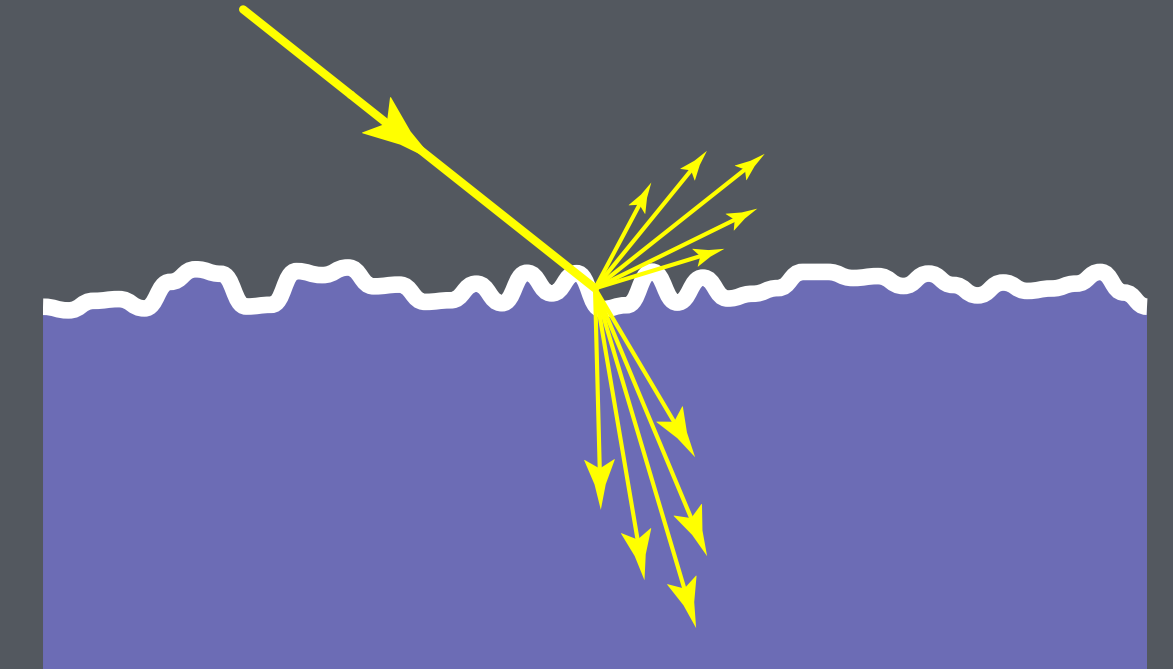
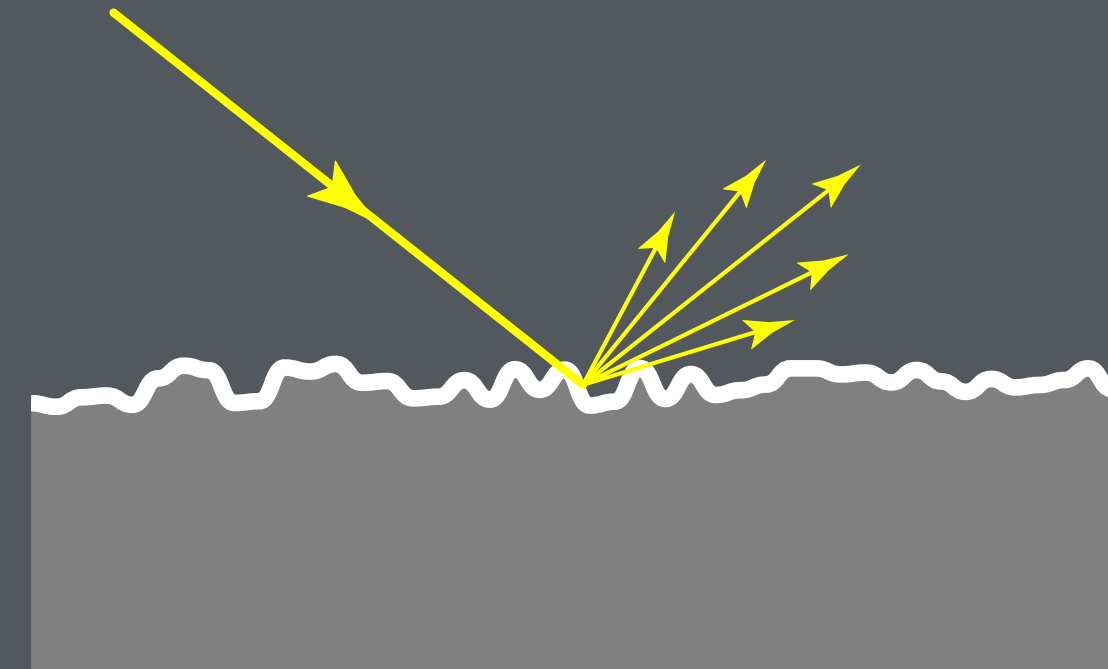




# More complex scattering

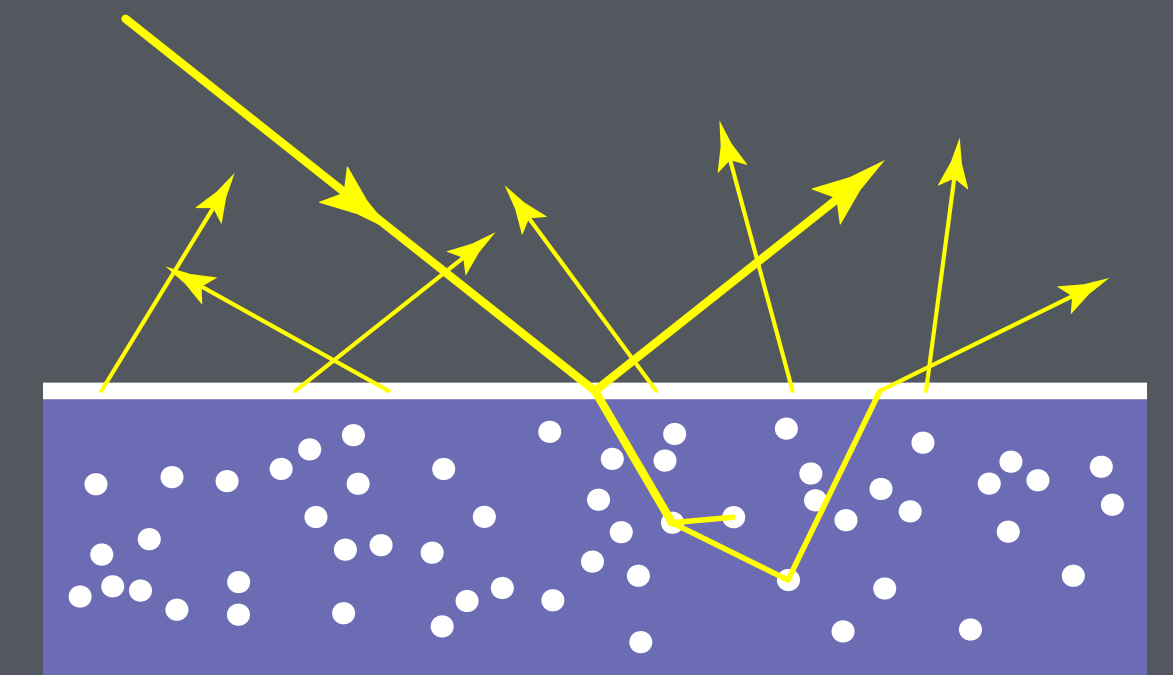
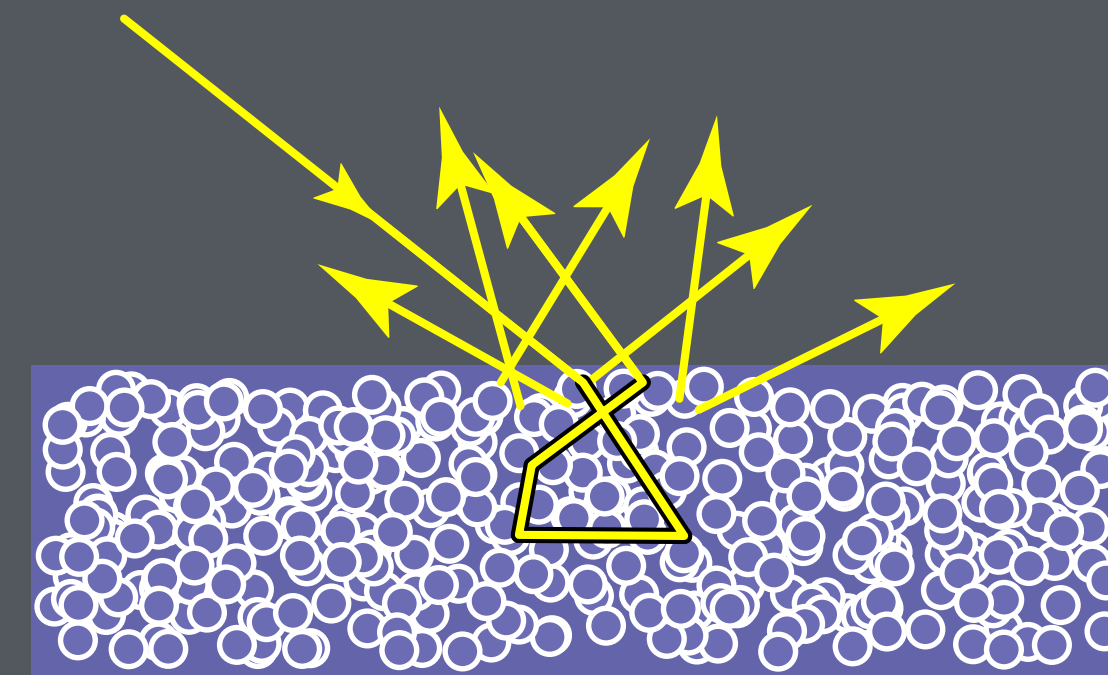
## Rough interfaces

- metal interfaces: blurred reflection
- dielectric interfaces: blurred transmission

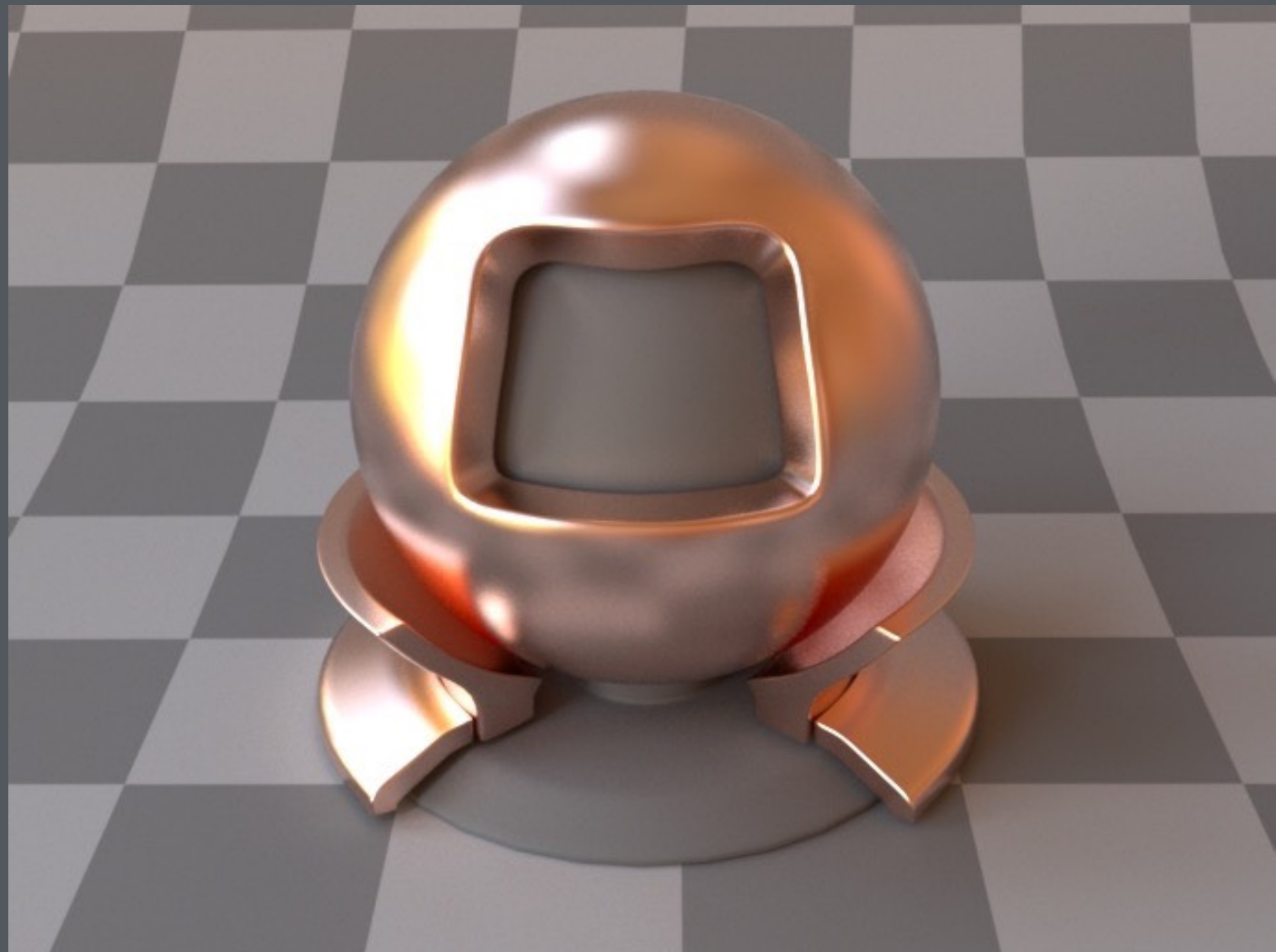


## Subsurface scattering

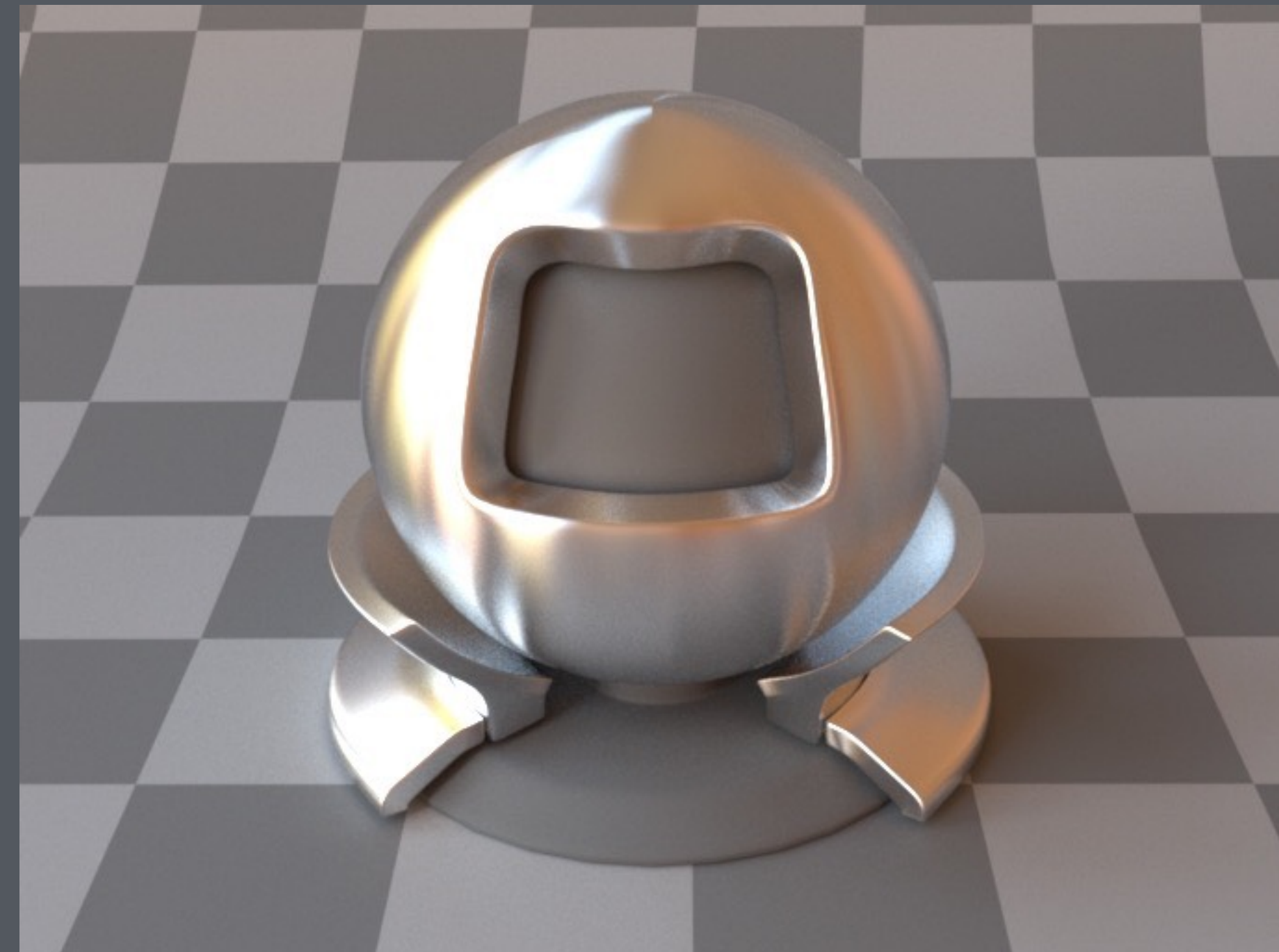
- liquids—milk, juice, beer, ...
- coatings—paint, glaze, varnish, ...
- natural materials—wood, marble, ...
- biological materials—skin, plants, ...
- low optical density leads to *translucency*



# Reflection from rough metal interfaces



Cu ( $\alpha = 0.1$ )



Al (anisotropic)



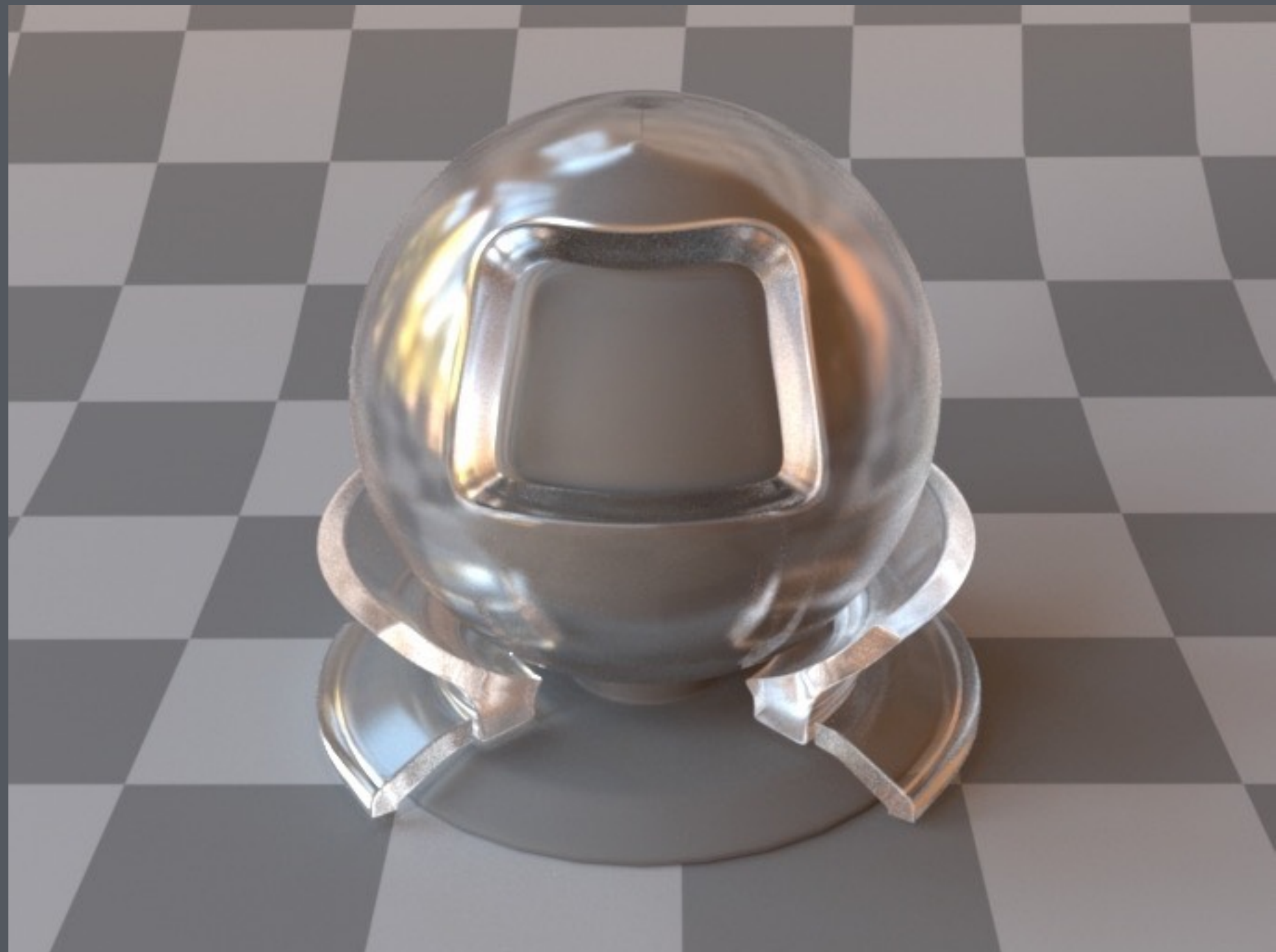




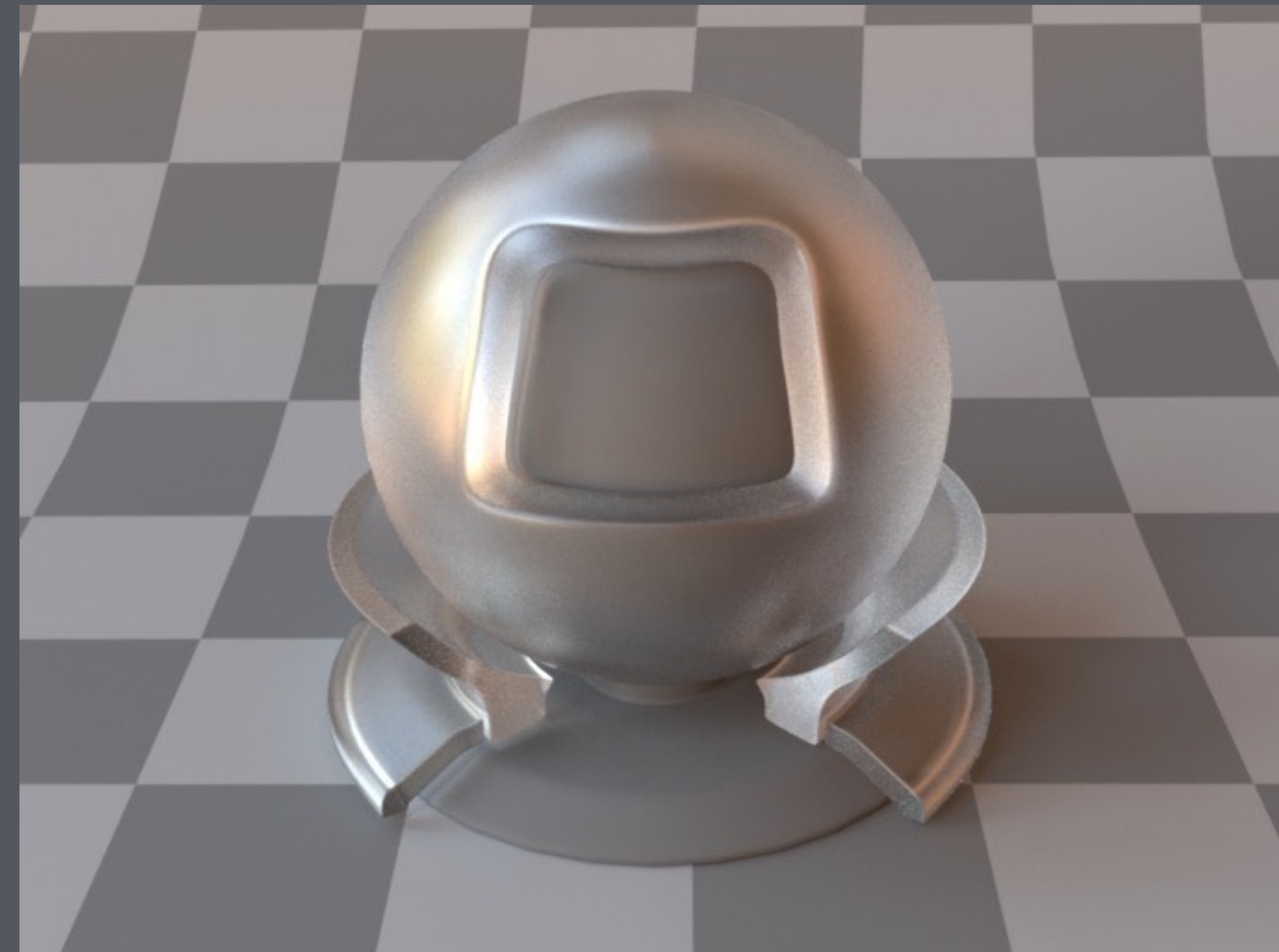




# Reflection and refraction at rough dielectric interfaces



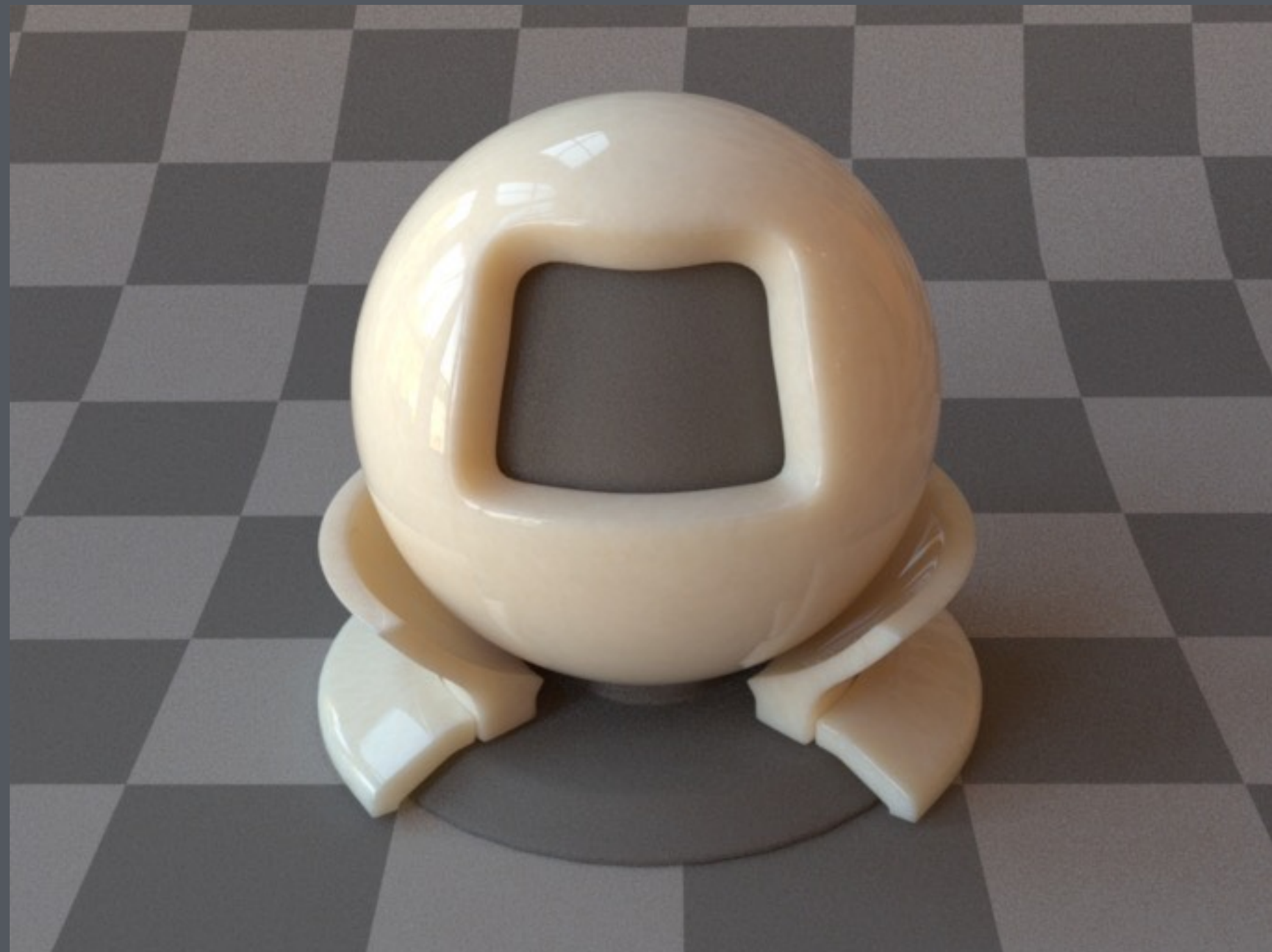
Anti-glare glass ( $\alpha = 0.02$ )



Etched glass ( $\alpha = 0.1$ )



# Translucent materials



“skim milk”

Wenzel Jakob / Mistuba



low  
optical  
density



high  
optical  
density

Wenzel Jakob / Mistuba



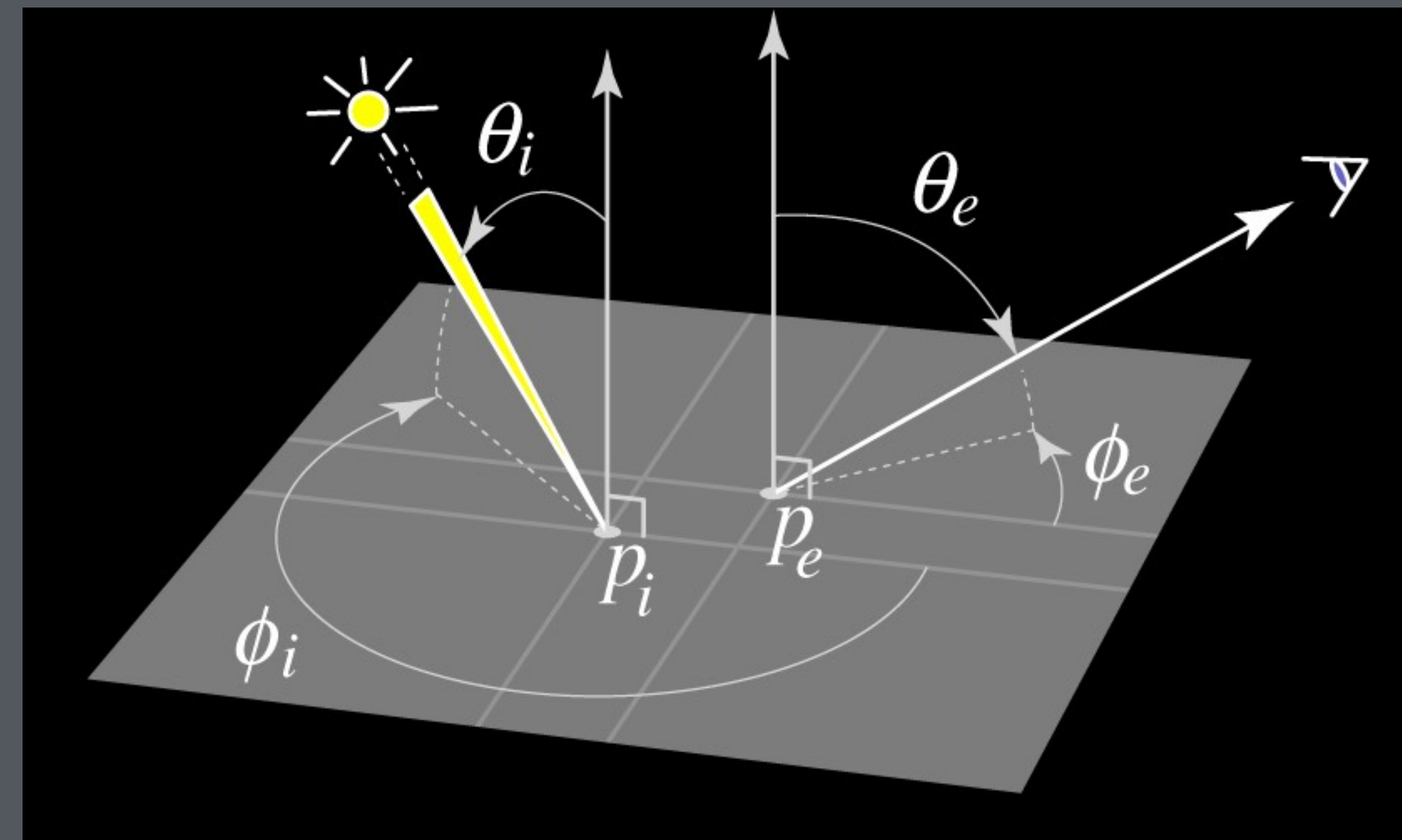
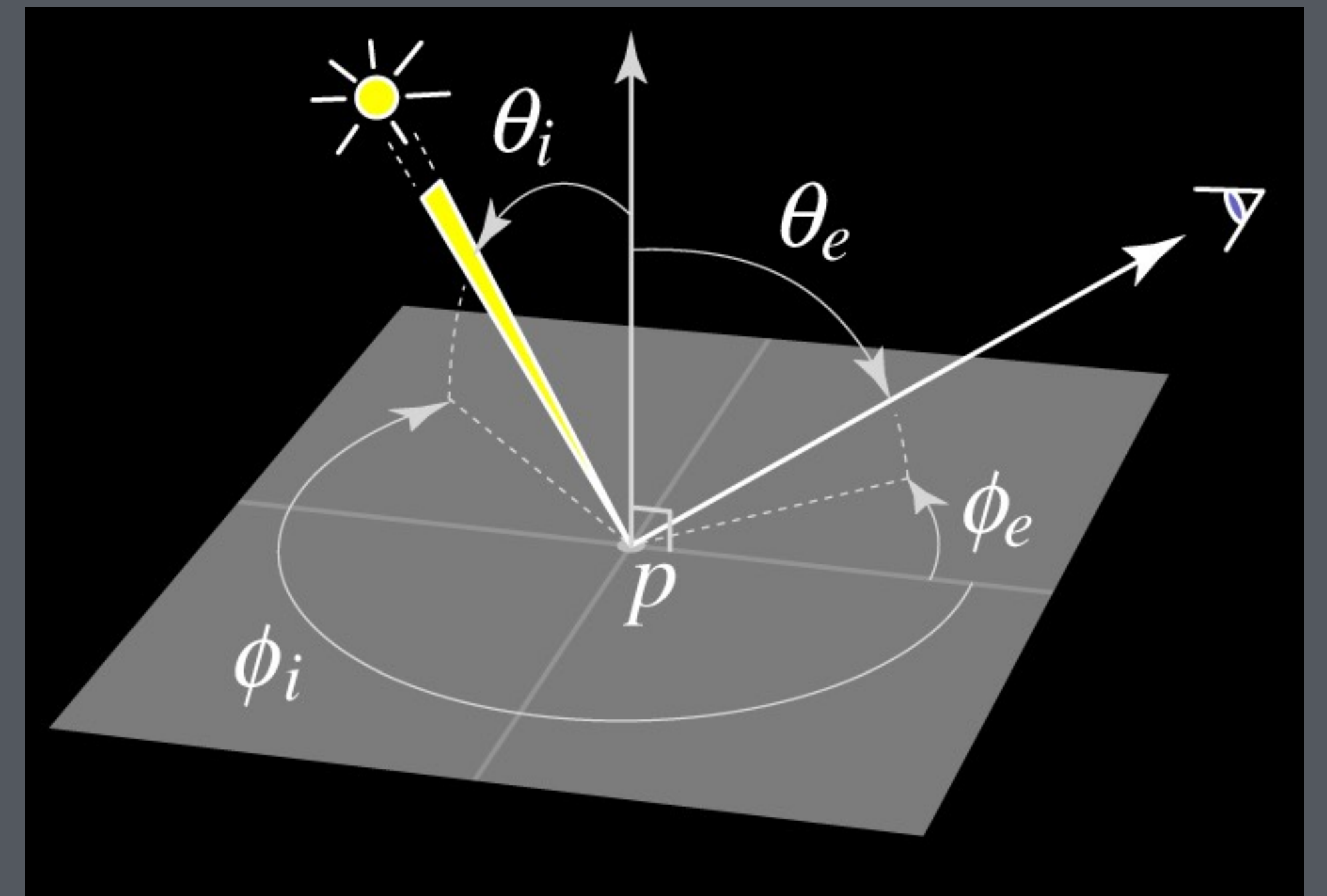
# Modeling complex scattering

## Opaque materials

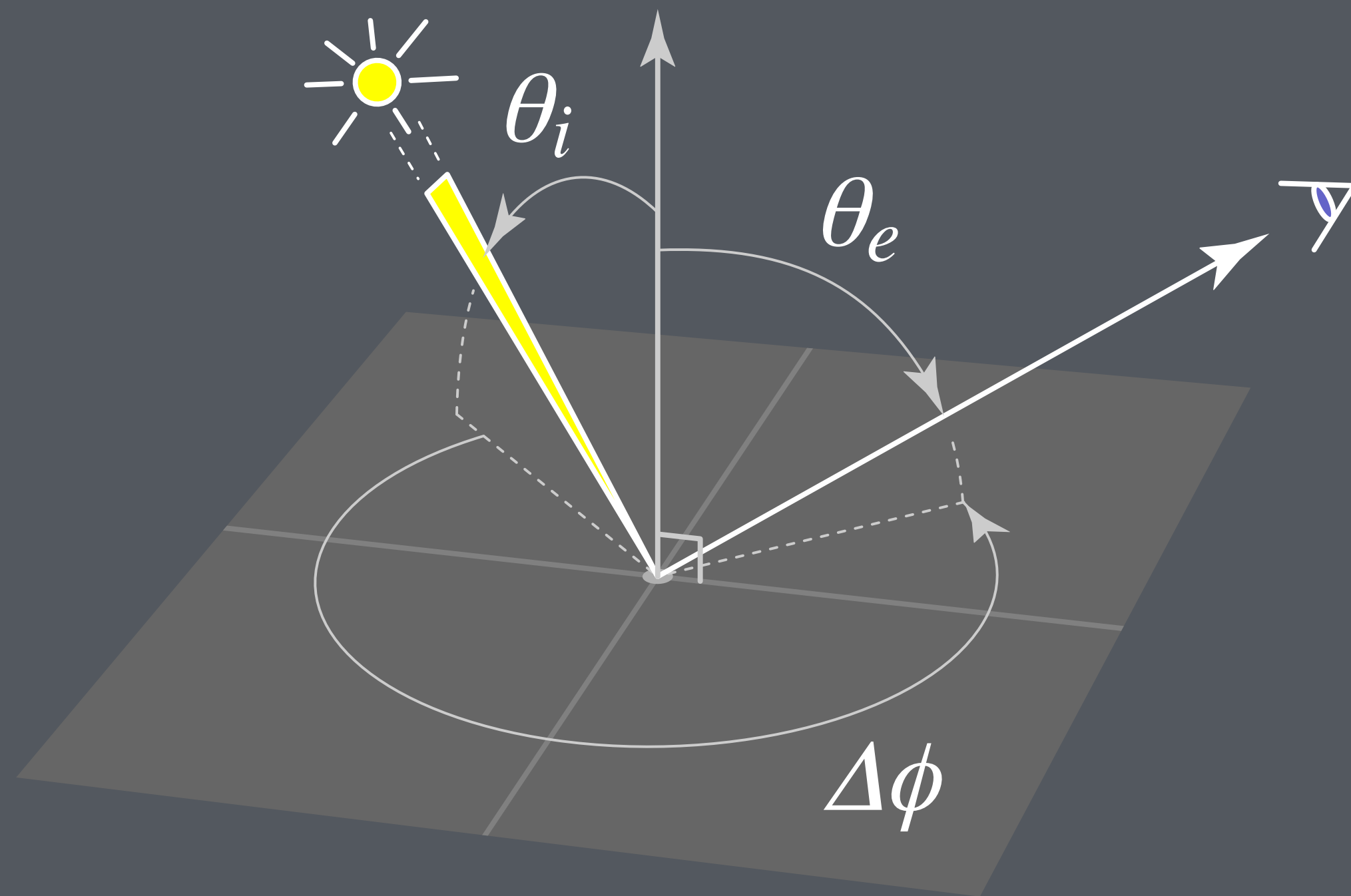
- reflection: bidirectional reflectance distribution function (BRDF)
- transmission: bidirectional transmittance distribution function (BTDF)
- both: bidirectional scattering distribution function (BSDF)

## Translucent materials

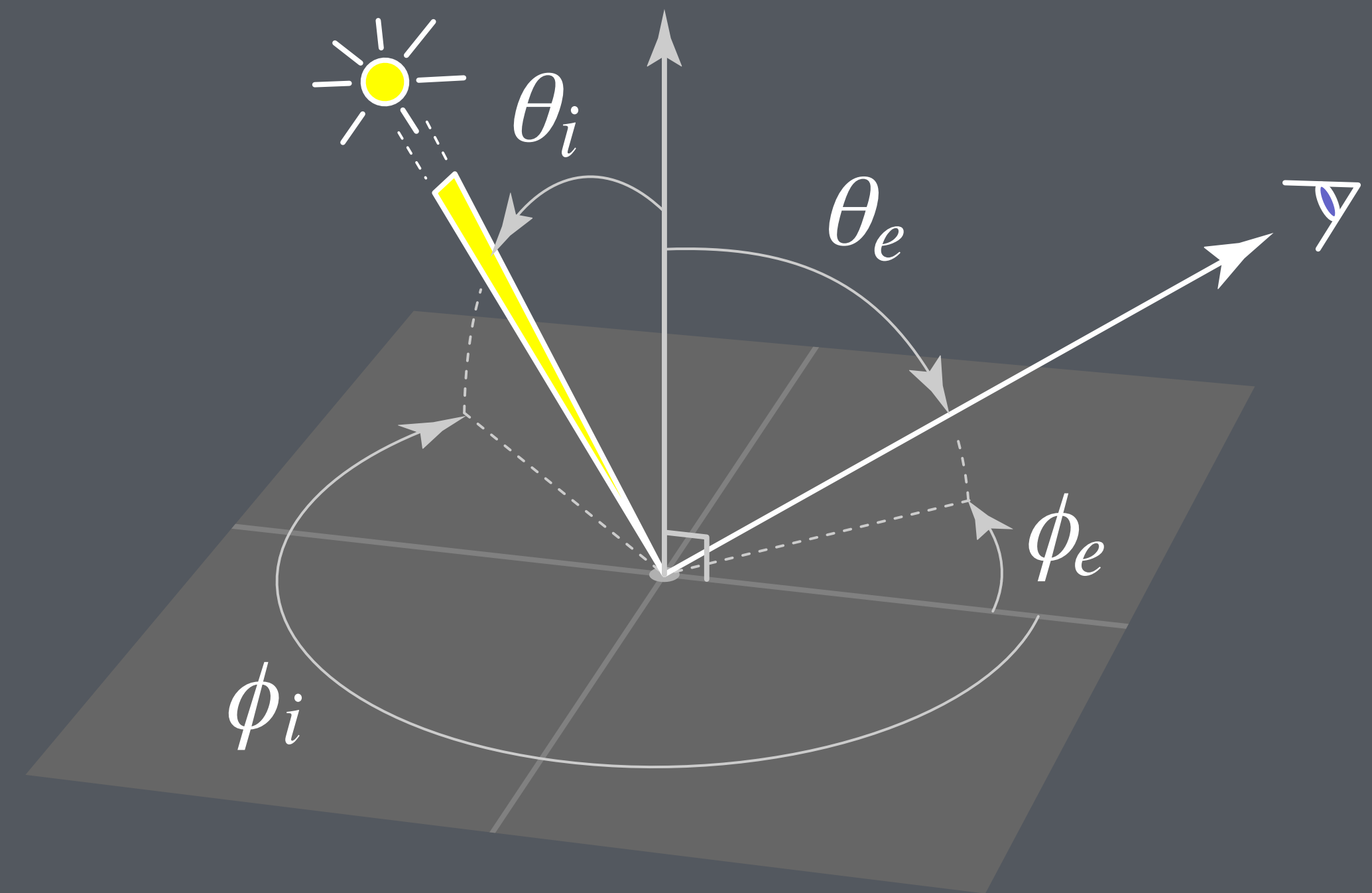
- bidirectional subsurface scattering reflectance distribution function (BSSRDF)
- more on this later, maybe



# Isotropy vs. anisotropy



**isotropic**

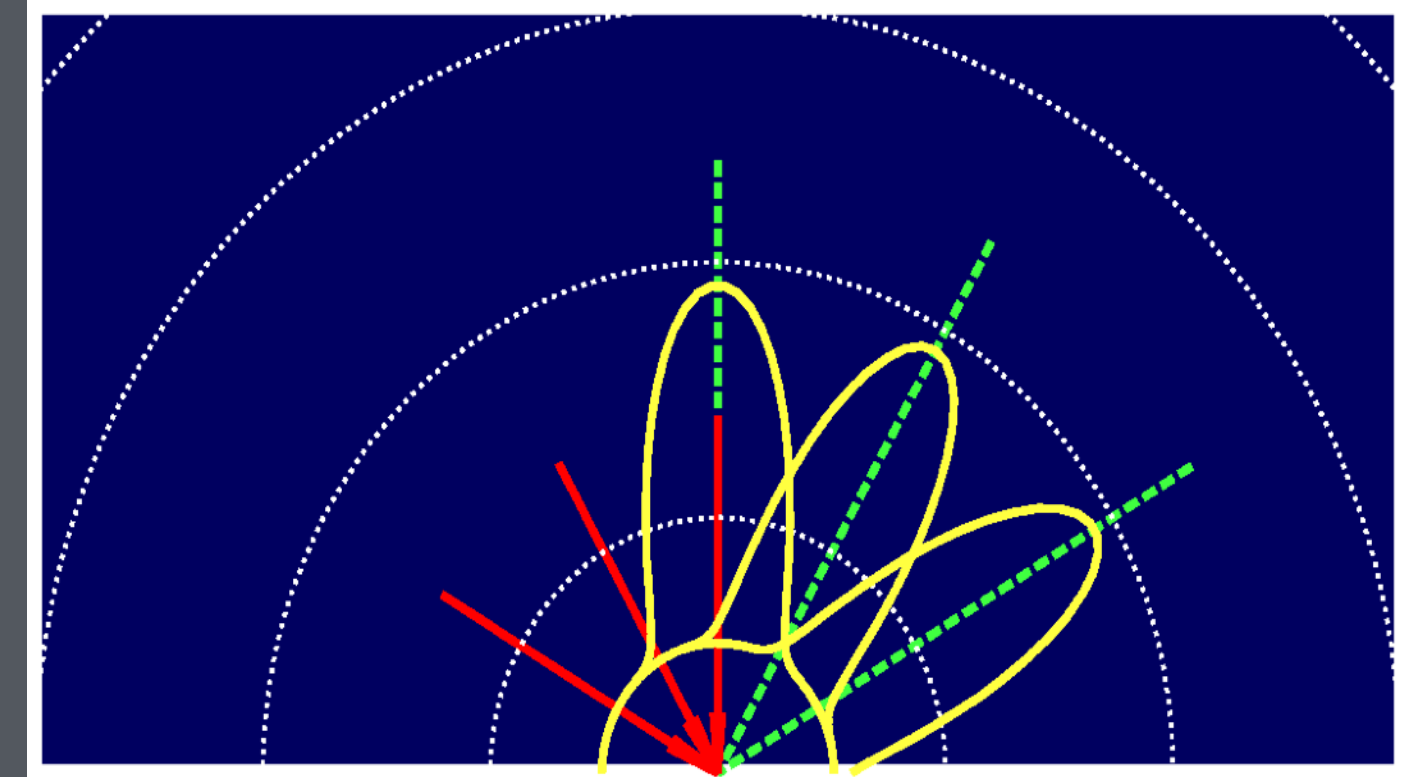


**anisotropic**

# Types of BRDF/BSDF models

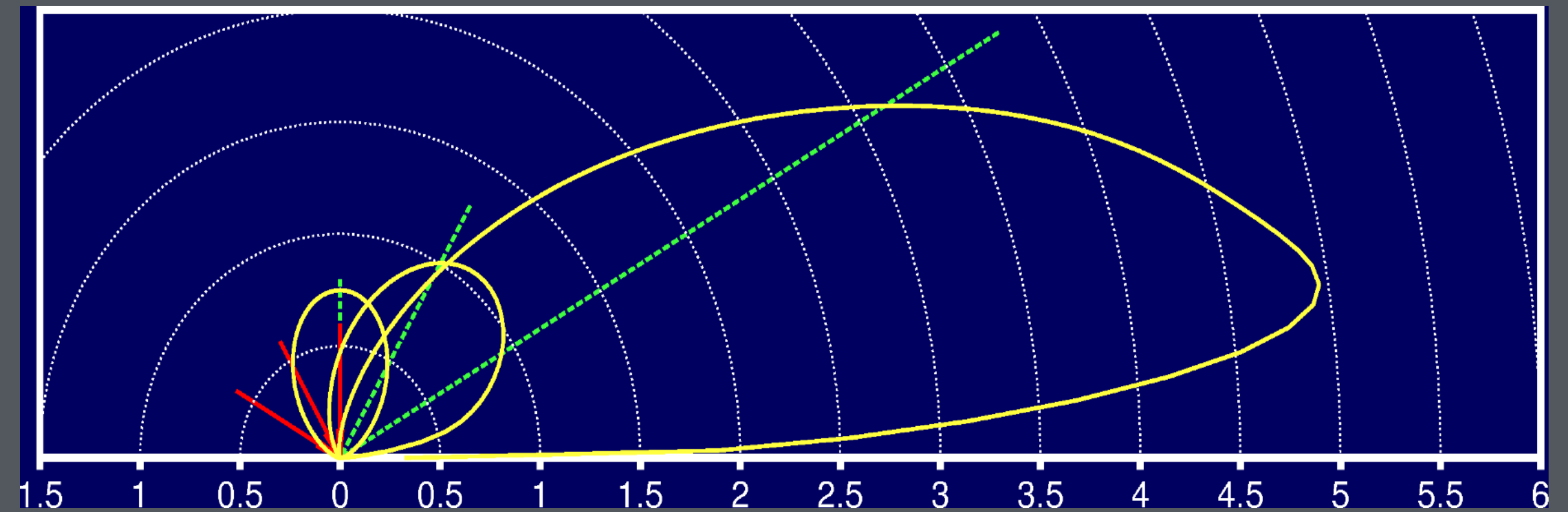
## Ad hoc formulas

- e.g. Blinn-Phong



## Physics-based analytical models

- Lambertian
- Microfacet-based models
- Kirchhoff-based models



## Measured data

- tables of data from pointwise BRDF measurements
- image-based BRDF measurements

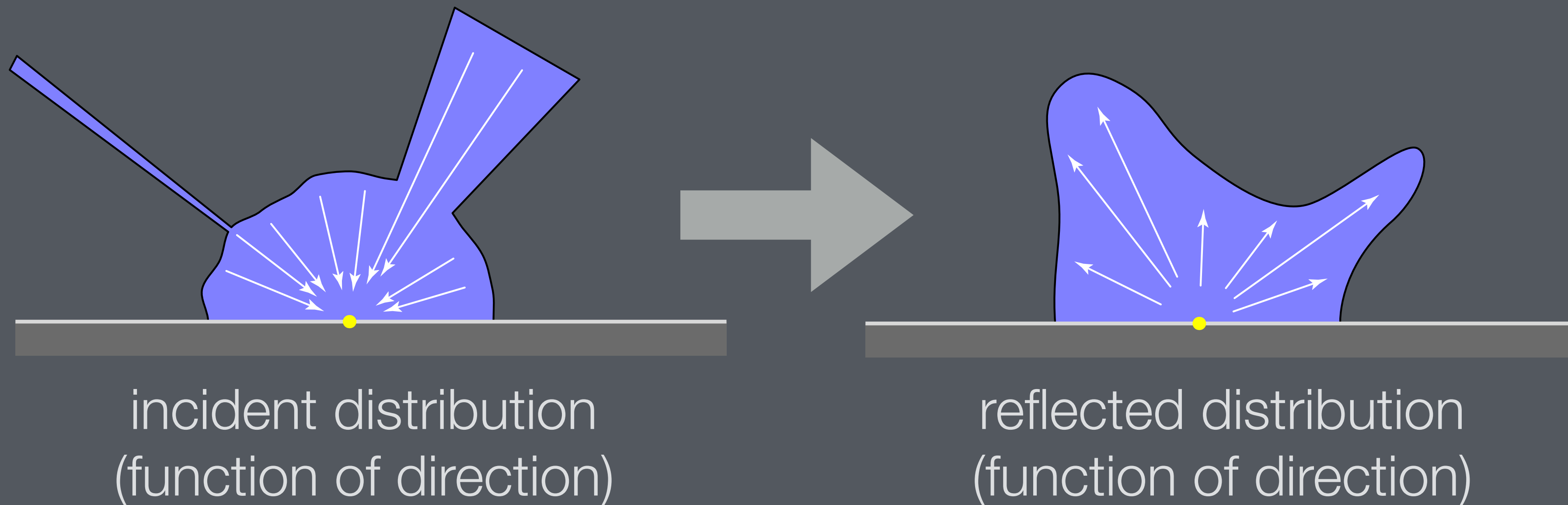


Light reflection in shaders

# Light reflection: full picture

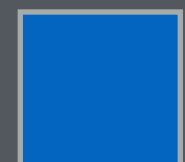
## **all types of reflection reflect all types of illumination**

- diffuse, glossy, mirror reflection
- environment, area, point illumination



# Categories of illumination

	diffuse	glossy	mirror
indirect	soft indirect illumination	blurry reflections of other objects	reflected images of other objects
environment	soft shadows	blurry reflection of environment	reflected image of environment
area	soft shadows	shaped specular highlight	reflected image of source
point/directional	hard shadows	simple specular highlight	point reflections



= easy to compute using standard shaders



# How to compute shading

**Basic case: point or directional lights; diffuse or glossy BRDF**

**Type in BRDF model, plug in illumination and view direction**

- can write down model in world space, use world-space vectors
- can write down model in surface frame, transform vectors
- really not different

**Subtleties are all about what frame to use for shading**

# Interpolated shading

**Coarse triangle meshes are fast**

**Discontinuities are bad**

**Therefore: interpolate geometric quantities across triangles**

- goal: shading is smooth across edges

**What do we interpolate?**

- what do we need to compute shading?

# Shading frames

## **When we carry around a normal, we are defining a tangent plane**

- interpolated normal defines an approximate, smoothly varying tangent plane

## **For some purposes, the tangent plane is enough**

- e.g. computing shading for isotropic BRDFs
- any coordinate system conforming to the normal is equally good

## **In other cases, need a complete frame**

- whenever directions within the plane are inequivalent
- e.g. anisotropic BRDFs
- e.g. tangent-frame normal maps

**How to compute these from normals and texture coordinates?** (blackboard)

# What to interpolate

**Need plane: can just interpolate a normal**

**Need frame: interpolate enough data to define a tangent frame**

**One and a half vectors rounds up to two**

- normal and one tangent vector
- two tangent vectors

**Rebuilding a frame from the vectors**

- worry about handedness matching texture coordinates (or not)
- orthonormality gets broken by interpolation (when does that matter?)



# What you need for shading

## **When/why you need full frames**

- when you care (or not) what the orientation is
- when you care (or not) about orthonormality

## **What to interpolate**

- underlying math question: representation of frames
- representations that behave well under interpolation

## **How to author orientation**

- with maps
- by following a parameterization

## **How to deal with corner cases**