

PBR:应用于虚幻4引擎贴图 和材质创建的启示

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GAME DEVELOPERS CONFERENCE CHINA

SHANGHAI INTERNATIONAL CONVENTION CENTER

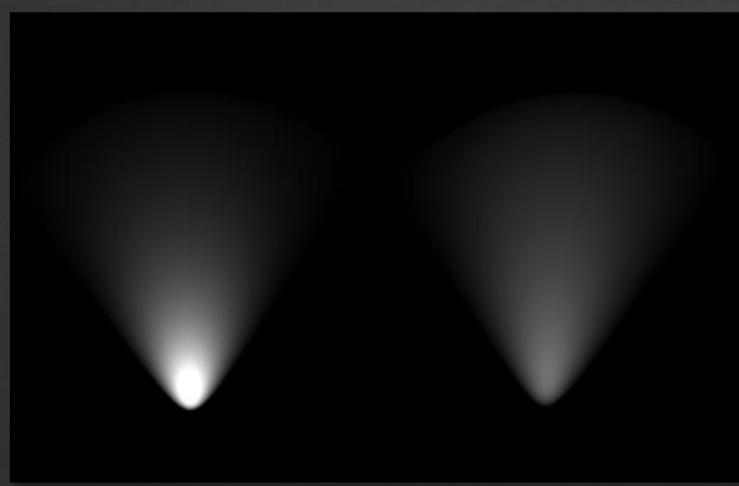
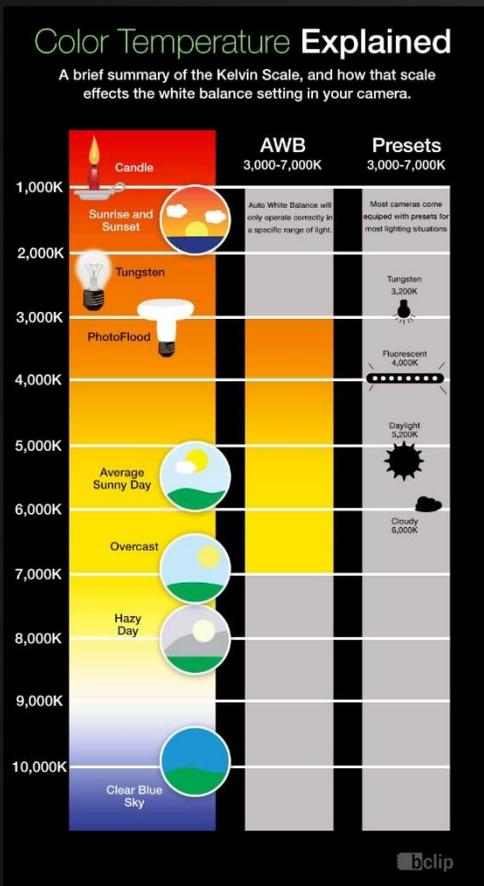
SHANGHAI, CHINA · OCTOBER 25-27, 2015



真实世界的属性

- 光源
- 线性，高动态
- 漫反射和镜面反射
- 绝缘体和导体
- 光线照到物体上后的行为
- 折射率/反射率
- 微表面
- 颜色
- 能量保存
- 菲涅尔现象

光的属性：颜色，亮度，衰减，强度，形状



多光源



线性， 高动态



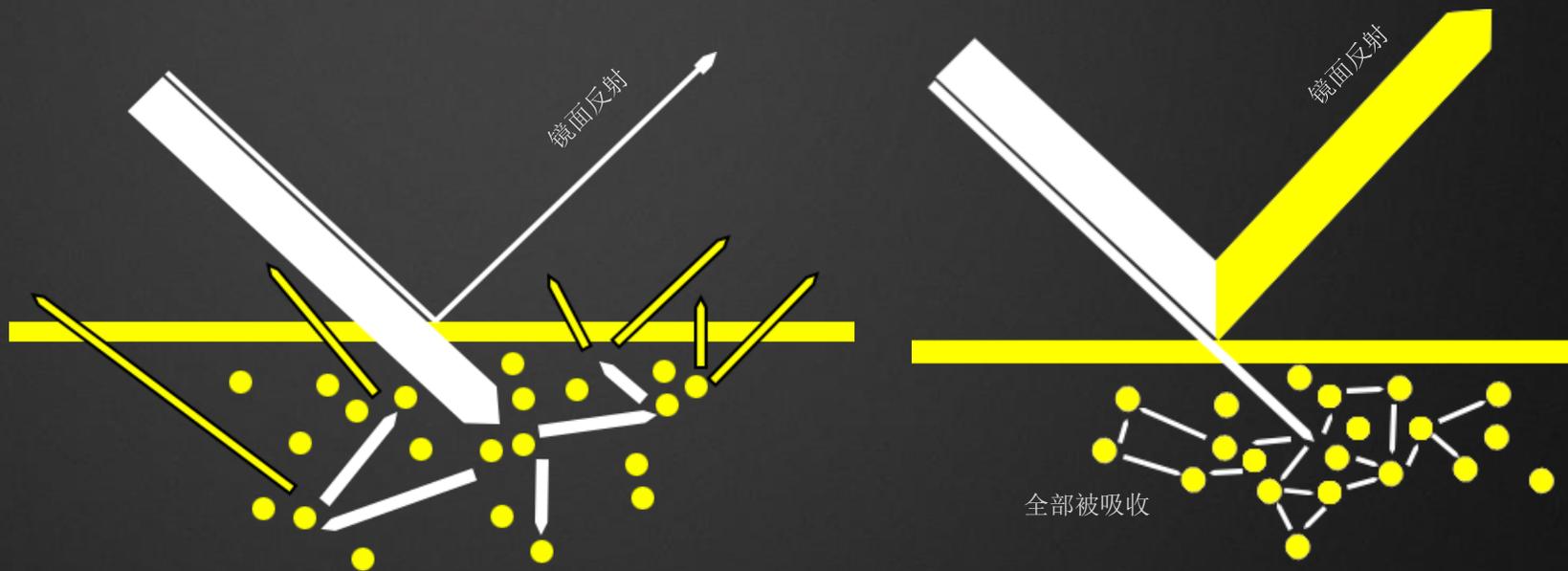
$$F(x+y)=f(x)+f(y)$$

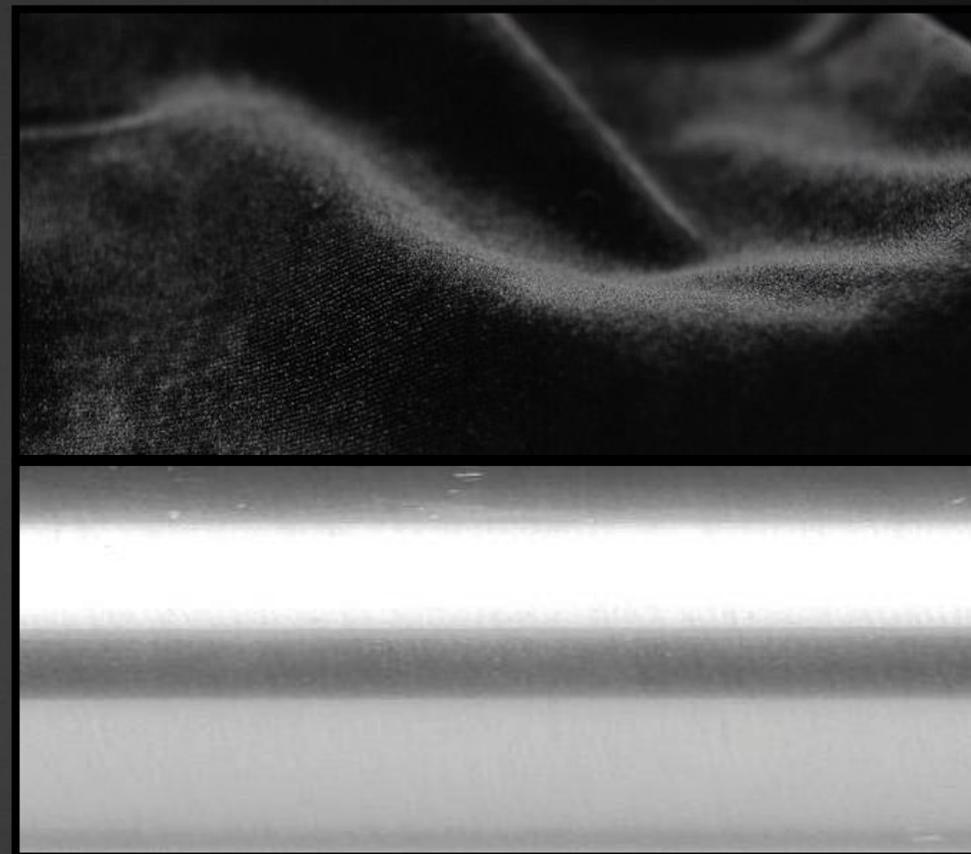
绝缘体和导体/电介质和非电介质/非金属和金属
漫反射和镜面反射
颜色

- 金属有强烈反射70-90%，其余被完全吸收。如果吸收的是特定波长，反射有颜色
- 非金属少许反射4%，同光源颜色；其余折射，有部分吸收，部分离散（漫反射），如果吸收的是特定波长，漫反射有颜色



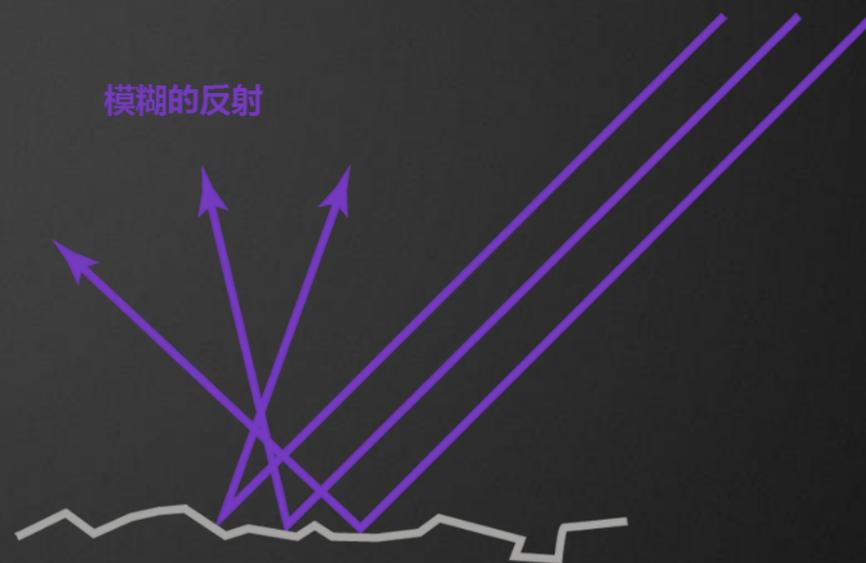
反射，吸收，离散



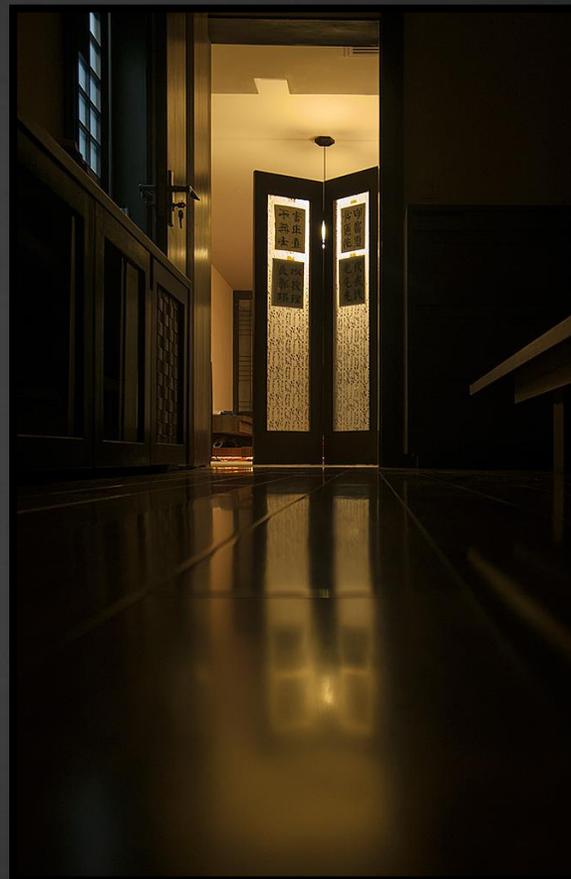
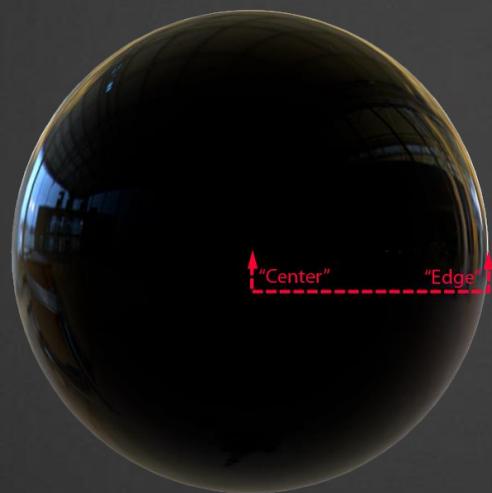
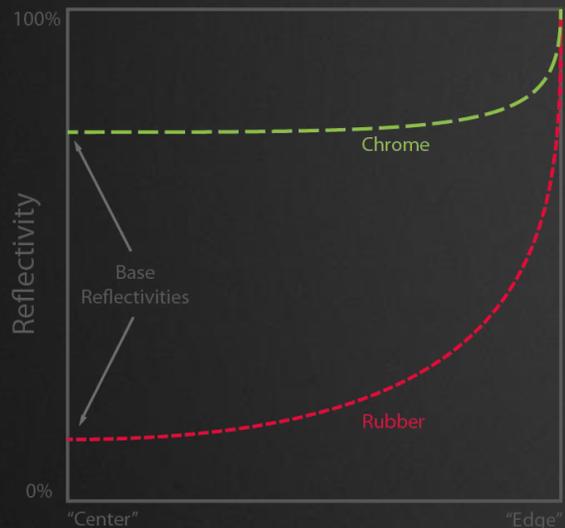


微表面

显微镜下的玻璃



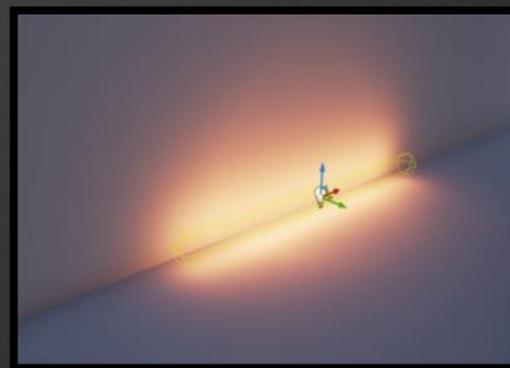
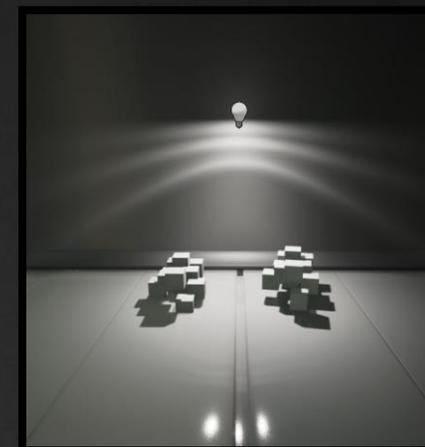
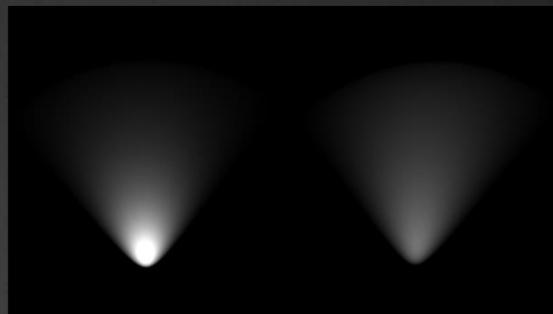
菲涅尔现象



UE4里是如何模拟的

灯光:

- 衰减
- 区域光以Lumi为单位
- 非点光源: 面光源/长光源
- 色温控制
- 高动态 (HDR) 非直接镜面反射和高光
- IBL



明暗

Diffuse BRDF

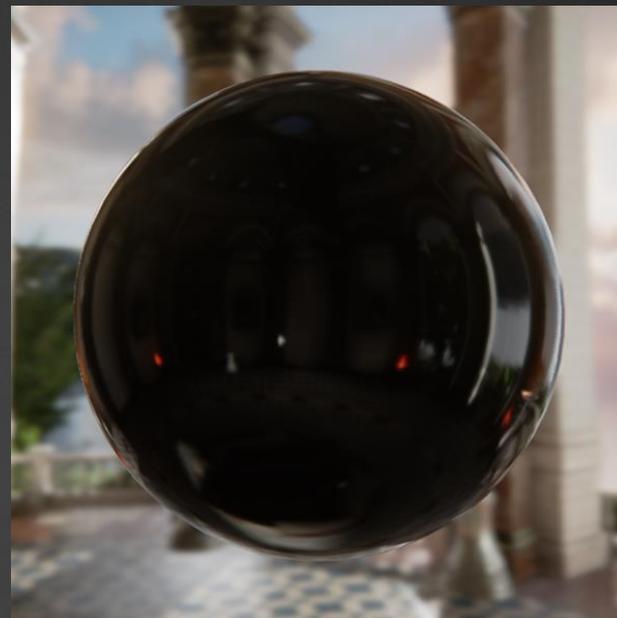
Specular BRDF

Specular Distribution

Geometric Shadowing

Fresnel

Image-based Lighting



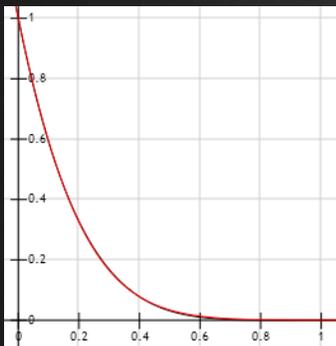
Specular distribution:GGX



Diffuse BRDF



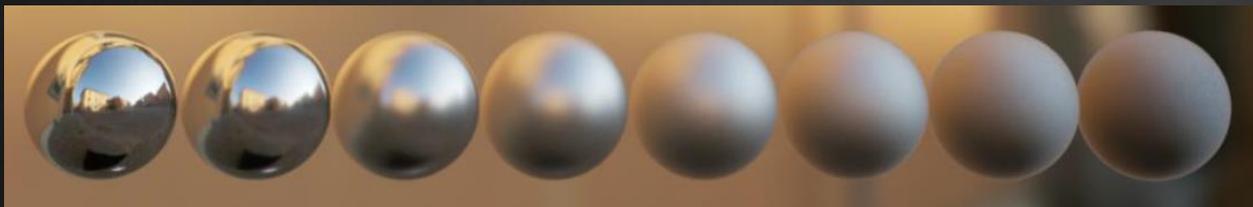
Fresnel: Schlick



$$f(l, v) = \frac{D(h)F(l, h)G(l, v, h)}{4(n \cdot l)(n \cdot v)}$$

Geometric shadowing:Schlick

Environment BRDF



```

3  /*=====
4     BRDF.usf: Bidirectional reflectance distribution functions.
5  /*=====
6
7  #ifndef __BRDF_COMMON__
8  #define __BRDF_COMMON__
9
10 // Physically based shading model
11 // parameterized with the below options
12
13 // Microfacet specular = D*G*F / (4*NoL*NoV) = D*Vis*F
14 // Vis = G / (4*NoL*NoV)
15
16 // Diffuse model
17 // 0: Lambert
18 // 1: Burley
19 // 2: Oren-Nayar
20 #define PHYSICAL_DIFFUSE    0
21
22 // Microfacet distribution function
23 // 0: Blinn
24 // 1: Beckmann
25 // 2: GGX
26 #define PHYSICAL_SPEC_D    2
27
28 // Geometric attenuation or shadowing
29 // 0: Implicit
30 // 1: Neumann
31 // 2: Kelemen
32 // 3: Schlick
33 // 4: Smith (matched to GGX)
34 #define PHYSICAL_SPEC_G    3
35
36 // Fresnel
37 // 0: None
38 // 1: Schlick
39 // 2: Fresnel
40 #define PHYSICAL_SPEC_F    1
    
```

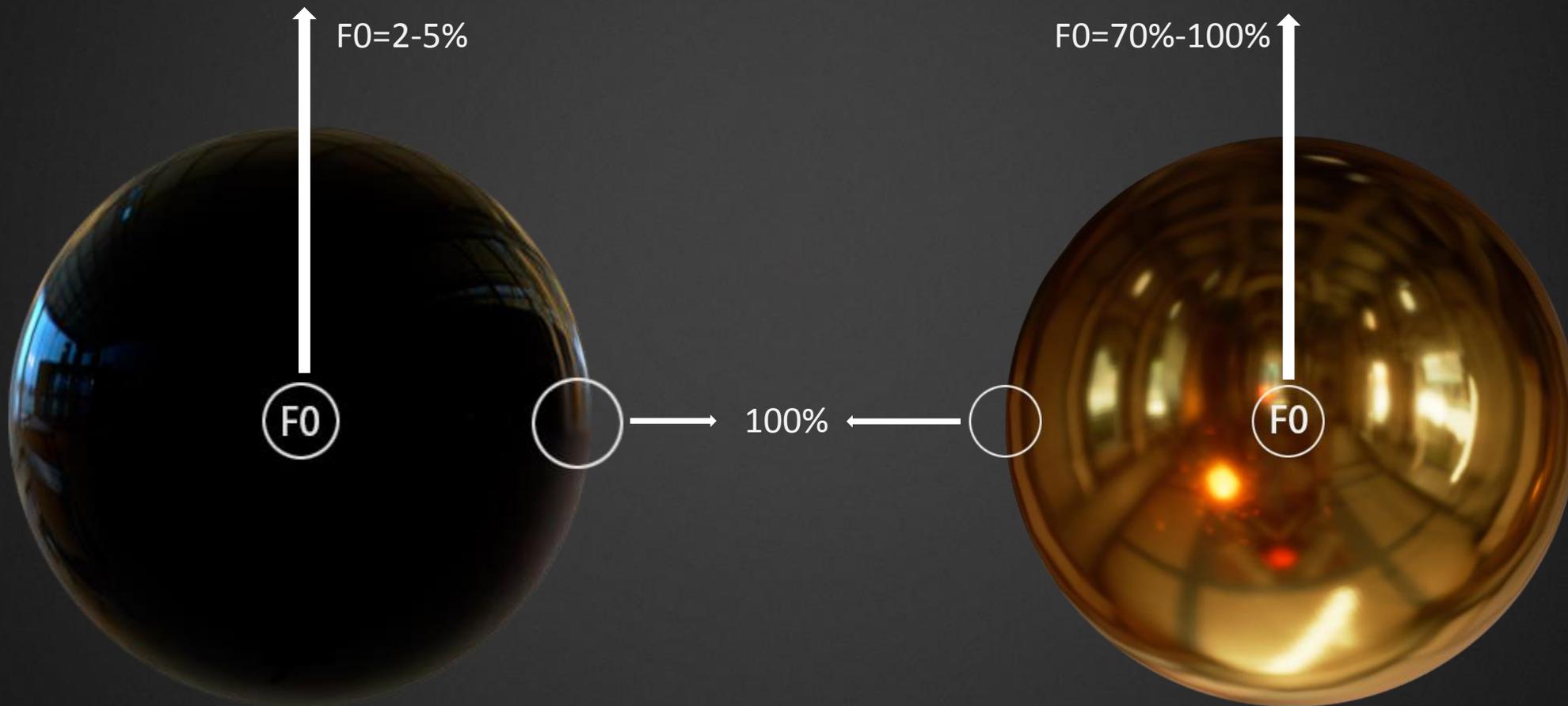
F0

水

塑料

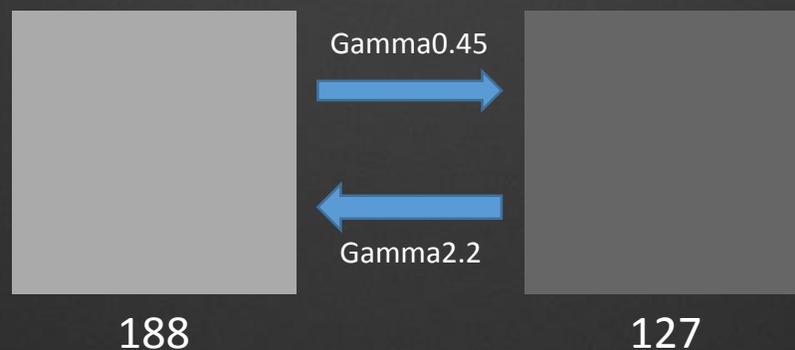
铁

银



UE4中线性空间转换行为

- 把sRGB贴图转换到线性空间
- 进行shader和灯光计算
- 渲染后的图片转换到sRGB空间



材质模型

UE4默认参数:

BaseColor=0

Metallic=0

Specular=0.5 (0-1)

Roughness=0.5 (0-1)

Ambient Occlusion=1

- Base Color
- Metallic
- Specular
- Roughness
- Emissive Color
- Opacity
- Opacity Mask
- Normal
- World Position Offset
- World Displacement
- Tessellation Multiplier
- Subsurface Color
- Clear Coat
- Clear Coat Roughness
- Ambient Occlusion
- Refraction
- Pixel Depth Offset

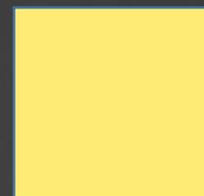
- Base Color
- Metallic

• Metal金属:

BaseColor: F0值, 及反射值及颜色。视觉上反映为镜面反射的强度和颜色

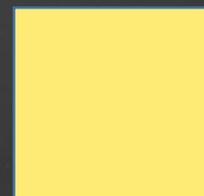
• None metal非金属:

BaseColor: 漫射值。视觉上反映为固有色的强度和颜色



1

- Base Color
- Metallic



0

- Base Color
- Metallic

Specular

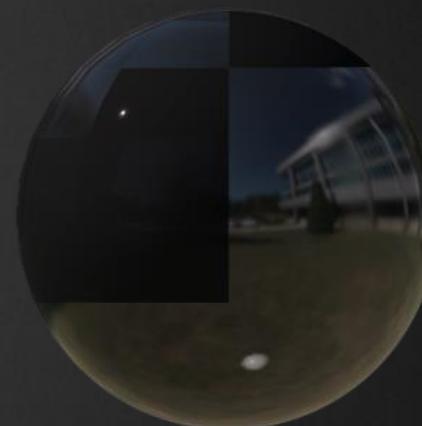
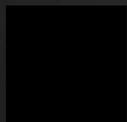
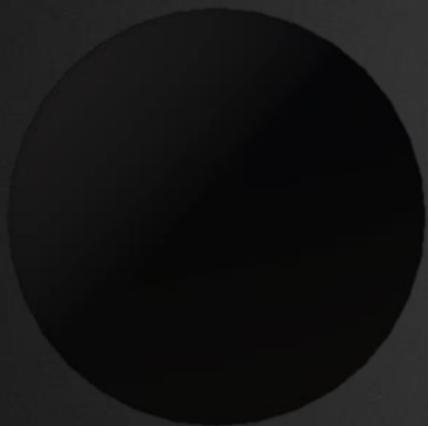
注意:

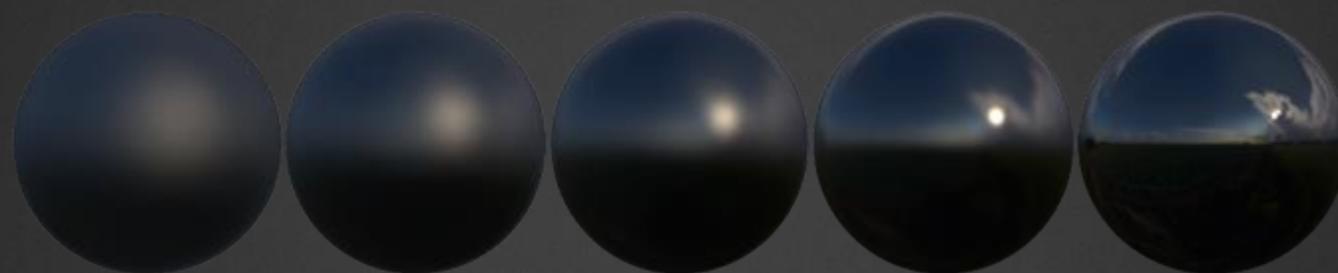
任何表面都有高光，高光视觉感受上的强弱很大程度上取决于分散还是聚焦

不要试图用Specular来控制高光的强度

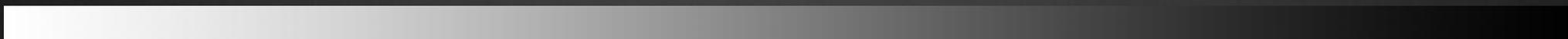
使用粗糙度来控制高光强度

高光通道只能用来模拟被遮挡的微小凹陷处无法对眼睛产生高光的区域





Roughness

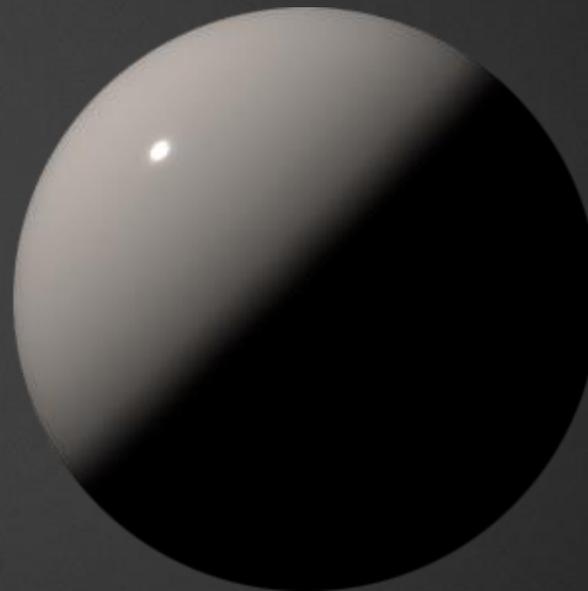


Specular恒定，减小Roughness值



▶ Ambient Occlusion

AO=1或默认



AO=0,非直射光漫射和反射都被完全屏蔽

如何表现

观察/设计/素材

方式（复用？CG or Game? 需要改变贴图吗？编辑器内还是外）

软件工具的选择（DDO, Substance, Photoshop, Bipmap2Material, UE4）

基本材质研究以及创建

区分材质

添加基本材质上的细节

高品质的法线贴图是关键

灯光

• 观察/设计/素材

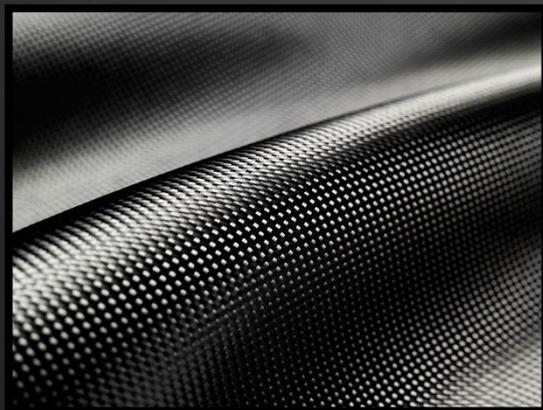
Polished steel



Polished steel



Carbon fiber



Painted Metal(Matte)



Bare Metal(semi-Reflective)



Rubber

- 应用需求

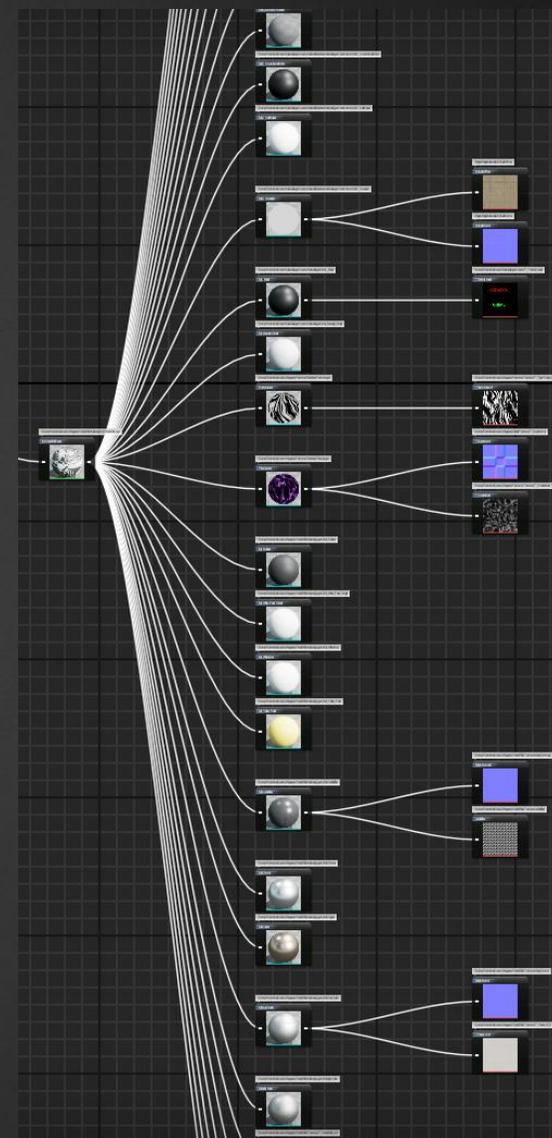
材质需要共用吗？

贴图的精度要求高吗？

材质需要统一管理，迅速迭代吗？

需要自定义或允许改变外观吗？

效率/内存：材质能够多复杂？贴图能够支持多少？



- 基本材质研究及创建



	a m r		a m r		a m r		a m r
rust		leaves		satin		wood	
	a m r		a m r		a m r		a m r
painted metal		ceramic		plastic (glossy)		brushed metal	

a = albedo (sRGB)
m = microsurface (linear)
r = reflectivity (sRGB)


- 区分材质



- 添加基本材质上的细节

划痕

污渍

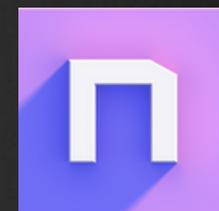
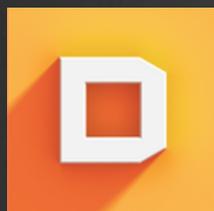
环境元素



- 基本材质+细节



软件工具的选择（ UE4 ， Photoshop, DDO, Substance, Bipmap2Material... ..）



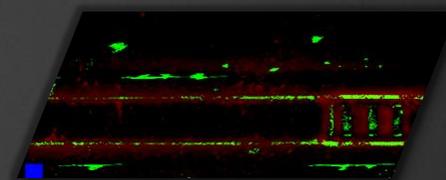
高模+低模



基本信息: Normalmap, ID MASK, AO/Cavity



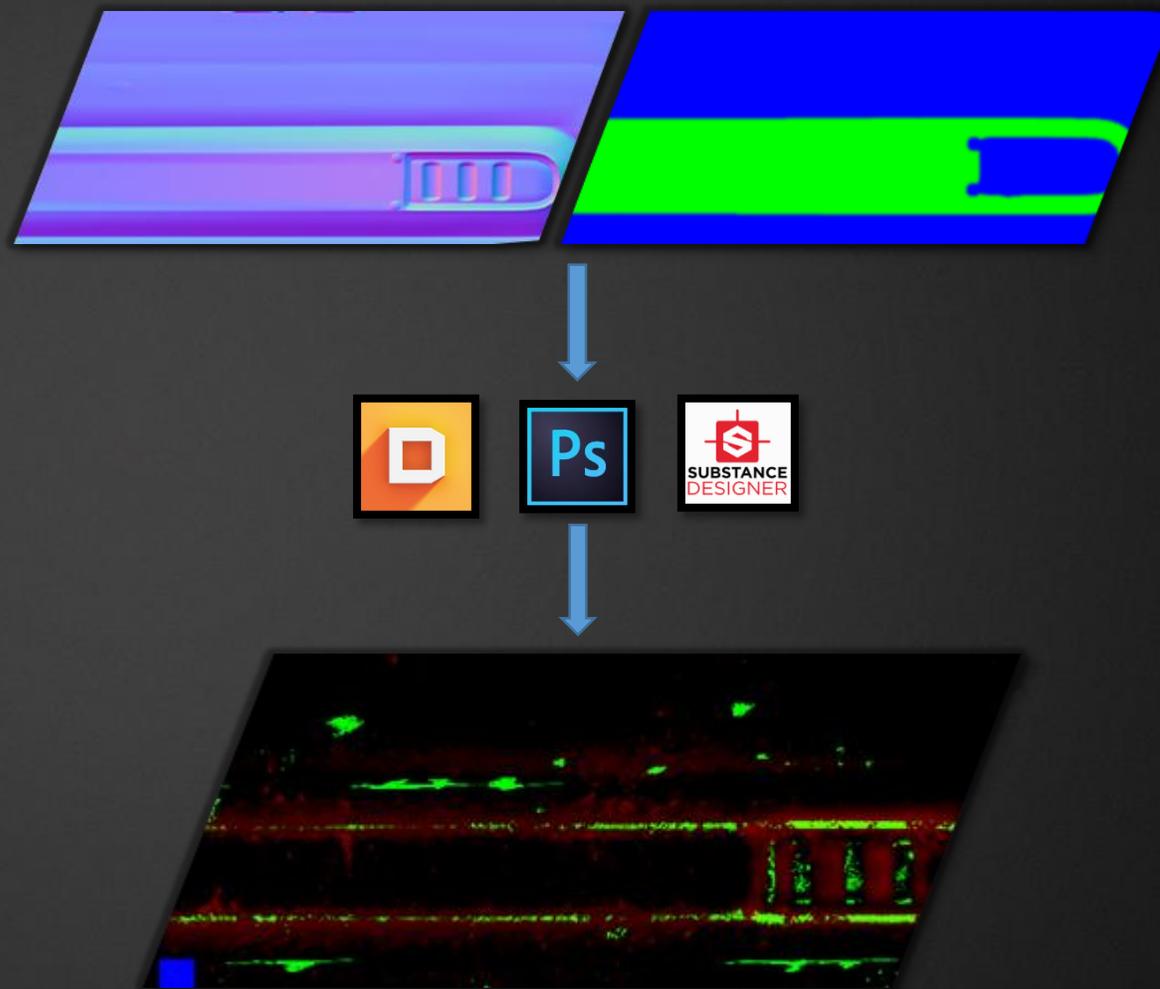
添加细节 (划痕, 污渍, 环境特征等)



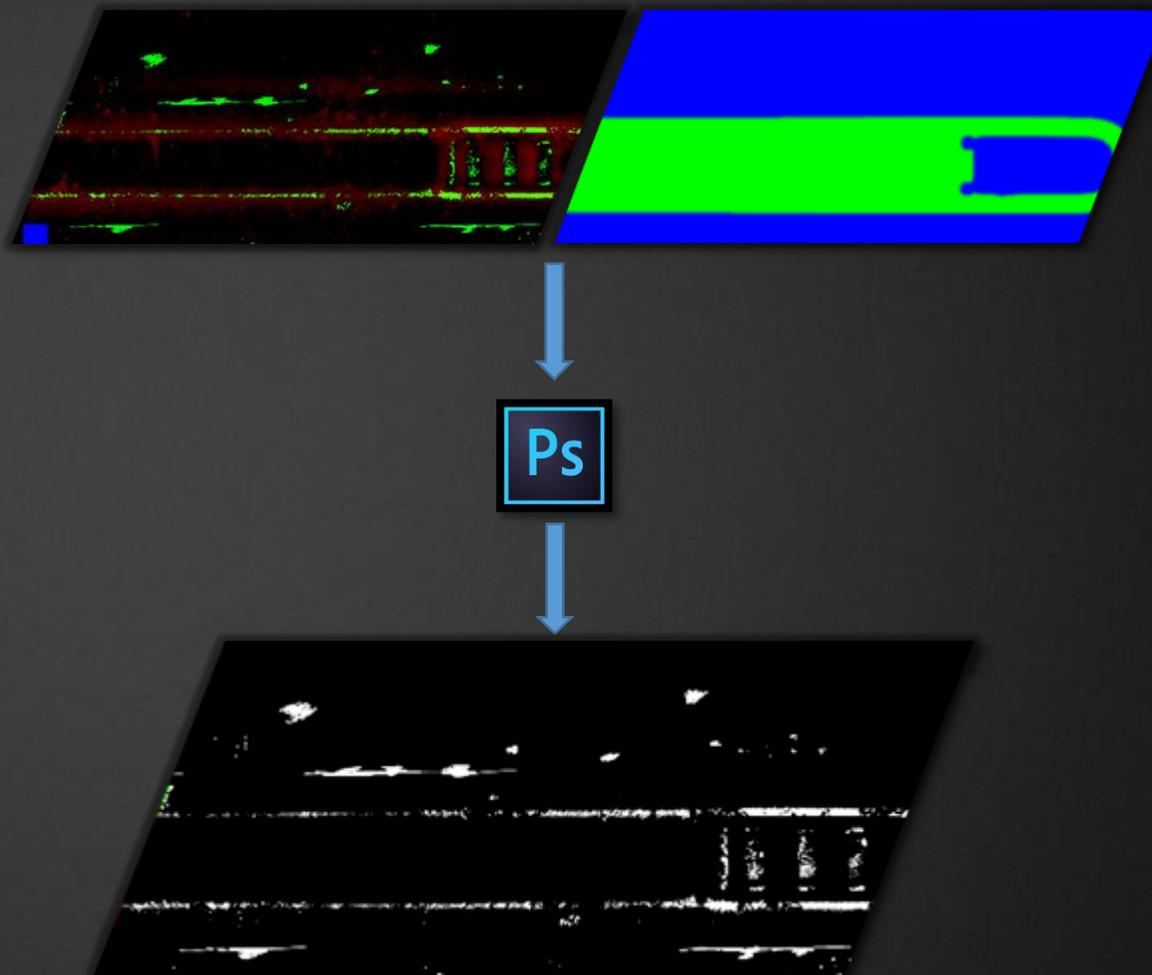
UE4(导入)



- 细节MASK贴图



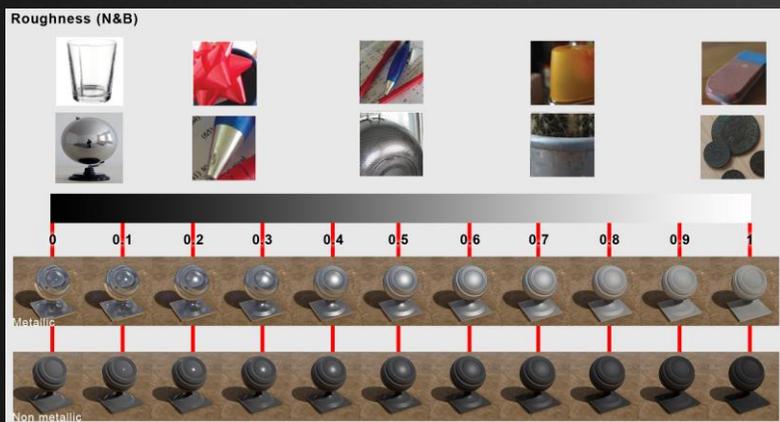
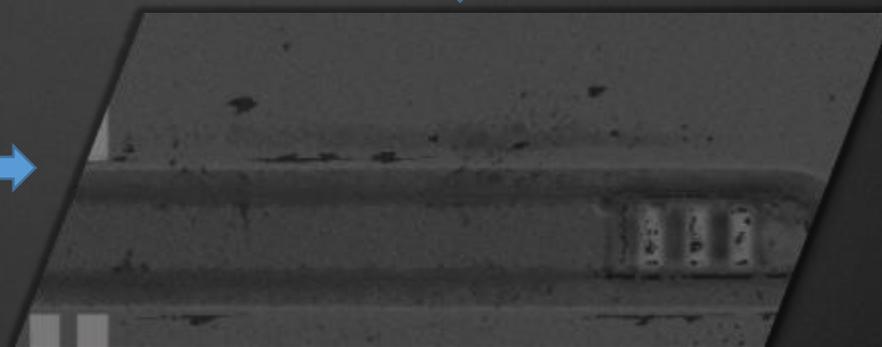
- Metallic/金属性



- BaseColor



- Roughness



- Specular

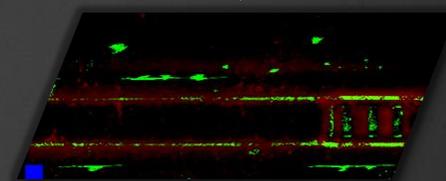
Cavity/Curvature



基本信息: Normalmap, ID MASK, AO/Cavity



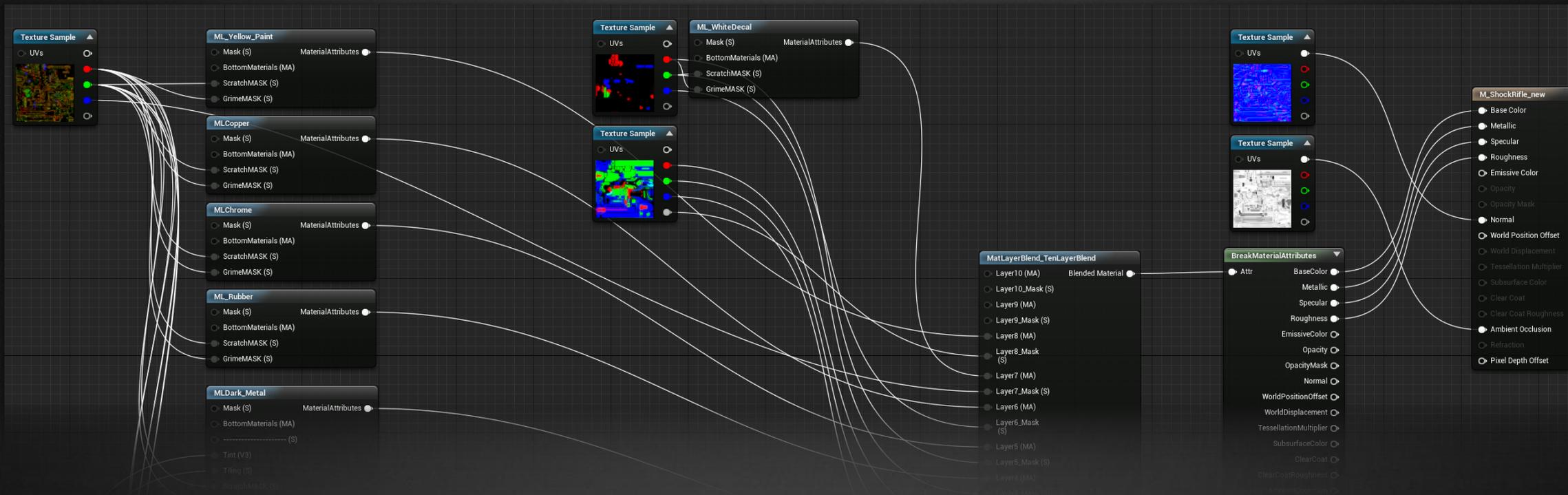
添加细节 (划痕, 污渍, 环境特征等)



UE4

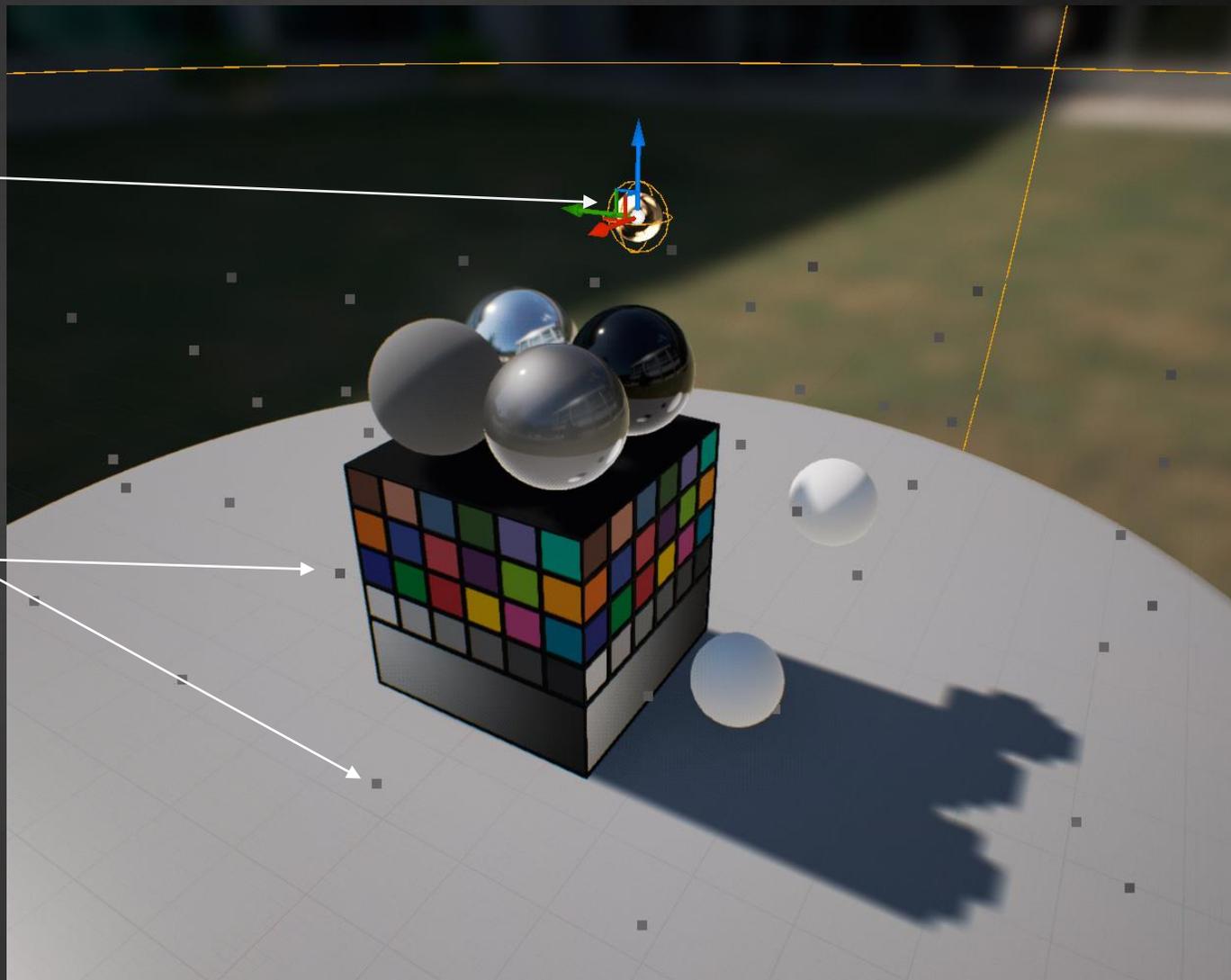
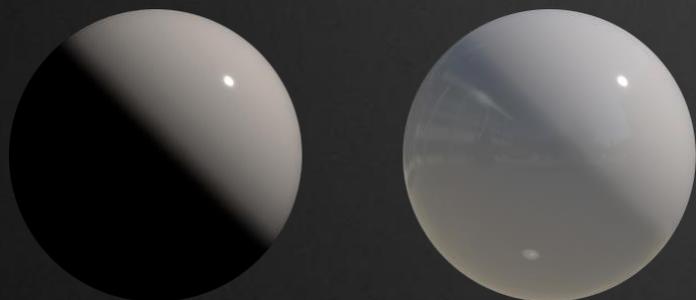
创建基本材质(Material Function)
 基本材质中添加细节 (Material Function)
 材质母创建: 混合基本材质
 添加更多变化: 图案, 潮湿度/多孔性
 创建材质实例, 并调整实例参数





Sphere reflection capture

Volume lighting samples



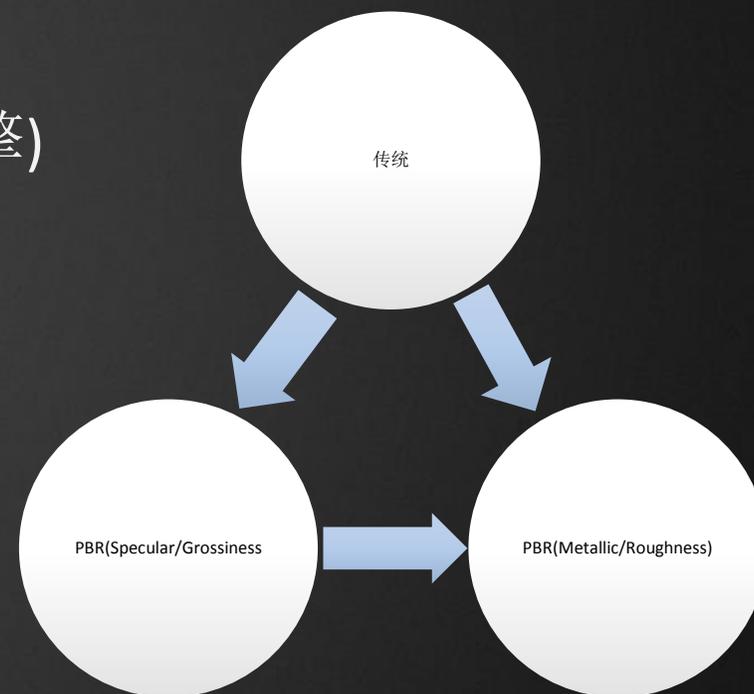


其他流程资源转换到PBR流程资源

哪些变了？

从传统到PBR（Metallic/Roughness）

从Specular/Glossiness到Metallic/Roughness(从其他引擎)



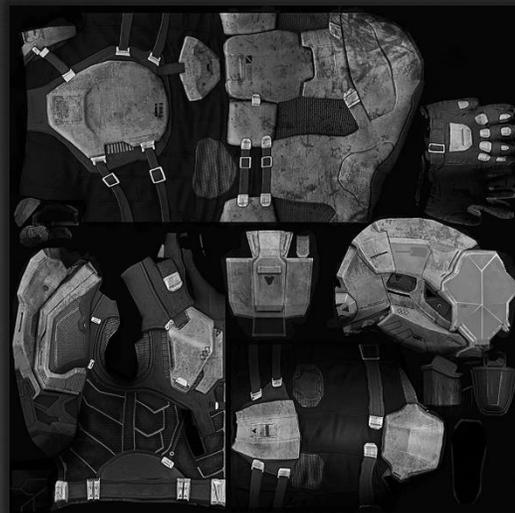
哪些变了？

灯光：不需要把灯光信息画上去Basecolor: 去掉AO, 阴影, 高光, 反射, micrsurface信息等

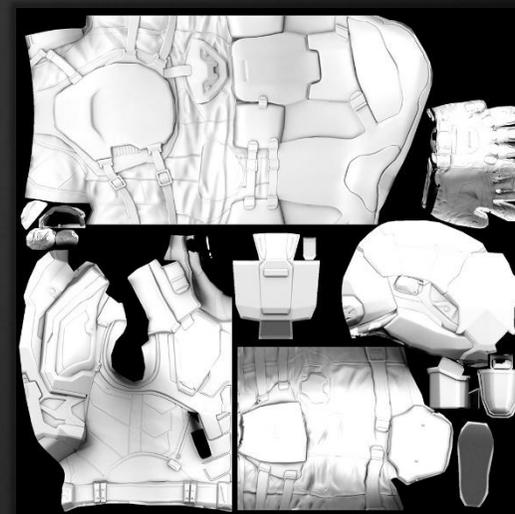
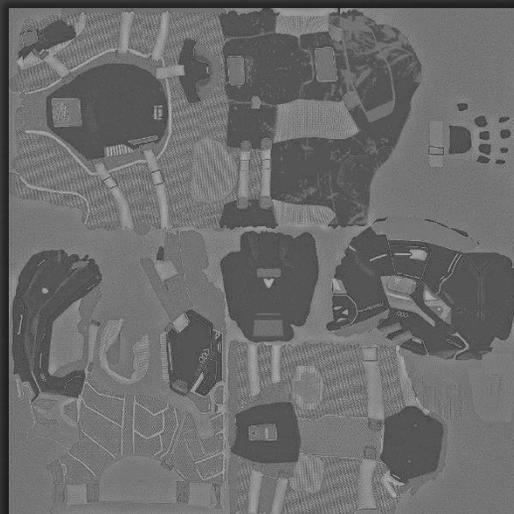
材质模型：输入通道不同了, 把高光放在哪里？

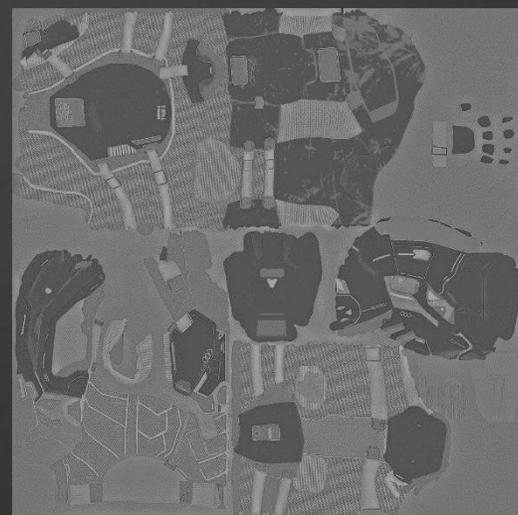
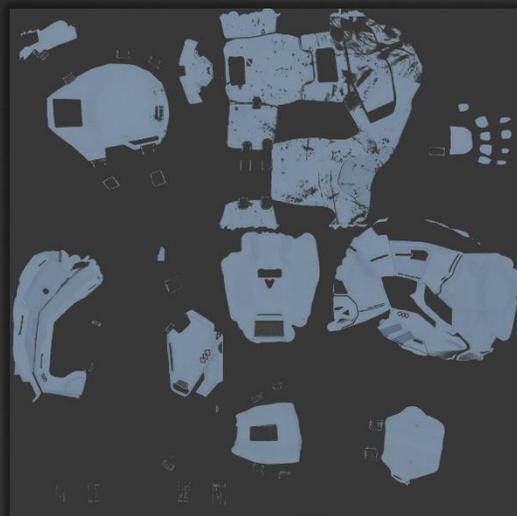
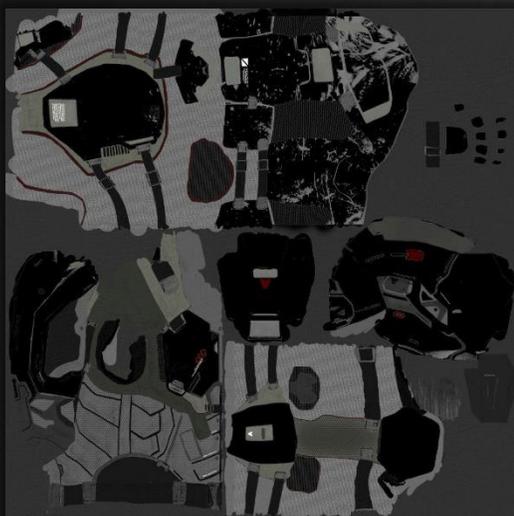
明暗：微表面很大程度上对质感起决定性作用了, 这是以前没有的概念

线性空间：在sRGB下工作, Basecolor最佳的明度范围是？



从传统到PBR (Metallic/Roughness)





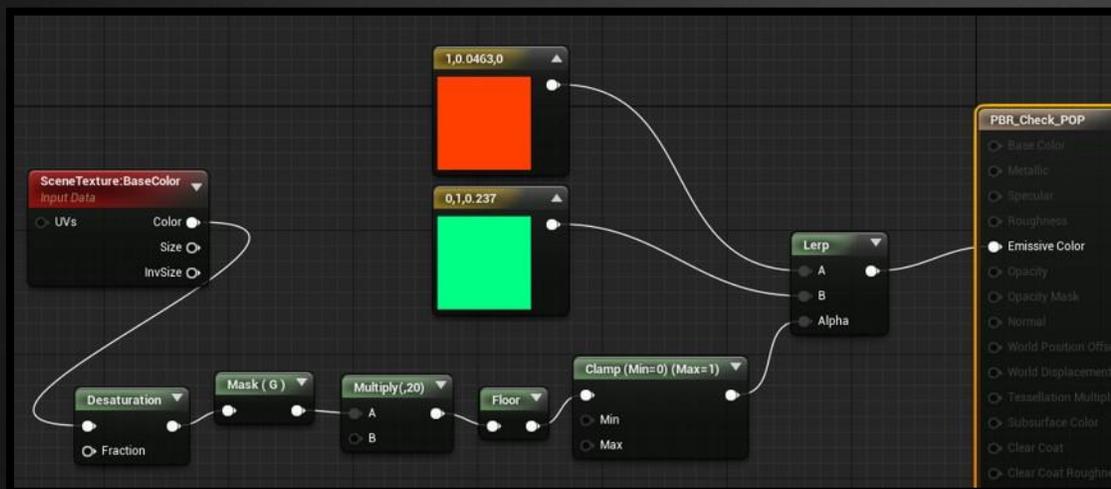
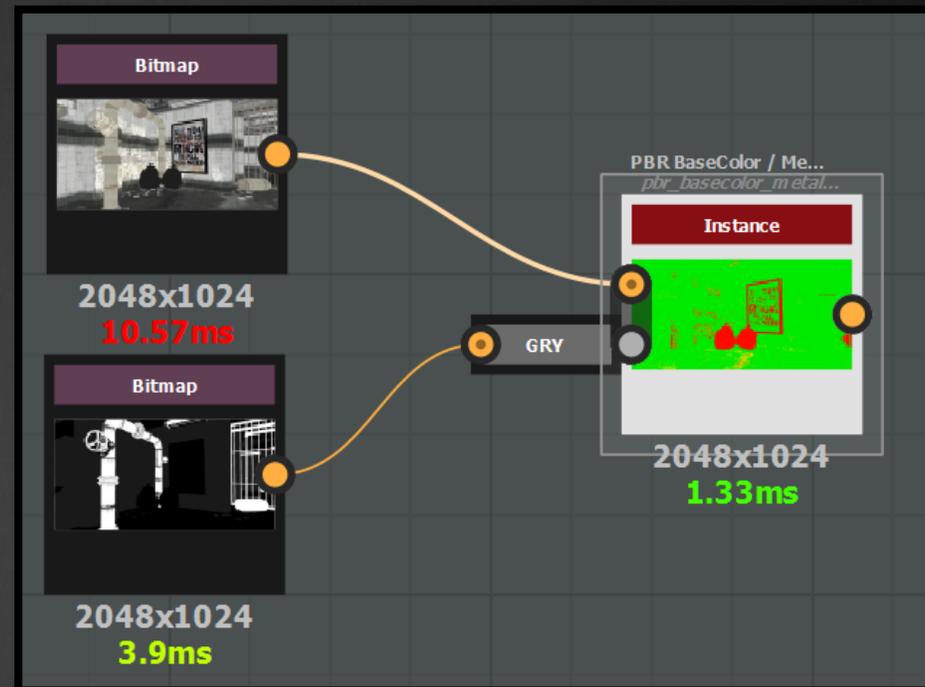
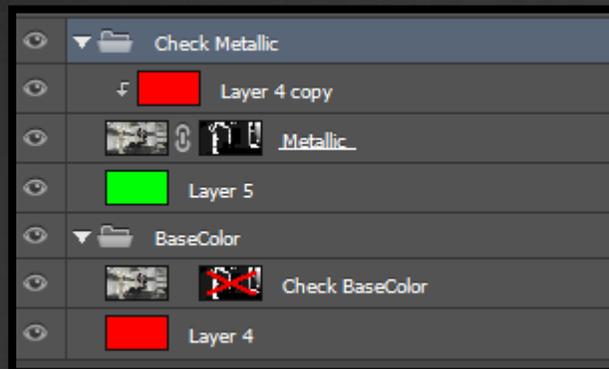
从Specular/Grossiness到Metallic/Roughness

常见问题

- 使用Specular来定义更多高光
- Base color太暗/对比太强/不理解其对金属的特殊意义
- 真的需要Specular了吗？有的时候真实滥用了
- 让材质变的正确请注意Basecolor和Metallic；让材质变的漂亮请多花些时间在Roughness上
- 多孔性的讨论？

检查

- 检查BaseColor
- 检查Specular
- 检查Metallic是否和Specular匹配



参考资源链接

<https://www.unrealengine.com/blog/physically-based-shading-in-ue4>

<https://forums.unrealengine.com/showthread.php?13453-PBR-Implications-for-texture-creation>

<https://forums.unrealengine.com/archive/index.php/t-3869.html>

<https://answers.unrealengine.com/questions/91750/normal-shaders-to-pbs.html>

<http://artisaverb.info/PBR.html>

http://www.makinggames.de/index.php/..._based_shading

<http://www.marmoset.co/toolbag/learn/pbr-practice>

<https://www.unrealengine.com/blog/ph...shading-in-ue4>

http://www.chrisevans3d.com/pub_blog...based-shading/

<http://interplayoflight.wordpress.co...sed-rendering/>

谢谢

