NVISION 08
THE WORLD OF VISUAL COMPUTING

Life on the Bleeding Edge: More Secrets of the NVIDIA Demo Team

Eugene d'Eon

NVIDIA

Run the Demo

Concept Artwork

Concept Artwork

Concept Artwork

Concept Artwork

Concept Artwork

Skin Shading

Skin Shading

- Same shader as the Human Head demo

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- Doug Jones’s assets transformed into the warrior

Skin Shading

- Same shader as the Human Head demo
- Doug Jones’s assets transformed into the warrior
- New capture for the medusa face

Reusing Assets

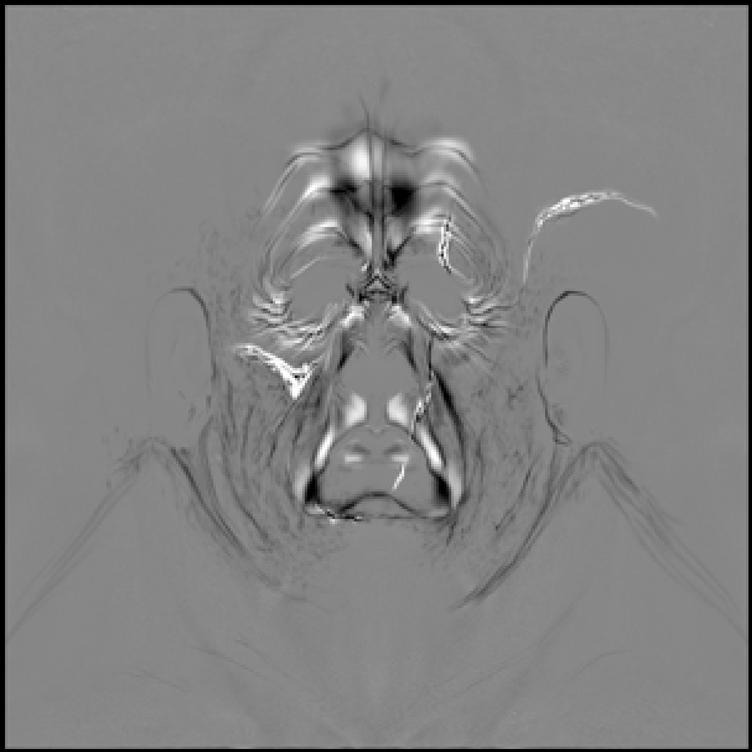
- Much of the realism of the Human Head demo comes from the high resolution face mesh
- We were successful at reusing the fine detail for a different face

Reusing Assets: Color

Human Head demo
color map

Warrior
color map

Reusing Assets: Normal



Scar displacement from Zbrush adds to original normals from the Human Head demo

Reusing Assets: Result

Reusing Assets: Result

Acquiring New Assets

- Female Medusa face:
  – New die cast and scan

Acquiring New Assets

- Female Medusa face:
  - New die cast and scan
  - New color map acquisition

Acquiring New Assets

- Female Medusa face:
  - New die cast and scan
  - New color map acquisition
  - Also captured lower resolution morph targets

Acquiring New Assets

Acquiring New Assets

Kenneth Wiatrak's studio

- Five high resolution synchronized cameras
- Also captures low resolution geometry

Kenneth Wiatrak's studio

Kenneth Wiatrak's studio

- Five high resolution photos
- Projected onto high resolution mesh by XYZRGB
- Combine to produce final high resolution color map

Medusa's Face

Medusa's Face

Medusa's Face

Kenneth Wiatrak's studio

Kenneth Wiatrak's studio

- Became a reference for the creation of the 65 facial blend shapes
- Weren't able to use the color maps

Skin shader

Start →

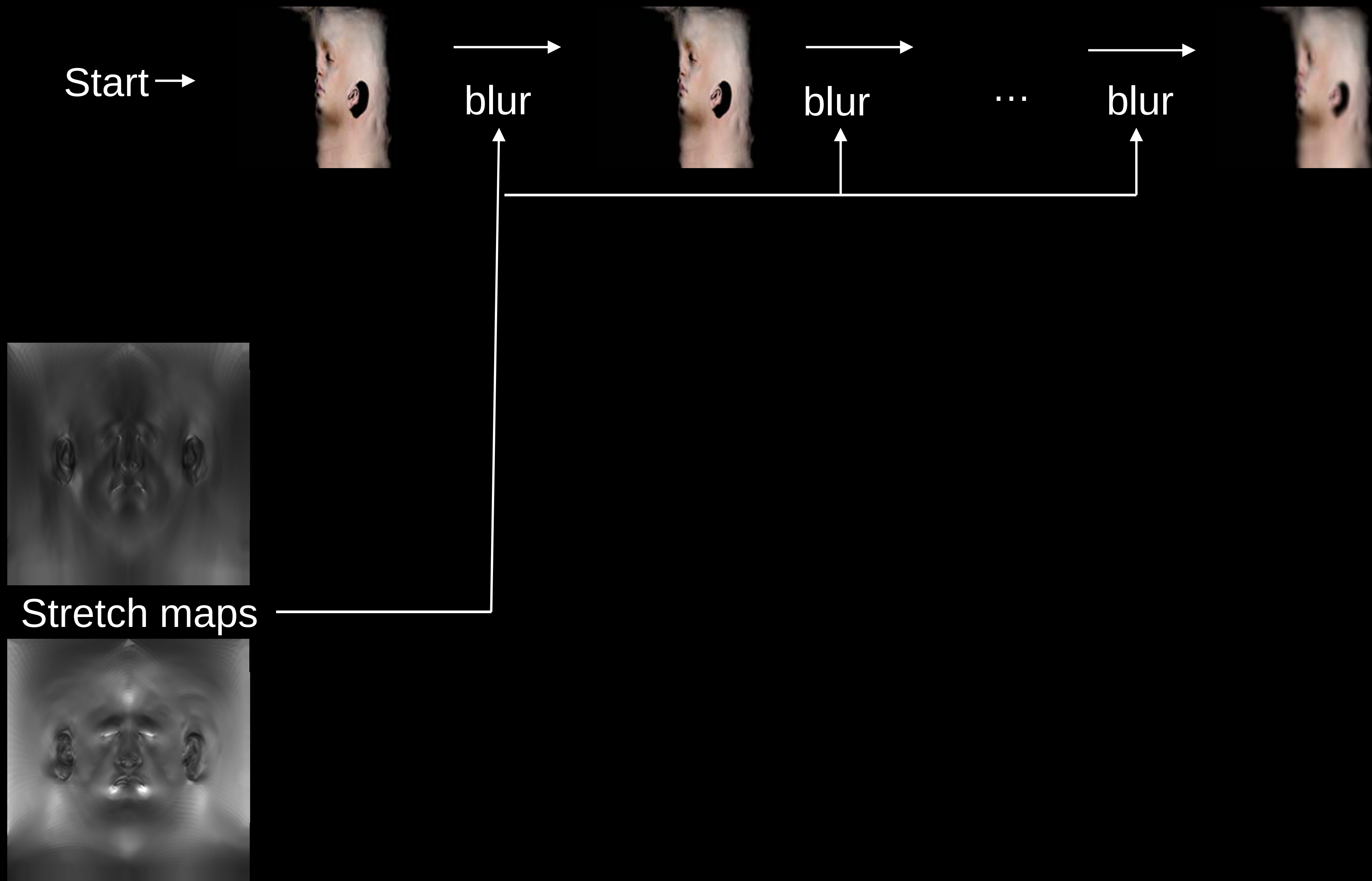
Skin shader

Start →

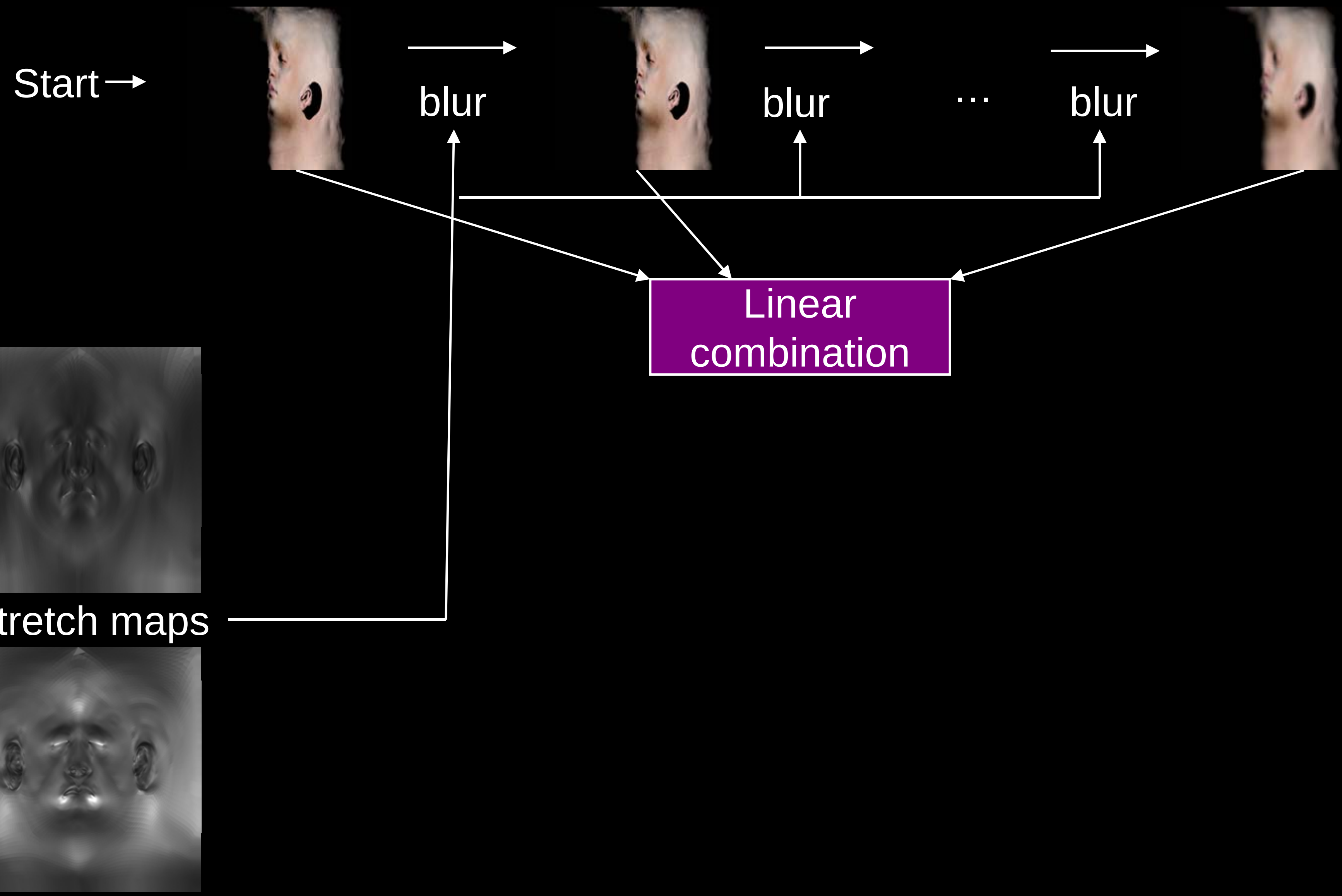
→ blur

Skin shader

Skin shader



Skin shader



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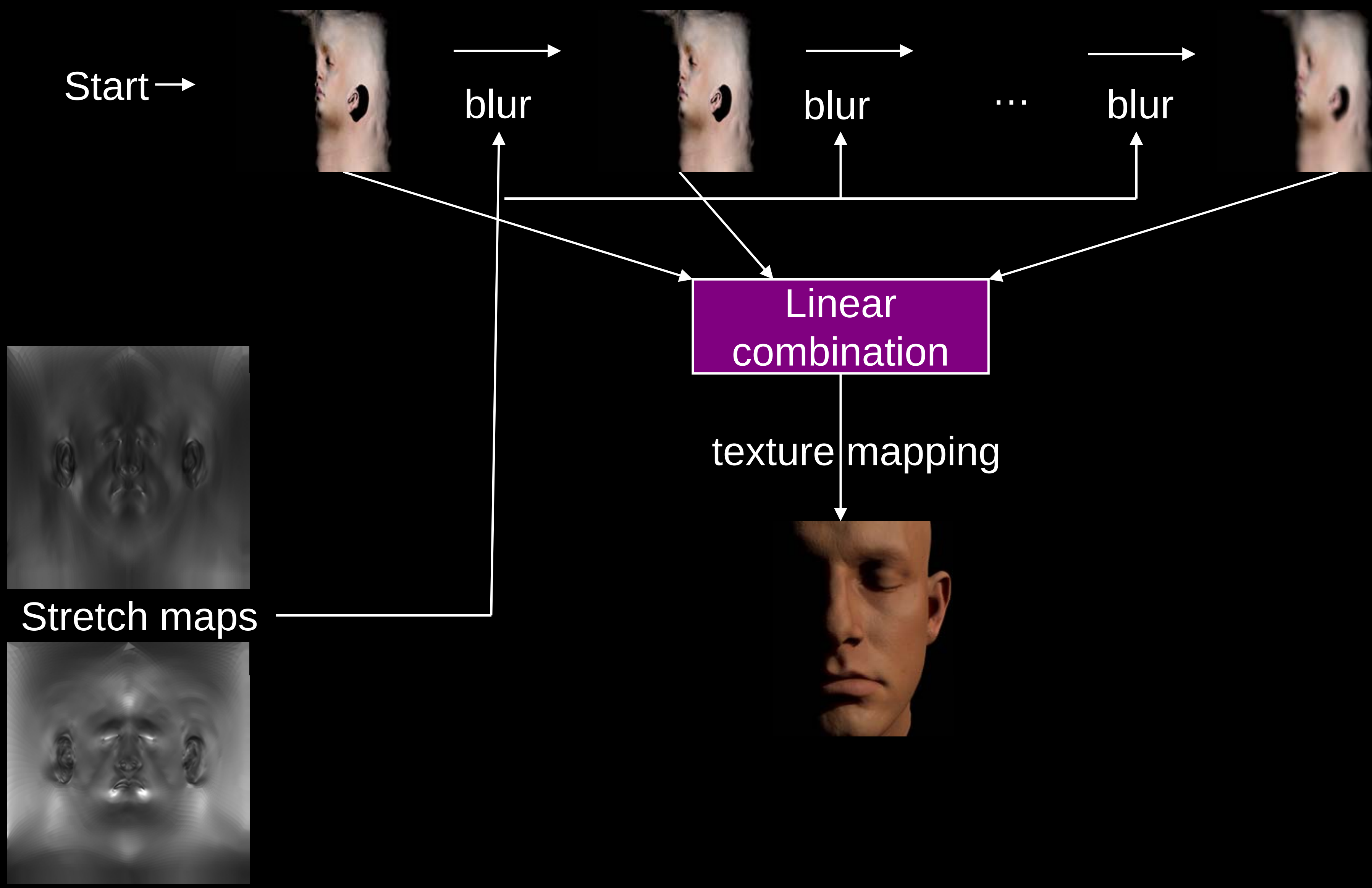
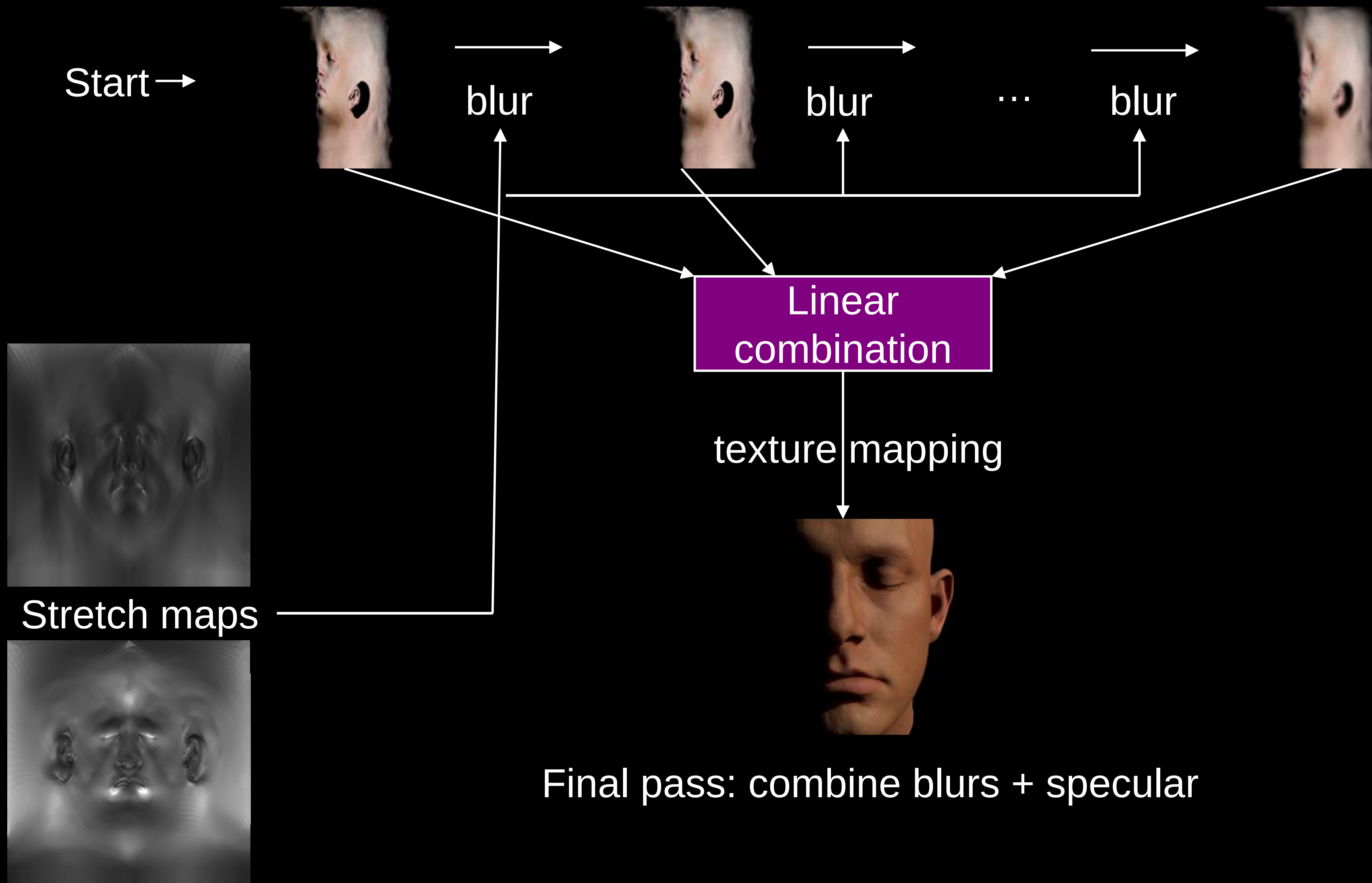
Skin shader



Start
blur
blur
...
blur
Linear combination
texture mapping
Stretch maps

Skin shader



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Linear combination
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Final pass: combine blurs + specular

Skin Shader Optimizations

- Reuse blur targets for multiple skin surfaces

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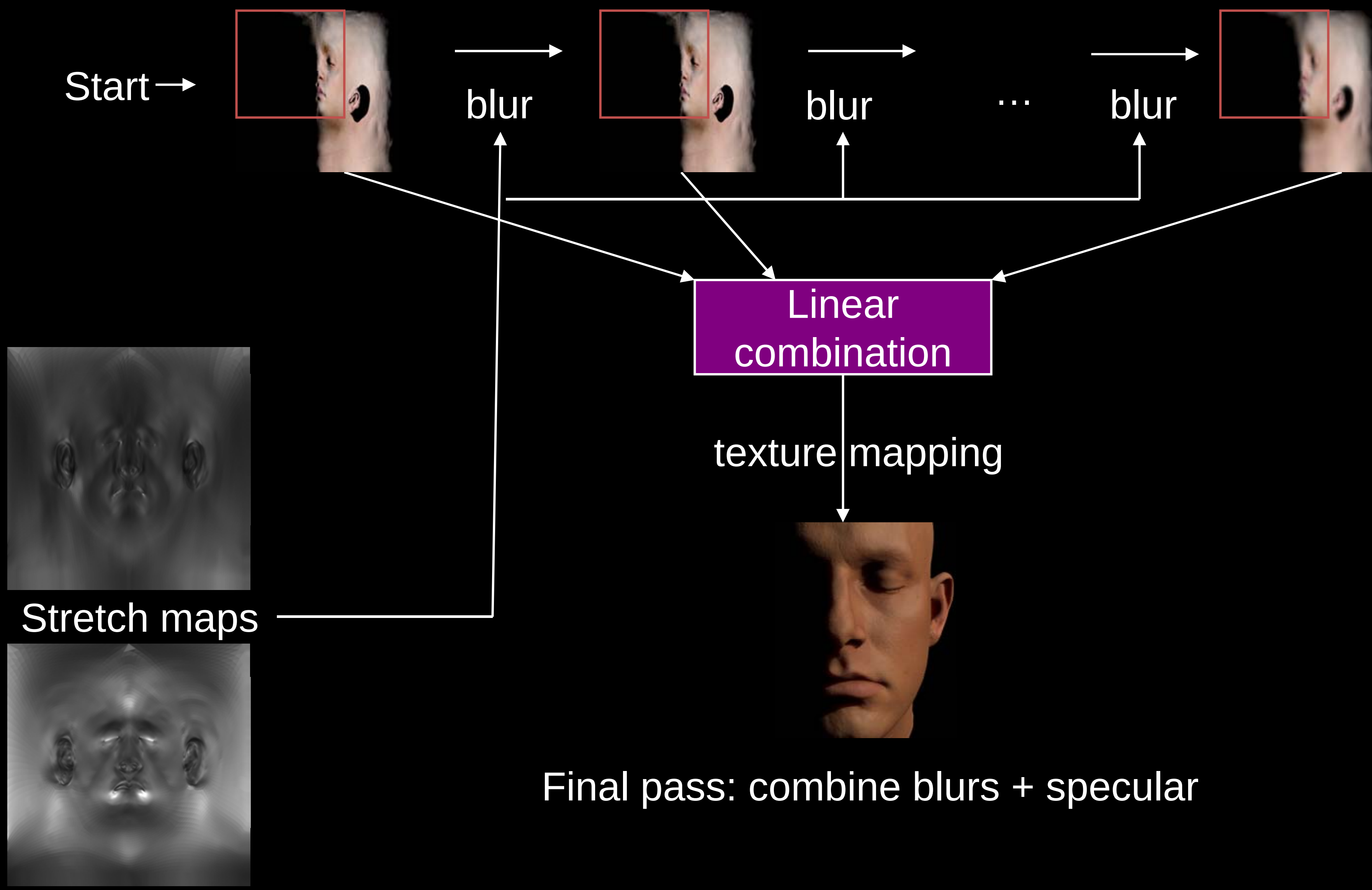
Skin Shader Optimizations

- Reuse blur targets for multiple skin surfaces
- skinDetailScale
  - Texture space lighting at 1024x1024 for close up shots
  - Reduce viewport in renderpasses to be % of total for
    - Texture space lighting pass
    - Each iterative blur pass
    - Facial shadow pass

Skin shader



Start
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...
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Linear combination
texture mapping
Stretch maps
Final pass: combine blurs + specular

Skin Shader Optimizations

- skinDetailScale determined
  - Per shot (for Medusa)
  - Per frame based on bounded sphere projection on screen
- Significant performance gain

Screen-space bump mapping

- Alternate form of bump mapping

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- Store only single-channel displacement value over surface

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Screen-space bump mapping

- Alternate form of bump mapping
- Store only single-channel displacement value over surface
- Each fragment being rendered accesses the displacement map 3 times
- Decide where to look in the displacement map based on the current view of the object

Screen-space bump mapping

- Use ddx and ddy of the texture coordinates to consider the displacement:

Screen-space bump mapping

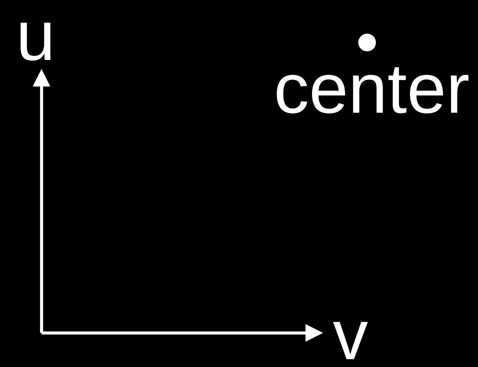
- Use ddx and ddy of the texture coordinates to consider the displacement:
  - One pixel to the right
  - One pixel up

Screen-space bump mapping

- Use ddx and ddy of the texture coordinates to consider the displacement:
  - One pixel to the right
  - One pixel up
- Helps reduce aliasing
  - Wide spacing in displacement map:
    - Appropriate mip level of the displacement map

Screen-space bump mapping

- How do we compute the new normal?



Screen-space bump mapping

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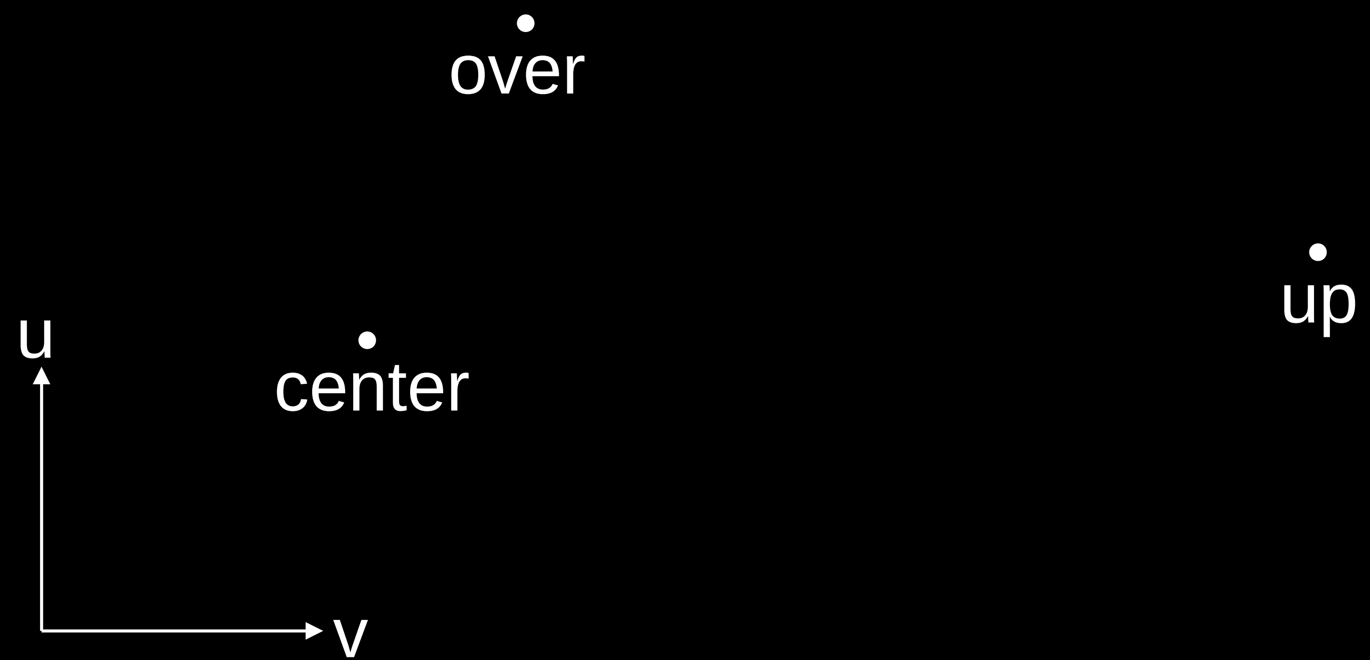

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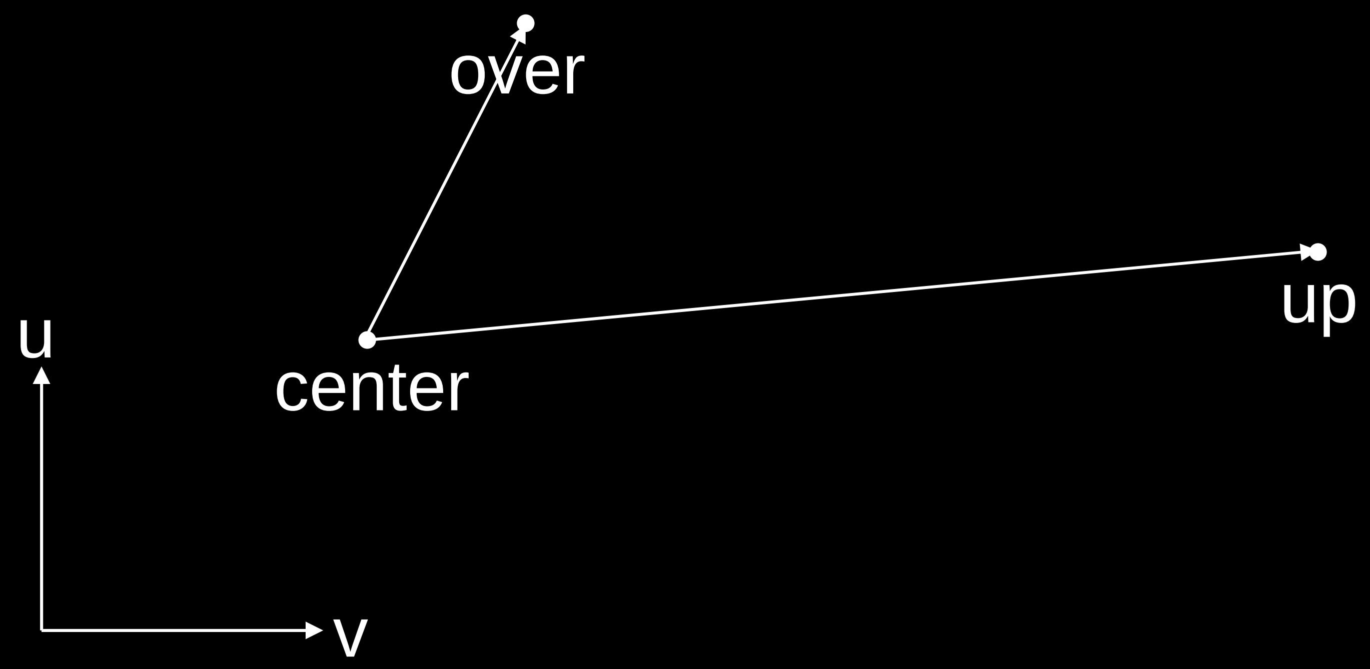

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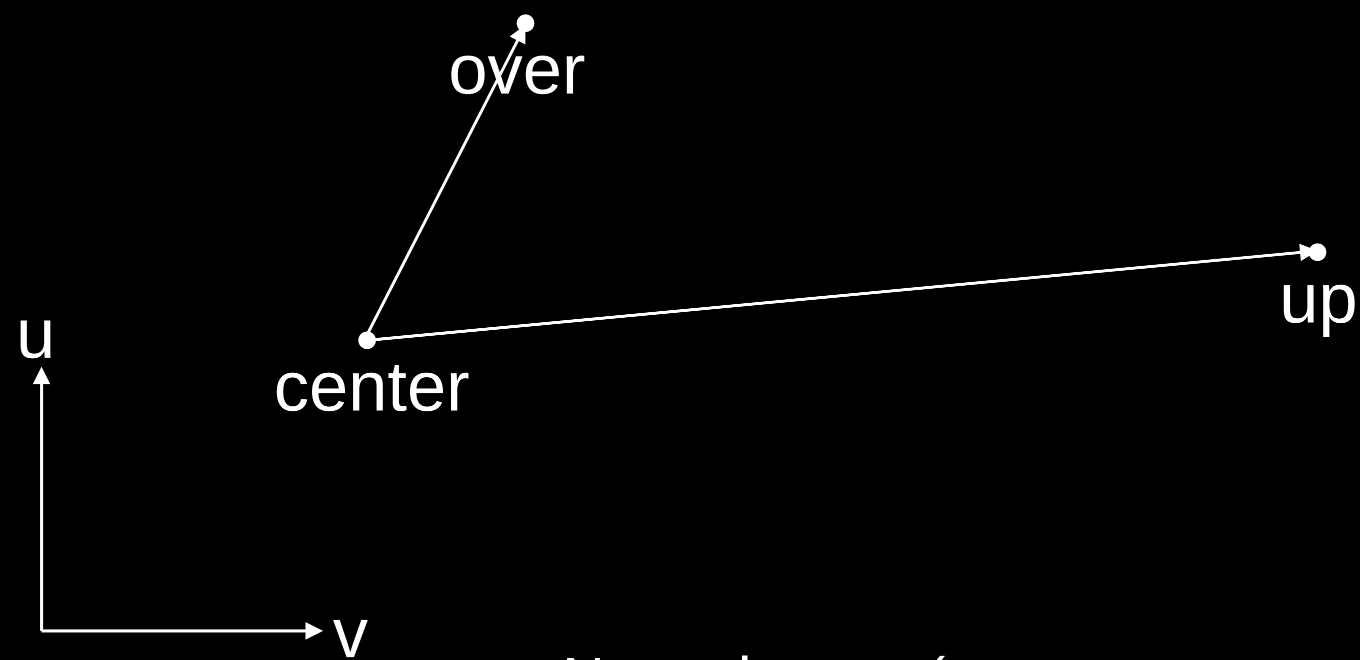

tanNormal=cross(over - center, up – center)

Screen-space bump mapping

- Advantages
  - 1/3 storage of a texture-space normal map

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  - Anisotropic filtering

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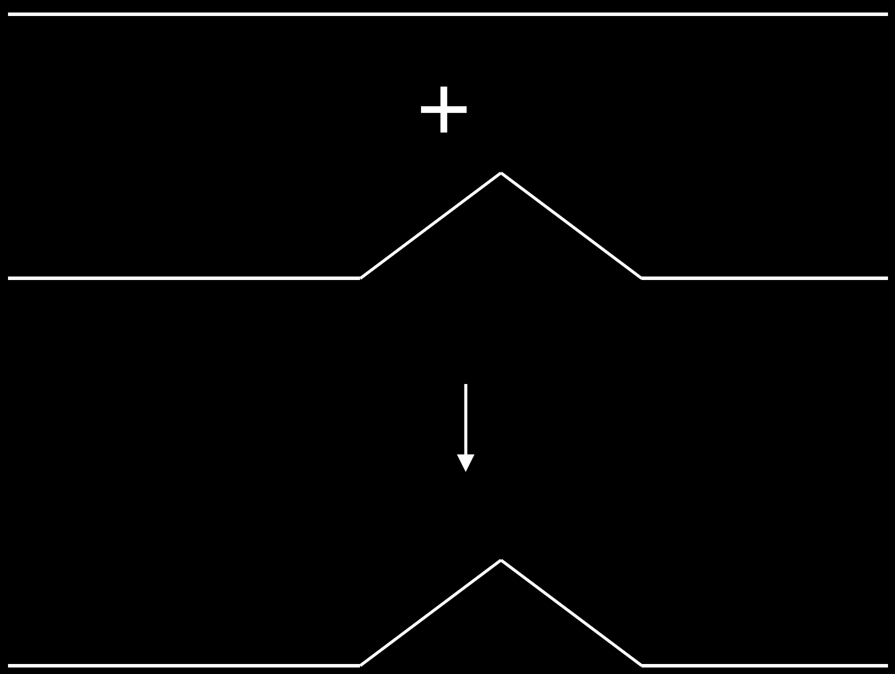
  - MIP mapping normals doesn’t
  - Anisotropic filtering
  - Reduced aliasing

Screen-space bump mapping

- Allows for multiple displacement maps to combine



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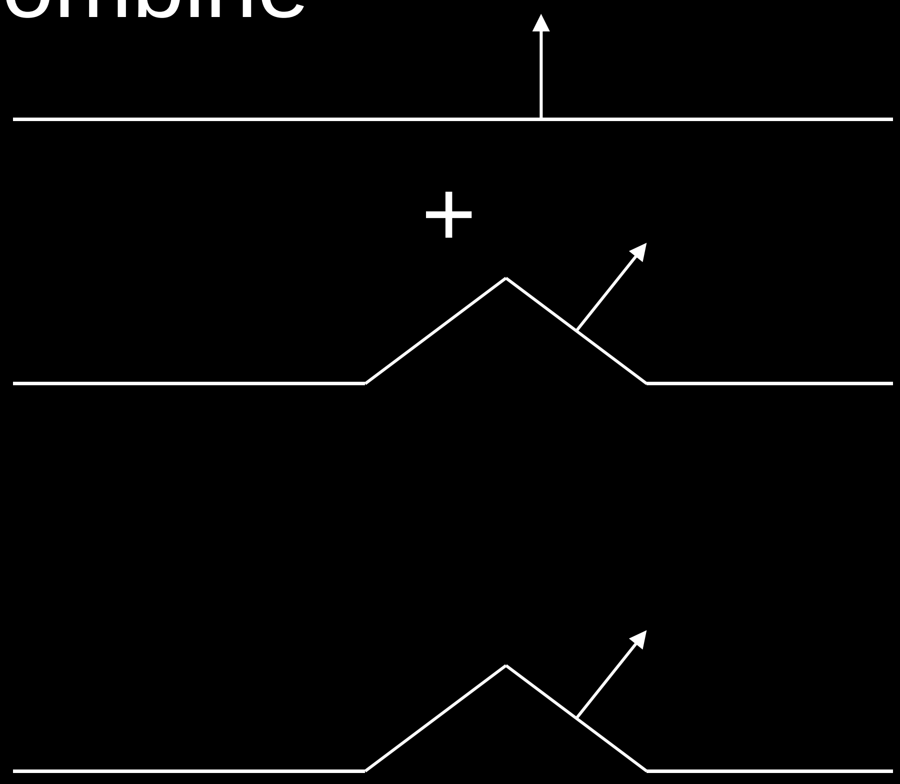

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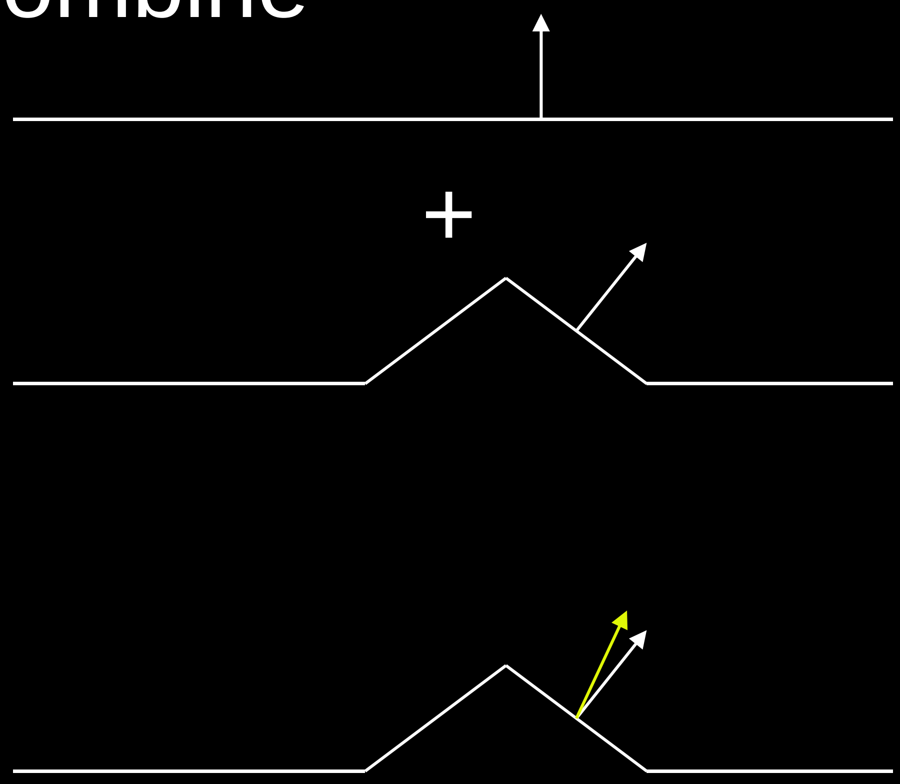

Screen-space bump mapping

```
float  normalTap      = dispTex.Sample(TrilinearClamp, g2f.tex.xy);
float2 uv_offset_over = ddx( g2f.tex );
float2 uv_offset_up   = ddy( g2f.tex );
float  normalTapOver  = dispTex.Sample(TrilinearClamp, g2f.tex.xy +
   uv_offset_over);
float  normalTapUp    = dispTex.Sample(TrilinearClamp, g2f.tex.xy +
   uv_offset_up);

float displacementCenter = displacementHeight * normalTap;
float displacementOver   = displacementHeight * normalTapOver;
float displacementUp     = displacementHeight * normalTapUp;

float3 tanNormalBump = normalize( -cross( float3( uv_offset_over.x,
   uv_offset_over.y, ( displacementOver - displacementCenter ) ),
                              float3( uv_offset_up.x, uv_offset_up.y, (
   displacementUp - displacementCenter ) ) ) );

float3 Nbump = normalize( T * tanNormalBump.x + B * tanNormalBump.y + N *
   tanNormalBump.z );
```

Screen-space bump mapping

Rainbow Boas

Artist requested this for medusa scales…

Cause?

- Two conflicting explanations on the web

Cause?

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  - Thin-film interference amongst many scale layers

Cause?

- Two conflicting explanations on the web
  - Thin-film interference amongst many scale layers
  - Natural diffraction gratings grow on the scale surface

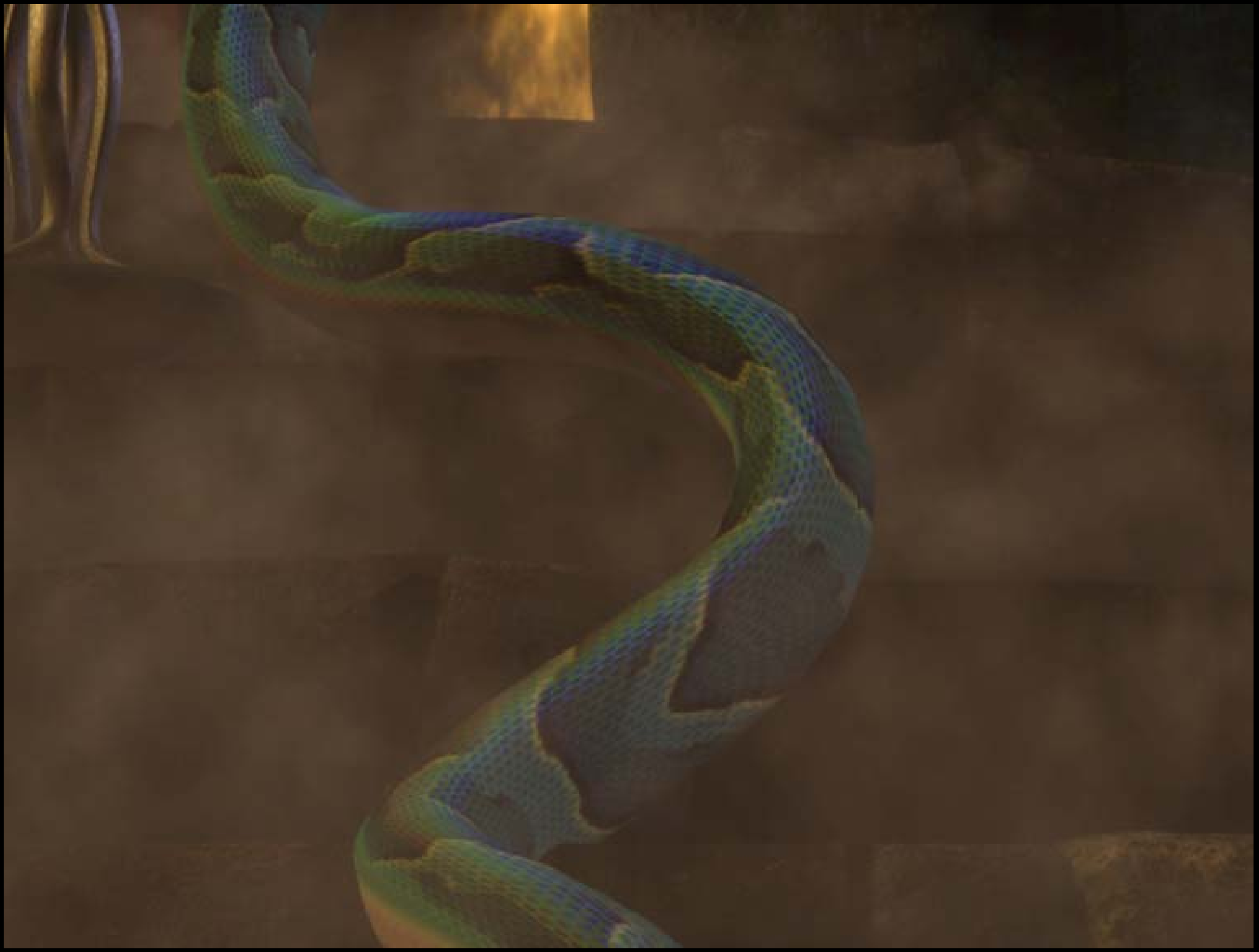
Took a Guess: Diffraction

- We tried diffraction and it looked pretty good
- Solution: GPU Gems 1: Jos Stam's diffraction chapter
- Simple fragment shader computes a colored diffraction term

Rainbow boa scale shader

Diffraction term

Rainbow boa scale shader



Diffraction term + diffuse term

Rainbow boa scale shader

Diffraction term + diffuse term + specular term

Crystals

Crystal Appearance

- Combination of refracted and reflected light

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- Combination of refracted and reflected light
- Reflected light is easy

Crystal Appearance

- Combination of refracted and reflected light
- Reflected light is easy
- Refracted light: not so easy

Previous work

- SIGGRAPH 2004
  - “Graphics Gems Revisited – Fast and Physically-Based Rendering of Gemstones”
    - Stephane Guy, Cyril Soler

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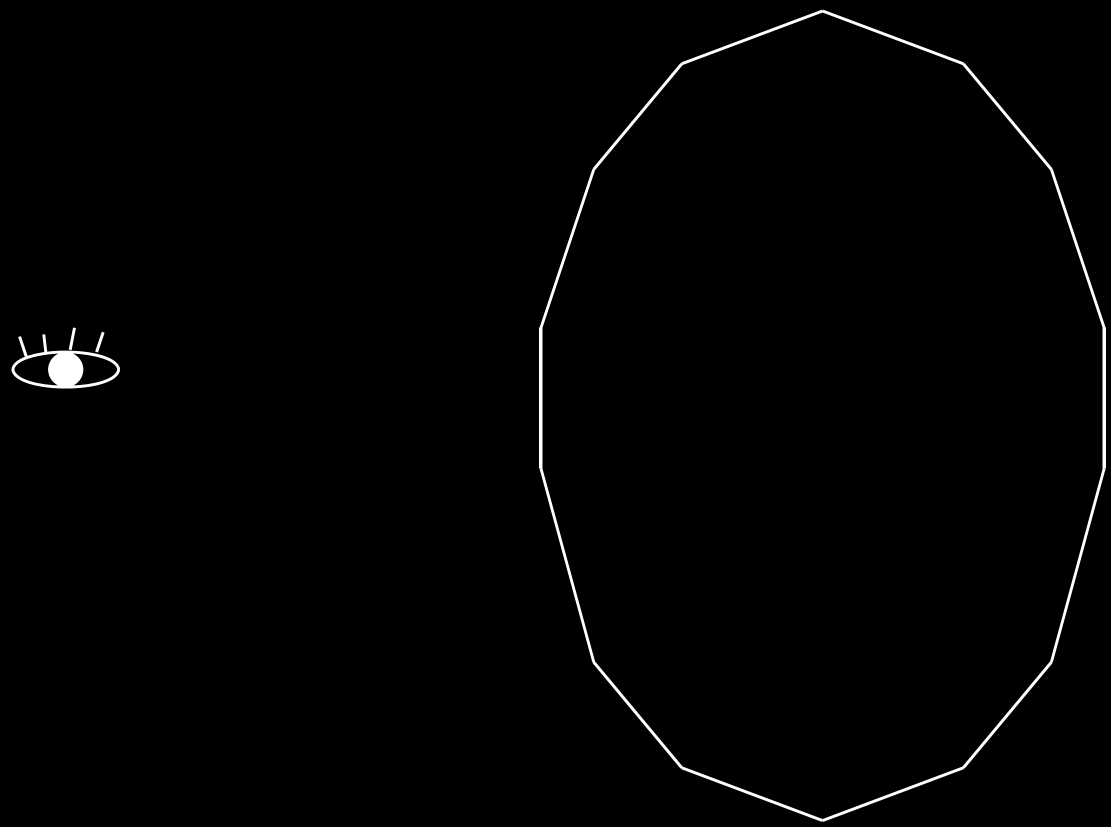
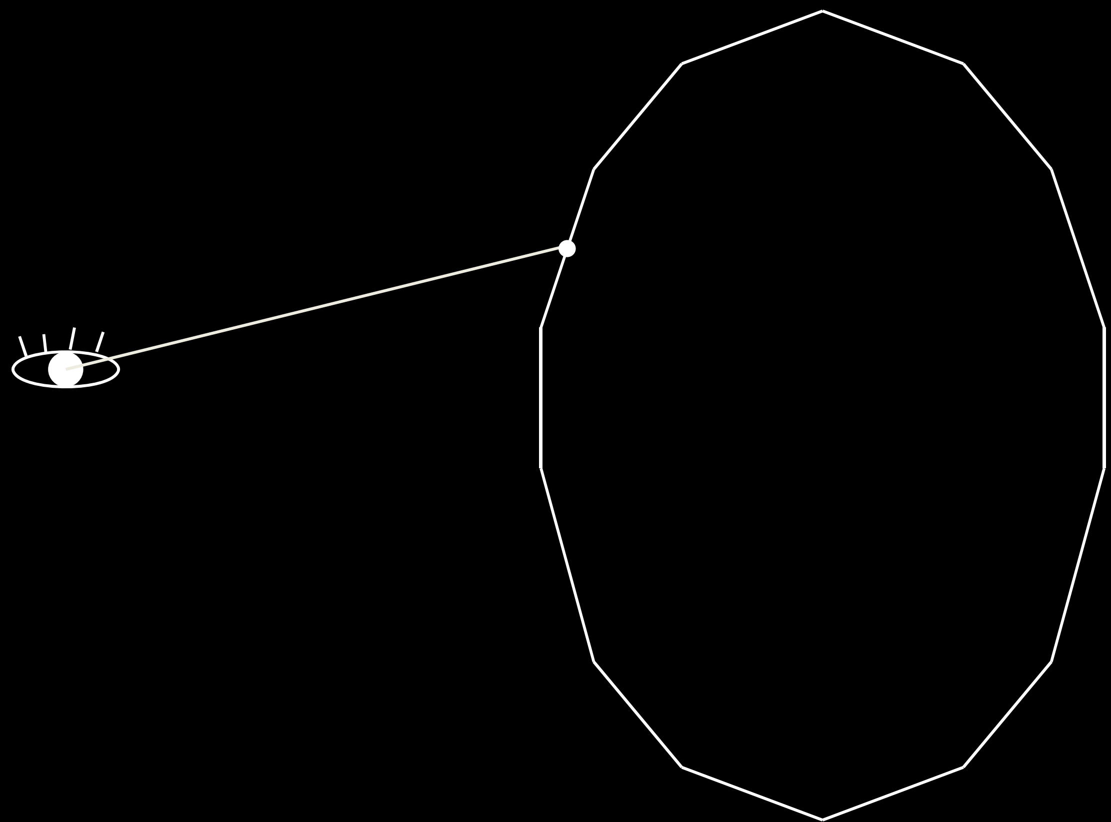
Previous work

- SIGGRAPH 2004
  - "Graphics Gems Revisited – Fast and Physically-Based Rendering of Gemstones"
    - Stephane Guy, Cyril Soler
- Very accurate images
- GPU implementation
- Fairly complex method
- If possible: find something cheaper

Crystal Reflectance



Crystal Reflectance



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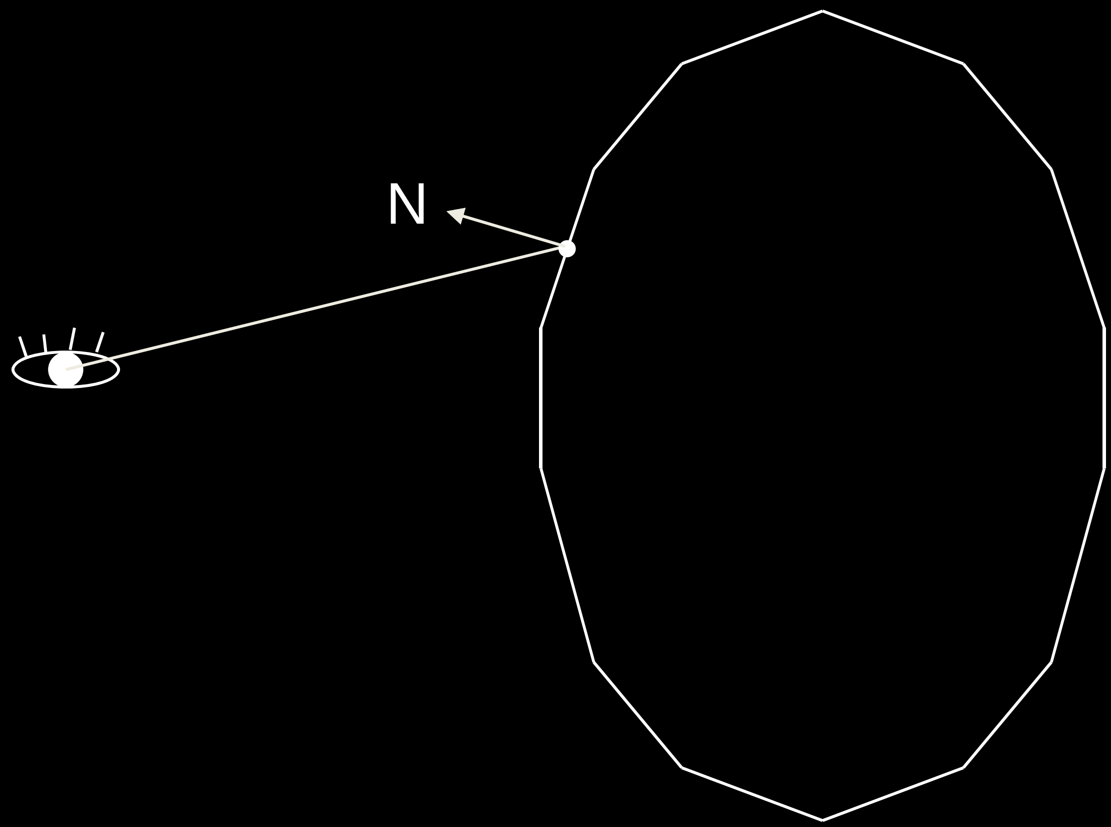

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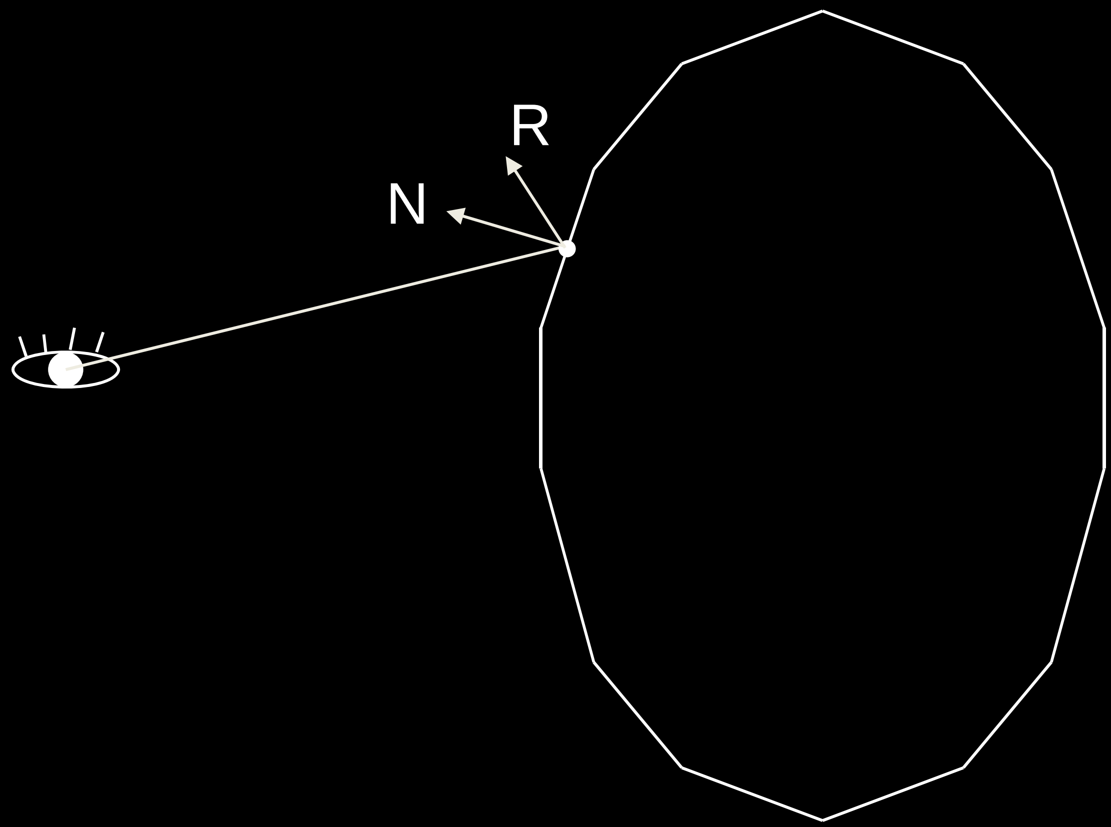

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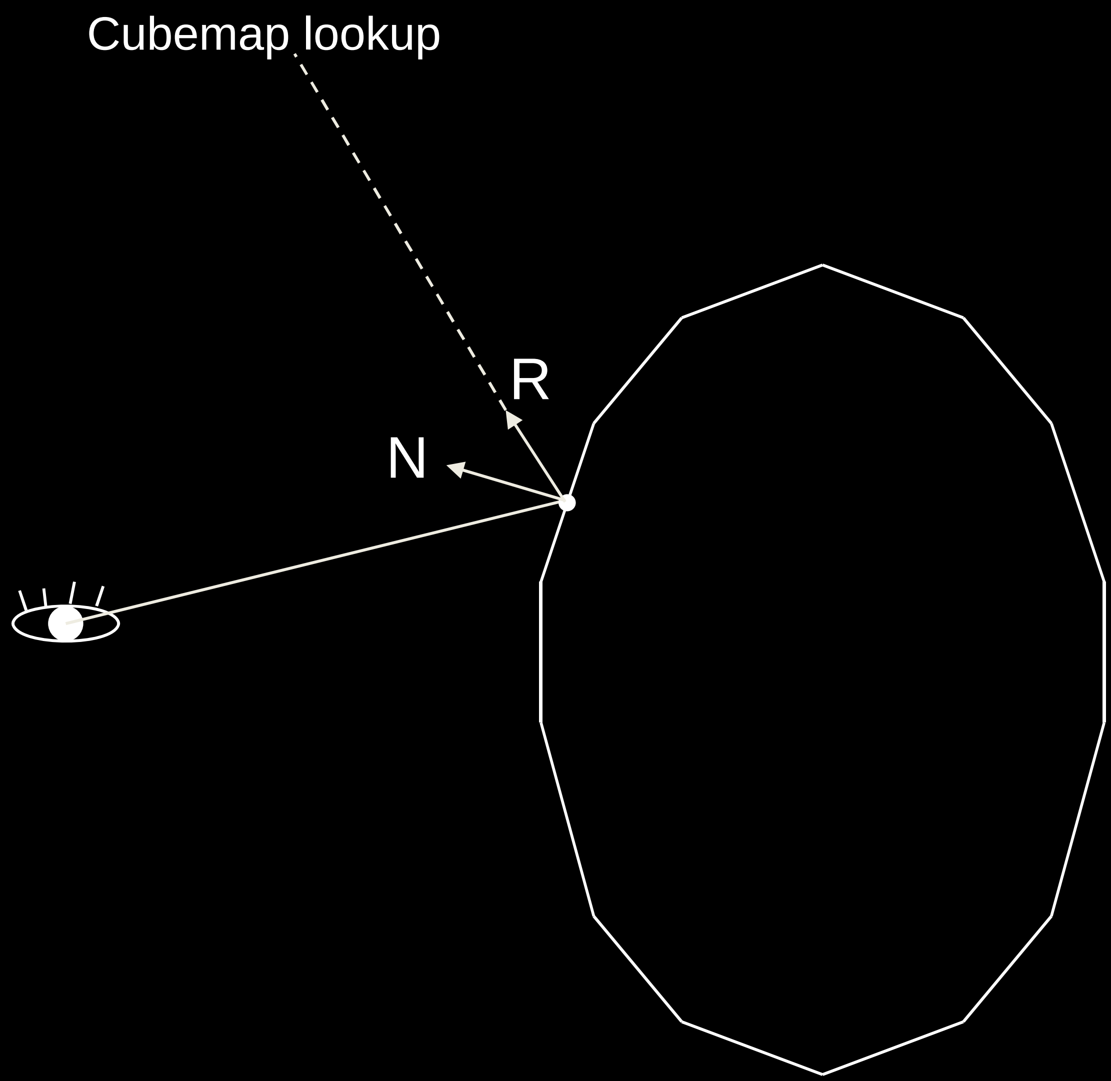

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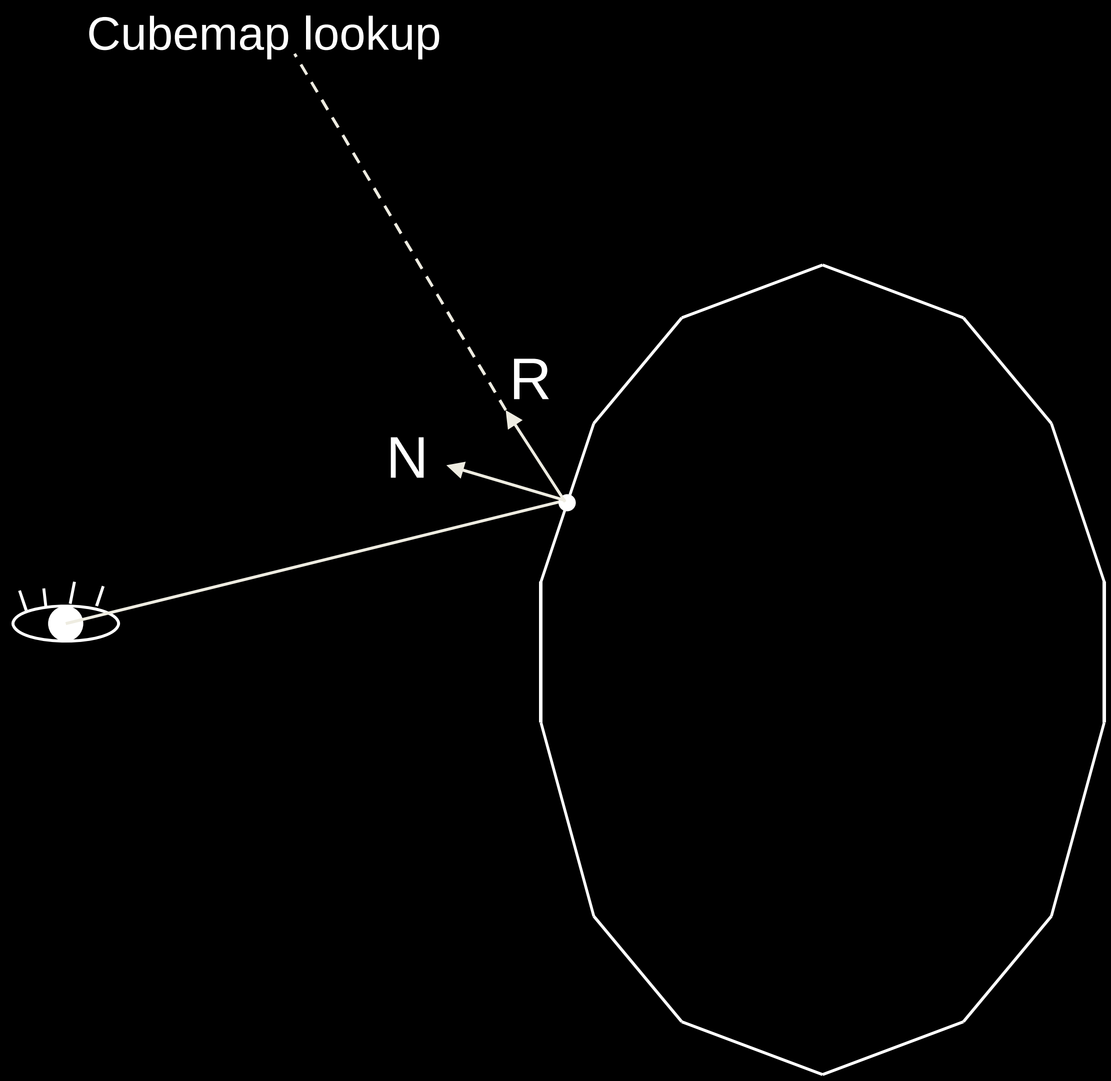
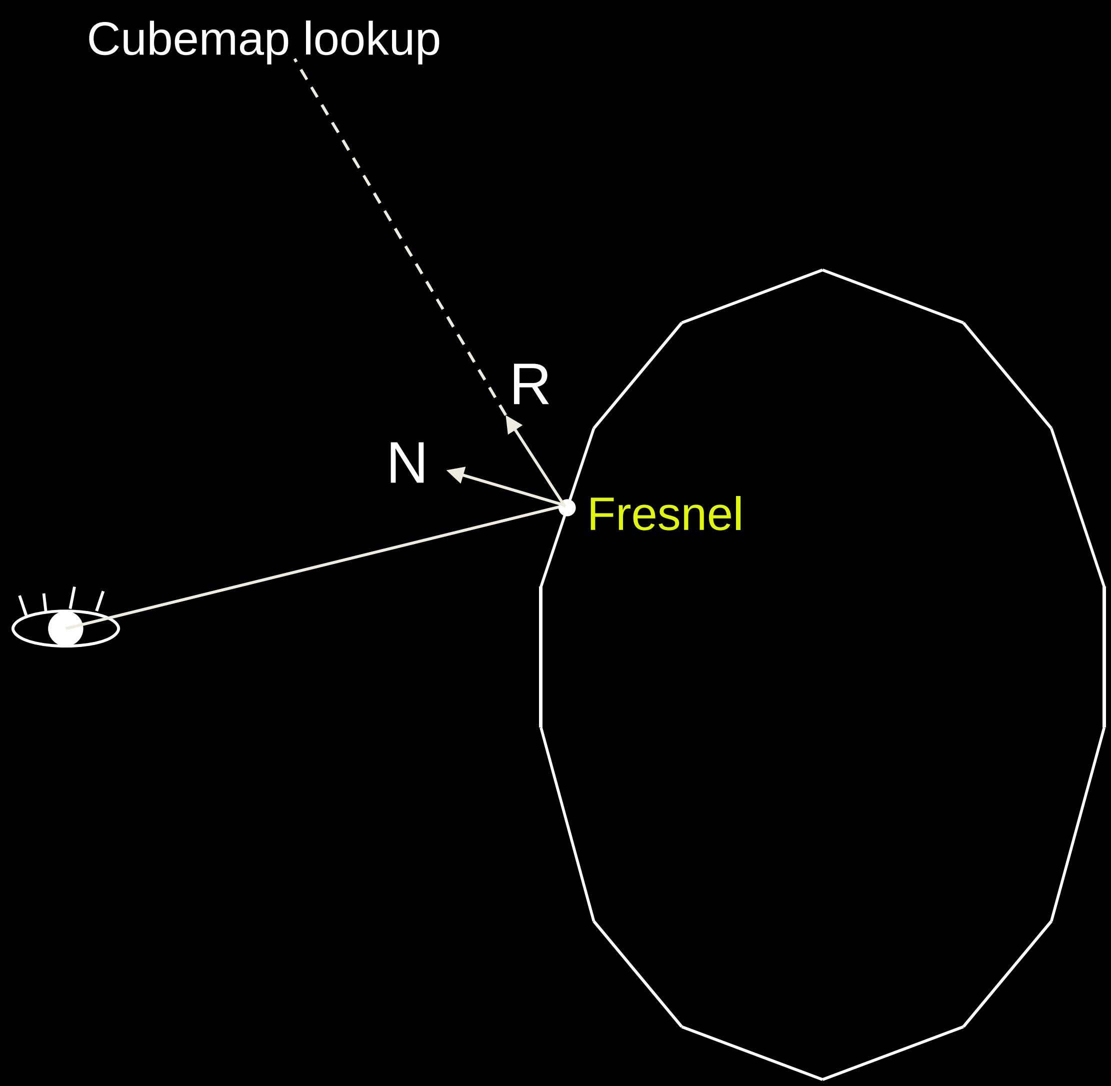
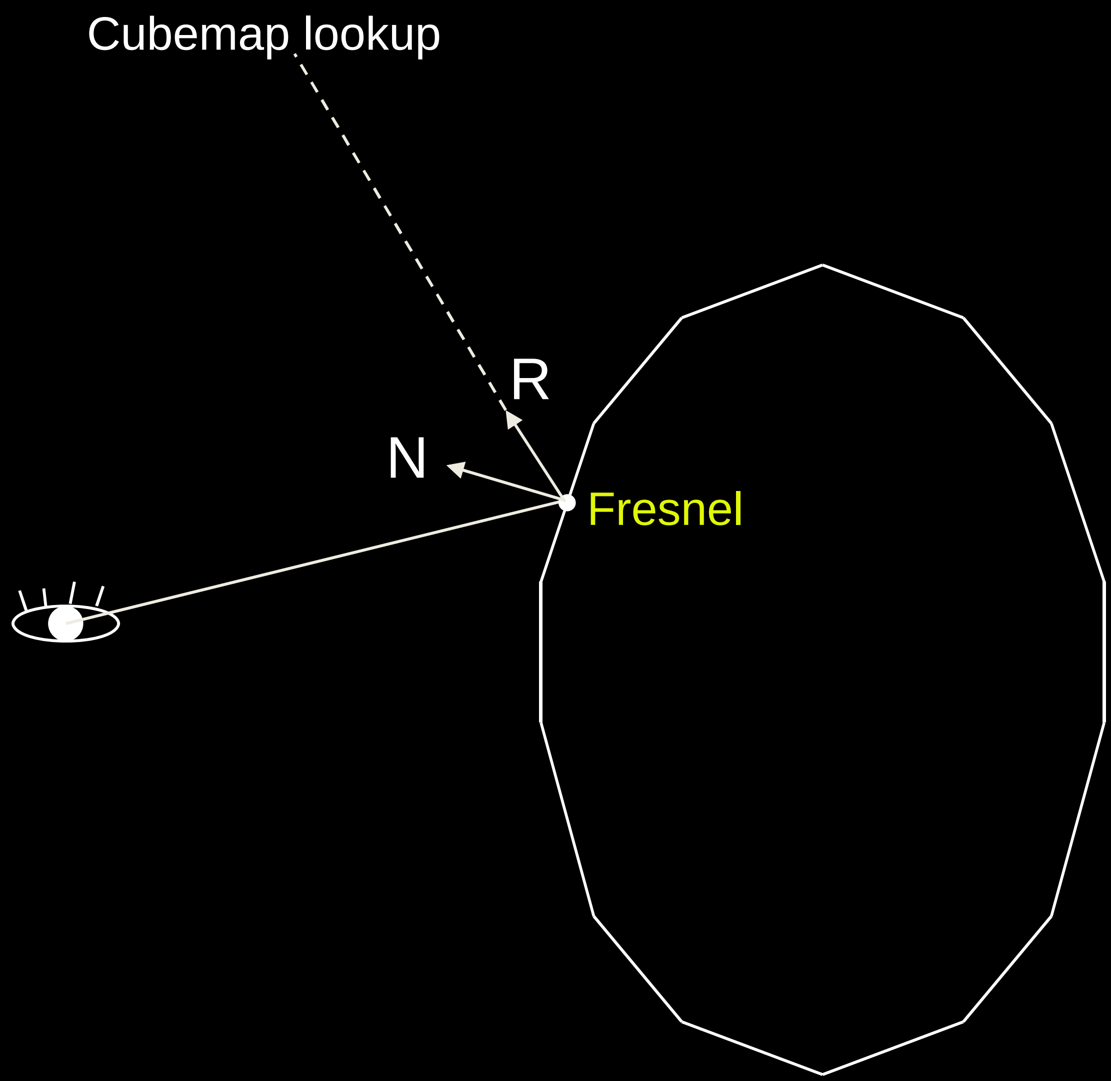


Reflectance only

Crystal Reflectance



Crystal Reflectance



Fresnel attenuated reflectance

Fresnel terms

```
// reflectance at normal incidence:
float F0 = pow( (1.0 - index)/(1.0 + index), 2.0 );
```

Fresnel terms

```
// reflectance at normal incidence:
float F0 = pow( (1.0 - index)/(1.0 + index), 2.0 );

// Schlick's approximation
float fresnelReflectance( float3 N, float3 V, float F0 )
{
  float base = 1.0 - dot( N, V );
  float exponential = pow( base, 5.0 );
  return exponential + F0 * ( 1.0 - exponential );
}
```

Fresnel terms

```
// reflectance at normal incidence:
float F0 = pow( (1.0 - index)/(1.0 + index), 2.0 );

// Schlick's approximation
float fresnelReflectance( float3 N, float3 V, float F0 )
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  float base = 1.0 - dot( N, V );
  float exponential = pow( base, 5.0 );
  return exponential + F0 * ( 1.0 - exponential );
}

// note:
// fresnelTransmittance = 1.0 - fresnelReflectance
```
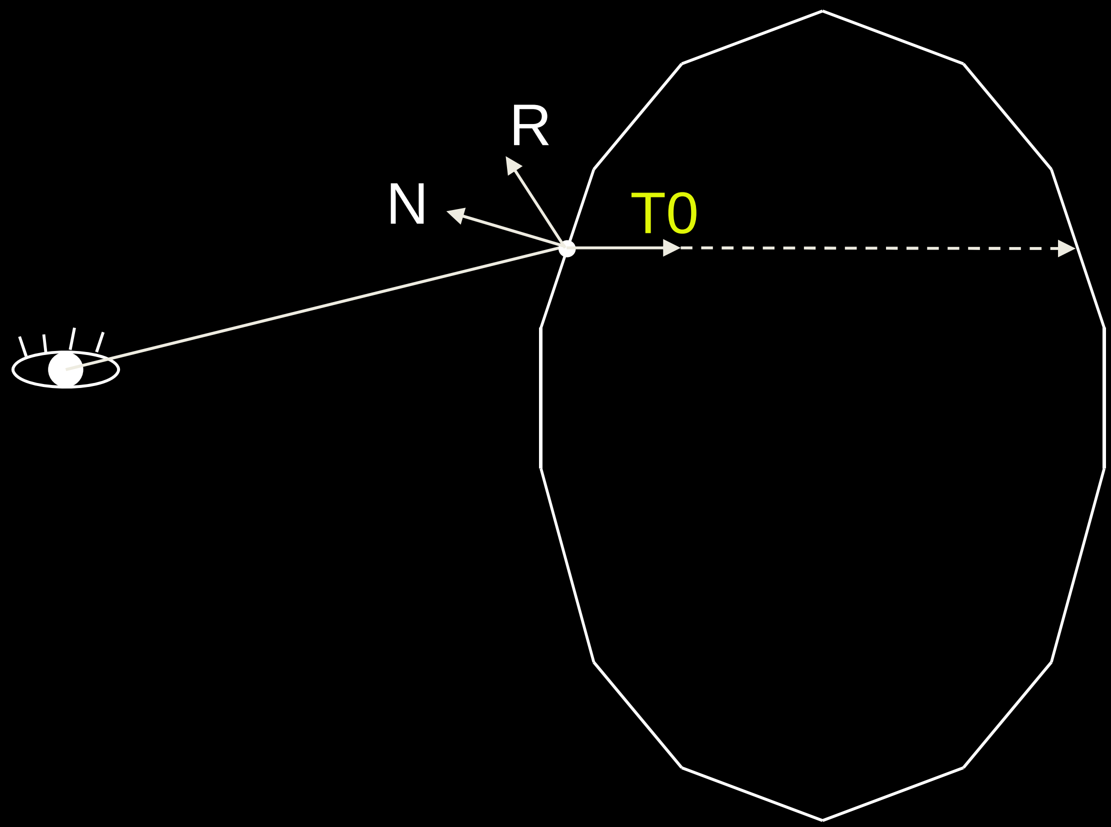
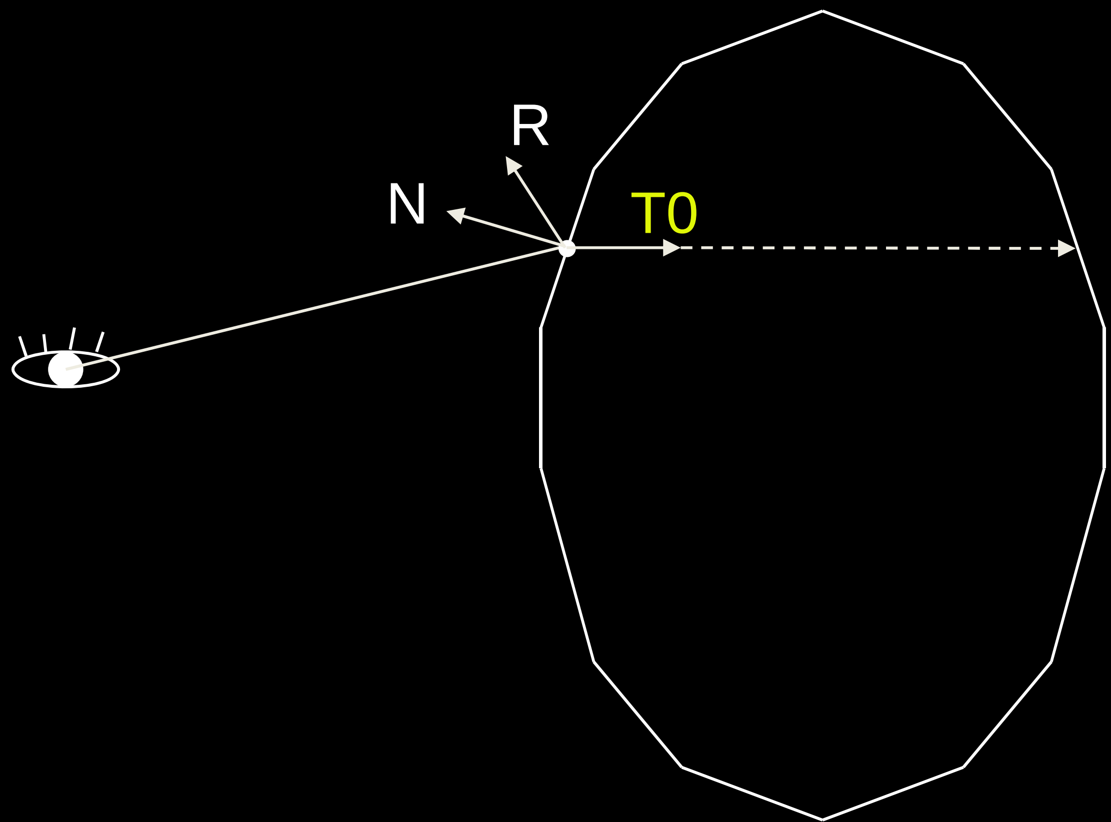

Fresnel terms

```
// NOTE: for crystal->air interactions use
float F0_out = pow( (index - 1.0)/(1.0 + index), 2.0 );
```

Crystal Transmittance

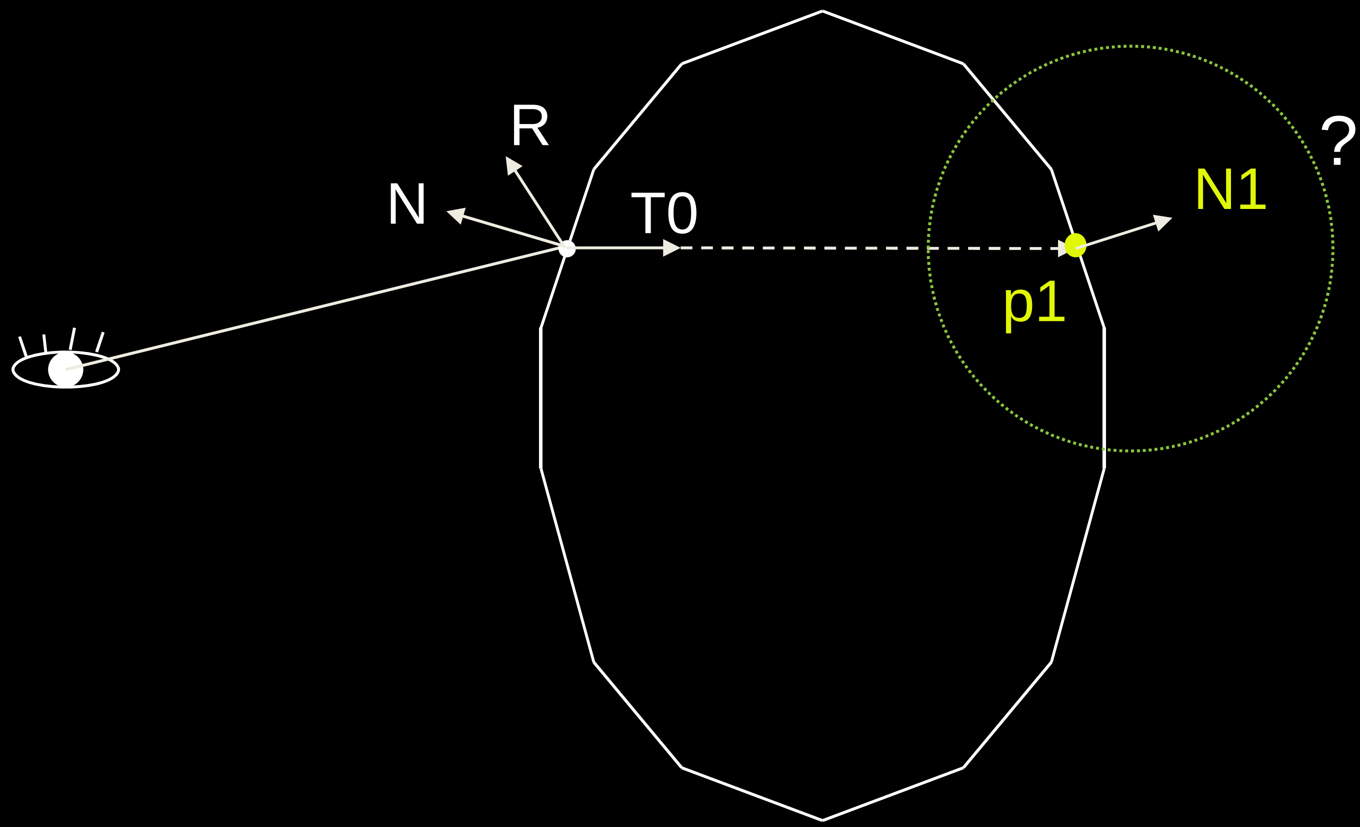


Crystal Transmittance



float3 T0 = refract(-V, N, 1.0 / index);

Computing ray-crystal intersections



Computing ray-crystal intersections

- Avoid ray-tracing the exact crystal triangle set

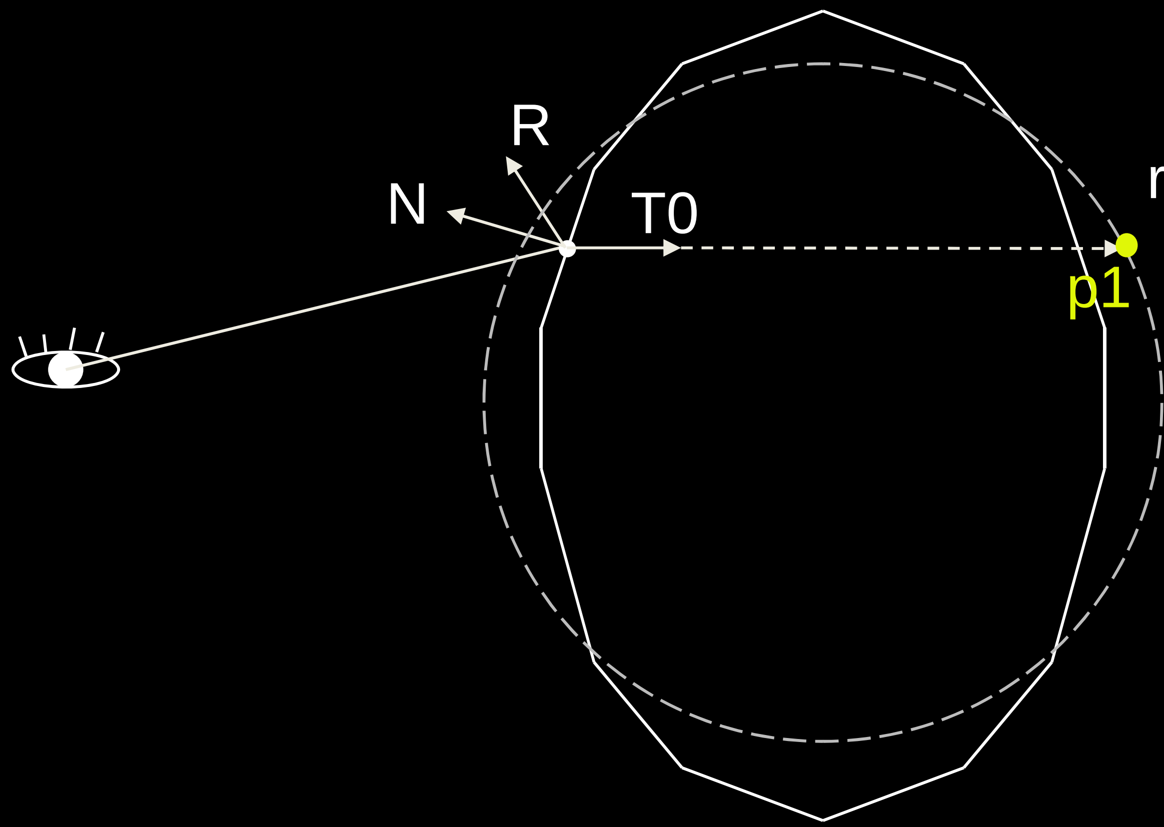
Computing ray-crystal intersections

- Avoid ray-tracing the exact crystal triangle set
- The crystal is roughly a sphere

Computing ray-crystal intersections

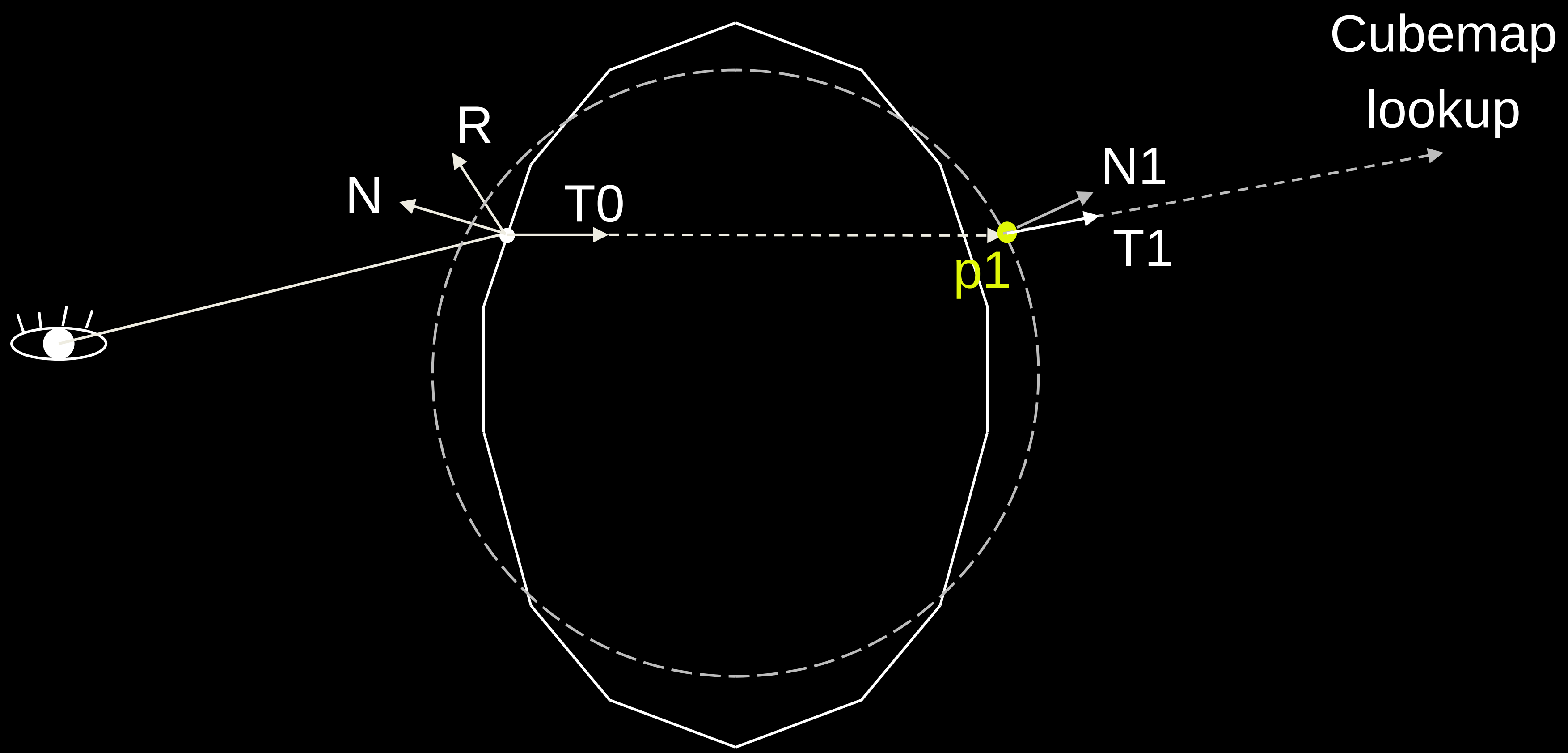
- Avoid ray-tracing the exact crystal triangle set
- The crystal is roughly a sphere
- Ray-sphere intersections are cheap

Computing ray-crystal intersections



Use a simple ray-sphere intersection to find p1

Computing ray-crystal intersections



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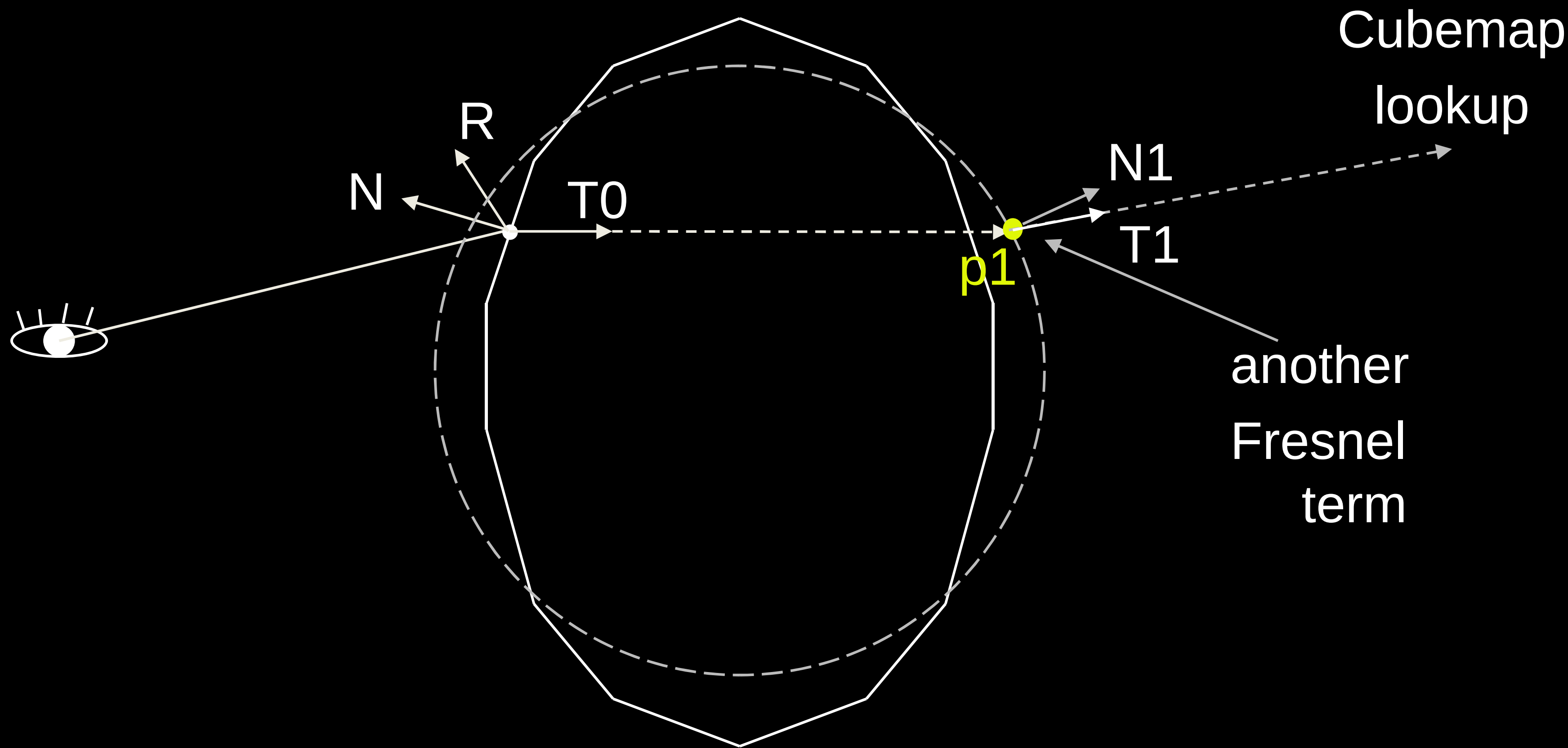

float3 T1 = refract(T0, -N1, index);

fresnel1 = fresnelReflectance(N1, T0, F0_out);

Sphere Approximation

- Transmitted light is too uniform

Second Idea

- Change the normals on the sphere to be faceted

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```
float3 facetNormal( float3 N, float facetSize )
{
  float3 scaledNormal = N * facetSize;



}
```

Second Idea

- Change the normals on the sphere to be faceted

```
float3 facetNormal( float3 N, float facetSize )
{
  float3 scaledNormal = N * facetSize;
  float3 scaleandround = float3( round( scaledNormal.x ),
    round( scaledNormal.y ), round( scaledNormal.z ) );


}
```

Second Idea

- Change the normals on the sphere to be faceted

```
float3 facetNormal( float3 N, float facetSize )
{
  float3 scaledNormal = N * facetSize;
  float3 scaleandround = float3( round( scaledNormal.x ),
     round( scaledNormal.y ), round( scaledNormal.z ) );
  return normalize( scaleandround );
}
```

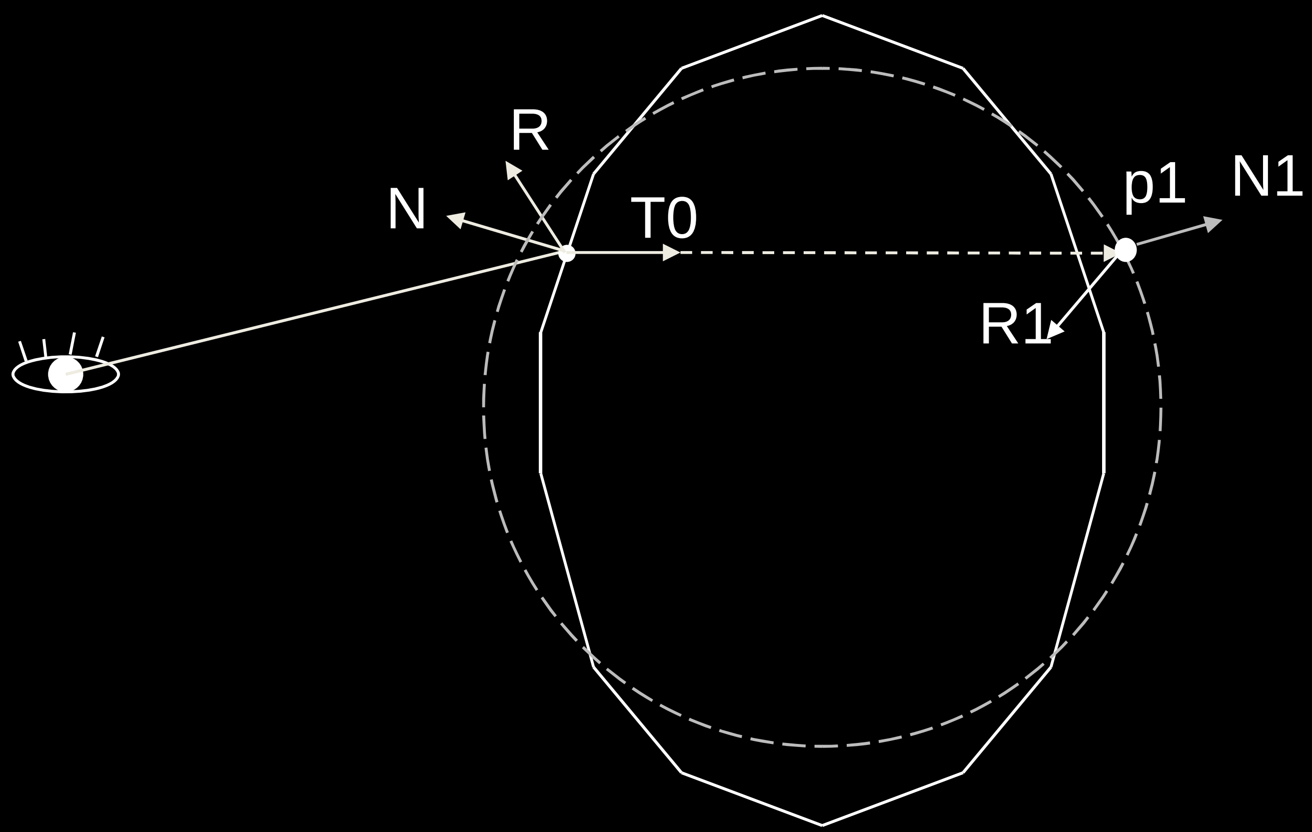
Faceted Normals

- Voila!

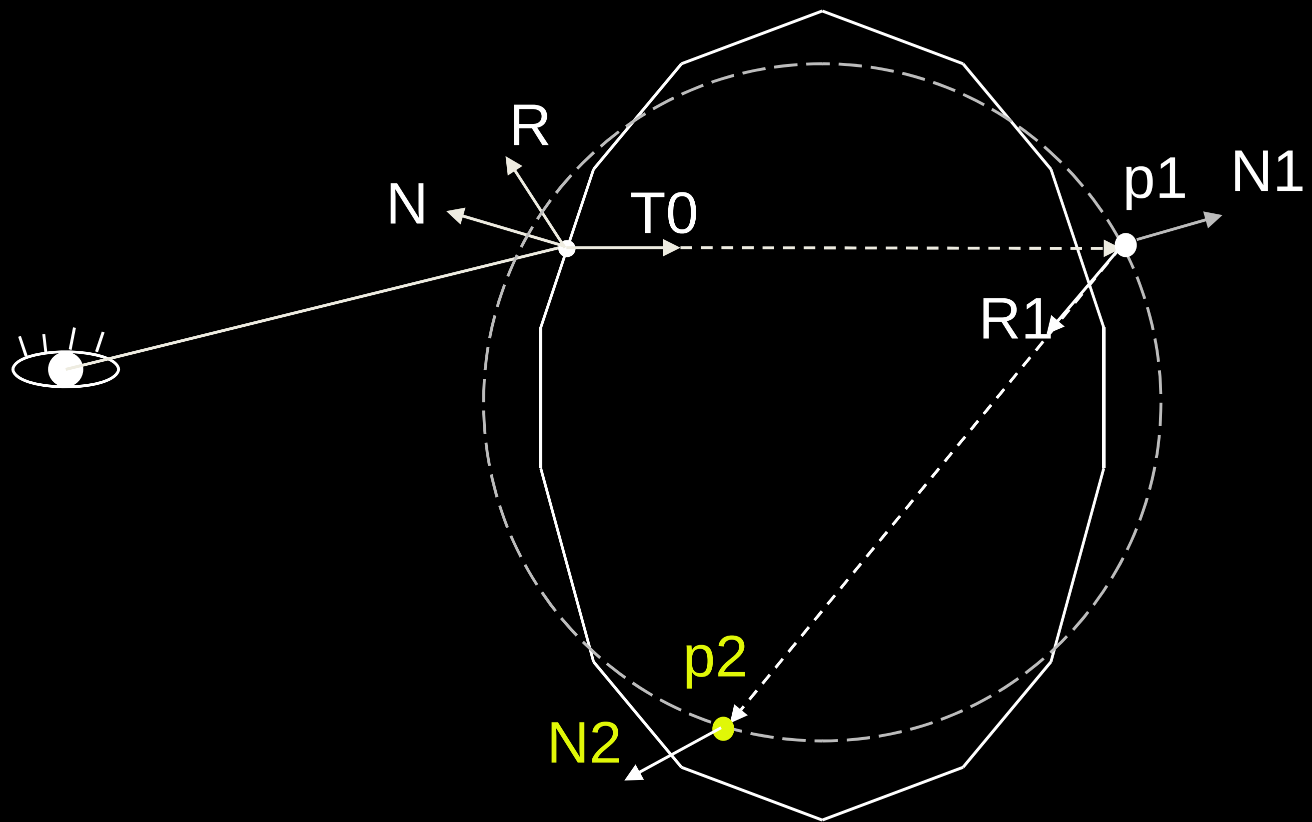
Faceted Normals

- Change the facet_size to your liking

Further transmission



Further transmission



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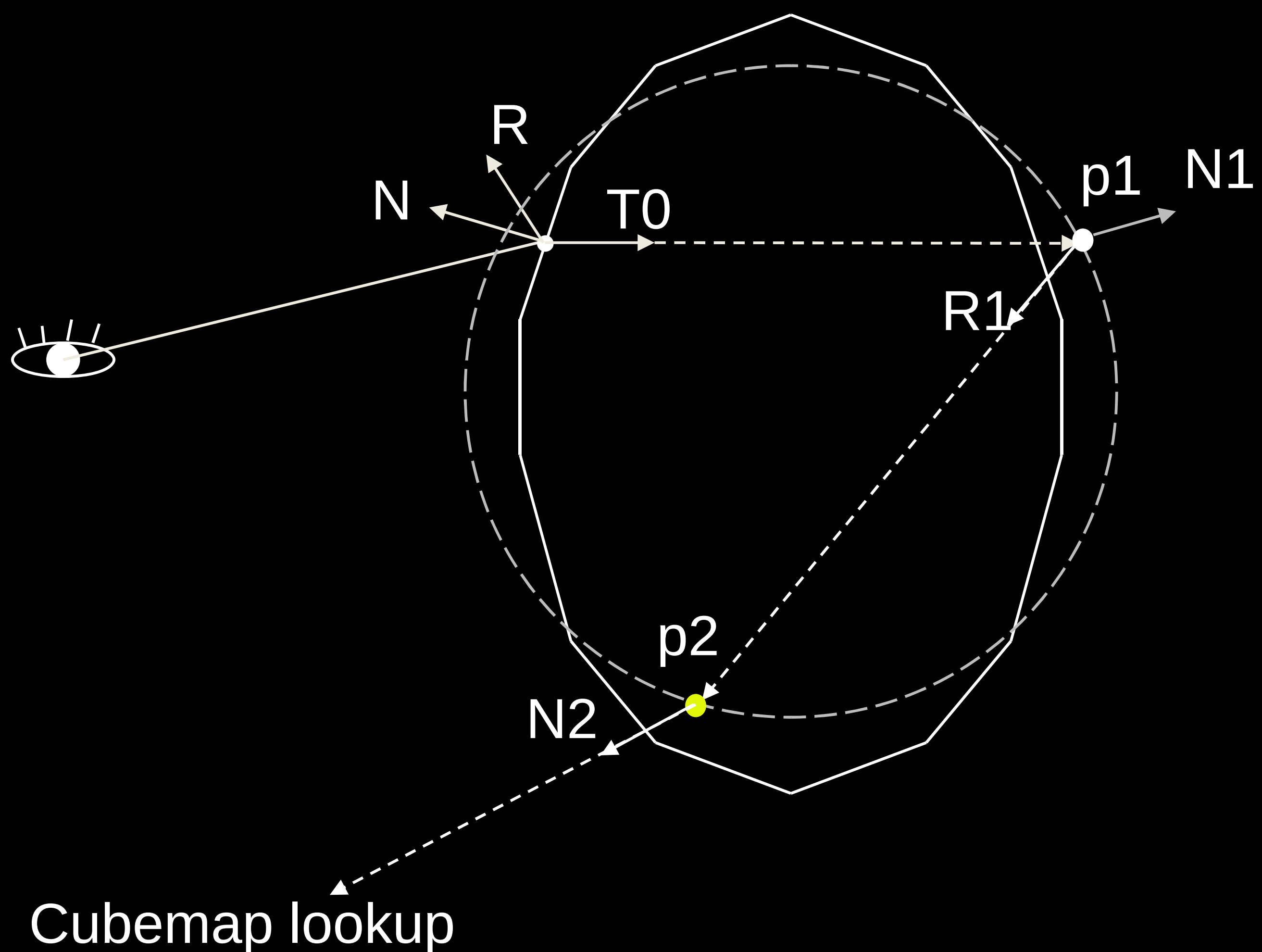

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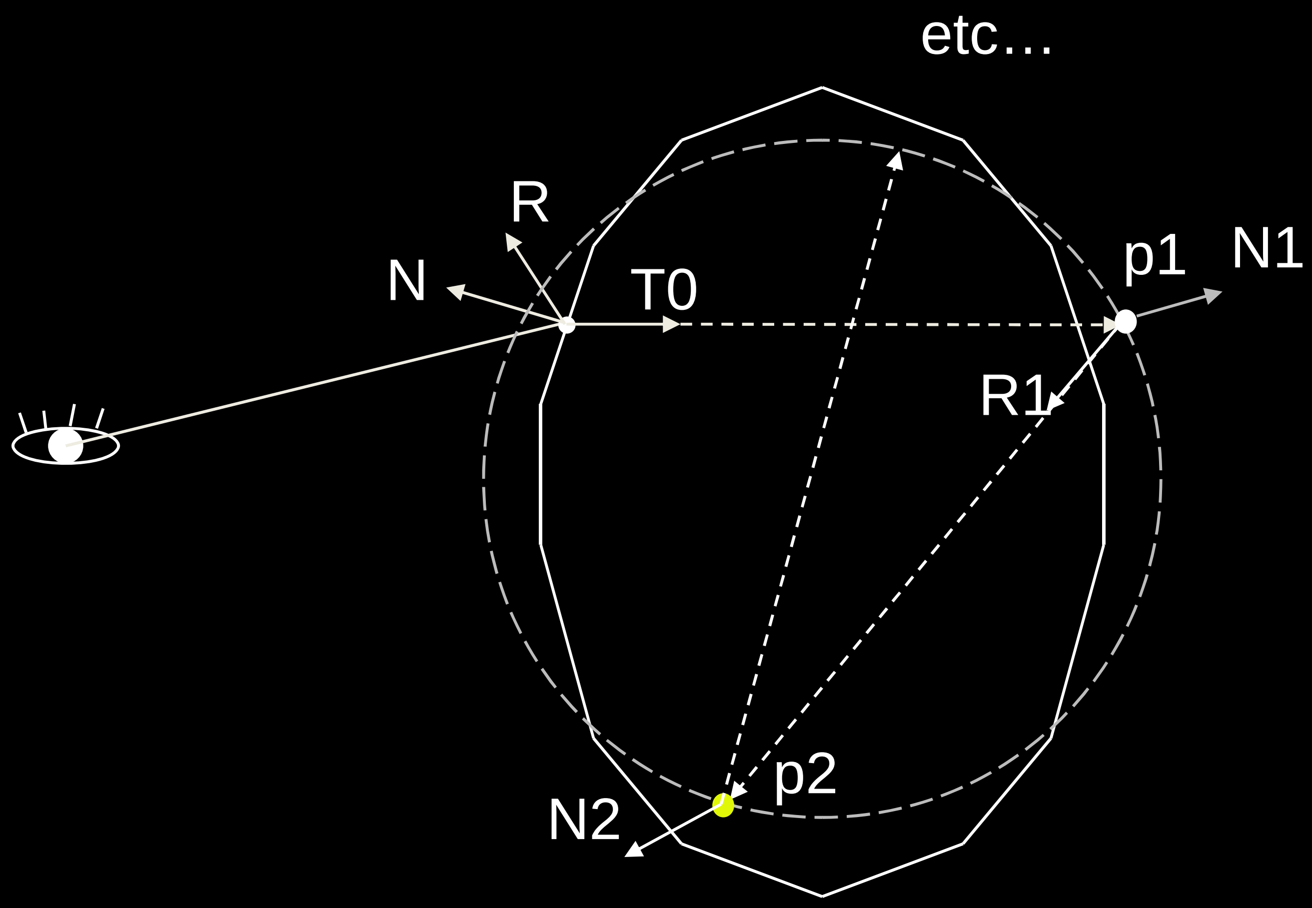
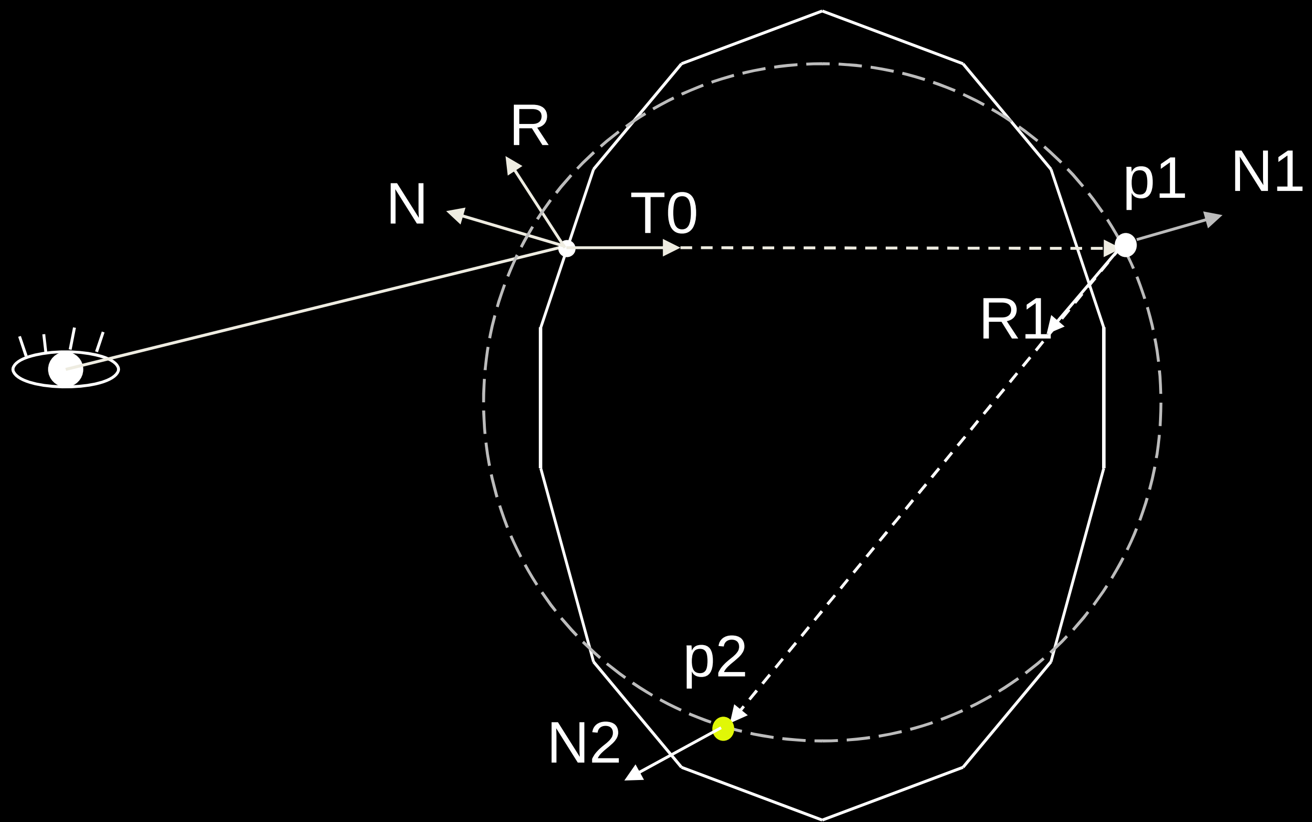


Colored Gemstones

- Light travelling through the crystal is absorbed based on distance



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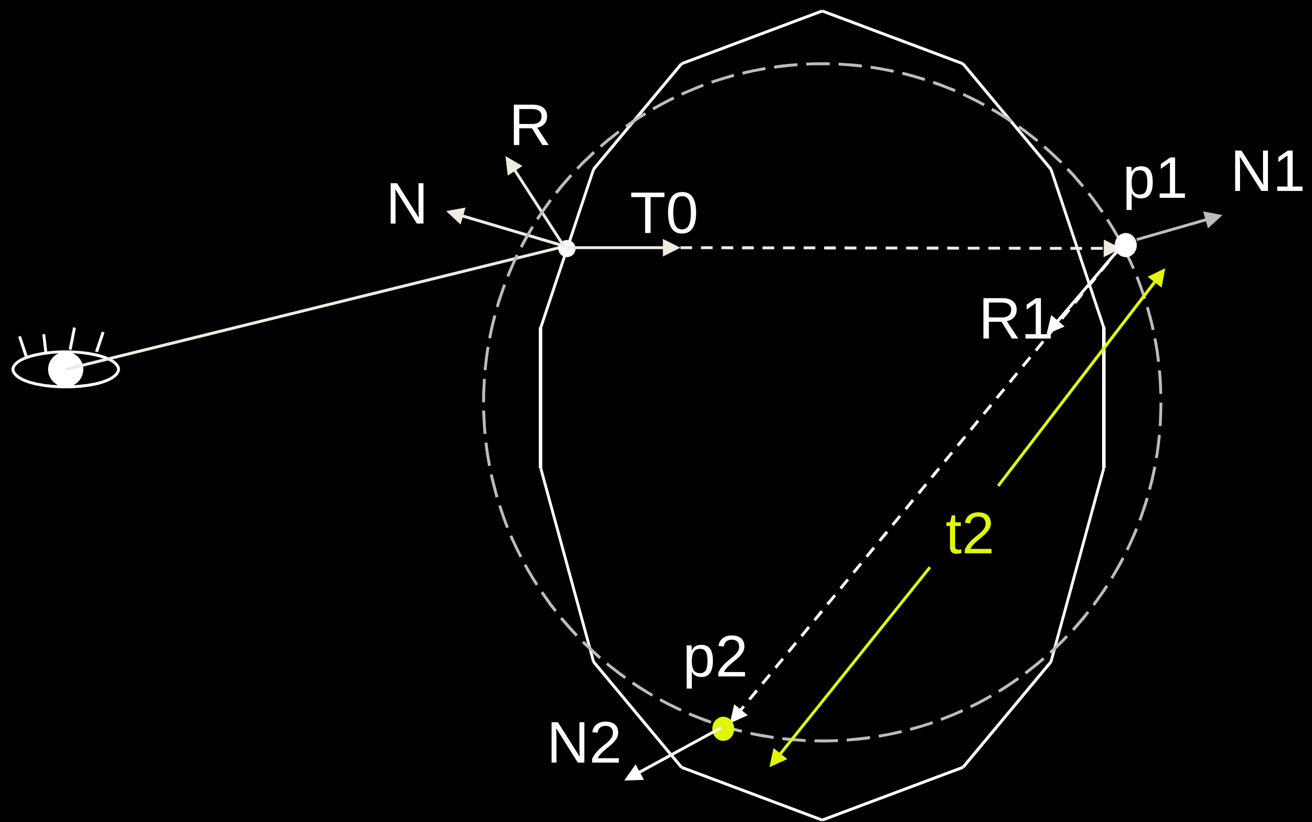

Attenuate by: exp(-t2 * absorp)

Final Crystal Reflectance

```
result.xyz = specularLight;
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0;
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
);
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
   exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1
   )
  );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
    exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1
    )
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    )
  );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
   (
     exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1 +
     fresnel1 * exp( -t2 * absorp ) * ( ( 1.0 - fresnel2 ) * cube2
      ) )
   );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
    exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1 +
    fresnel1 * exp( -t2 * absorp ) * ( ( 1.0 - fresnel2 ) * cube2 +
    fresnel2 * exp( -t3 * absorp ) * ( ( 1.0 - fresnel3 ) * cube3
    ) ) )
  );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
    exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1 +
    fresnel1 * exp( -t2 * absorp ) * ( ( 1.0 - fresnel2 ) * cube2 +
    fresnel2 * exp( -t3 * absorp ) * ( ( 1.0 - fresnel3 ) * cube3 +
    fresnel3 * exp( -t4 * absorp ) * ( ( 1.0 - fresnel4 ) * cube4  )
    ) ) )
  );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
    exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1 +
    fresnel1 * exp( -t2 * absorp ) * ( ( 1.0 - fresnel2 ) * cube2 +
    fresnel2 * exp( -t3 * absorp ) * ( ( 1.0 - fresnel3 ) * cube3 +
    fresnel3 * exp( -t4 * absorp ) * ( ( 1.0 - fresnel4 ) * cube4 +
    fresnel4 * exp( -t5 * absorp ) * ( ( 1.0 - fresnel5 ) * cube5 ) )
    ) ) )
  );
```

Final Crystal Reflectance

```
result.xyz = specularLight + fresnel0 * cube0 + ( 1.0 - fresnel0 ) *
  (
    exp( -t1 * absorp ) * ( ( 1.0 - fresnel1 ) * cube1 +
    fresnel1 * exp( -t2 * absorp ) * ( ( 1.0 - fresnel2 ) * cube2 +
    fresnel2 * exp( -t3 * absorp ) * ( ( 1.0 - fresnel3 ) * cube3 +
    fresnel3 * exp( -t4 * absorp ) * ( ( 1.0 - fresnel4 ) * cube4 +
    fresnel4 * exp( -t5 * absorp ) * ( ( 1.0 - fresnel5 ) * cube5 +
    fresnel5 * exp( -t6 * absorp ) * ( ( 1.0 - fresnel6 ) * cube6 ) ) )
    ) ) )
  );
```

Final Crystal Reflectance

+

reflectance

Final Crystal Reflectance

+

+

reflectance

1st transmittance

Final Crystal Reflectance


+

+

+

reflectance | 1st transmittance | 2nd transmittance

Final Crystal Reflectance

reflectance

+

1st transmittance

+

2nd transmittance

+

4th transmittance

Final Crystal Reflectance

reflectance

+

1st transmittance

+

2nd transmittance

+

4th transmittance

6th transmittance

+

Final Crystal Reflectance

reflectance

+

1st transmittance

+

2nd transmittance

+

4th transmittance

6th transmittance

+

specular

=

Final Crystal Reflectance


reflectance

+


1st transmittance

+


2nd transmittance

+


4th transmittance


6th transmittance

+


specular

=


final result

Questions?