NVIDIA

SIGGRAPH 2013

Shaping the Future
of Visual Computing

GPU Ray Tracing & NVIDIA Advanced Rendering Solutions

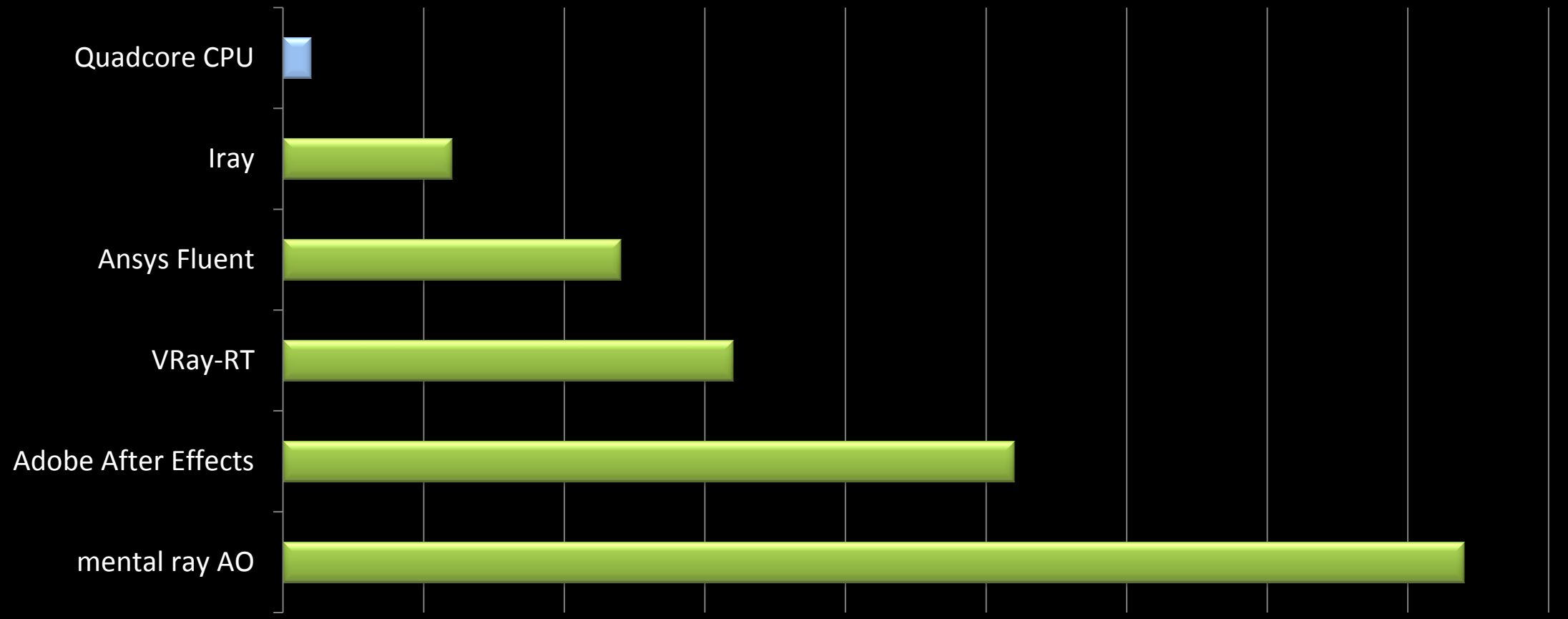
Phillip Miller & Lutz Kettner

Agenda

- GPU Ray Tracing Overview
- OptiX
- Iray
- MDL
- Iray+

GPU Ray Tracing – what's the big deal?

Single GPU speedups in commercial ray tracing app's vs CPU



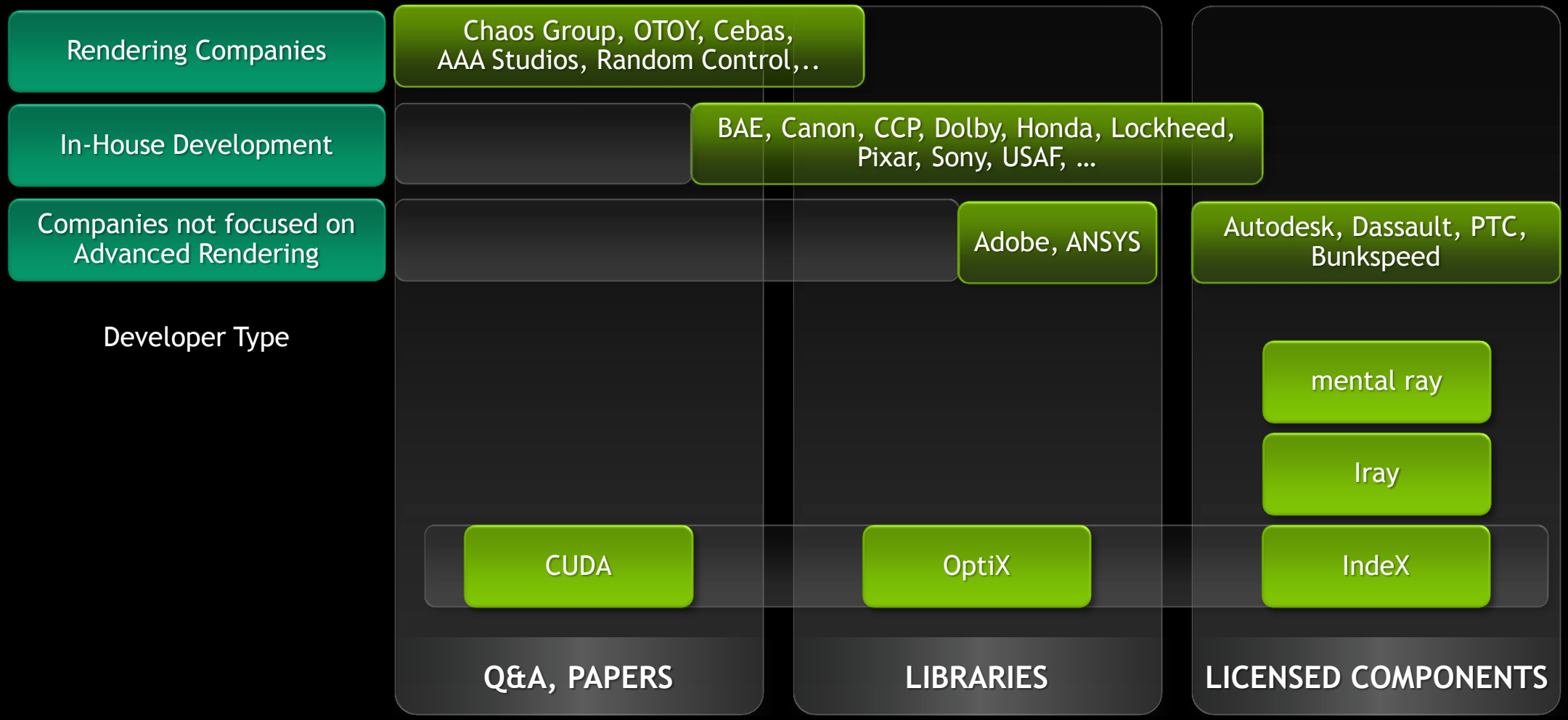
GPU Ray Tracing in Commercial Products

Adobe After Effects	OptiX API	Out of Core
Arion	CUDA C,	
CentiLeo	CUDA C	Out of Core
finalRender	CUDA C	
Furry Ball	OptiX API	
Iray Photoreal	CUDA C	
Iray Interactive	OptiX API	
mental ray 3.11 (in 3ds Max, Maya, SI)	OptiX API	Out of Core
Octane	CUDA C	
Optis	OpenCL	
RedShift	CUDA C	Out of Core
V-Ray RT	CUDA C (and OpenCL for x86)	
Pixar (in-house, Lighting)	OptiX API	Out of Core
Weta (in-house, Panta Ray)	CUDA C	Massive Out of Core

Ray Tracing with NVIDIA

- **CUDA** – language and computing platform
  - The primary choice for building *entirely custom GPU solutions from scratch*
- **NVIDIA OptiX™** – toolkit for ray tracing developers
  - Good choice for developers *with domain expertise* building *custom ray tracing solutions* who prefer to *leave GPU details to NVIDIA*
- **Iray® & mental ray®** – commercial rendering products
  - Good choice for companies wanting *ready-to-integrate rendering* which is *maintained and advanced for them*
  - Iray focusing on Interactive Design; mental ray focusing on Film Production

NVIDIA Assisting Companies with Rendering



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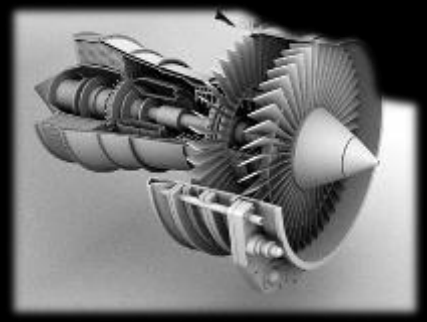
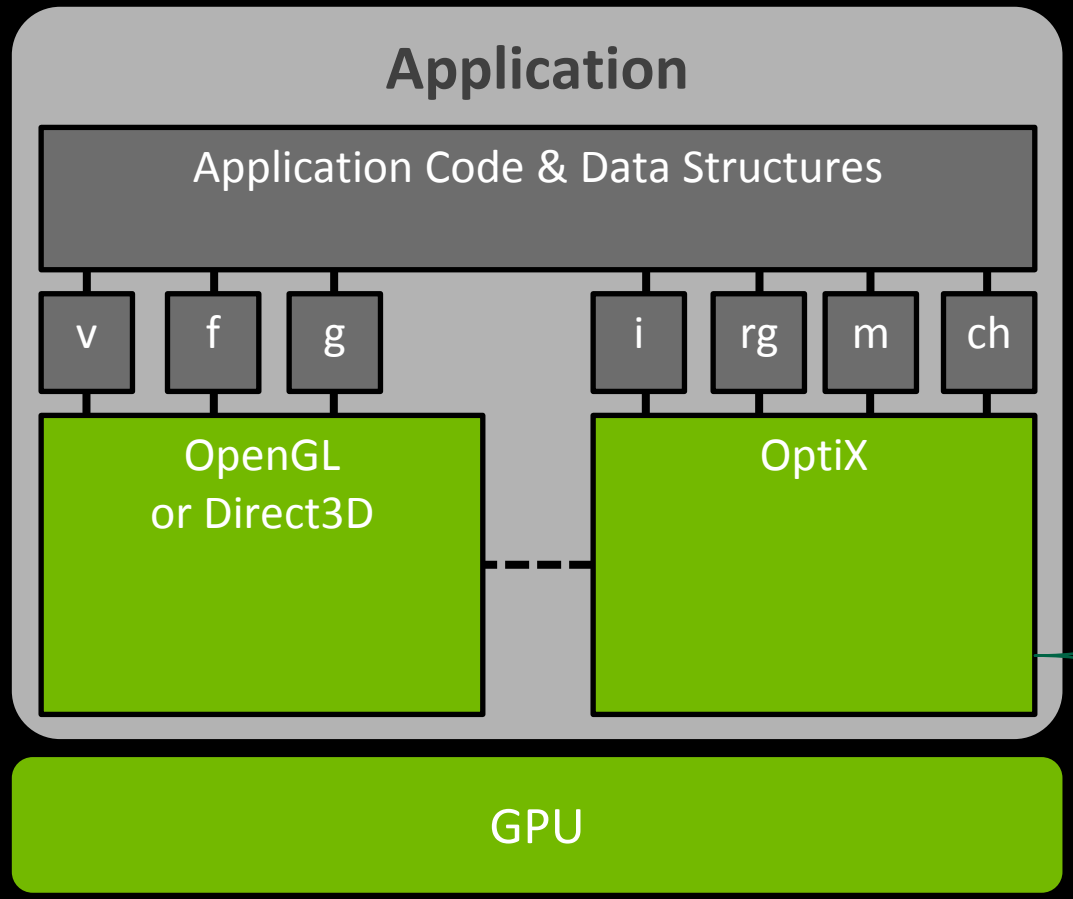
NVIDIA OptiX

NVIDIA® OptiX™ ray tracing engine

- A programmable ray tracing framework enabling the rapid development of high performance ray tracing applications – from complete renderers to discrete functions (collision, acoustics, ballistics, radiation reflectance, signals, etc.)
  - Use your techniques, methods, and data for your application with simple programs and a single-ray programming model
  - OptiX does the "heavy lifting" of ray tracing, with straight forward APIs, for traversal, intersection, acceleration structures, and (optionally) shading – *allowing you to concentrate on technique*
  - OptiX handles GPU aspects for you, handling load balancing, parallelism, scaling, paging, and optimizing per GPU architecture



OptiX: Analogous to OpenGL



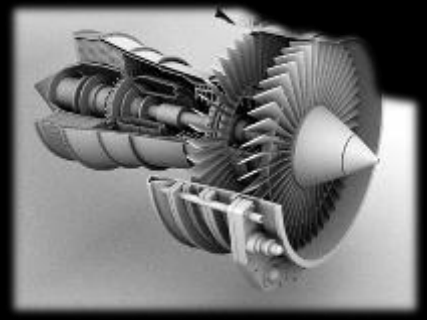
- C-based Shaders/Functions (minimal CUDA exp. reqd.)

- Small, Custom Programs
- Acceleration Structures Build & Traversal
- Optimal GPU parallelism and Performance
- Memory Management
- Paging

OptiX Across Markets and Disciplines

Designed for Generality:

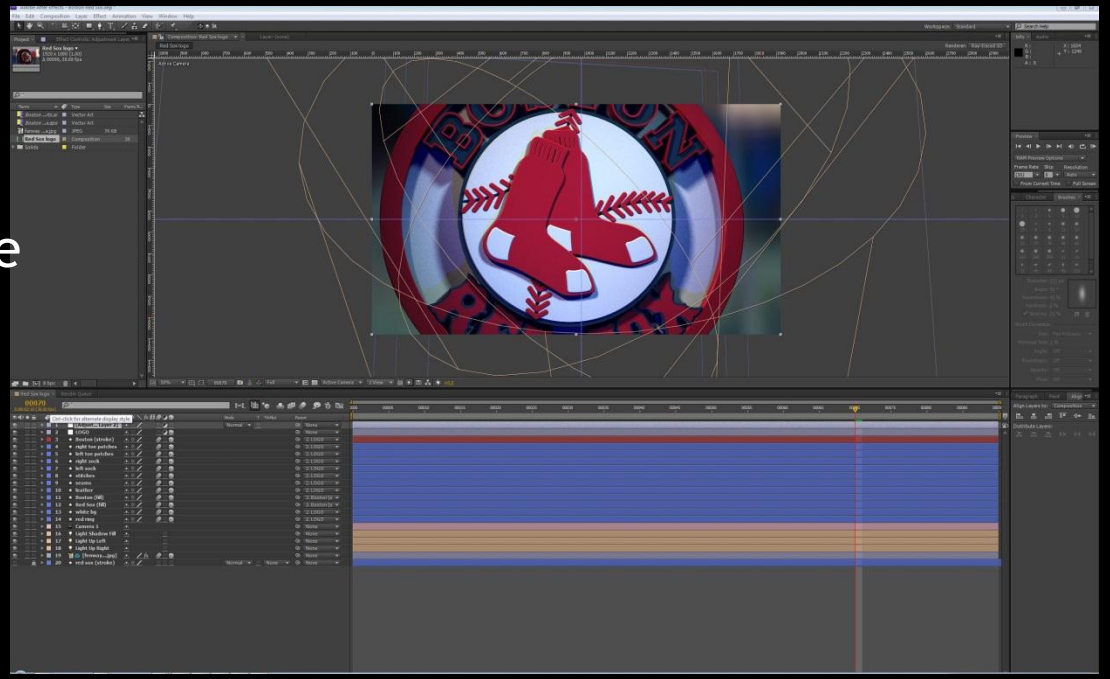
- No assumptions on technique, shading language, geometry type, or data structure
- Supports custom ray generation, material shading, object intersection, scene traversal, ray payloads
- Programmable intersection for custom surface types (procedurals, patches, NURBS, displacement, hair, fur, etc.)
- As many as 1/3 of OptiX applications don't "render", and a very simple **Traversal API** makes this even easier for applications that only need to trace rays
  – 5 lines of code and you're ray tracing on the GPU



Ray Tracing in Compositing

Adobe After Effects (starting with Creative Suite 6)

- Ray traced compositing feature
- 100% OptiX – no x86 code
- Includes CPU Fallback
  - Done automatically
  - Transparent to developer
  - Currently exclusive to Adobe



Ambient Occlusion Baking for Games

Original Rendering

Ambient Occlusion

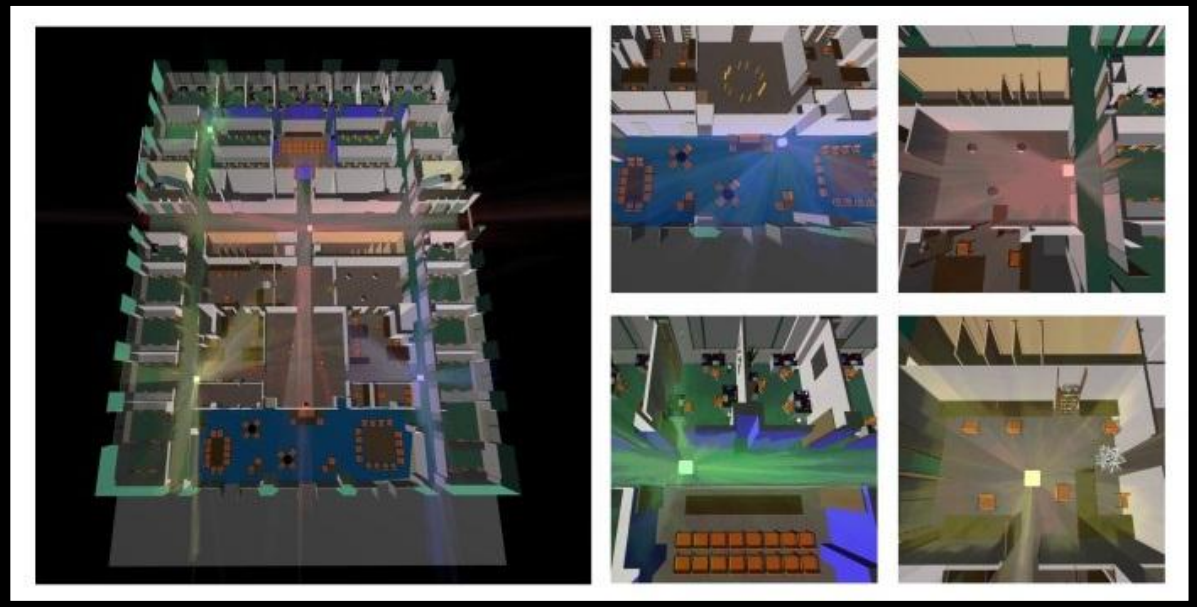
Resulting Higher Quality Game Experience

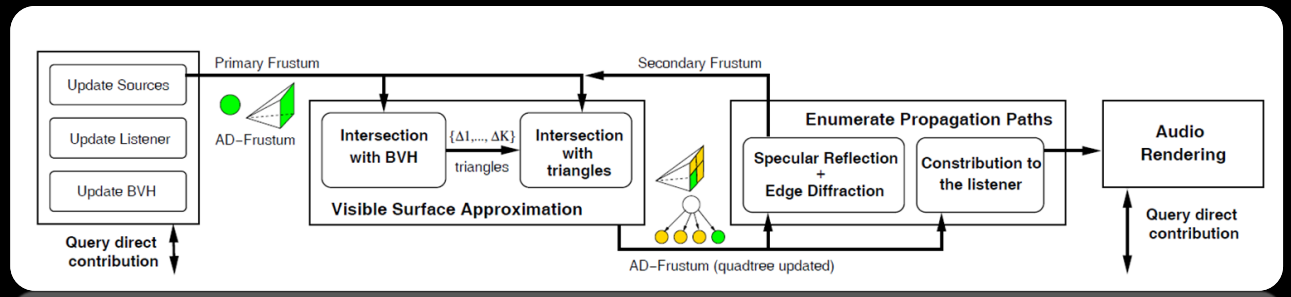
Courtesy of Wolfire Games

Light Baking for Game Development

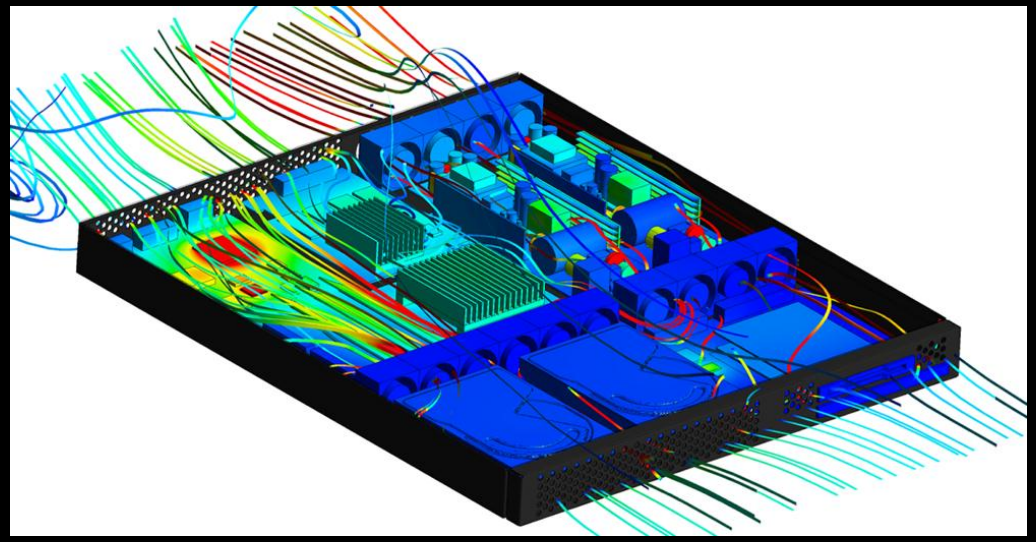
Geomerics

Sound Propagation for Acoustics



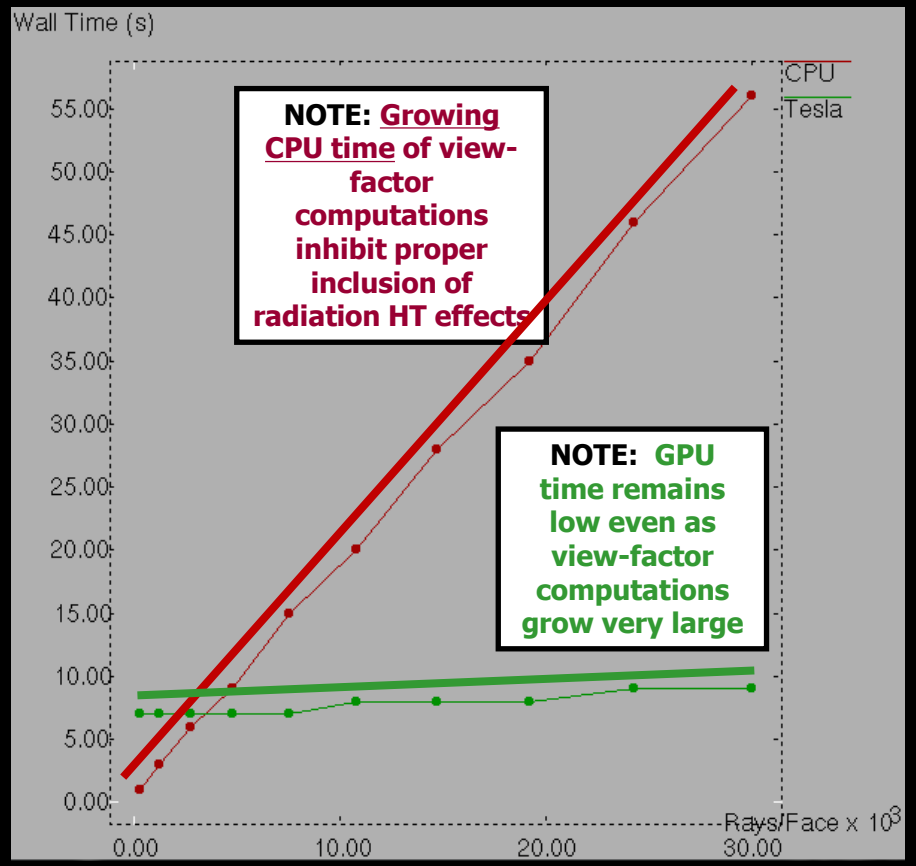


Radiation Heat Transfer



Part of version 14.5

ANSYS® FLUENT®



Holograph Rendering

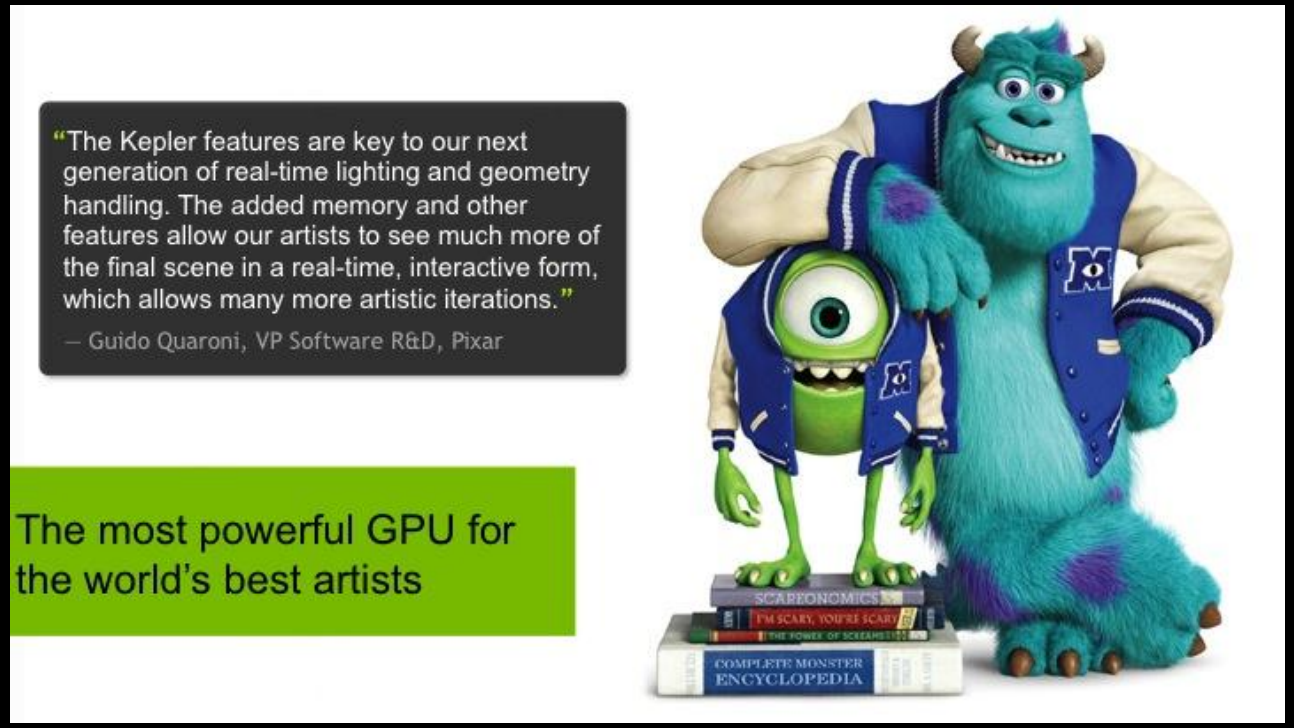
ZEBRA IMAGING®

OptiX within a Renderer for Maya

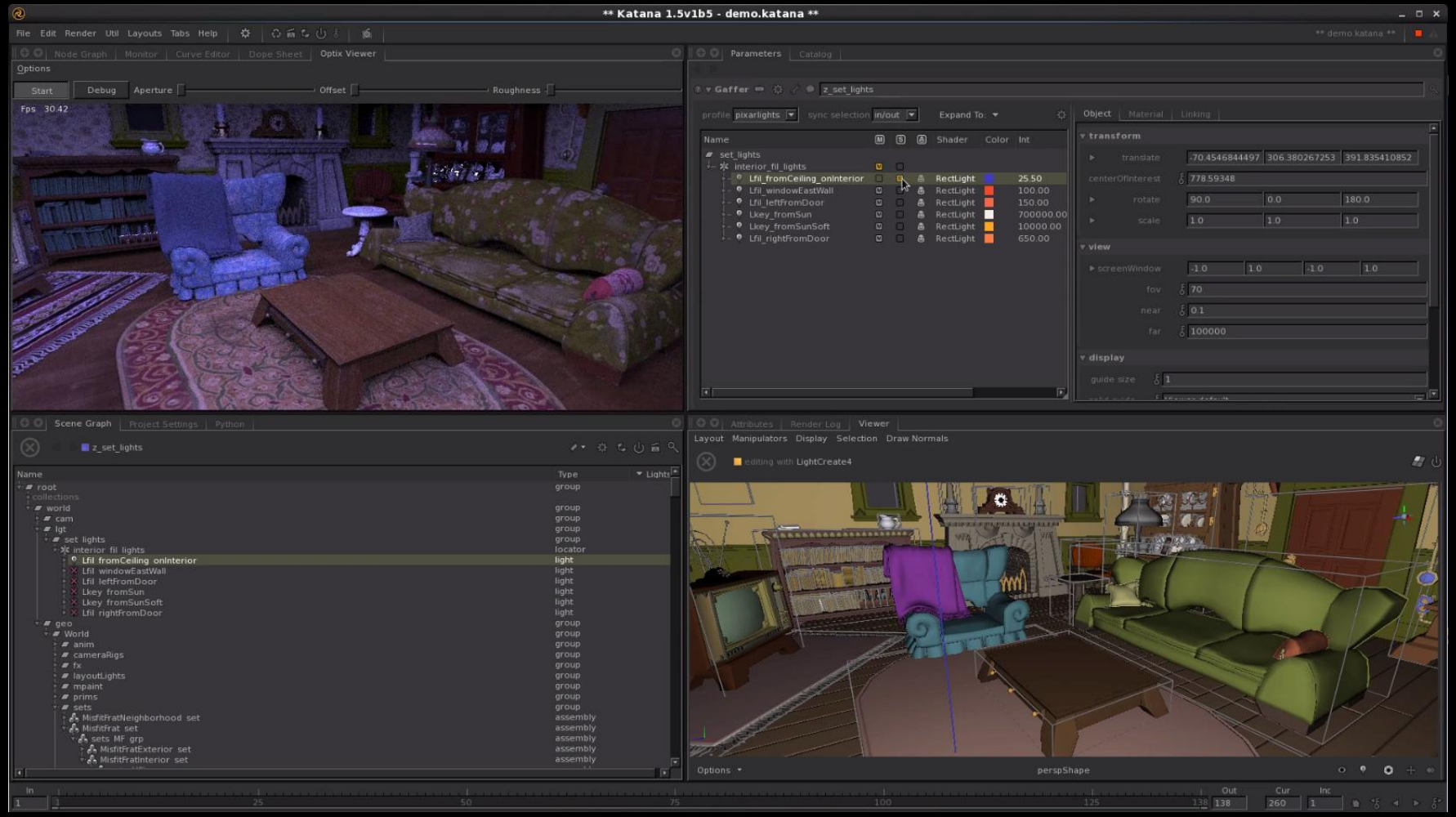
- **Furry Ball** for Maya from Art And Animation Studio
- A multi-pass D3D renderer until now
- Added ray tracing via OptiX in just 3 months

OptiX at Pixar Studios

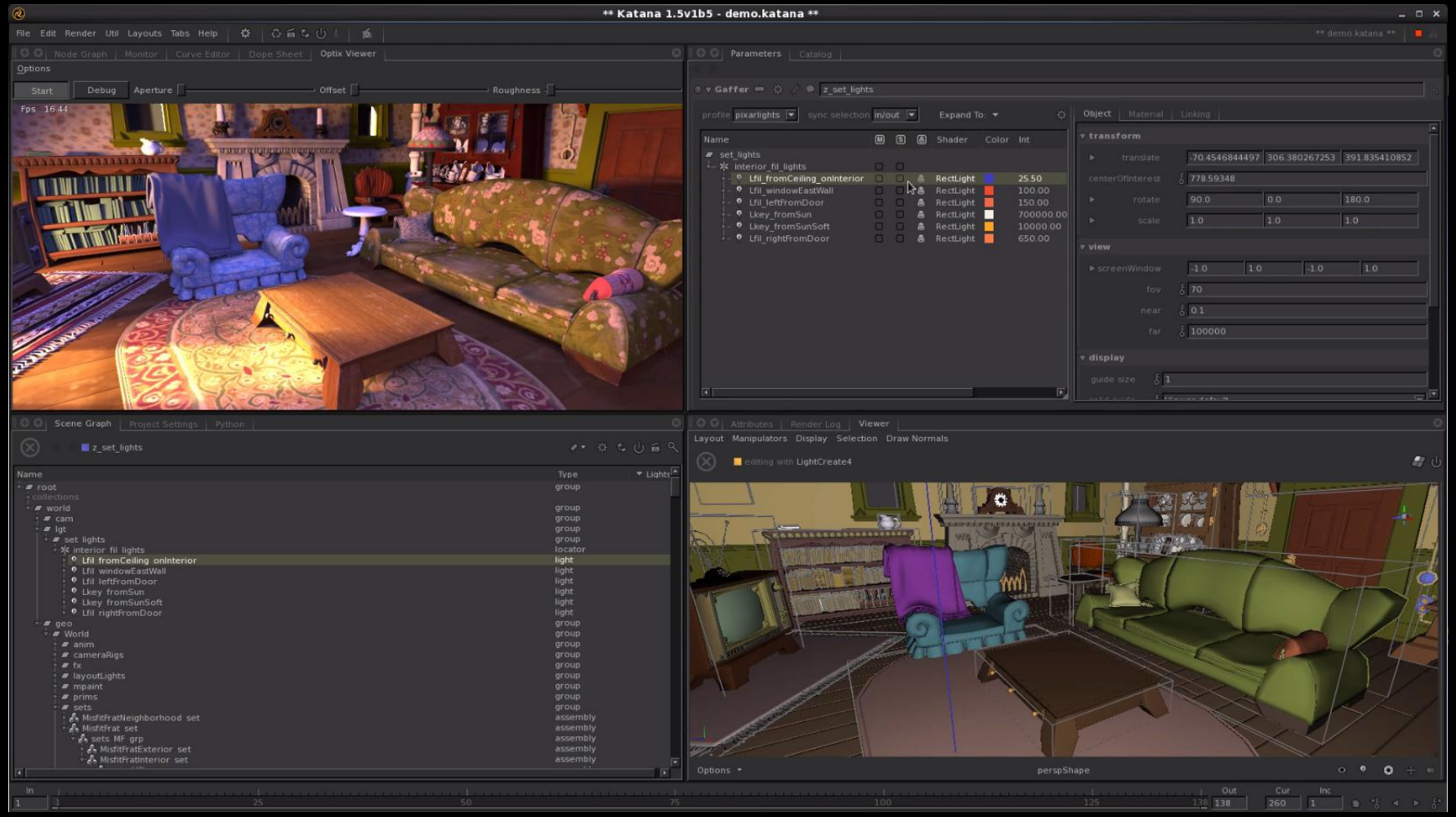
- Pixar Studios showing an in-house tool for Katana built upon OptiX
- Achieves about 100million rays per second on a single GPU
- Transforms the lighting process – making it interactive



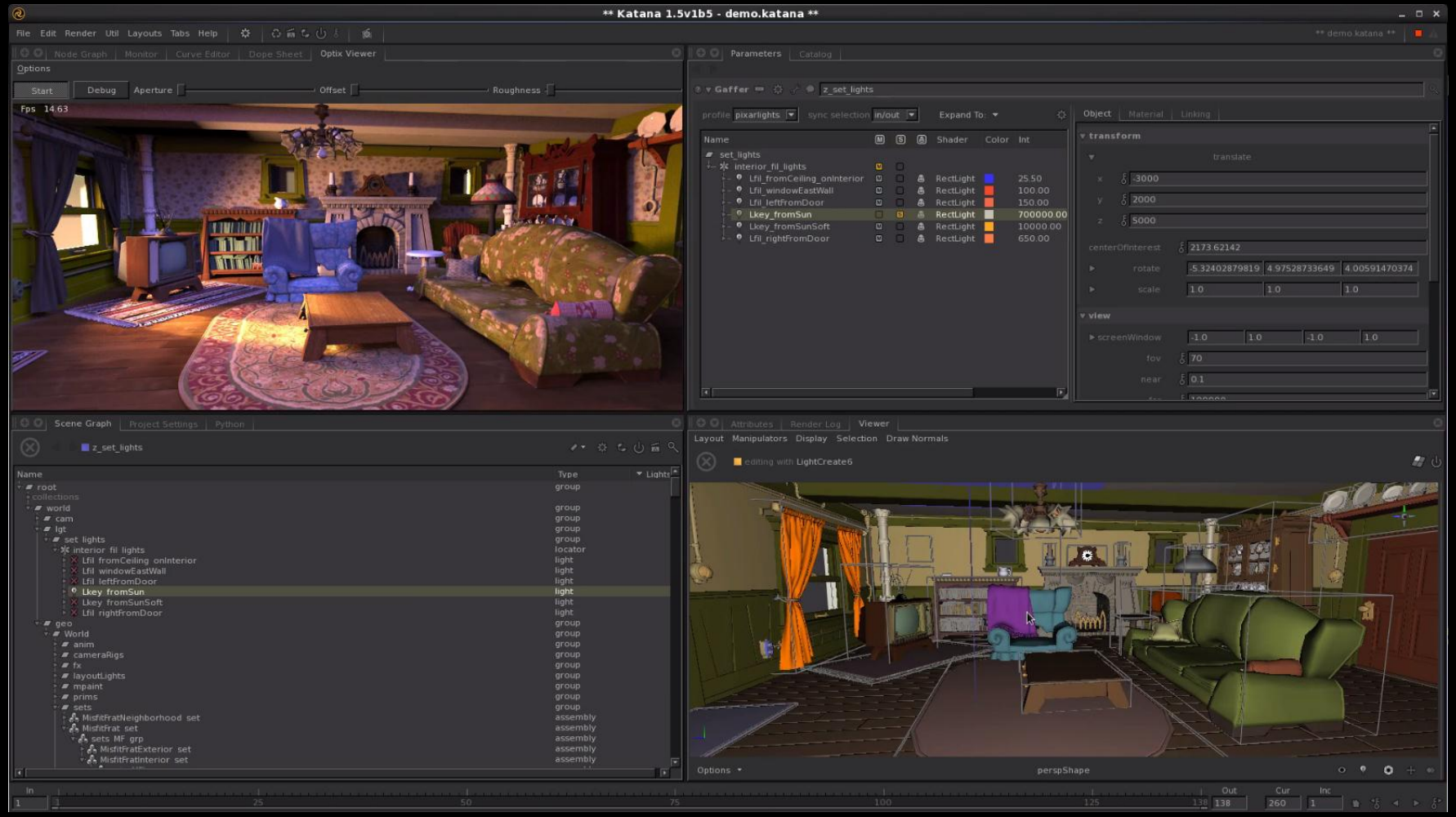
OptiX at Pixar Studios



OptiX at Pixar Studios

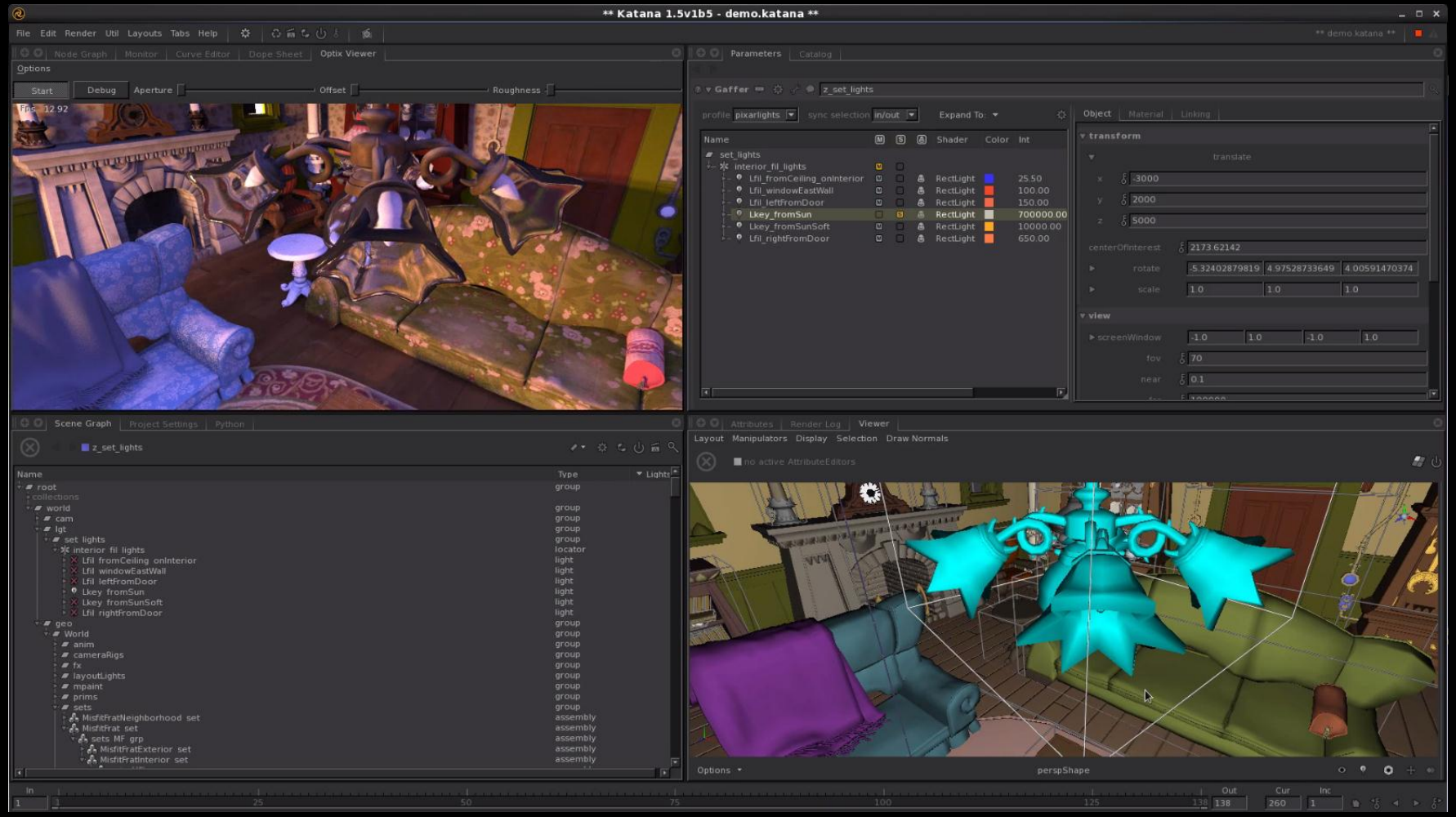


OptiX at Pixar Studios

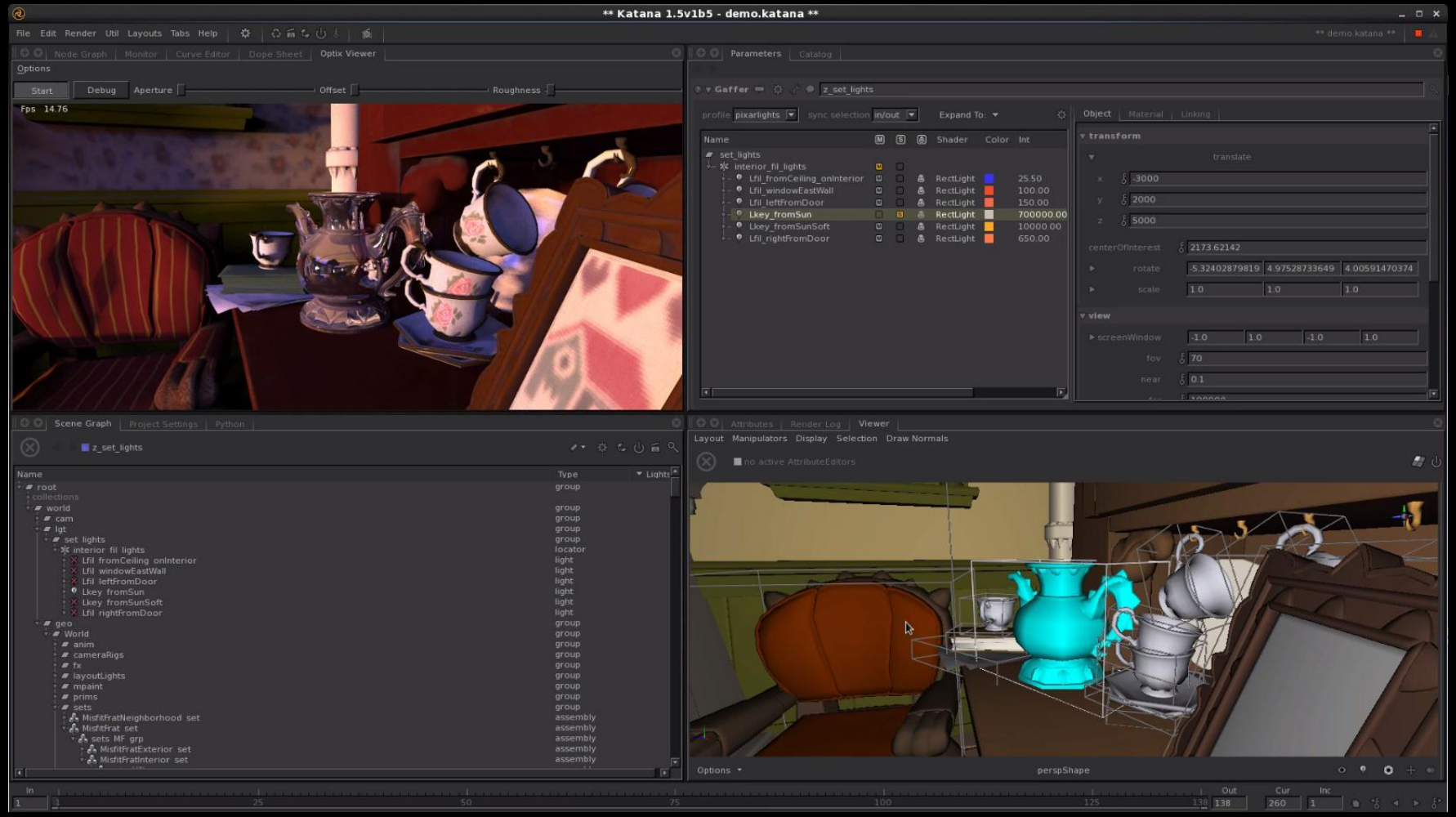


OptiX at Pixar Studios

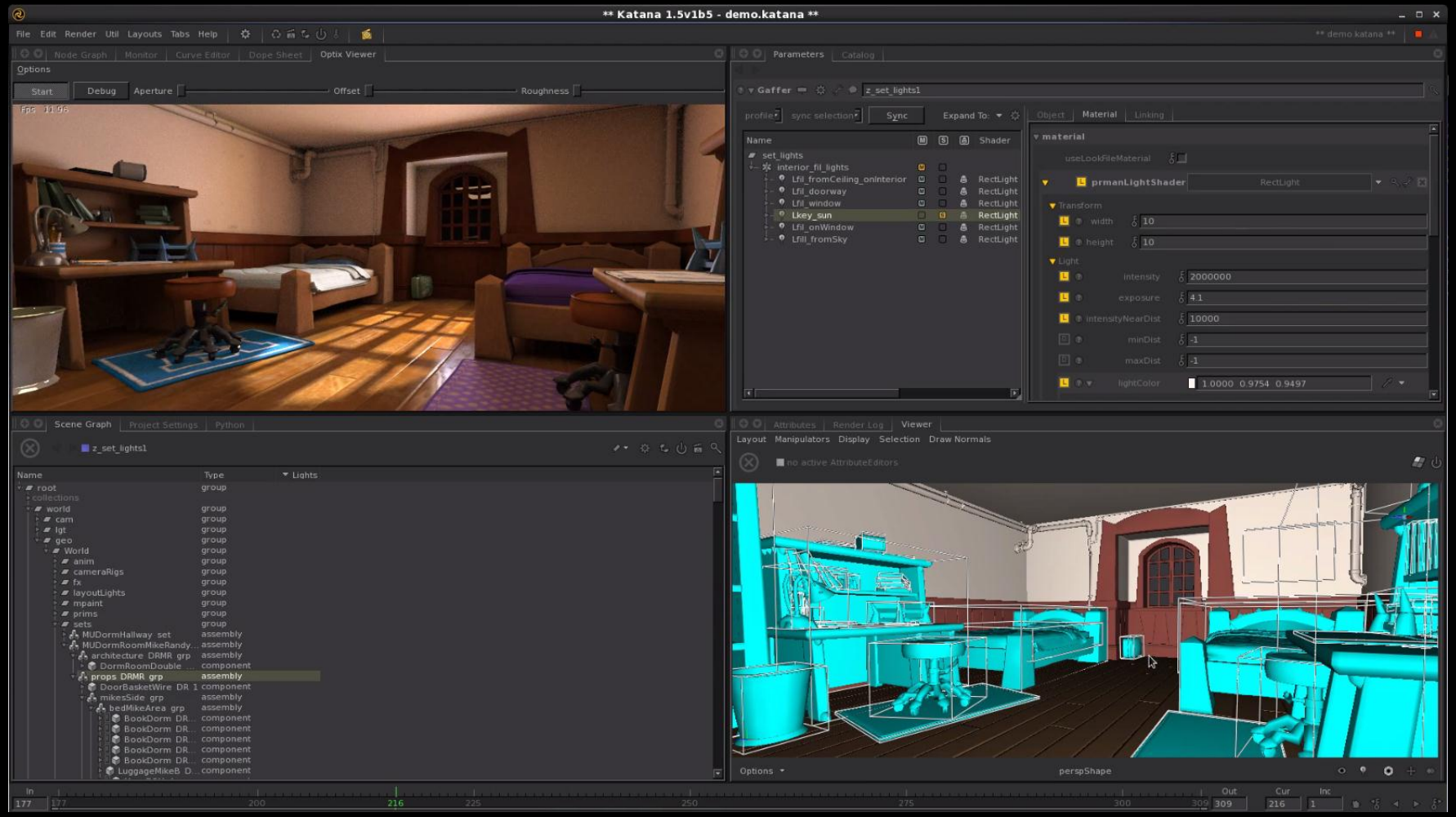
OptiX at Pixar Studios



OptiX at Pixar Studios

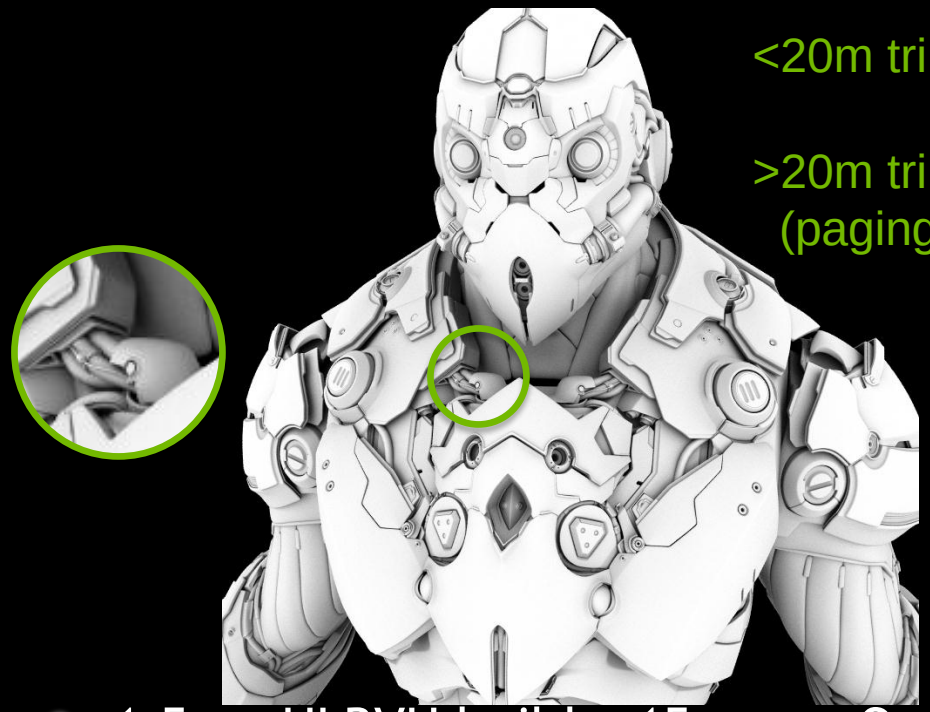


OptiX at Pixar Studios



OptiX in mental ray 3.11

- mental ray 3.11 ambient occlusion processing,
  now shipping in v2014 of Autodesk Maya, Softimage, and 3ds Max



<20m tri = **25– 70X** quadcore

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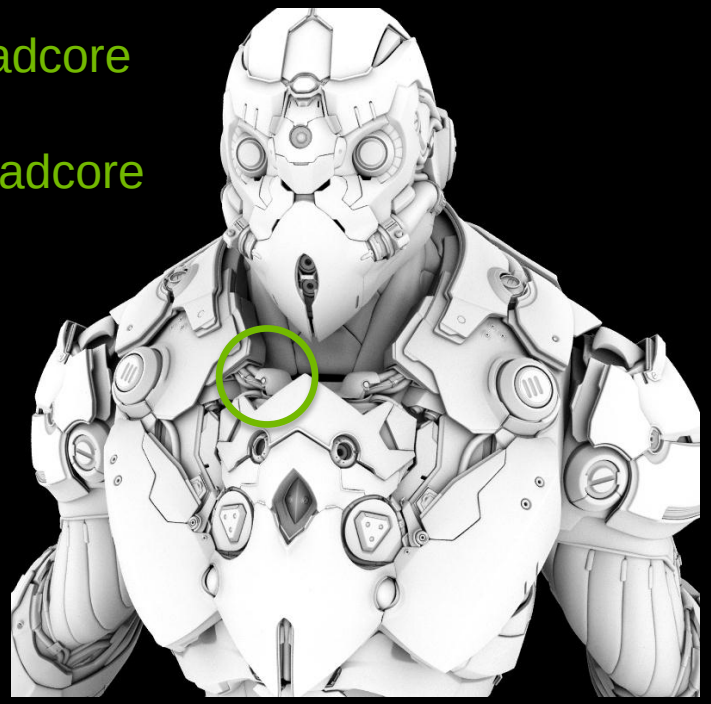
(paging)



- 1.5sec HLBVH build + 15sec on Quadro 6000 vs. 20 minutes on CPU

- **Plan of record is to increase GPU acceleration within mental ray each year**

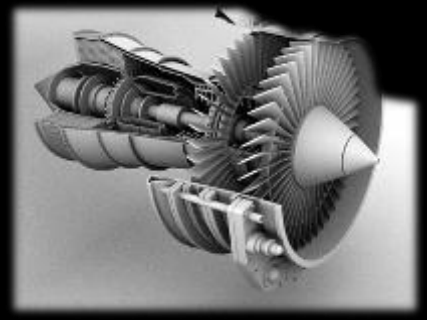
OptiX in Iray 2013

- Iray Photoreal
  - Interactive but “noisy”
  - The overall scene resolves in a couple of minutes

- Iray Interactive (on OptiX)
  - Interactive with minimal noise
  - The overall scene resolves in a couple of seconds

OptiX - Recent Advances

- Out of Core support (paging to system RAM)
- Optimized for CUDA 5 and NVVM (aka LLVM for CUDA)
- CUDA Interop – for sharing CUDA contexts and pointers
- Callable Programs – for shade trees, etc.
- Much faster Acceleration Structure building - up to 8X faster SBVH
- BVH refitting on all AS Builders
- GPU Direct for faster GL interop buffers
- Eliminated unnecessary compiles at run time



OptiX - Next Up

- Much faster Traversal API
  - As simple as ever to implement
  - a perfect pairing to wavefront approaches
- Faster building, high quality acceleration structures
- Details on this in David McAllister's following talk
- OptiX "higher tier"
  - An elevated offering bringing a higher level of support, samples and capabilities than is available in the base OptiX version

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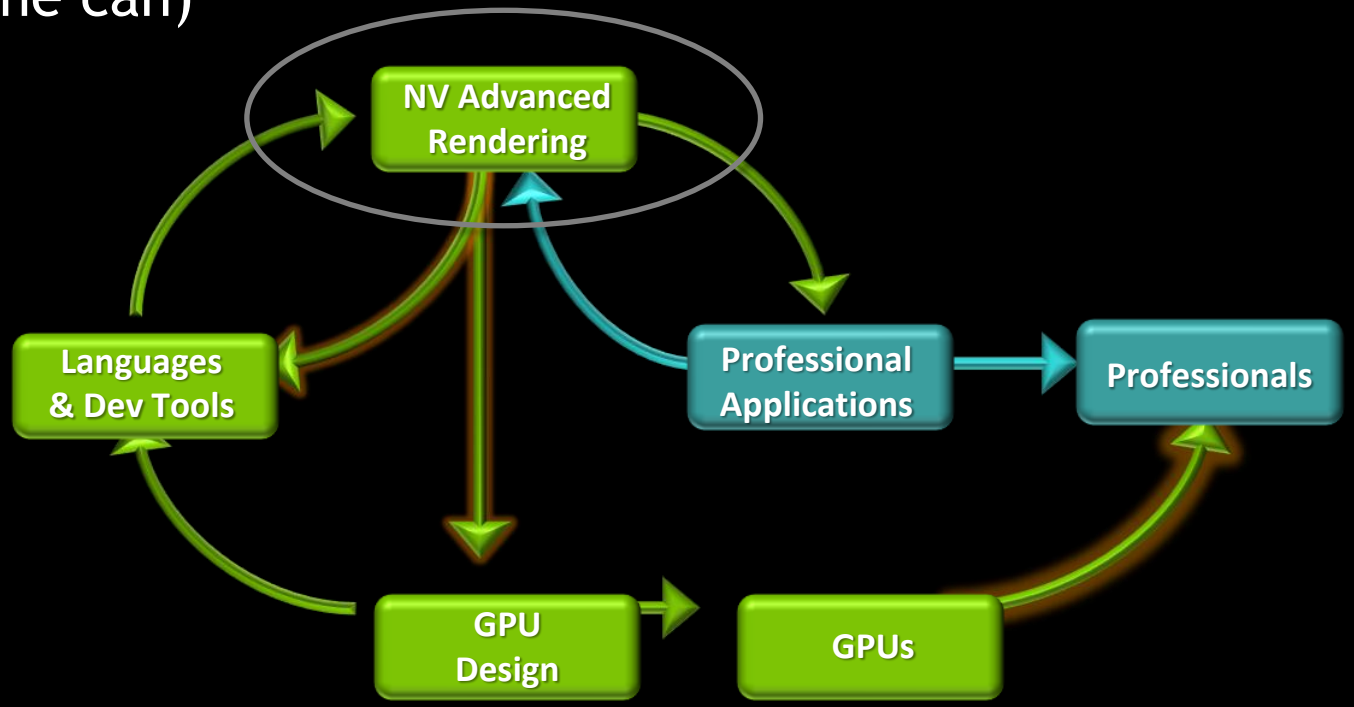
NVIDIA Iray

NVIDIA Commercial Rendering Offerings

- Solve meaningful rendering problems, while showing what's possible via GPUs
- Completes a vital Feedback Loop to rapidly influence NVIDIA (long before products alone can)



- Result: best of class solutions exploiting & influencing the full ecosystem

Iray – photorealism

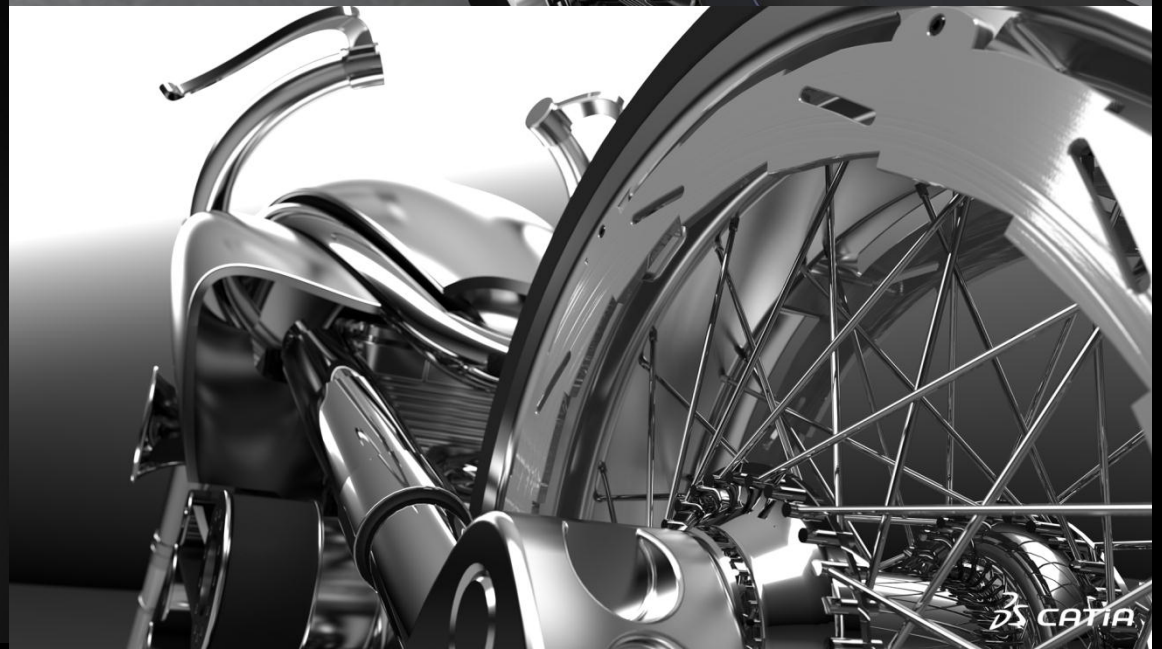
- Physically based rendering, resulting in a strong parallel to photography

Iray 2013 – in use

Iray 2013 - in use

Iray 2013 – in use

Iray 2013 - in use



Iray 2013 - in use

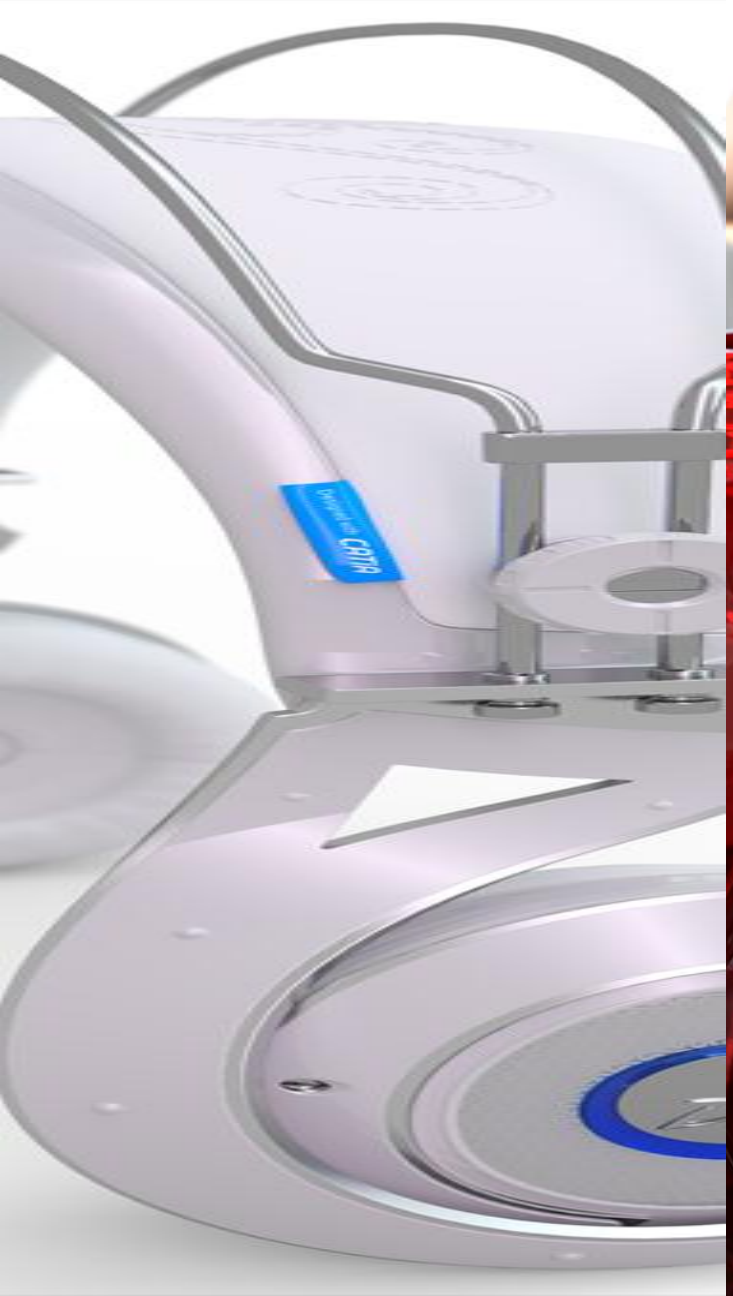
Iray 2013 - in use

Iray 2013 - in use

Iray 2013 - in use

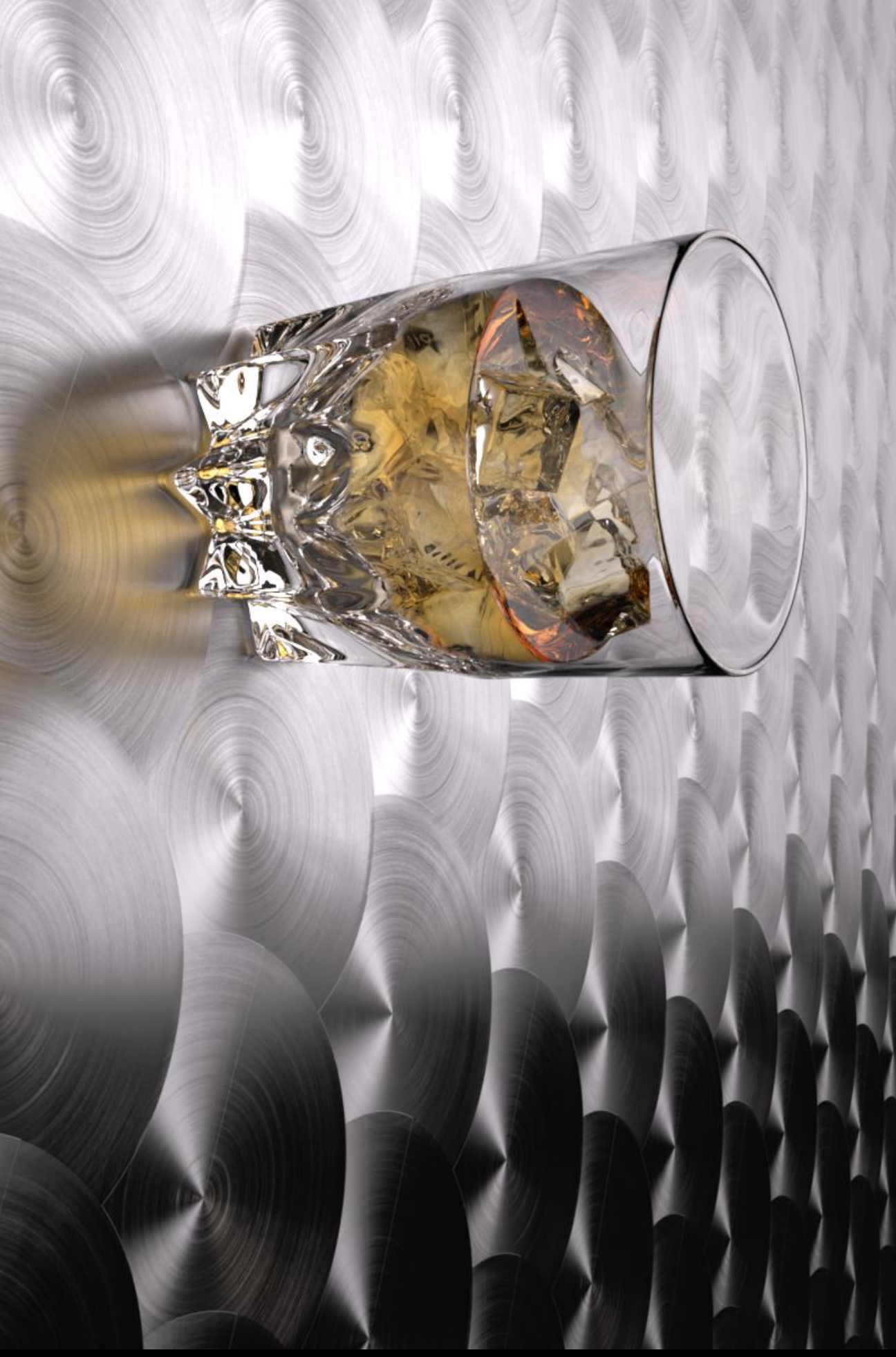

pininfarina
CATiA

Iray 2013 – in use



Iray 2013 - in use

Iray 2013 - in use

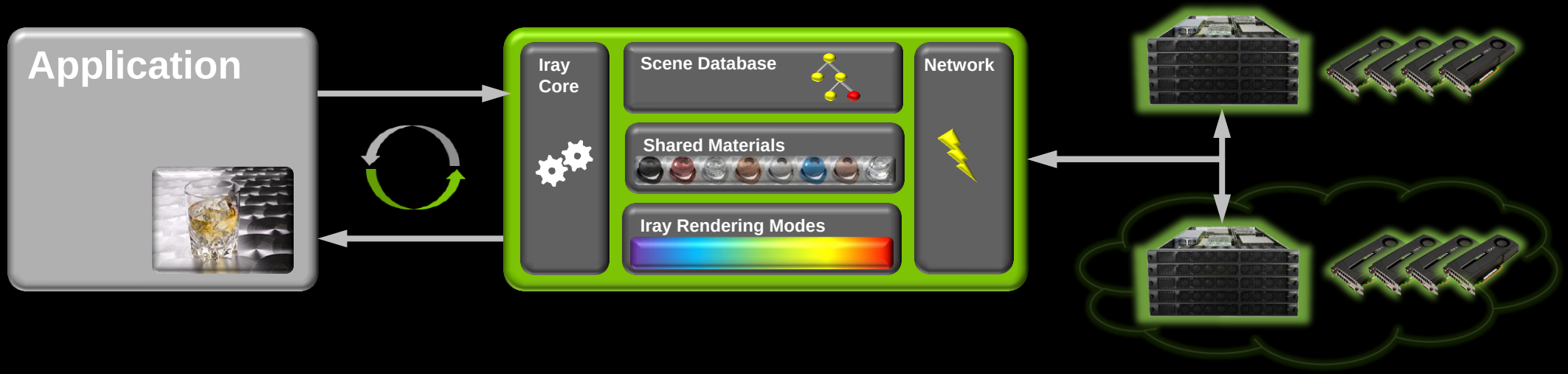


Iray 2013 – in use

Iray 2013 integrating into products now

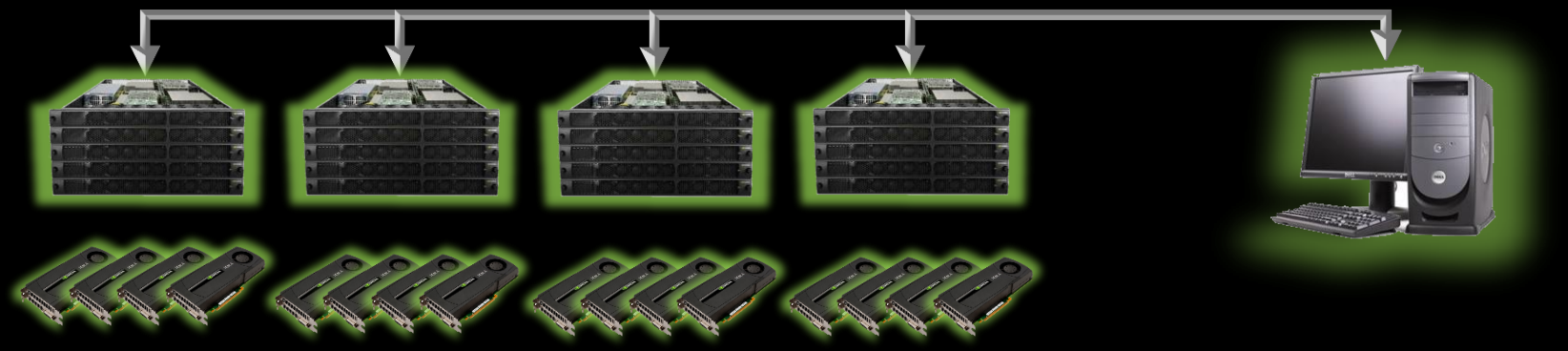
- For Software Developers wanting to add physically based rendering to their applications that is easy to use, highly interactive and scalable
- Now with render modes, shared materials, cluster management, and cloud rendering

- A rich API handshakes with Application manipulation for interactive updates



Iray Cluster

- Near linear scaling for production rendering
- Incremental updates rapidly propagate scene changes, giving full cluster processing after the scene change completes.
- Includes a cluster configuration front end for dynamically allocating networked resources.



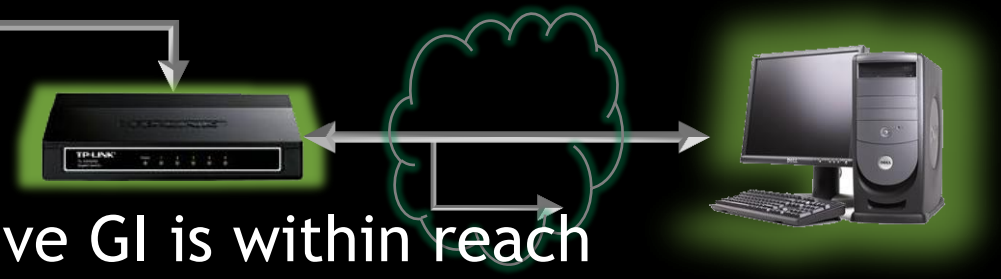
Iray Cloud

- Scalable rendering power on demand – for WAN
- Network protocols to handle private and public clouds (e.g., AWS)
- Assets are only ever sent once – for minimal upload times
- All edits are handled incrementally – for rapid updates
- Scene updates get faster the more you use it

Iray on Grid Tech Demo at SIGGGRAPH

NVIDIA GRID Appliances

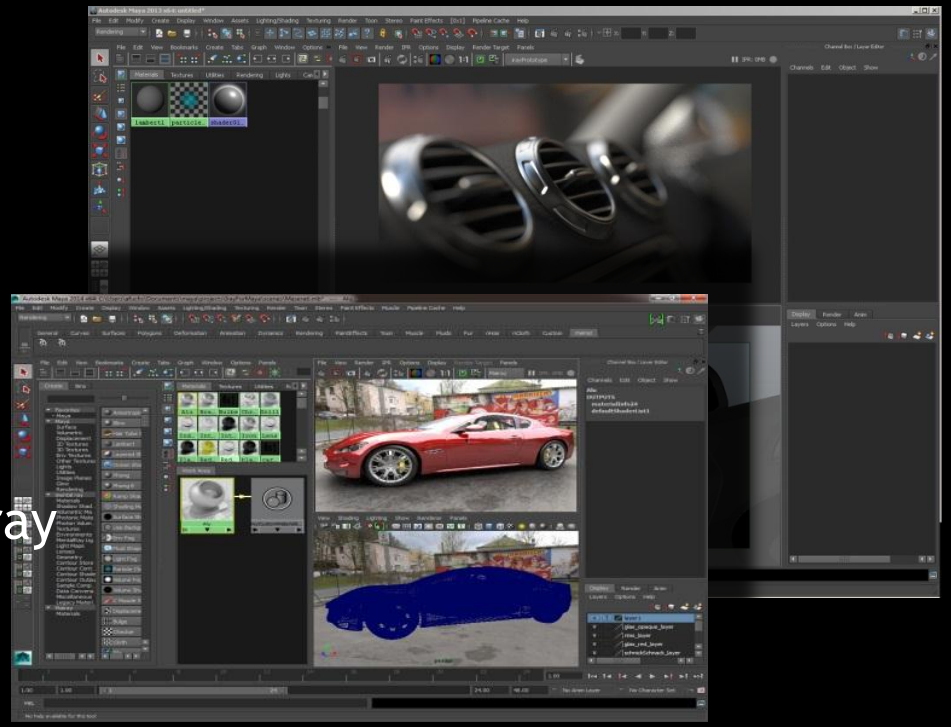
- Connecting to an offsite cluster of NVIDIA Grid Appliances using multiple partner applications
- Scaling Interactive Performance as well as Offline
  - Native InfiniBand support
  - Performance limited only by cluster size



- Noiseless, interactive GI is within reach
- Slated to be a commercial option for Iray 2014

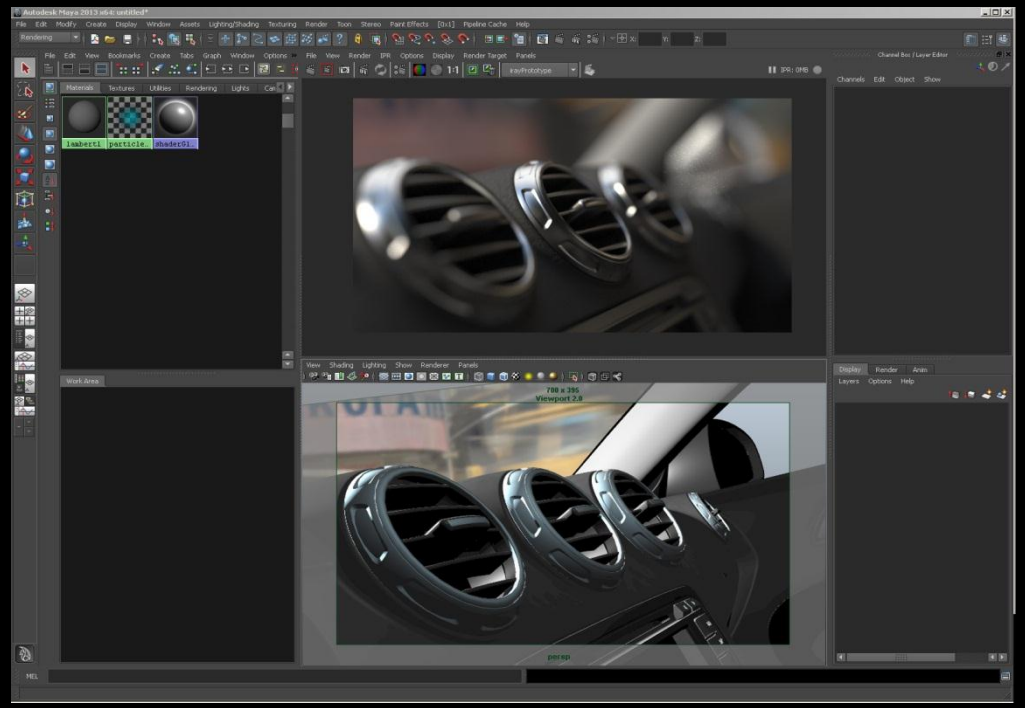
Debuting at SIGGRAPH: Iray® for Autodesk Maya®

- Coming from 0X1 Software later this year
  |
- Fully integrated Iray 2013
  - Extremely Interactive
  - Extremely Scalable
  - Latest Material Possibilities
  - Designed to work hand in hand with mental ray for the widest range of production needs



- Contact chris@0x1-software.com to apply for private Beta

Iray for Maya - sneak peek



Fully integrated Iray 2013

- Fully integrated Iray 2013
  - Extremely Interactive
  - Extremely Scalable
  - Latest Material Possibilities
- Shipping later this year

contact: : chris@0x1-software.com

Iray 2013 = Render Modes

- Multiple rendering modes, provide a quality/speed continuum

Iray Realtime	Iray Interactive	Iray Photoreal
120 FPS ⟷ 15 FPS*	20 FPS ⟷ 0.5 FPS	10 FPS ⟷ Minutes
Stereo Game Title Quality	Accurate Reflections Accurate Shadows	Degraded Simplified
Multi-Pass Effects Raster AO Soft Shadows, etc.	Soft Shadows Glossy Reflections Multi-Bounce Diffuse, etc.	Uncompromised Quality Increased Flexibility
Strength: Very High Resolutions	No / Little Noise while Interacting	Physically Based
Weakness: Physically Approximate	Physically Plausible	Noisy while Resolving

- API calls for which mode to use, with what features, what to do on mouse-up, etc. enable applications to have custom personalities for behavior and look
- Shipping now as part of Bunkspeed 2014 products

Iray 2013 Rendering Modes

- Iray Photoreal
  - Interactive but “noisy”
  - The overall scene resolves in a couple of minutes

- Iray Interactive
  - Interactive with minimal noise
  - Shadows, glossiness and AA resolve in a couple of seconds
  - Can be made faster with lower quality settings

Iray Photoreal in a few minutes

Iray Interactive in a few seconds

Making Modes Seamless – Shared Materials

- Physically Based for accuracy (BSDF)
- Layered for great flexibility
- Consistent appearance across modes
- Designed to accommodate measured data

MDL – Material Description Language

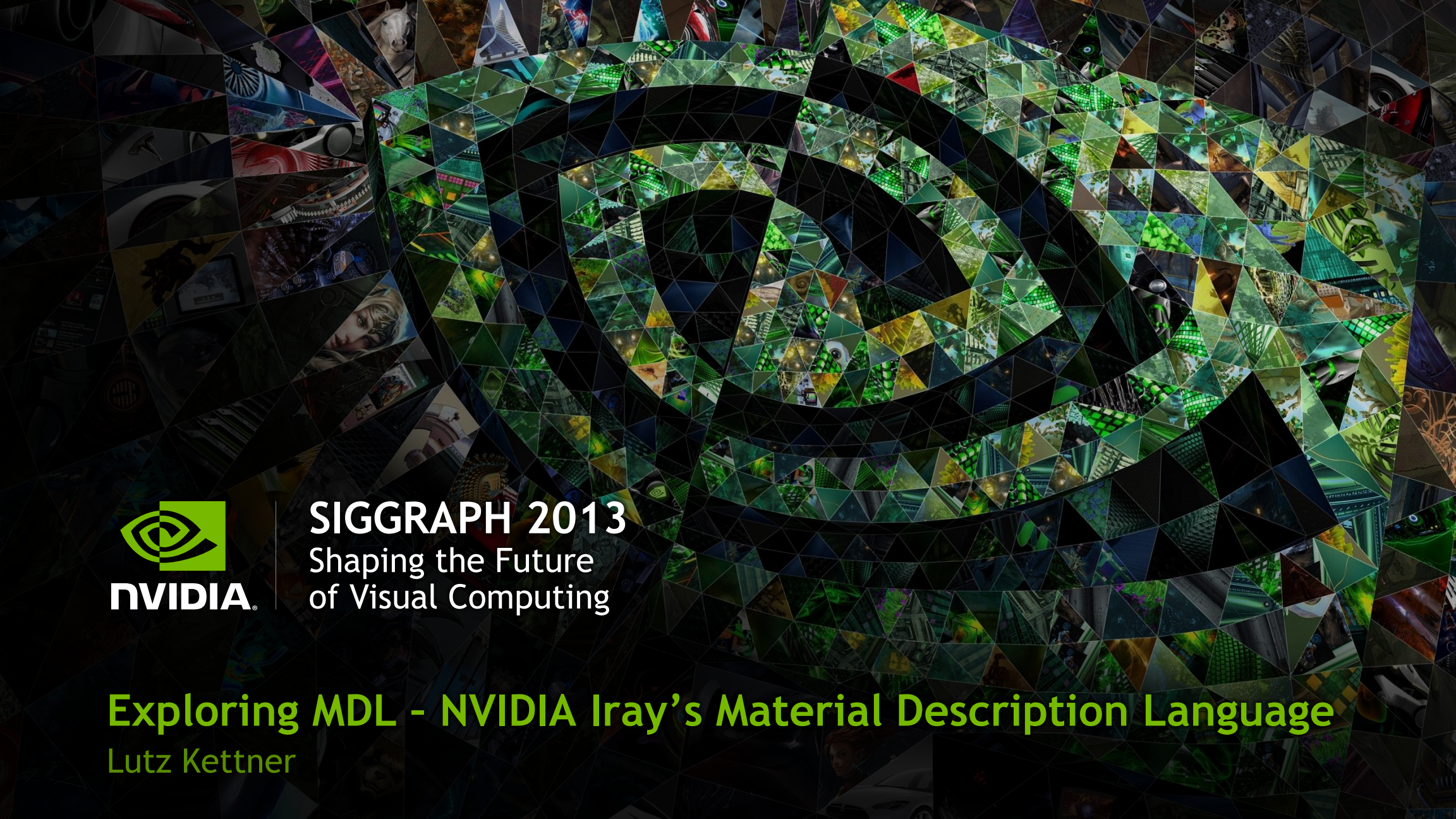
NOT a shading language, but a canonical representation which renderers can target as they see fit

For material artists:

- Easy to parse and understand
- No algorithmic knowledge required
- Parameters easily exposed

For end users:

- Assign and edit parameters at will



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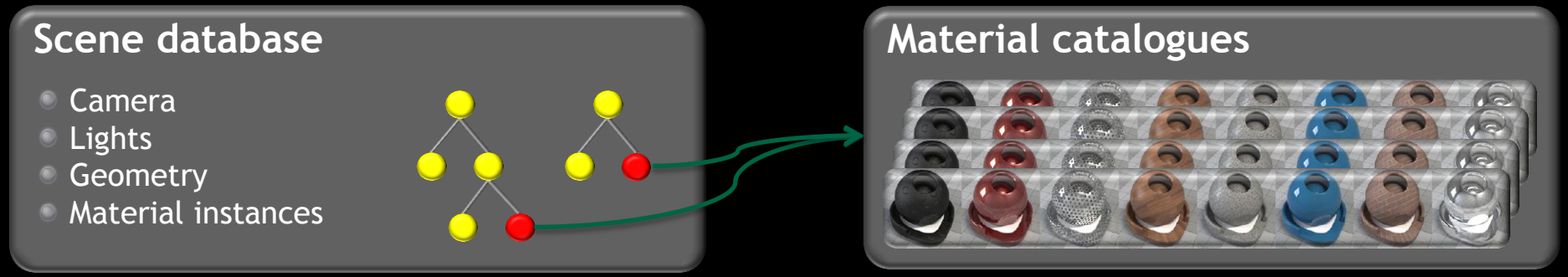
Exploring MDL – NVIDIA Iray's Material Description Language

Lutz Kettner

NVIDIA Iray 2013 - Rendering Modes

Iray Realtime	Iray Interactive	Iray Photoreal
120 FPS ⟷ 15 FPS	20 FPS ⟷ 2 FPS	10 FPS ⟷ Minutes

Goal:
Share Scene Database & Material Description
for a consistent look



Traditional Shading Language Elements

Texturing

- Texture lookups
- Procedurals
- uv-transforms
- Projectors
- Noise functions
- Math functions
- Render state

Material Definition

- Glossy reflection
- Transparency
- Translucency

Material Implementation

- Light loops / Trace N rays
- OIT / ray-continuation
- Ray-marching

MDL

Procedural Programming Language

- Texture lookups
- Procedurals
- uv-transforms
- Projectors
- Noise functions
- Math functions
- Render State

Declarative Material Definition

- Glossy reflection
- Transparency
- Translucency

Renderer

Rasterizer

- Light loops
- OIT

Ray Tracer

- Trace N rays

Path Tracer

- Ray-marching

MDL is Not a Shading Language

- MDL defines what to compute, ***not*** how to compute it
  - no programmable shading
  - no light loops or access to illumination
  - no trace call
  - no sampling
  - no camera dependence

MDL Key Features

- Hierarchical layered material model from NVIDIA Iray
  - More fine grain control than material layering alone
  - Simple elemental building blocks, no monolithic “uber-shader”
  - Easy ways of combining building blocks
    - layering – mixing – modification
    - truly hierarchical: combined parts can be used in further combinations
  - Examples:
    - *two materials plus a selection mask to model tile & grout patterns or mud splats on car paint*
    - *a complex glossy reflection lobe built from a mix of simple lobes as a building block for complex layered materials*

MDL Key Features

- Declarative material definition with physically-based material model
  - Easy-to-use paradigm
  - Independence from rendering algorithms
  - Support for modern rendering algorithms: path tracers, MIS, …
  - Material structure is known without executing any function
  - Early optimizations and simpler compiler

MDL Key Features

- Parameterized material definitions
  - Enables flexible, custom-built and domain-specific material catalogues
  - Material re-use and customization
- Module and package system
  - Supports packaging and distribution of material catalogues
- Pure, side-effect free functions and read-only render state
  - Support for highly parallel execution models

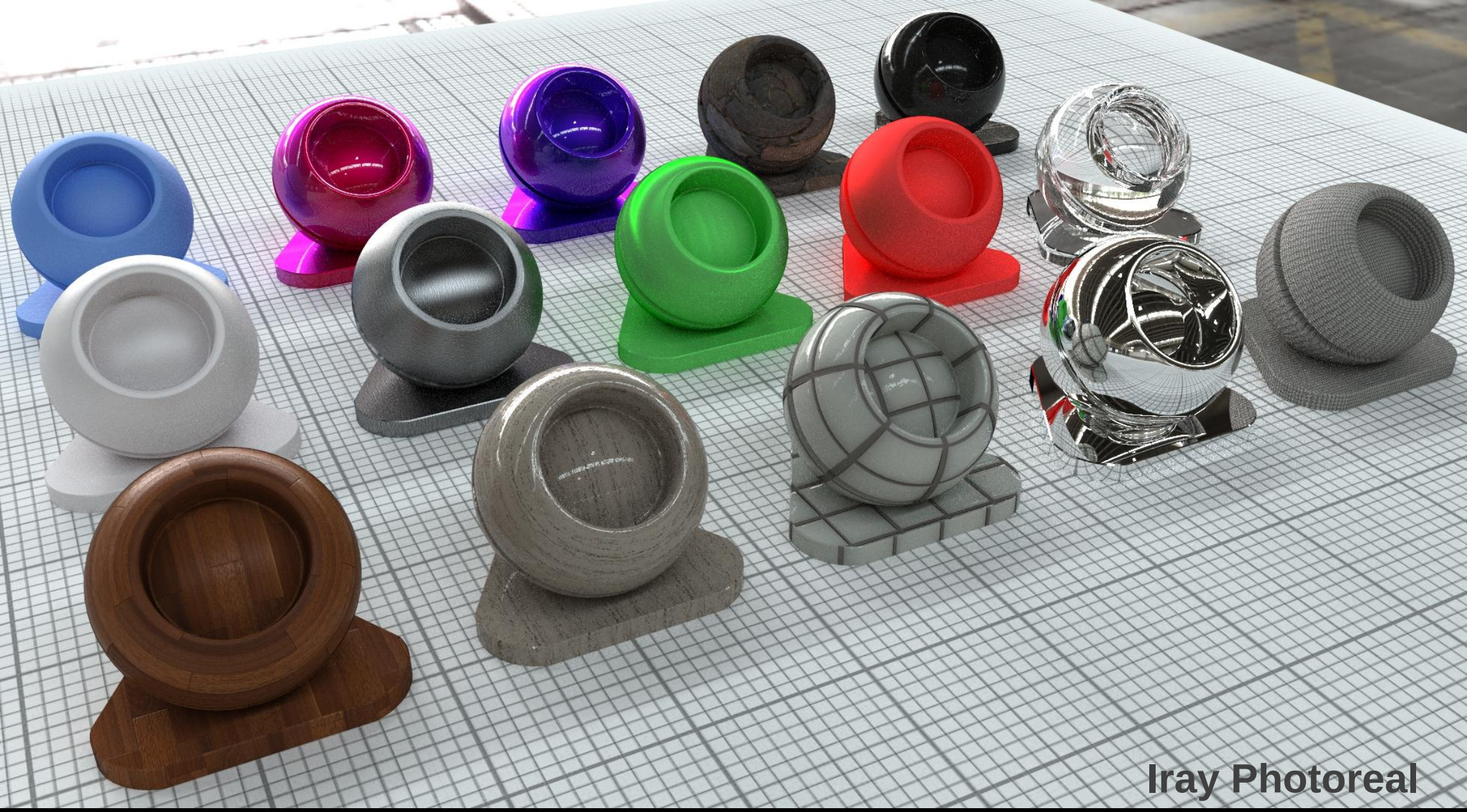
Example

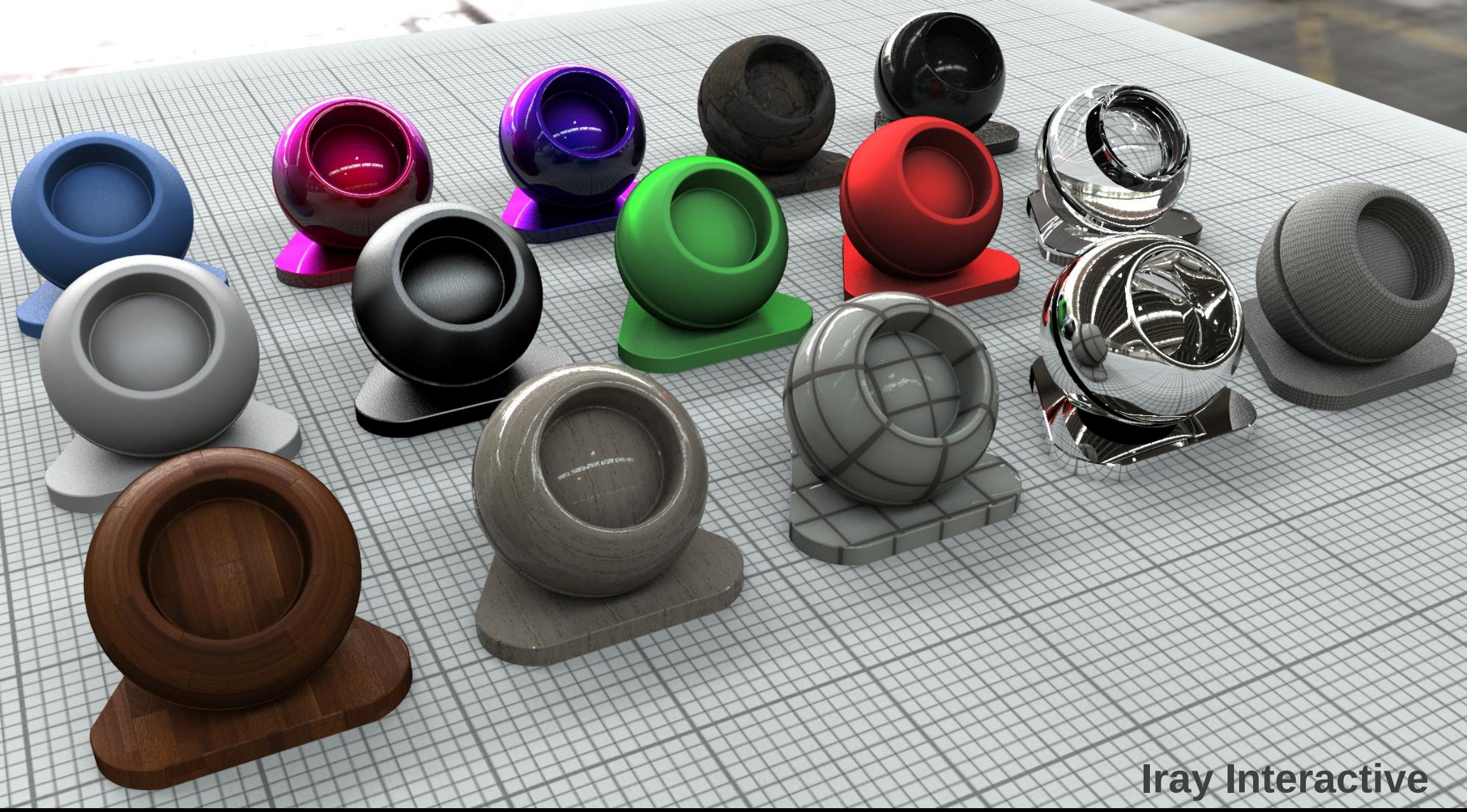
Consistency of MDL materials across
NVIDIA Iray Rendering Modes

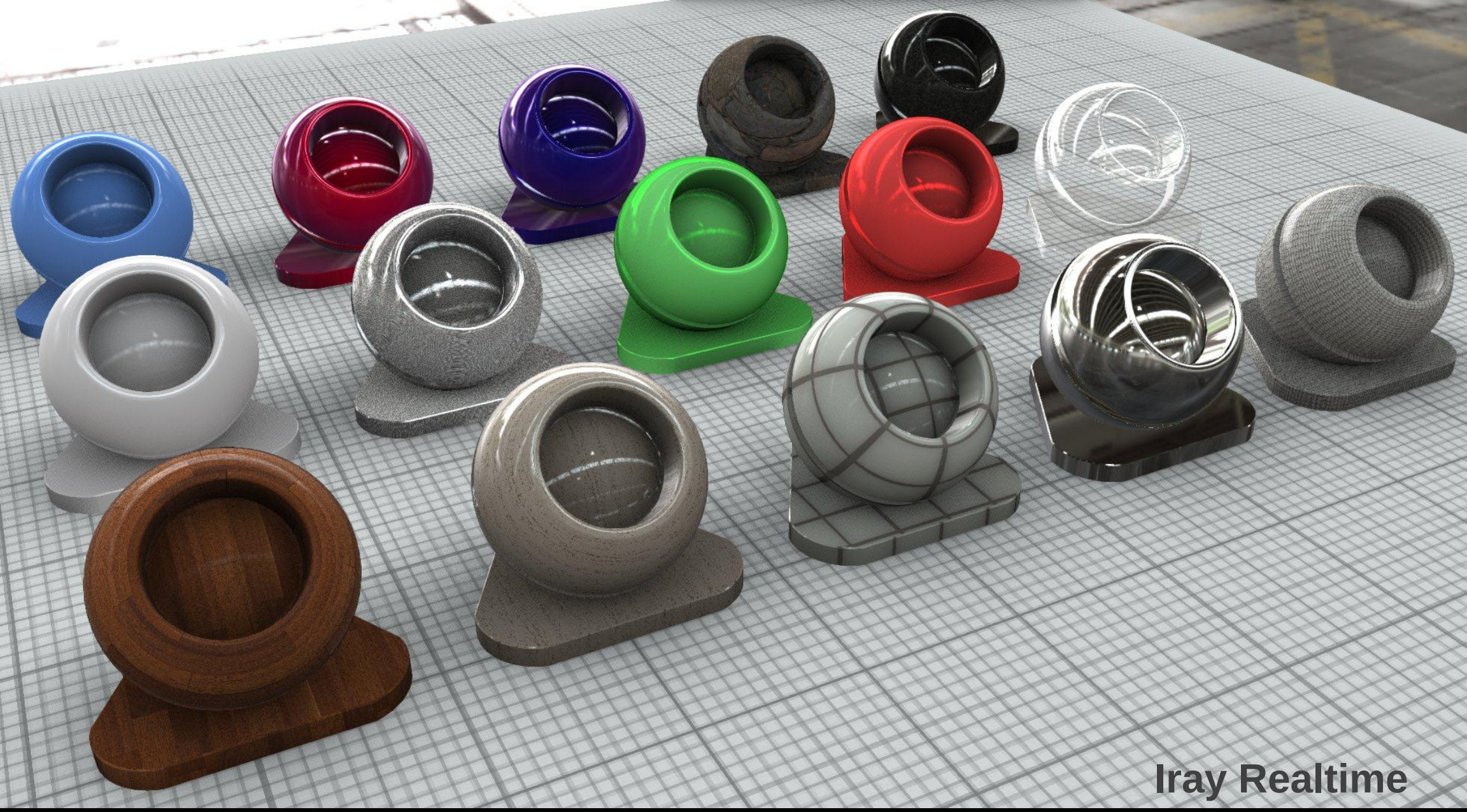
Iray Photoreal


B MI 2011
Iray Interactive


B MI 2011
Iray Realtime


Iray Photoreal


Iray Interactive

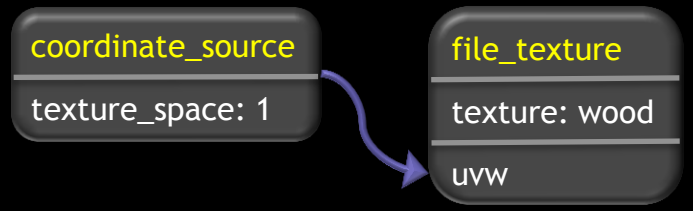

Iray Realtime

MDL Material Model

- Physically based
  - Bidirectional Scattering Distribution Functions (BSDF)
    - specular – glossy – diffuse
    - reflective – refractive
  - Emissive Distribution Functions (EDF)
  - Volume Distribution Functions (VDF)
- Hierarchical layered material model from NVIDIA Iray
  - Elemental building blocks – modifiers – layering operators
- Comprehensive texturing functionality
  - Scores of built-in functions provide a flexible instruction set for runtime execution (in NVIDIA Iray 2013, etc.)
  - Full programmability in the future – without losing GPU acceleration

Procedural Programming Language

- Pure side-effect free functions with read-only render state
- Function results feed into material and function parameters
- “Shader graphs” are equivalent to function call graphs

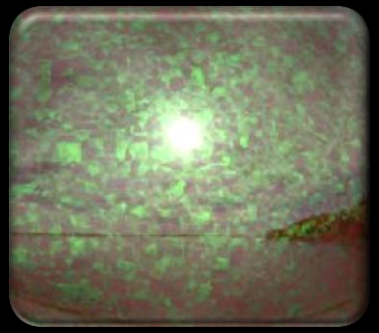


←→ file_texture(texture: wood,
uvw: coordinate_source(texture_space: 1))

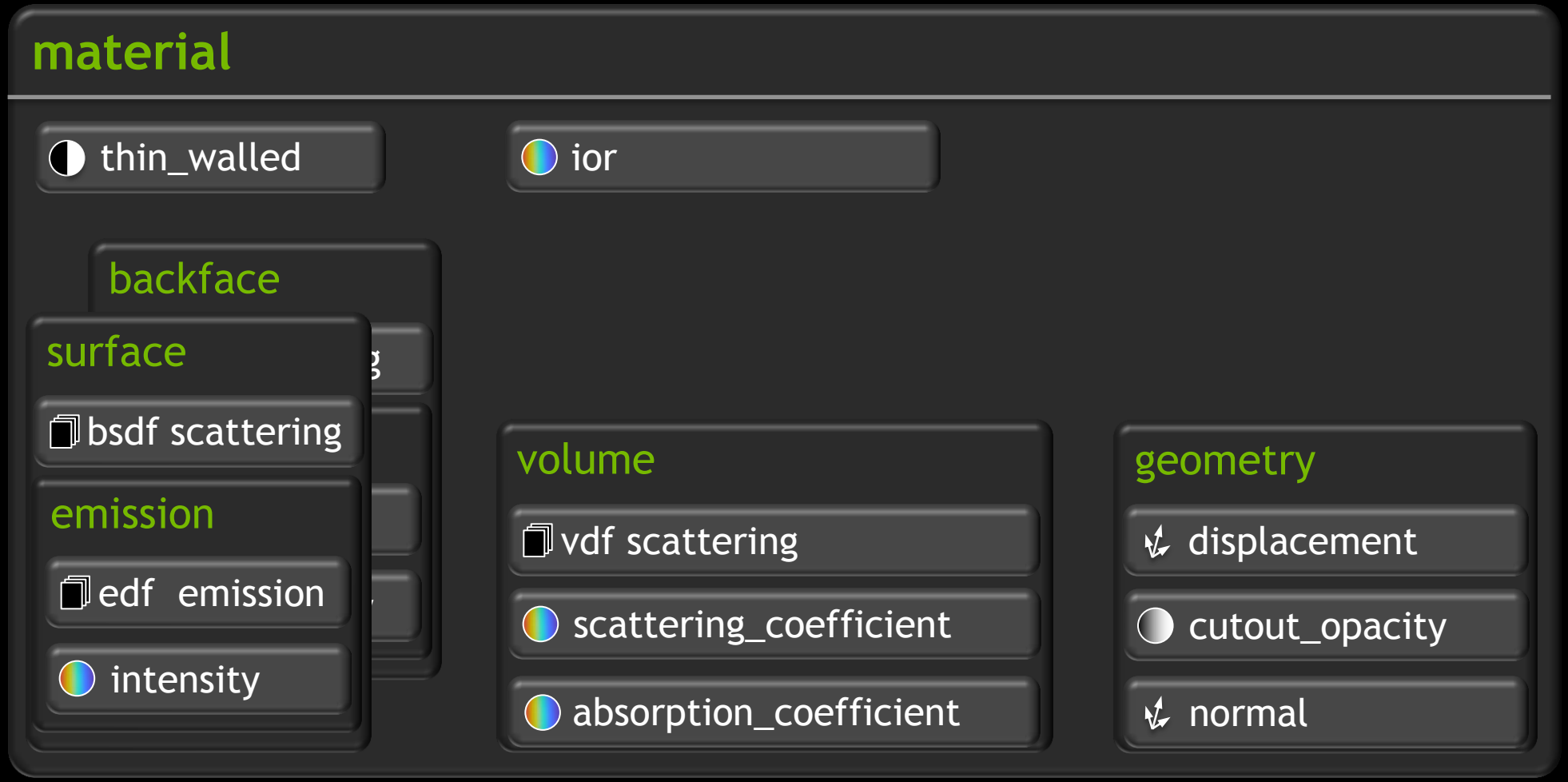
Texture lookup

Texture placement

Procedural textures



MDL Material Model



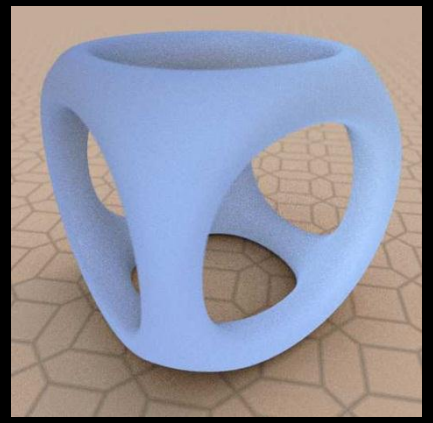
Elemental Distribution Functions

Bidirectional Scattering Distribution Functions (BSDF)

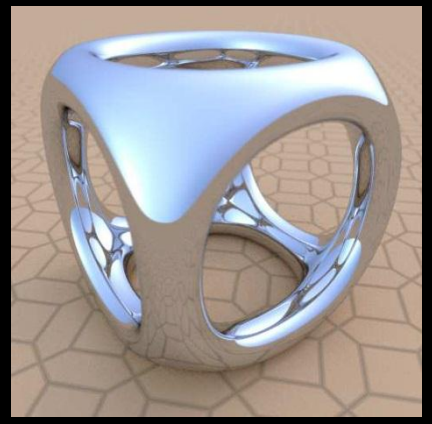
Diffuse Reflection

Diffuse Transmission

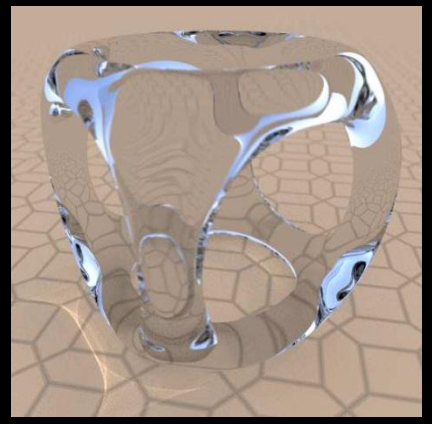
Simple Glossy



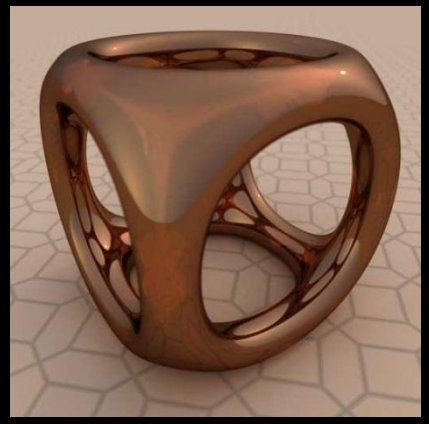
Backscattering Glossy



Specular
Pure Reflection



Specular Reflection
& Transmission

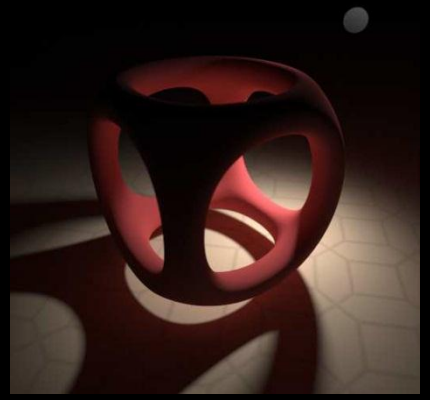


Specular Reflection
& Transmission

Elemental Distribution Functions

Emissive Distribution Functions (EDF)

Diffuse



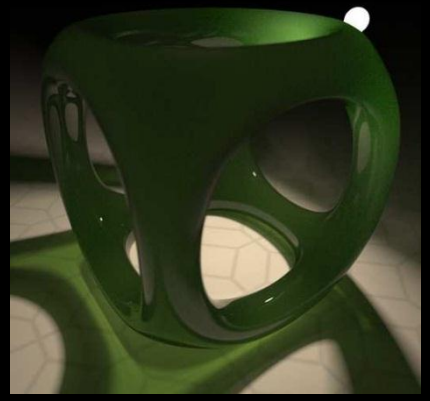
Spot

IES Profile

Volume Distribution Functions (VDF)

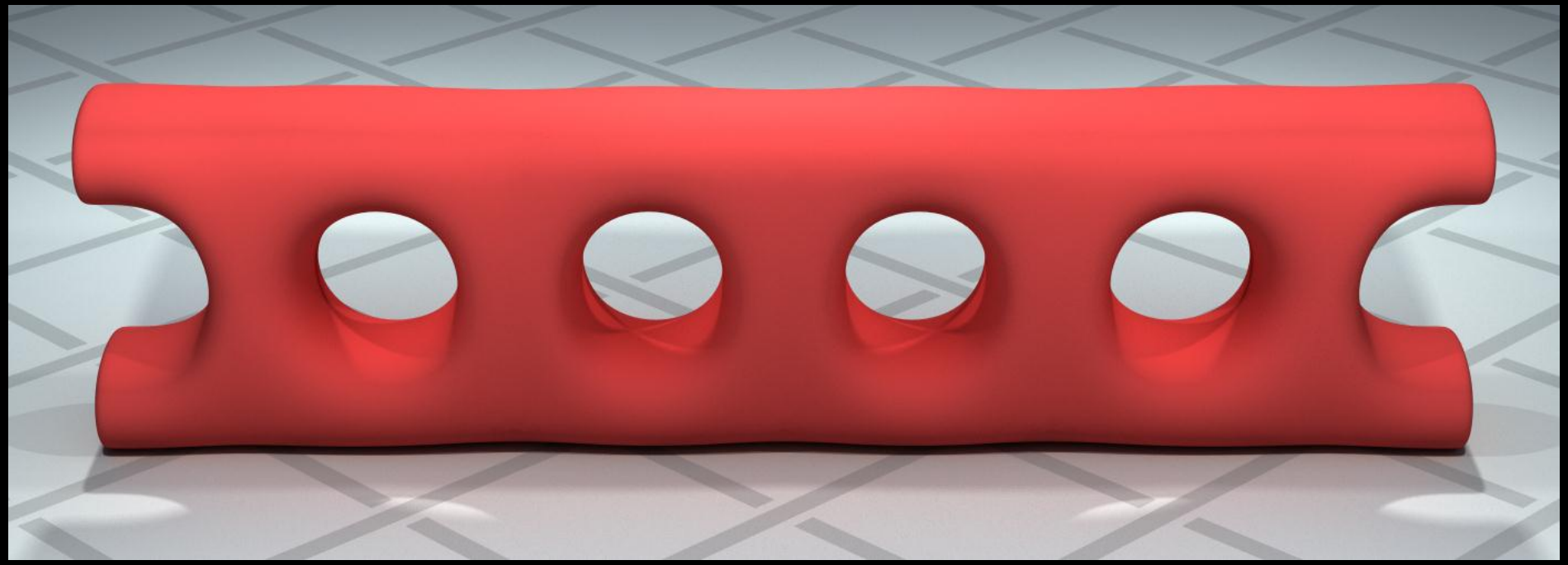
Anisotropic
Absorption & SSS

Anisotropic + IOR
& Internal Scattering



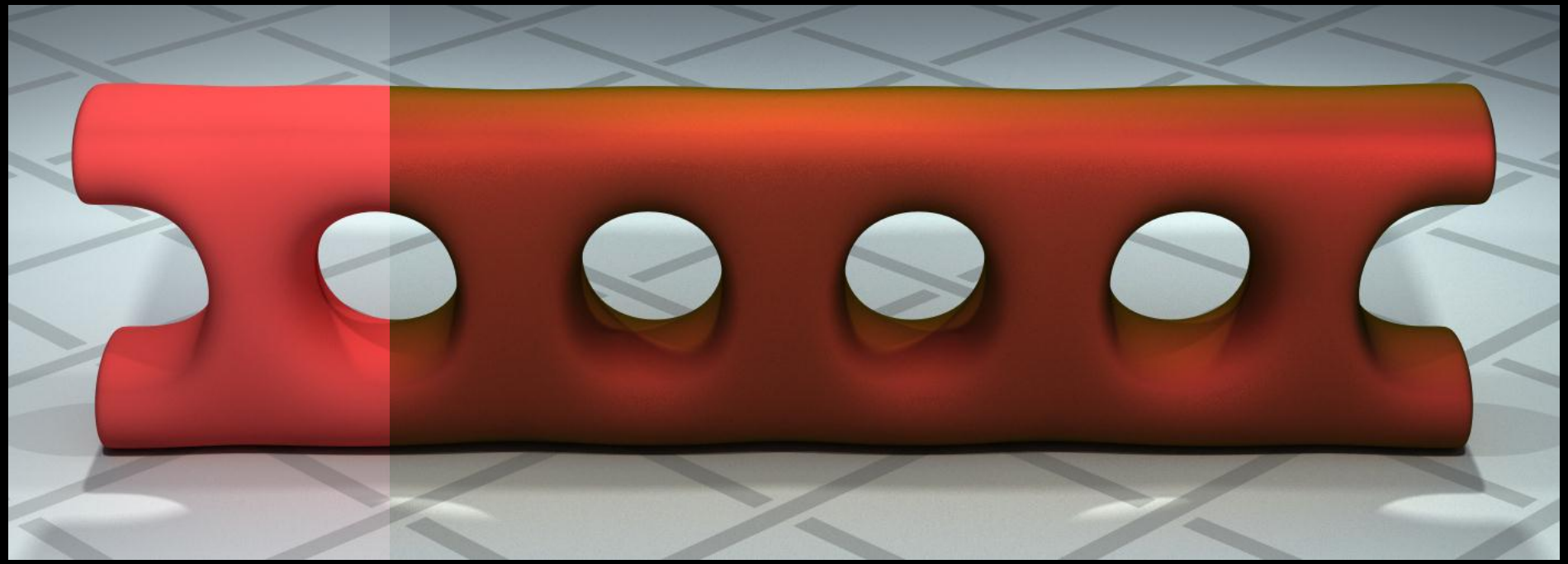
Anisotropic
w/ Light

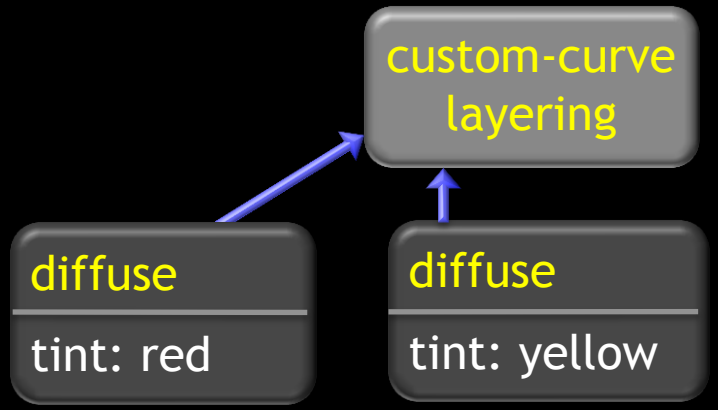
Layered Material Example

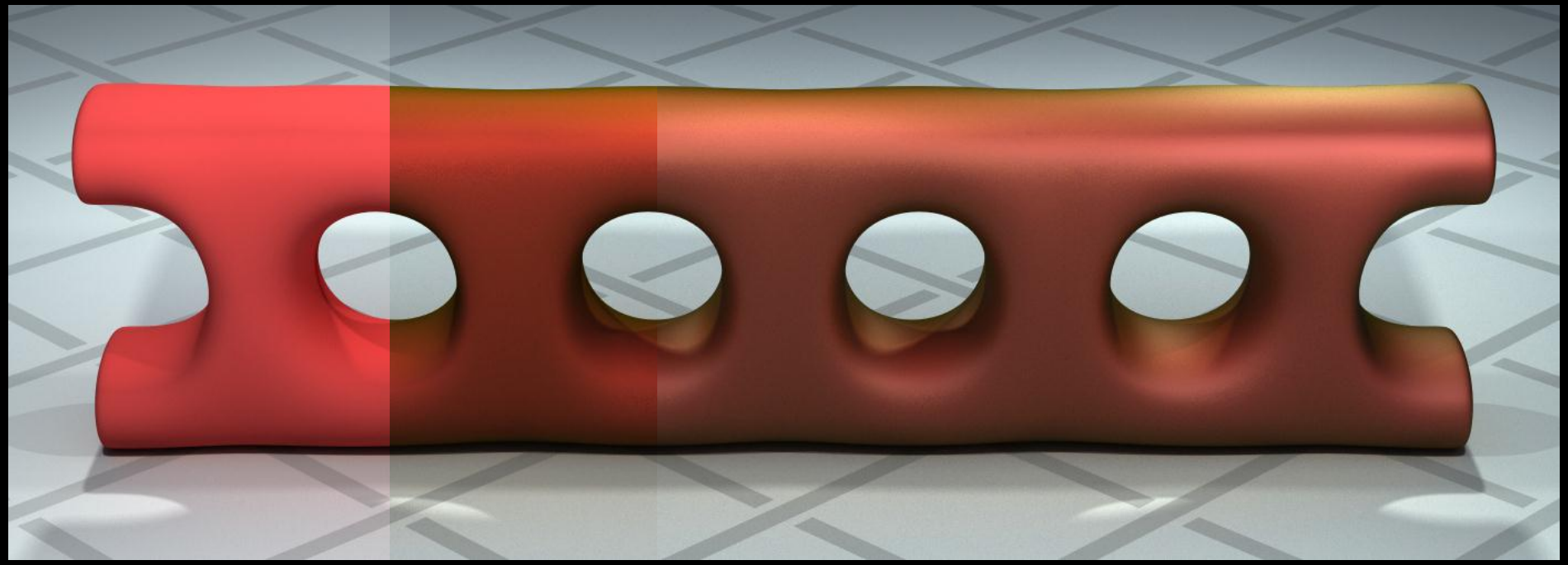


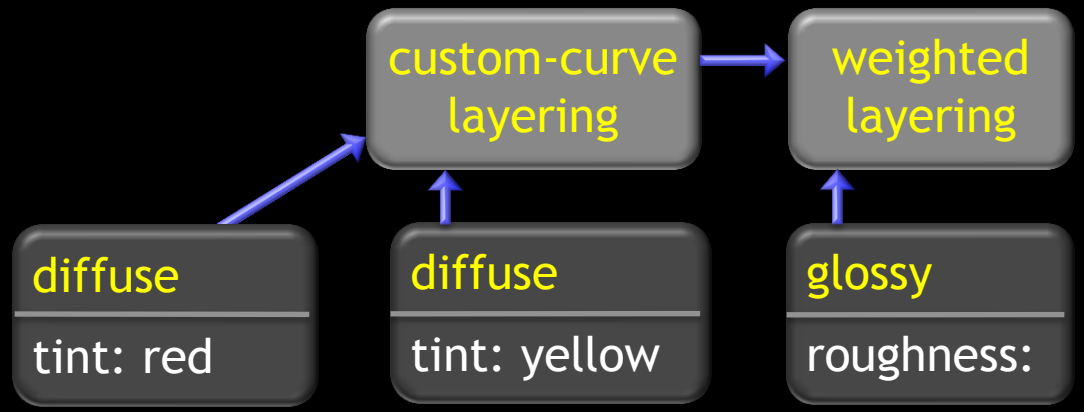
diffuse

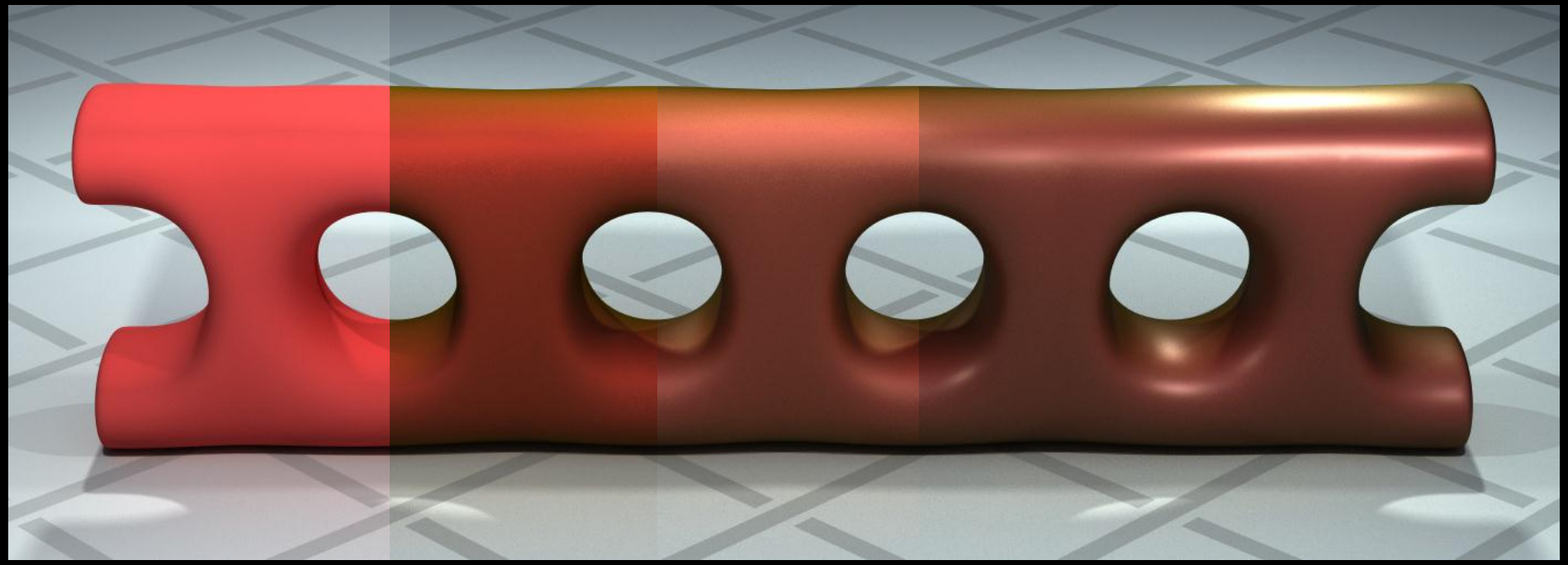
tint: red

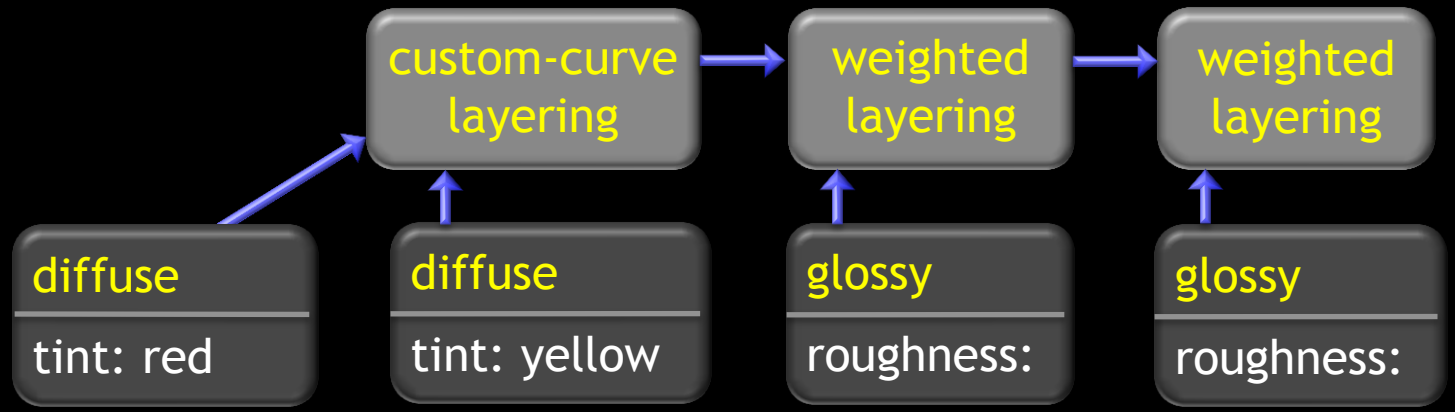


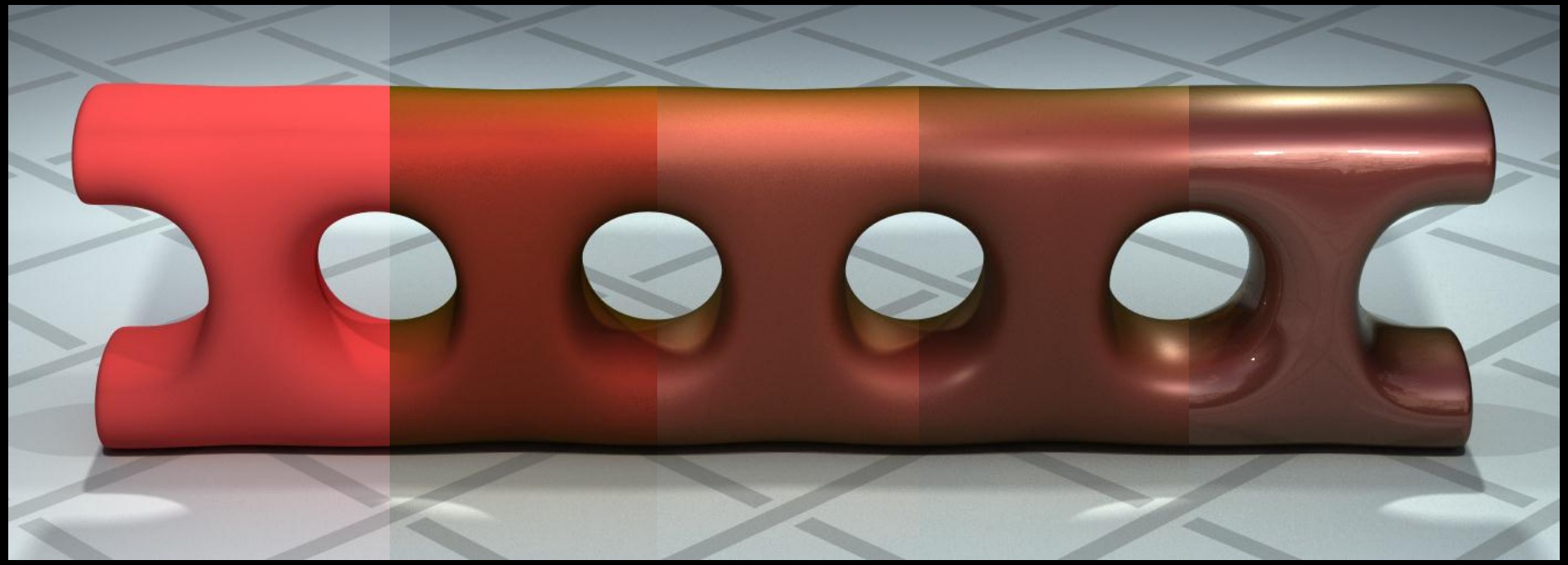

custom-curve layering
diffuse
tint: red
diffuse
tint: yellow

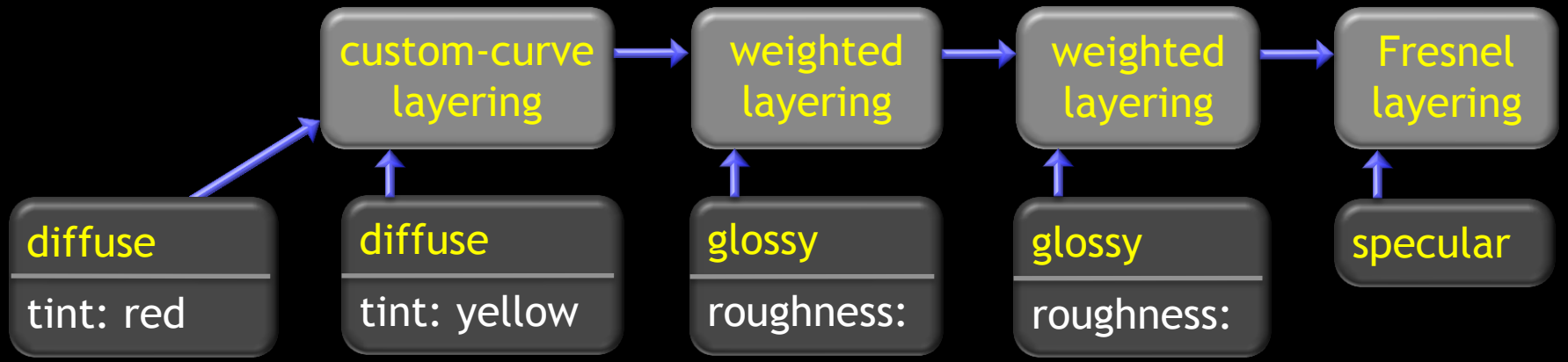



custom-curve layering
weighted layering
diffuse
tint: red
diffuse
tint: yellow
glossy
roughness:



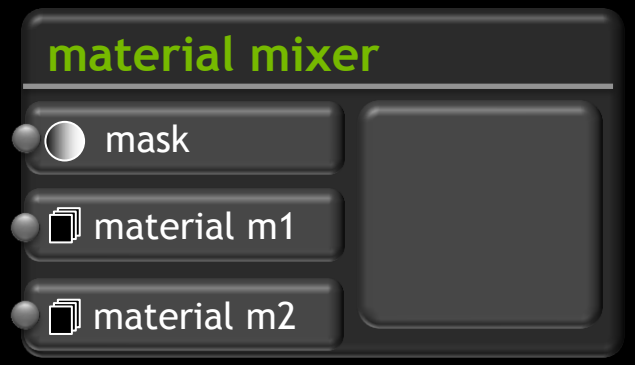

custom-curve layering
weighted layering
weighted layering
diffuse
tint: red
diffuse
tint: yellow
glossy
roughness:
glossy
roughness:



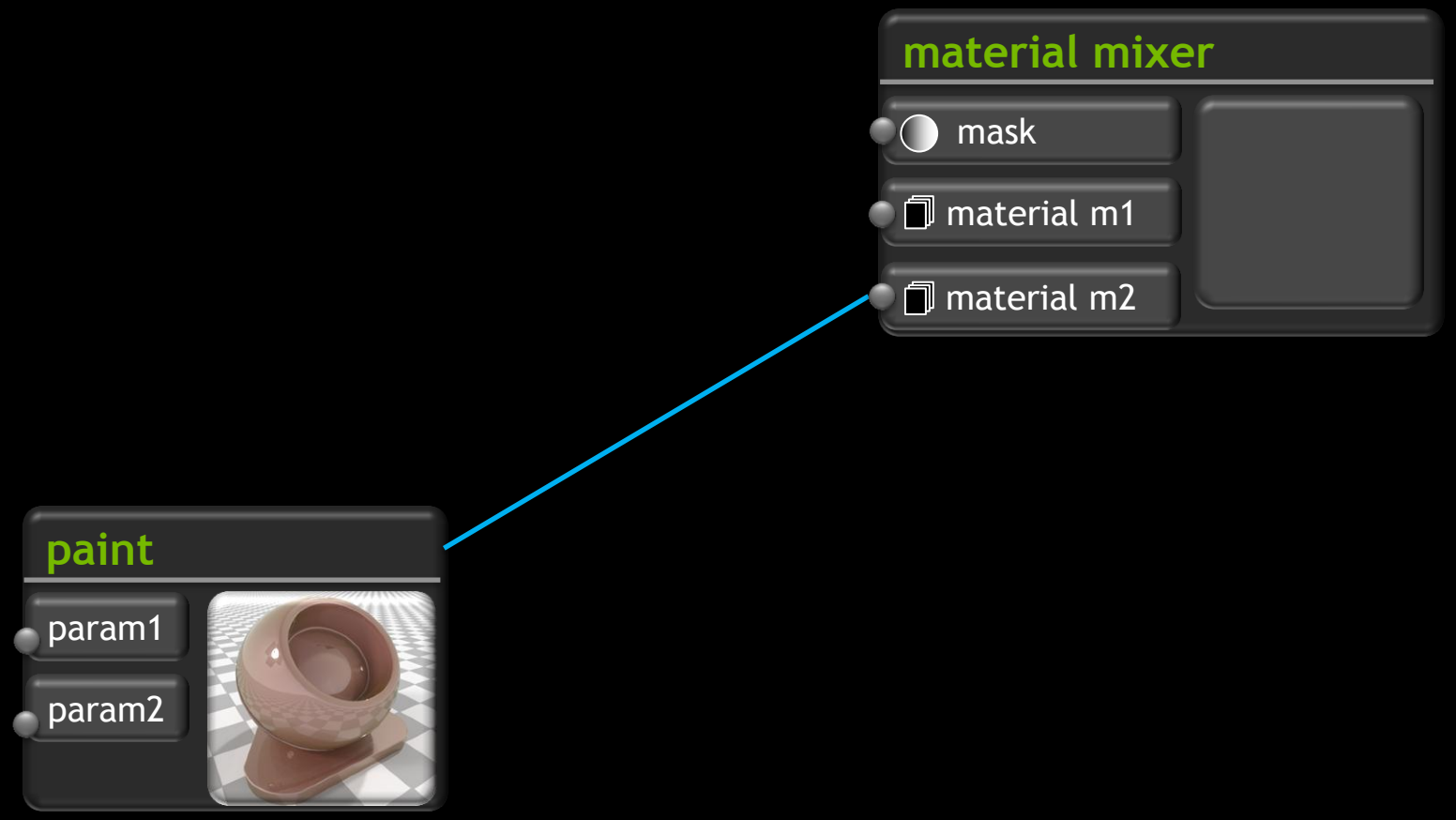

custom-curve layering
weighted layering
weighted layering
Fresnel layering
diffuse
tint: red
diffuse
tint: yellow
glossy
roughness:
glossy
roughness:
specular

Material Definition: Mixer

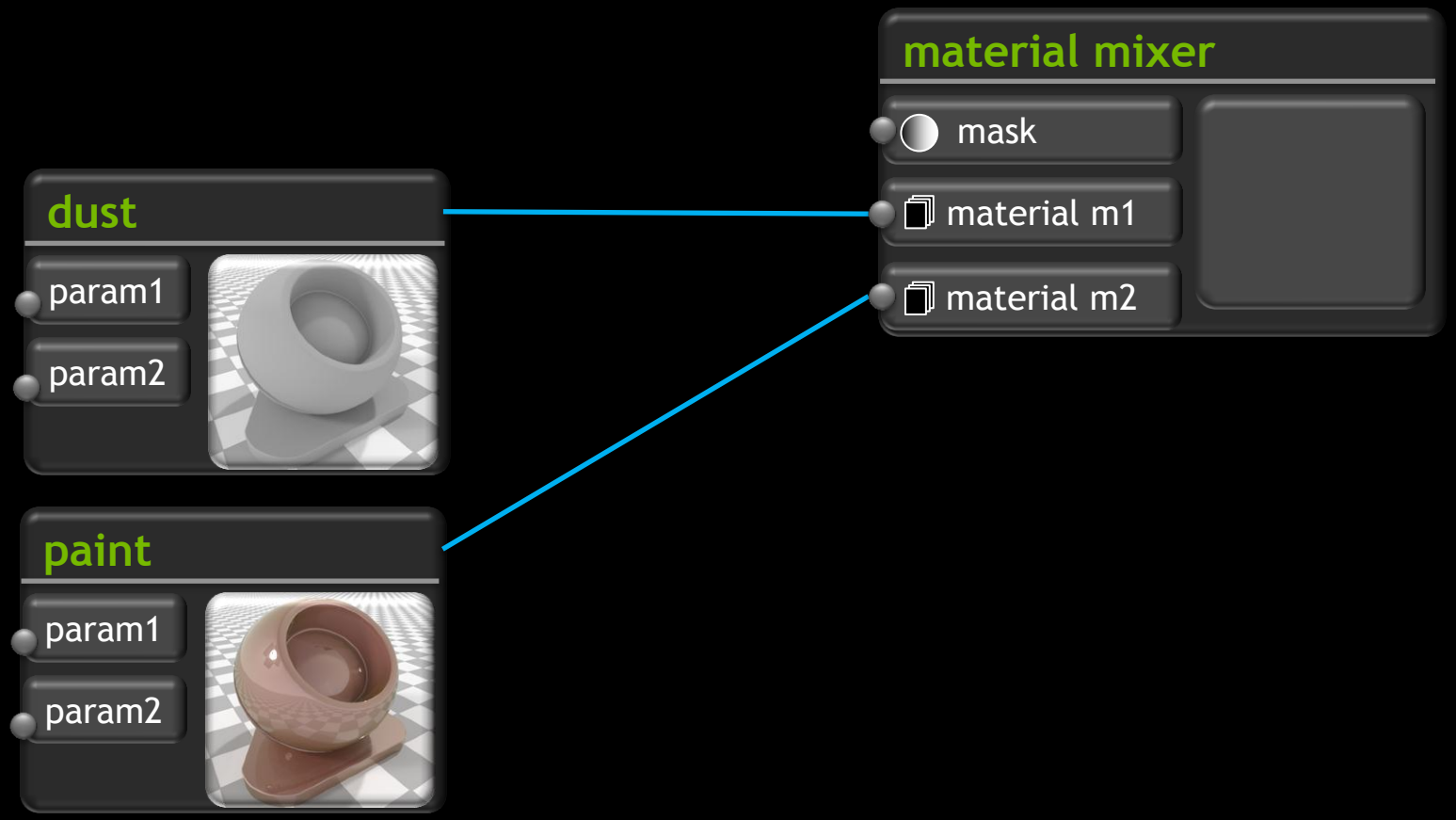
Material Definition: Mixer



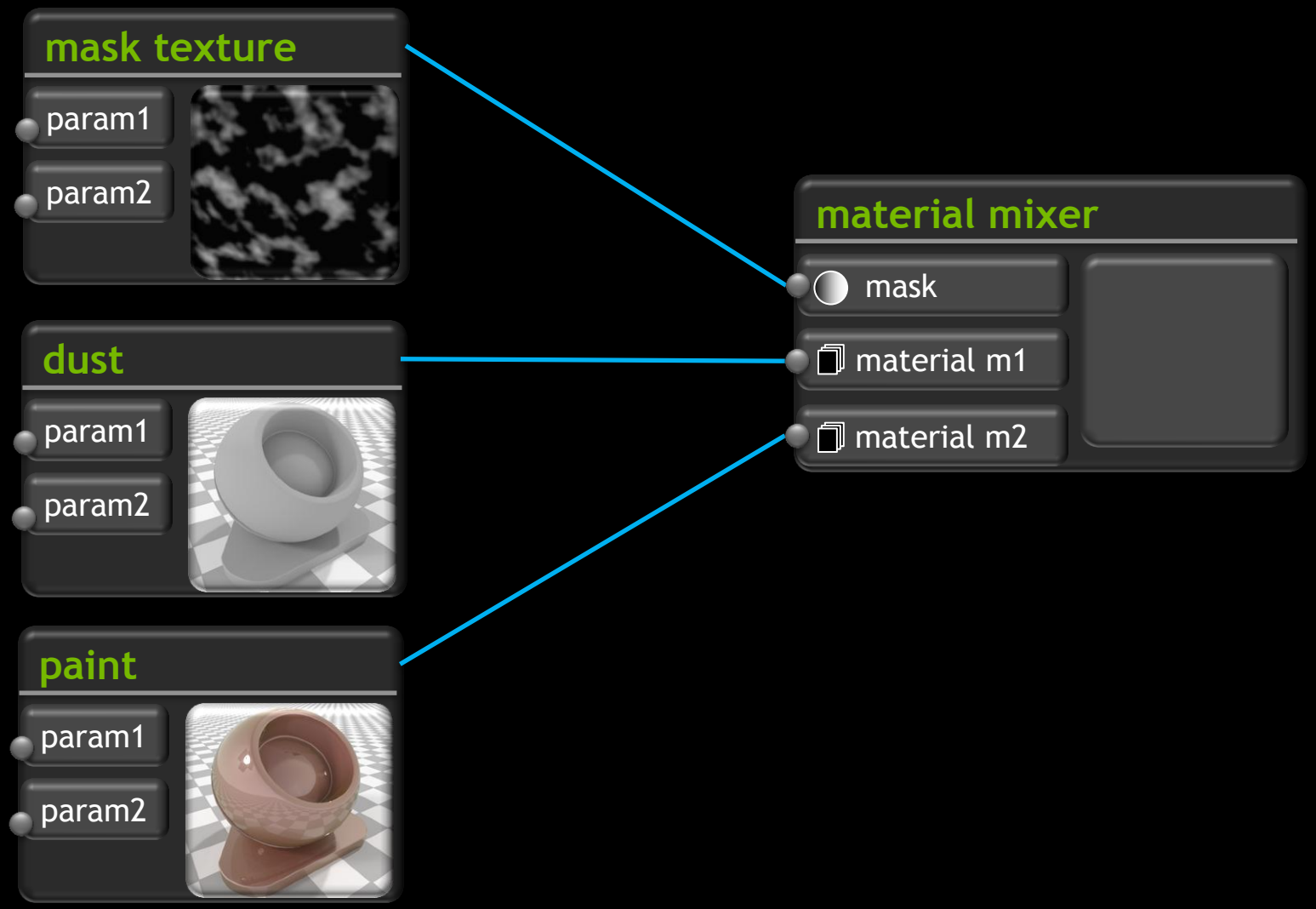
Material Definition: Mixer



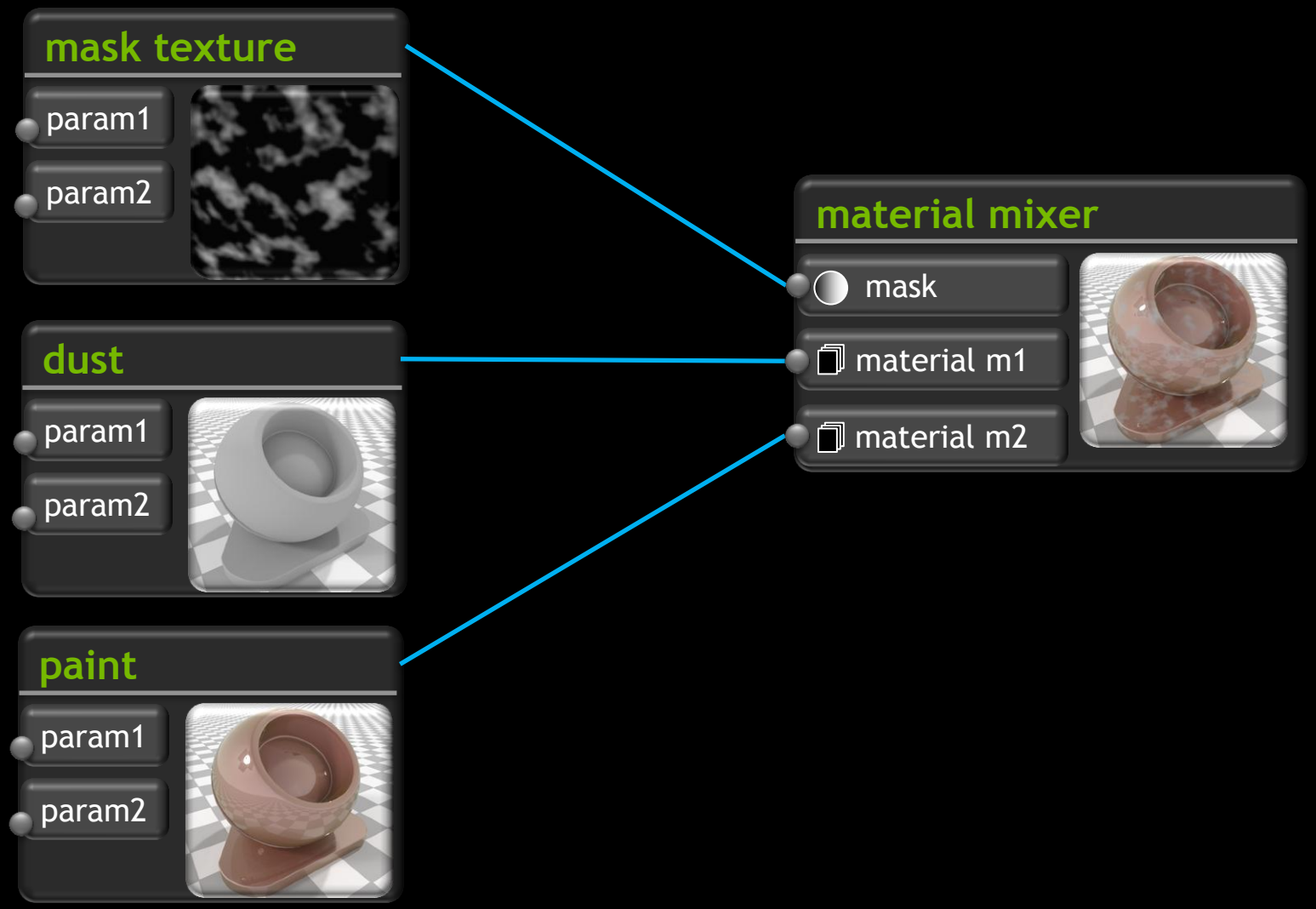
Material Definition: Mixer



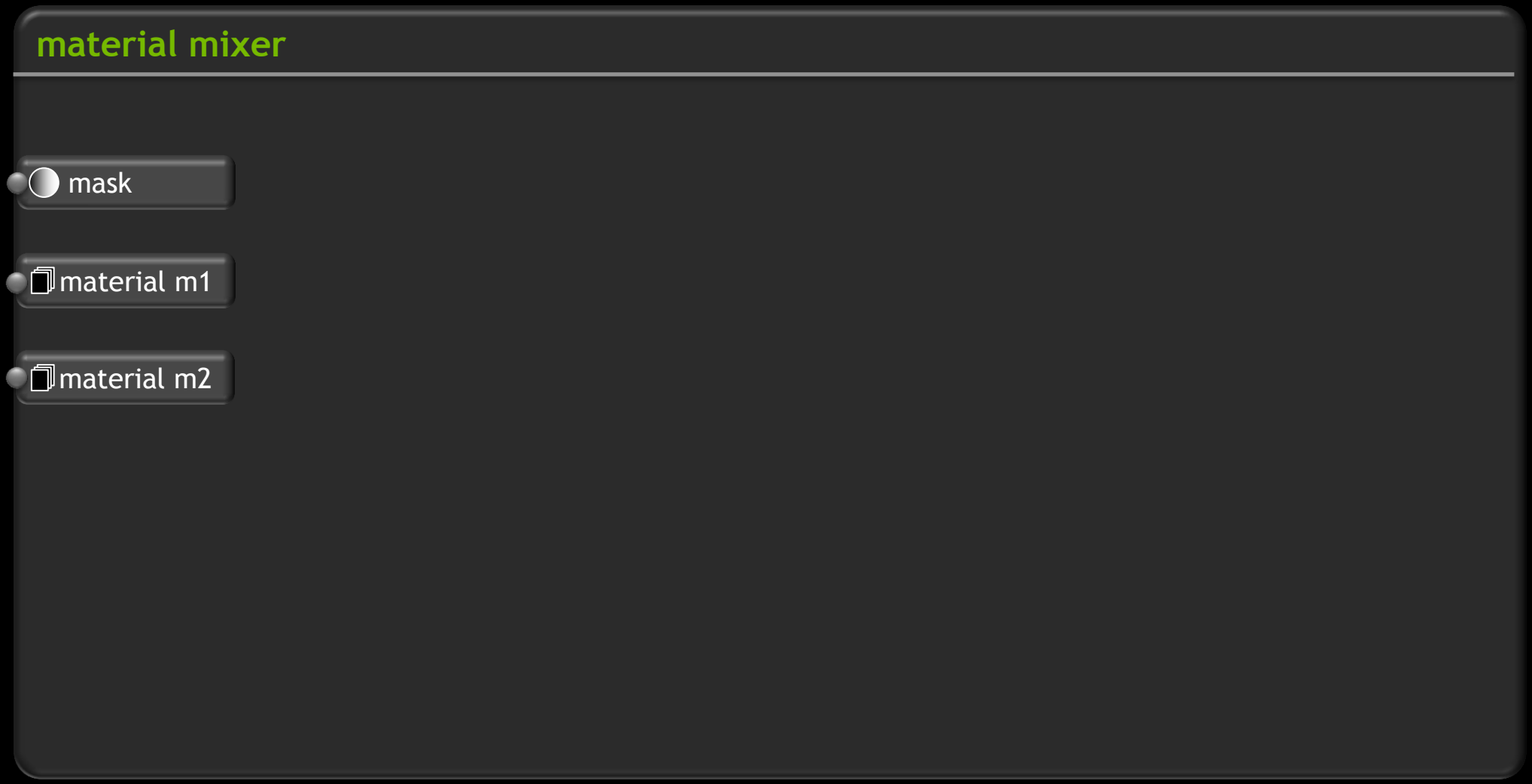
Material Definition: Mixer



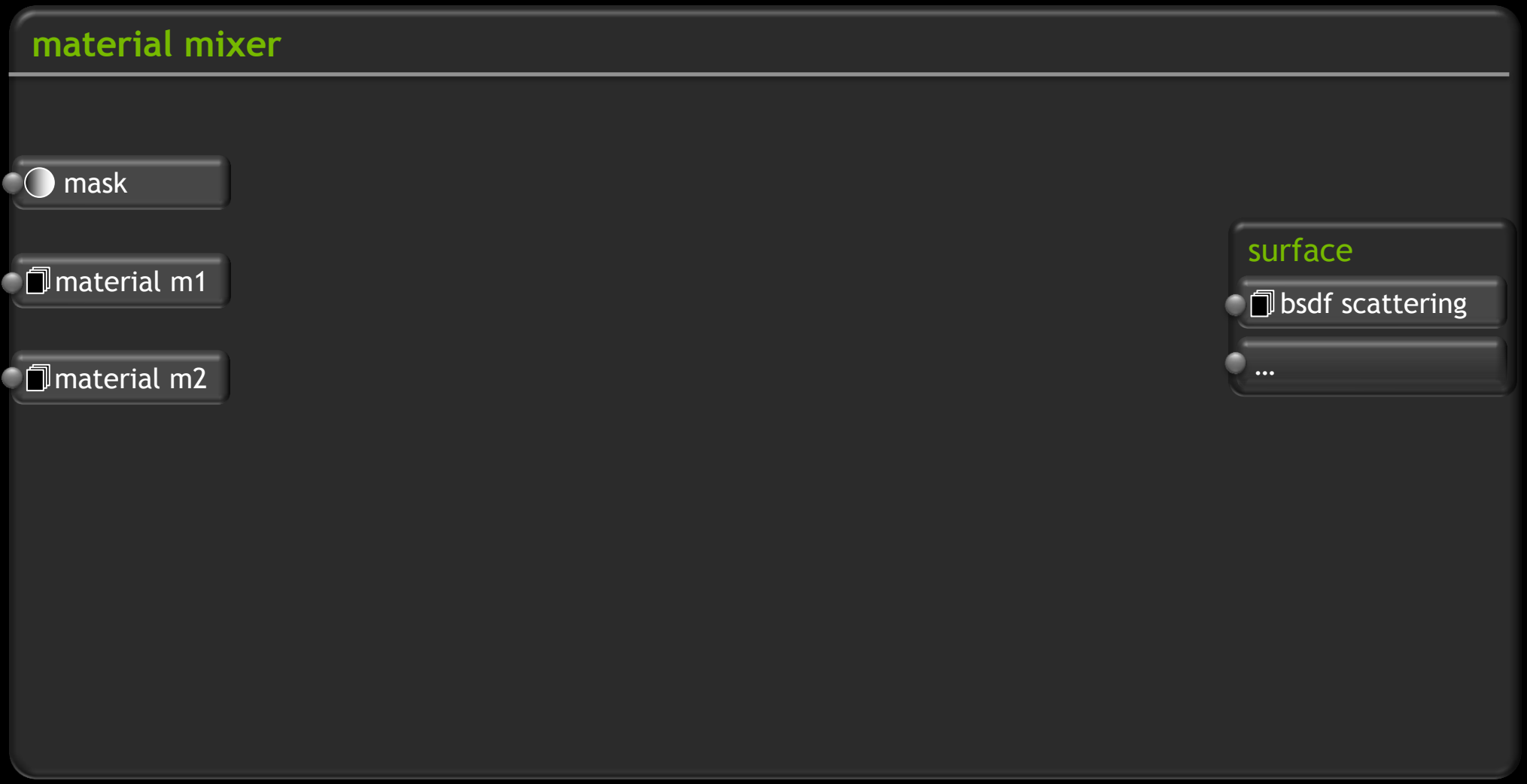
Material Definition: Mixer



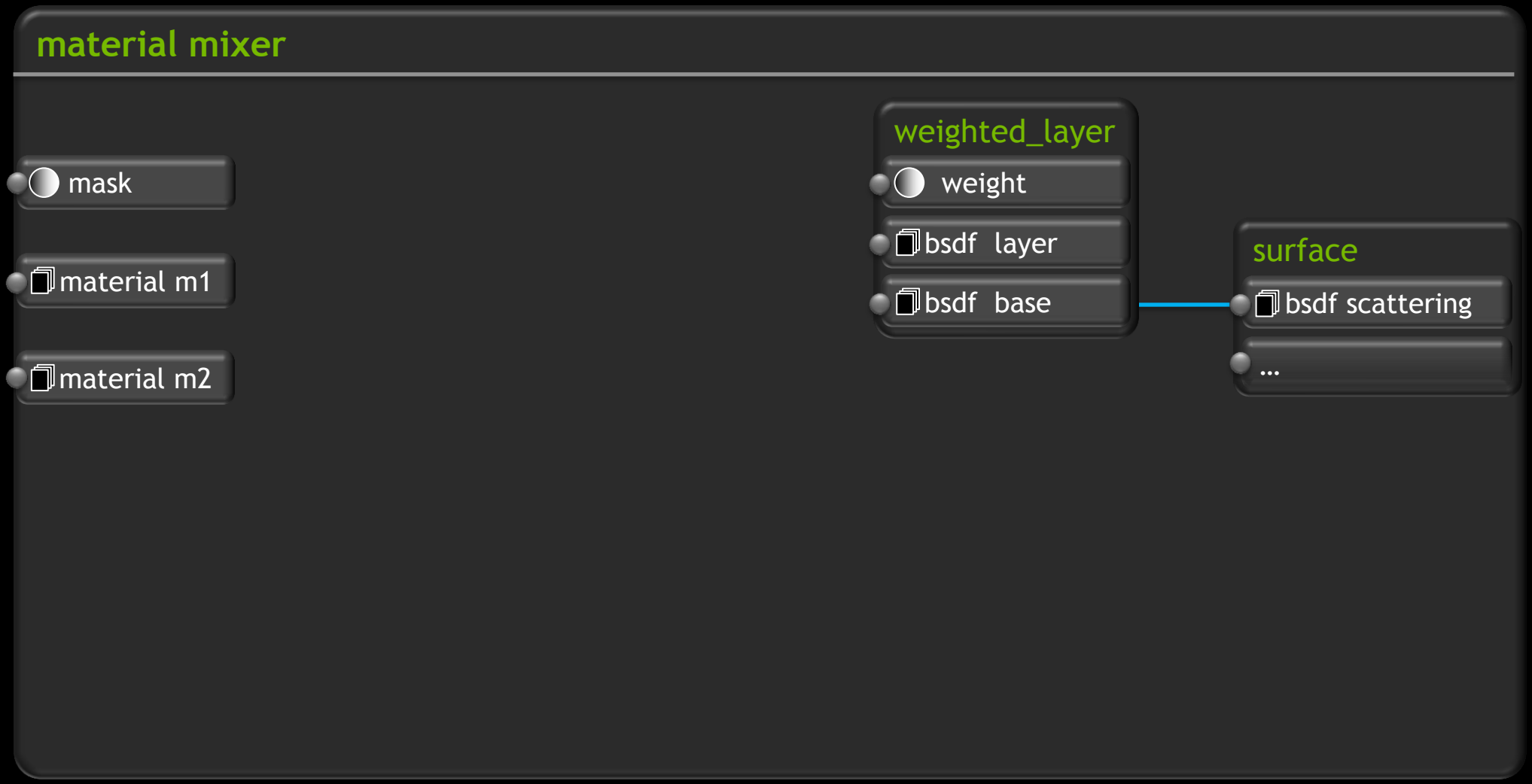
Material Definition: Mixer



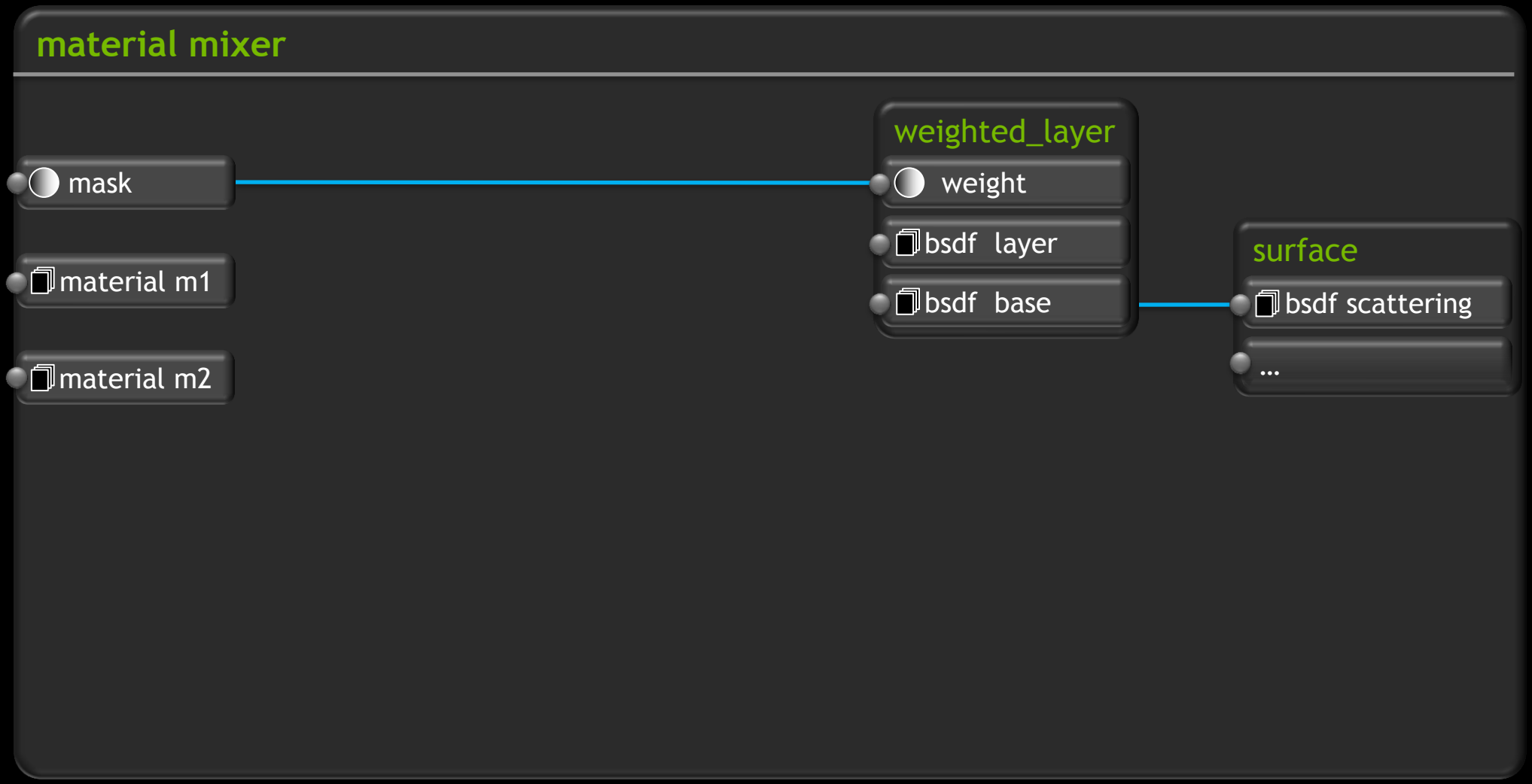
Material Definition: Mixer



Material Definition: Mixer



Material Definition: Mixer



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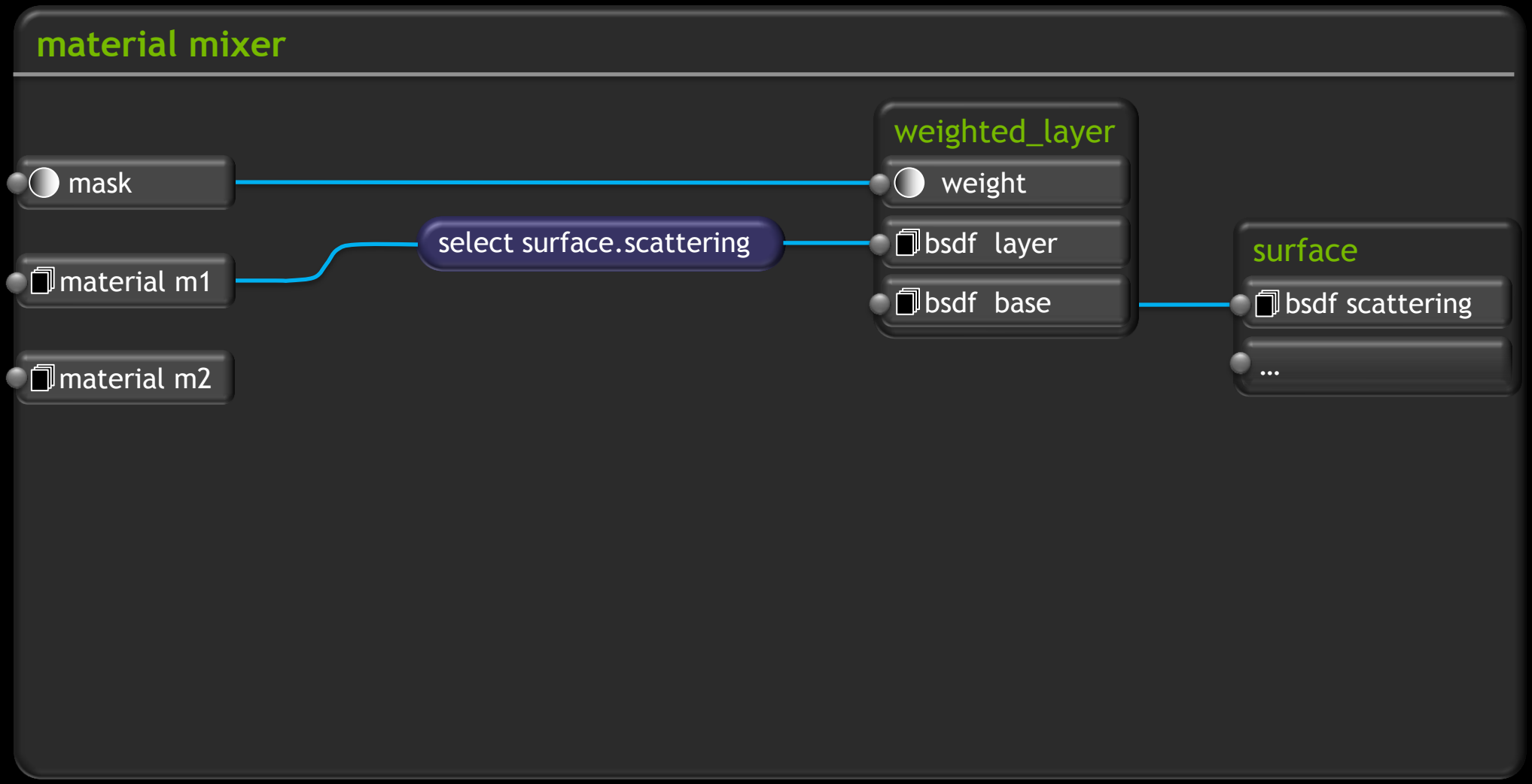
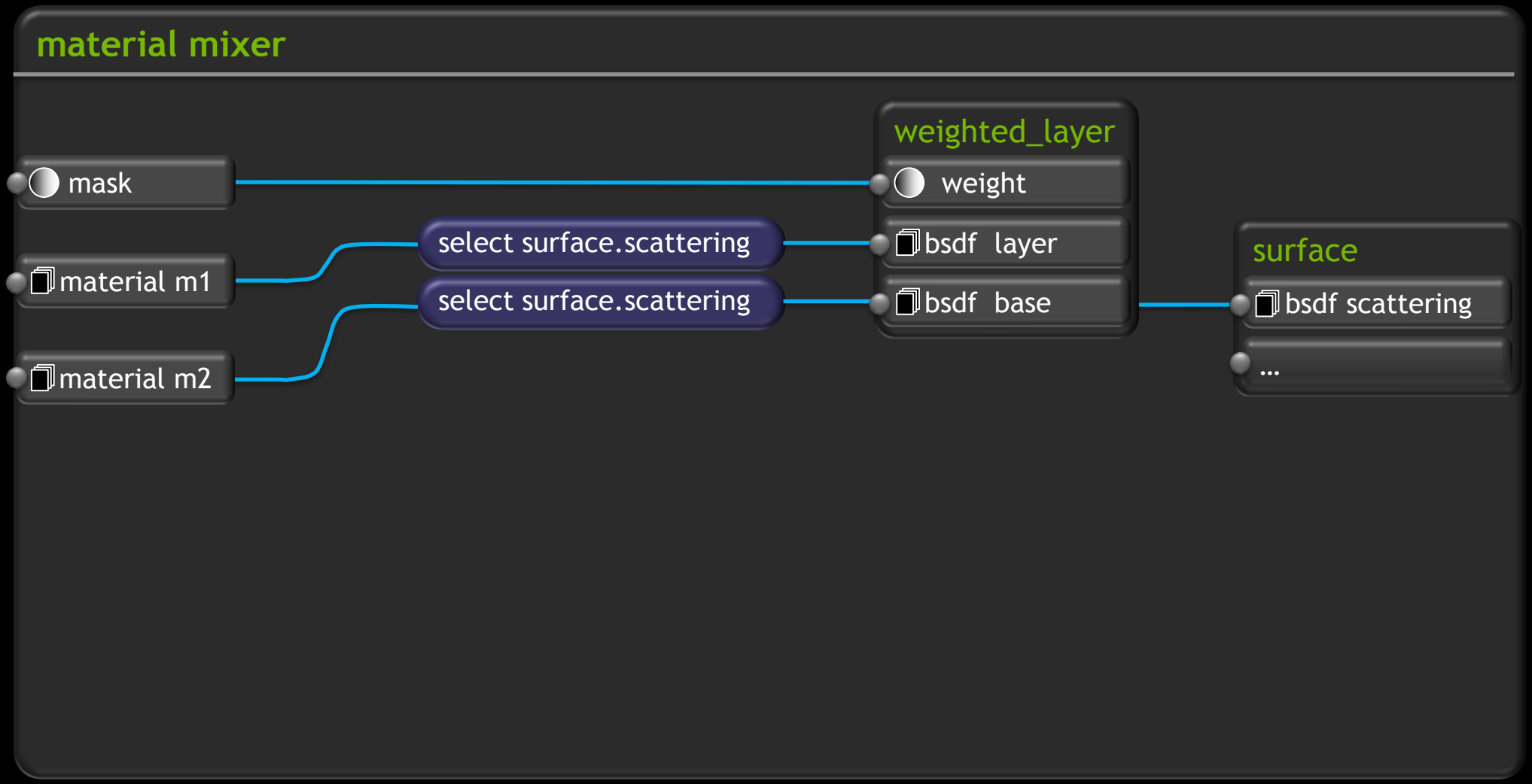
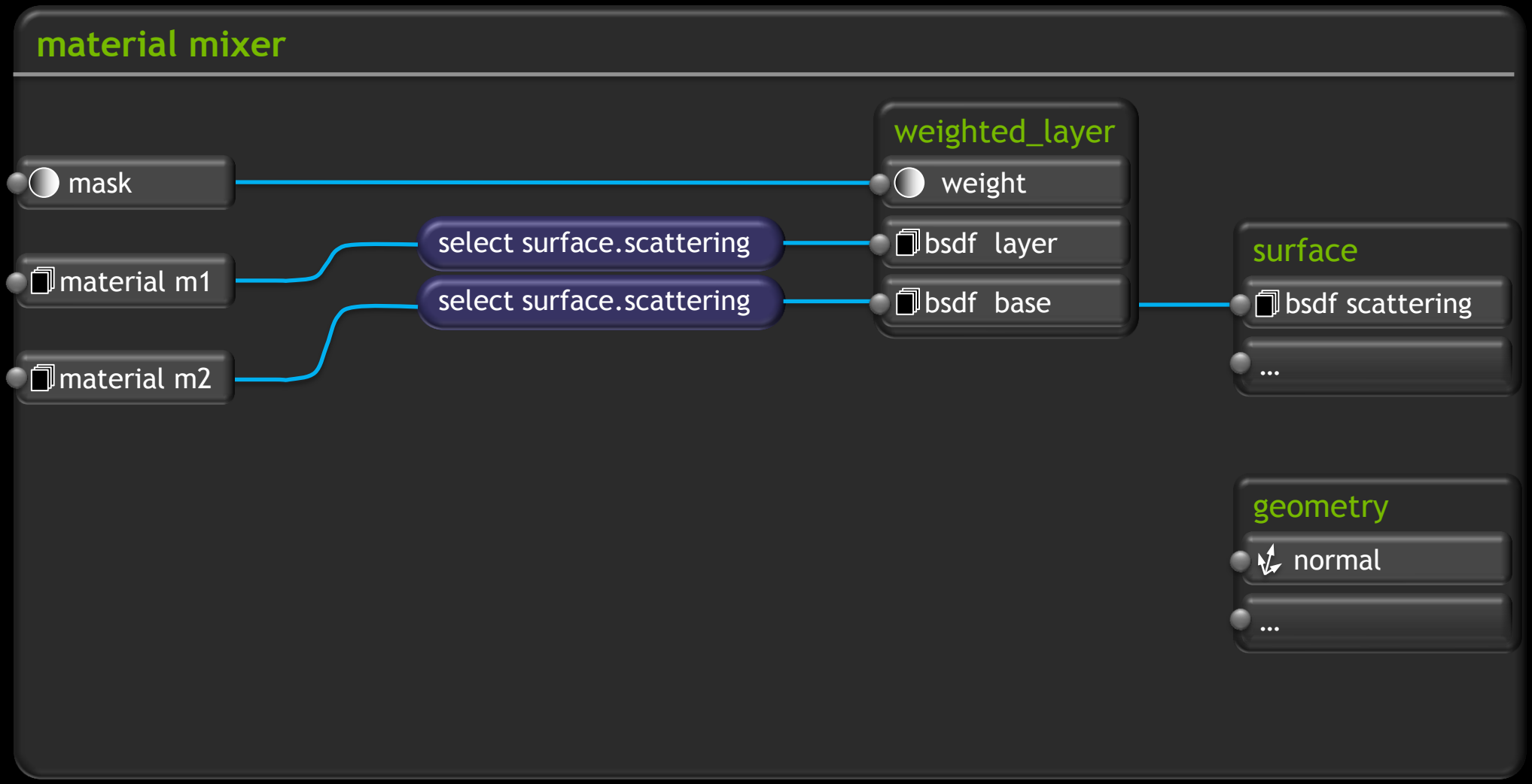


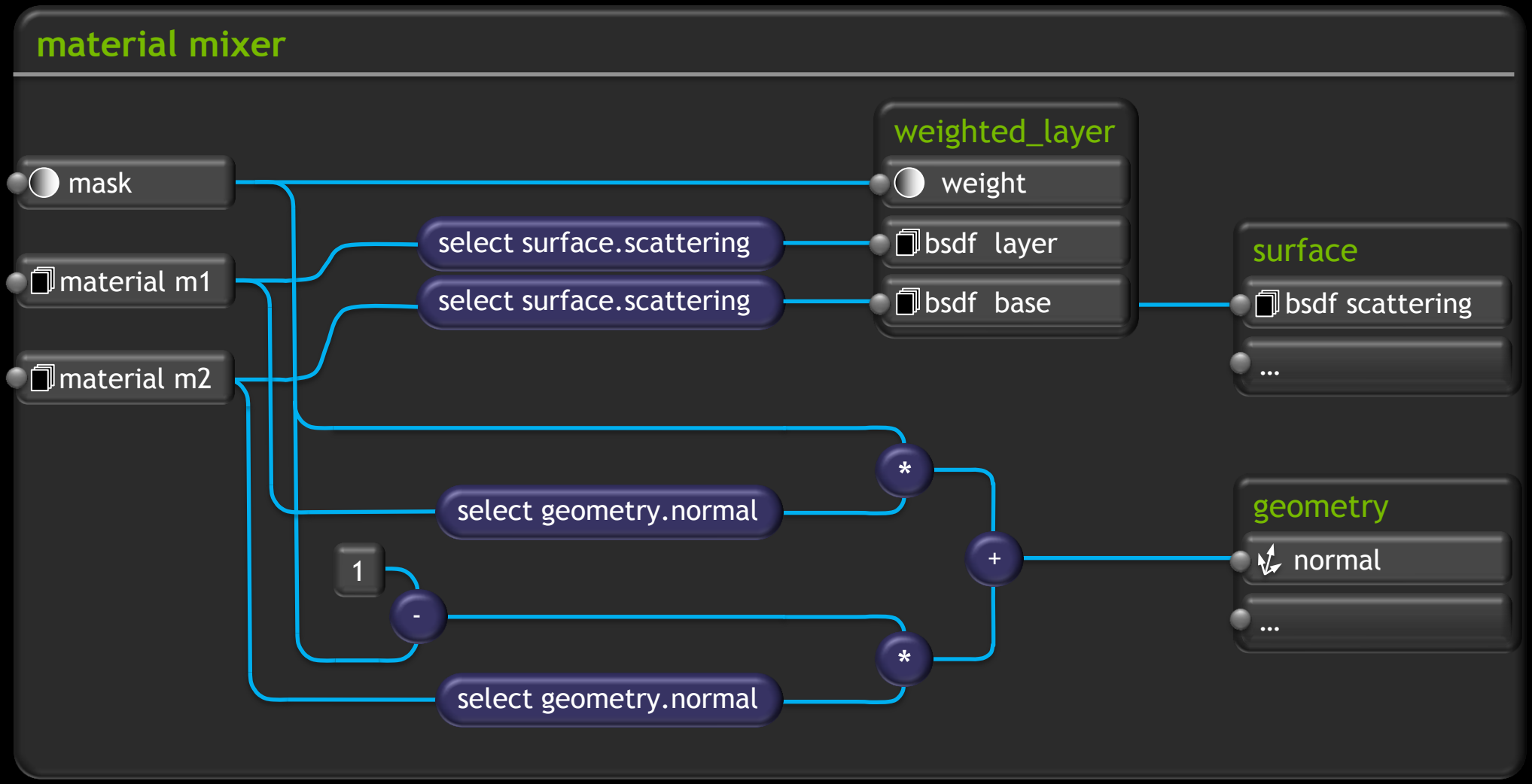
Material Definition: Mixer



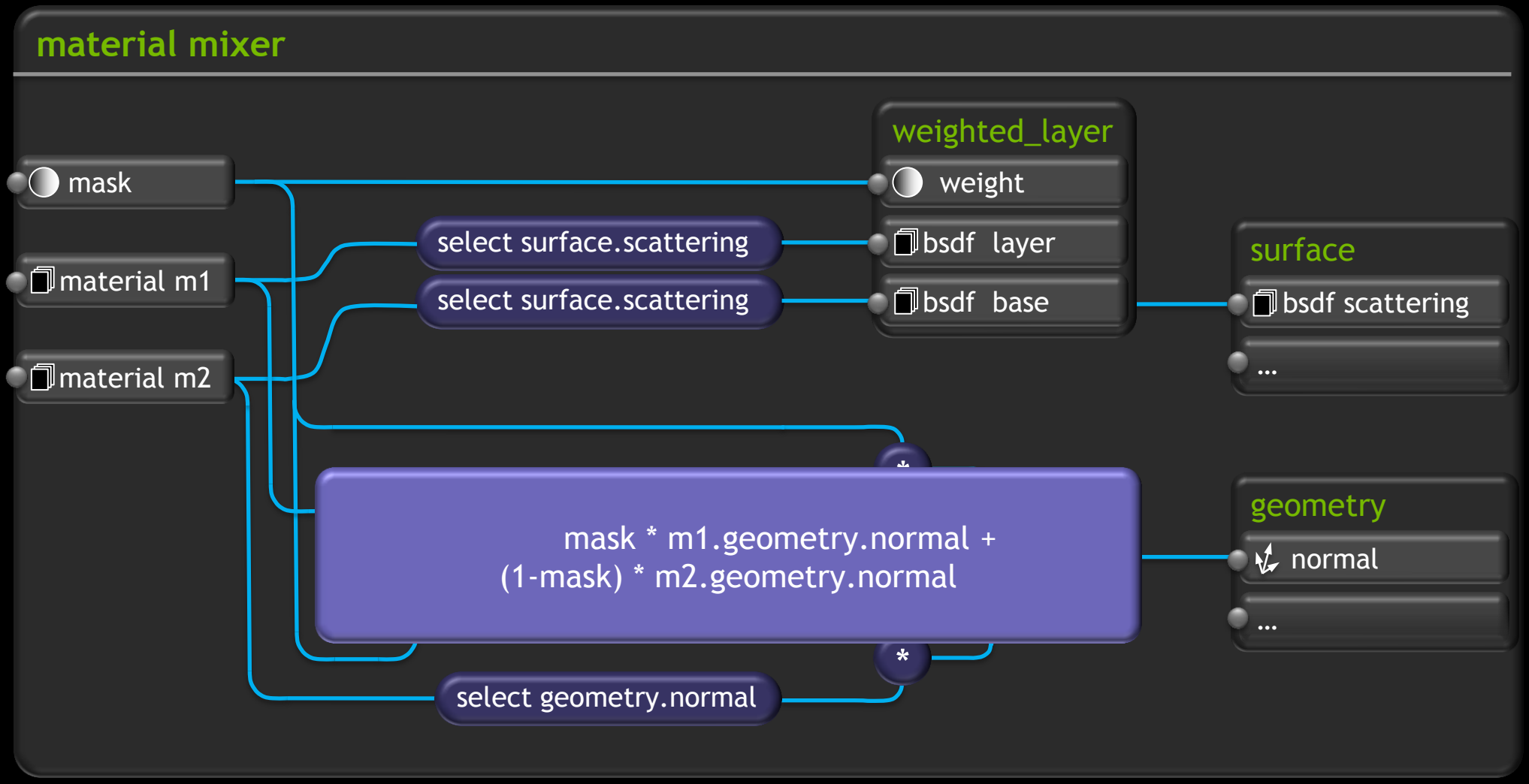
Material Definition: Mixer



Material Definition: Mixer



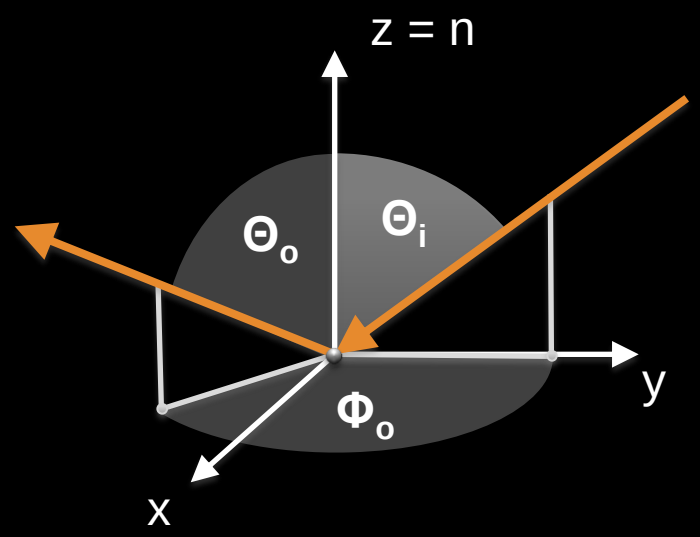
Material Definition: Mixer



Measured Materials with NVIDIA Iray 2014

Measured Isotropic BRDF

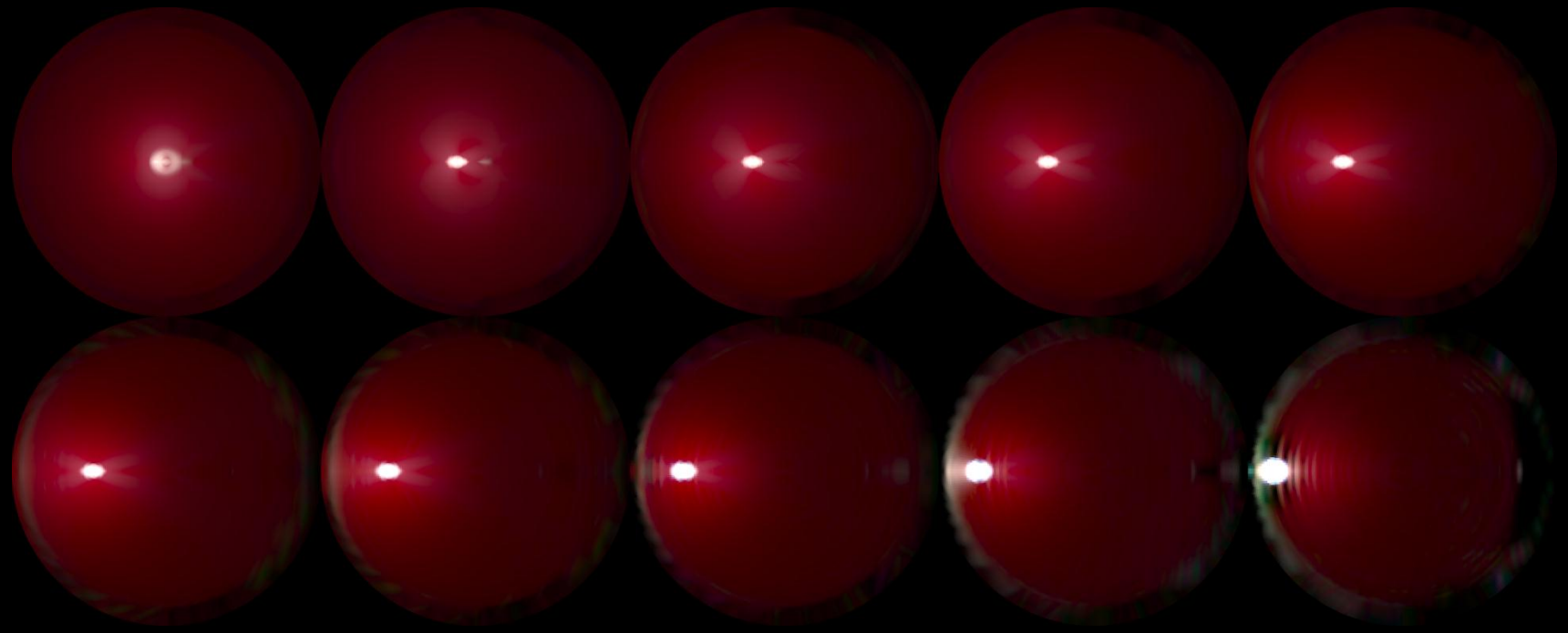
- 3d data
- MDL BSDF type measured_bsdf takes this data
- Can be used just as any other MDL BSDF
- Fully supported in Iray Photoreal and Iray Interactive



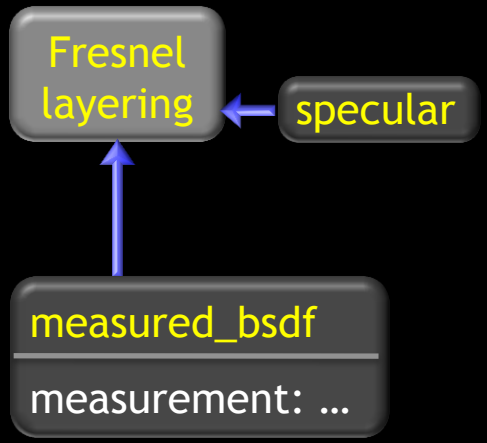
Measured Reflectance Curves

BRDF Measurement Example

- BRDF measurement provided by Ford Motor Company
- Data taken directly from Radiant Zemax IS device



BRDF Measurement Example



Building Material Systems on top of MDL

- MDL provides a few flexible concepts …
  - Constants, Enums, Types
  - Functions with input parameters; Return values feed into other parameters
  - Materials with input parameters
  - Materials are types too and can be used as material parameters
- … that can be used to realize many different material paradigms
  - Library of monolithic materials (possibly with parameters), or
  - Uber-materials with parameters for all uses, or
  - Strict sequential layering of materials, or
  - Hierarchical layering of materials or material components, or
  - Or whatever you dream up!

NVIDIA

SIGGRAPH 2013
Shaping the Future
of Visual Computing

Increasing Access to Iray with Lightwork Design

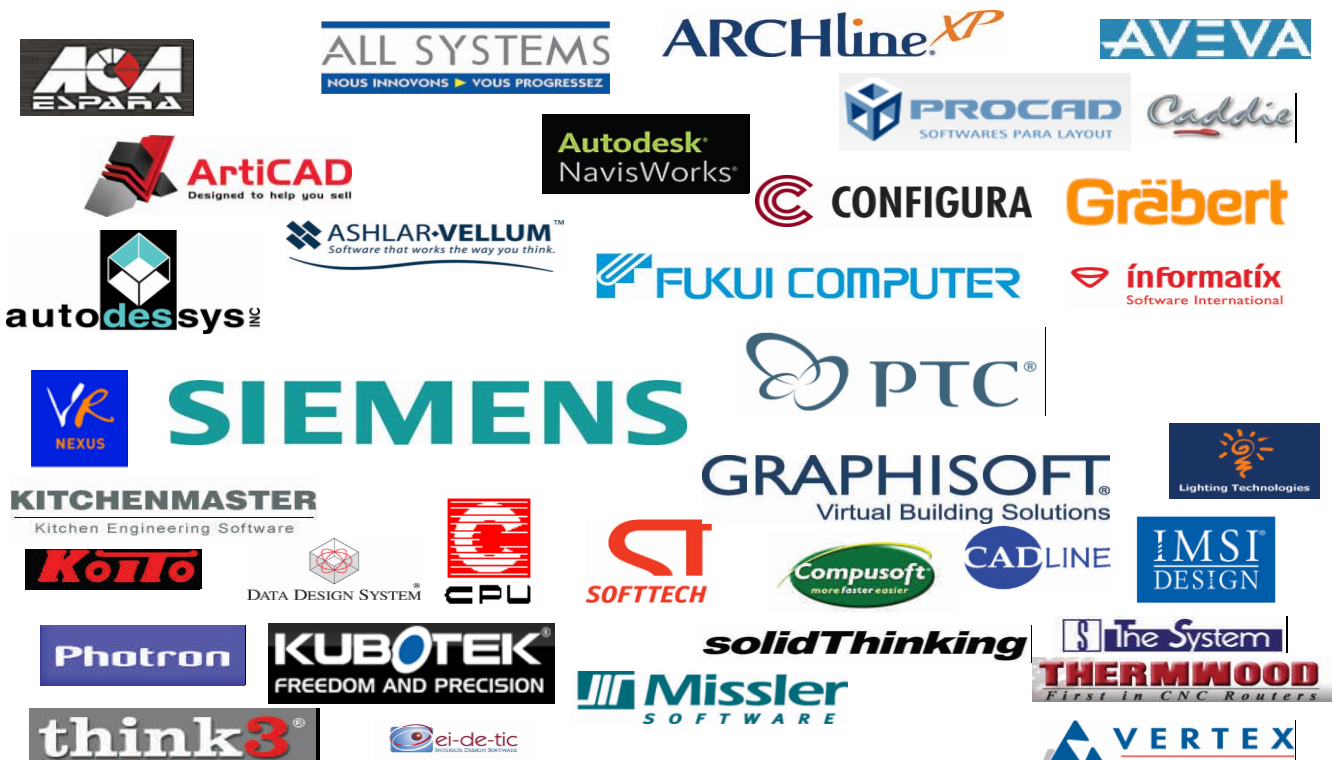
David Hutchinson from Lightworks

LIGHTWORKS
Rendering Realism

NVIDIA & Lightworks Unite on Iray®

- Lightworks – bringing to Iray decades of experience assisting +80 companies and sites with their rendering solutions

- Lightworks will now assist companies wanting to include Iray
- Making Iray quicker to integrate and even easier to use with Iray+



Iray®+ from Lightworks

- All the power of Iray
  - Packaged in a new and intuitive way
  - Reduce integration times from months to days
  - New approach to presenting MDL materials

- Initially
  - New level of ease of use to Iray through the Iray+ SDK
  - Fast to integrate and evaluate – days not months
  - UI concepts presented through the SDK

- Going forward
  - Iray+ will add more value in response to customer requirements
  - Remove barriers to use of Iray and break into new areas

Interested in Iray+ ?

- Contact iray@lightworkdesign.com
- Stand #154 at SIGGRAPH

- Expertise is servicing:
  - CAD Software OEMs
  - Point of Sale or Configurator solutions
  - Specialised Material requirements
  - Corporate Cluster and Cloud Rendering

LIGHTWORKS
Rendering Realism

Plugging into NVIDIA Rendering

www.nvidia-arc.com

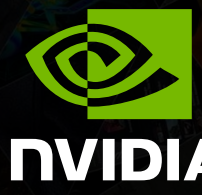
iray@lightworks.com

https://developer.nvidia.com/optix

NVIDIA Visualization Theater Booth Talks

- **Honda: Automotive Design Appearance Simulation**
  - Tuesday 10:00 AM - 10:30 AM
- **Dassault Systems: CATIA Live Rendering with NVIDIA Iray**
  - Tuesday12:00 PM - 12:30 PM
- **Pixar: Using OptiX™ for Lighting Preview in a Production Pipeline**
  - Tuesday 4:00 PM - 4:30 PM
  - Wednesday 2:00 PM - 2:30 PM
  - Thursday 10:40 AM - 11:10 AM
- **NVIDIA: Introducing Iray for Maya**
  - Tuesday 10:40 AM - 11:10 AM
- **Bunkspeed: Bringing NVIDIA Iray and Ease of Use to Designers**
  - Thursday 1:20 PM - 1:50 PM

Questions?



SIGGRAPH 2013
Shaping the Future
of Visual Computing

GPU Ray Tracing &
NVIDIA Advanced Rendering Solutions

Phillip Miller & Lutz Kettner