RENDERING PRECIOUS AND SEMI-PRECIOUS GEMS
Part of the research for my thesis – Glyptics Portrait Generator

Glyptics is the art of producing engraved gems

This seminar is the research of gemstone properties

Roman Emperor Caracalla engraved in amethyst
WHAT IS A GEM?

A precious stone of any kind, esp. when cut and polished for ornament; a jewel.
CLASSIFICATION

Gemstones

- Precious
- Semi-precious
Precious
only 4 gems

Can you name them?
CLASSIFICATION

Precious
only 4 gems

- Emerald
- Ruby
- Sapphire
- Diamond
CLASSIFICATION

- Agate
- Alexandrite
- Amethyst
- Ametrine
- Apatite
- Aquamarine
- Aventurine
- Azurite...

Semi-precious
too many to list all of them here

And those are not even all the gems, starting with an “A”
GENERAL PROPERTIES
GENERAL PROPERTIES

• Refraction and sometimes birefringence
  • Produces dichroism (multi-coloring) and doubling
GENERAL PROPERTIES

• Refraction and sometimes birefringence
• Internal reflections
  • Produce brilliance – light, reflected from the inside
GENERAL PROPERTIES

• Refraction and sometimes birefringence
• Internal reflections
• Dispersion
  • Produces fire – splitting light into colors of the spectrum
GEMSTONE CUTTING

Improper cutting affects internal reflectiveness => brilliance
REFRACTIVE INDEX

- Different gems have different refractive indices
- In case of birefringence, gems have two refractive indices
- Higher RI means higher brilliance
  - Diamond has a RI of 2.42, while ruby has 1.76

Refractometer – device for measuring refractive index
SO... HOW TO RENDER THAT?
SO... HOW TO RENDER THAT?

- Most common answer: ray tracing
- It has everything we need: refraction, reflection, dispersion
- Downside: computational complexity
SIMPLIFICATION OF FACETED GEMS RENDERING

• Guy and Coler [2004] propose a method of facet trees to achieve similar results without ray tracing

• Three passes
  • Facet tree construction
  • Facet tree rendering
  • Tone reproduction
SIMPLIFICATION OF FACETED GEMS RENDERING

Visualization of facet tree building algorithm and the resulting mesh
OPTICAL EFFECTS OF GEMSTONES

- Adularescence
- Chatoyancy
- Asterism
- Aventurescence

To be continued =>
OPTICAL EFFECTS OF GEMSTONES

- Color change
- Iridescence
- Play of color
- Pleochroism
ADULARESCENCE – APPEARANCE

Looks as if a gemstone has an internal light source, with its color ranging from milky white to blueish.

Can be observed in:
Moonstone, adularia, common opal, rose quartz, agate
ADULARESCENCE – PHYSICS

- Refraction and reflection from the lamellar structure of the gem causes the light to interfere, changing its wavelength to blue.
- The light which was refracted and reflected creates the phenomenon.

Moonstone
ADULARESCENCE – RENDERING

- Add a scaled-down glossy textured/moonstone-colored mesh inside the original one
- Make the original mesh transparent with glossy reflectivity

Moonstone
CHATOYANCY – APPEARANCE

Looks like a single bright, mobile reflective line of light

Similar to the cat’s eye, hence the name (French origin)

Requires the gem to be cut en cabochon (i.e. rounded, not faceted)

Can be observed in:
Quartz, chrysoberyl, beryl, aquamarine, charoite, tourmaline, labradorite, selenite, feldspar, apatite, moonstone, thomsonite, scapolite

Alexandrite (color change is also present)
• Fibrous structure of a material (tiger’s eye)

• Fibrous inclusions and/or cavities (chrysoberyl)

• Reflections from those inclusions cause the effect
Simulating the internal gem structure that causes chatoyancy produces the desired effect

One of the ways – inverted hair particle system :)

Rendered chatoyancy
ASTERISM – APPEARANCE

The reflected/refracted light forms a star on the surface of the gem

Can consist of 4, 6, 8 or even (rarely) 12 rays

Also requires the en cabochon cut

Can be observed in:
star ruby, star sapphire, star garnet, star diopside, star spinel, rose quartz star

Rose quartz star
Asterism is basically a combination of several chatoyancy effects, focused around the crystal axis.

200x zoomed photo of rutile inclusions inside sapphire.
suggestion

• Additional texture with light intensity multiplier

• Possible due to effect’s location being fixed around specific axis

Star sapphire
AVENTURESCENCE – APPEARANCE

A pattern of brilliant flashes and color spots inside the gem

Looks like glitter inside the material

Can be observed in:
Feldspar sunstone, ionite sunstone, aventurine quartz, goldstone (synthetic)

Aventurescence of synthetic gemstone - goldstone
AVENTURESCENCE – PHYSICS

Actually it is exactly like glitter!

The gem contains plate-like mineral inclusions, that reflect light under specific angles

If the inclusions are numerous, the whole gem’s color is affected

Green fuchsite inclusions in aventurine quartz
Multi-layer surface with procedural textures to mimic the inclusions

Such approach combines different Voronoi cell textures to create the desired effect
COLOR CHANGE – APPEARANCE

Has the ability to change color depending on the nature of the light (not the angle)

For example, alexandrite (as seen left), can have green tones in natural light and red tones in electric lighting

Can be observed in:
Alexandrite, color change garnet, color change sapphire, zultanite
COLOR CHANGE – PHYSICS

Every light source emits light, made up of different wavelengths

Color change gems absorb different wavelengths, so when the light has more of one color, it becomes the dominant color of the gem

Spectra of different light sources
COLOR CHANGE – RENDERING

- Light sources are usually not explicitly described with their spectra
- Additional inputs – light source type and color change gem type
- RGB channel values alteration based on these inputs
IRIDESCENCE – APPEARANCE

A rainbow-like effect on the surface or inside the gem

Can have full spectrum of colors (opal) or only some of them due to interference

Can be observed in:

Opal, ammonite, fire agate, moonstone, goethite, labradorite
Thin-film-like structure of iridescent gems is the reason of the phenomena. Such thin film causes different attenuation for different light wavelengths. Different iridescent gems do not have the exact structure, but the effect is present in all of them.
IRIDESCENCE – RENDERING

• Quite a few implementations of iridescent materials for Unity, Blender and Unreal Engine

• These can be achieved in different ways

• Spectrum of iridescence can be set as well (to have different gemstones)

• These materials should be mixed with others, as the gems are not perfectly iridescent or metallic
PLAY OF COLOR – APPEARANCE

Rainbow-like flashes of color that change with the angle of observation

Can be observed in:
Precious opal
Opals consist of stacked silica spheres. If the spheres are uniform in size and shape, they will diffract light. This creates play of color. Size of the spheres affects the produced color. Smaller produce blue and violet, bigger – red and orange.
PLAY OF COLOR – RENDERING

suggestion

• Several layers of iridescent material

• Existing solutions use Voronoi noise, similar to aventurescence

• Sometimes emissive color is used, which makes the final result more bright, but less physically correct

Opal rendered in Cycles Blender
PLEOCHROISM – APPEARANCE

Pleochroic gem appears to have different colors when observed from different angles

Different from color change – depends on angle and not light source

Can be observed in:
Ruby, sapphire, kunzite, tanzanite, andalusite, tourmaline
If the gem is birefringent (i.e. light is split into two separate rays inside the gem), it may have pleochroism. This happens if the split rays have different wavelengths. Pleochroic gems have different absorbance spectra depending on the light direction.
PLEOCHROMISM – RENDERING

- Internal structure causing such phenomenon is too granular to “brute force”
- Algorithm proposed by Guy and Soler takes pleochromism into account

Real tourmaline (left) and generated with the algorithm by Guy and Soler
CONCLUSION

• A lot of optical effects, coming from basic light behavior and internal material structure
  +
• Extremely appealing visually
  +
• Not often implemented in CG
  =

A lot of untapped potential
Do engraved gems usually have these effects?
• No, not really

Would it be interesting to see them however?
• Yes, absolutely
SHOOT YOUR QUESTIONS!
THANK YOU FOR ATTENTION