Aletheia Film Tools

Technical Reference & Development Documentation

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Contents

Chapter 1

Introduction

A comprehensive technical breakdown of the Aletheia color science pipeline: Alpha, Phi, Helix, and Omega. Each tool implements mathematically rigorous color transformations based on published research and manufacturer specifications.

1.1 System Architecture

Aletheia implements a complete film-style color pipeline:

```
Camera → Alpha → Phi → Helix → Omega → Display
           ↓       ↓      ↓       ↓
      [Gamut]  [Grade] [Detail] [Film]
```

Alpha — Color space transformation (camera to grading space) **Phi** — Primary and secondary color grading **Helix** — Texture and detail enhancement **Omega** — Film stock emulation with spectral accuracy

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1.2 Alpha — Color Space Bridge

1.2.1 Purpose

Alpha converts between camera color spaces and a unified grading space, enabling consistent color science regardless of acquisition format.

1.2.2 Source Code

`/01_OFX/03_Alpha/00_Source/Alpha.cpp`

1.2.3 Mathematical Foundation

1.2.3.1 Gamut Transformation

Color space conversion uses 3×3 matrix multiplication through AP1 (ACES) as the connection space:

```
Output = [AP1→Output] × [Input→AP1] × Input
```

Matrix application:

```
inline void mtx(float* out, const float* in, const float* m) {
    out[0] = in[0] * m[0] + in[1] * m[1] + in[2] * m[2];
    out[1] = in[0] * m[3] + in[1] * m[4] + in[2] * m[5];
    out[2] = in[0] * m[6] + in[1] * m[7] + in[2] * m[8];
}
```

1.2.3.2 Supported Camera Gamuts

Gamut	Matrix to AP1
ARRI Wide Gamut 4	[0.6806687, 0.2363636, 0.0829677; ...]
ARRI Wide Gamut 3	[0.6954522, 0.1406787, 0.1638691; ...]
Sony S-Gamut3	[0.6387886, 0.2723514, 0.0888600; ...]
RED Wide Gamut	[0.7830944, 0.0868578, 0.1300477; ...]
DaVinci Wide Gamut	[0.7529825, 0.1433601, 0.1036573; ...]
ACES AP0/AP1	Direct passthrough

1.2.3.3 Log-to-Linear Transfer Functions

ARRI LogC4

```
float logc4_to_linear(float x) {
    float a = 2231.82630906769f, b = 64.0f;
    float c = 0.0740005604622393f;
    float s = 0.0181680833820122f, t = 0.0729553821550654f;
    if (x >= t)
        return (pow(2.0f, (x - c) / 0.0573514609390792f) - b) / a;
    return (x - t) / s;
}
```

ARRI LogC3 (EI 800)

```
float logc3_to_linear(float x) {
    float cut = 0.010591f;
    float a = 5.555556f, b = 0.052272f;
    float c = 0.247190f, d = 0.385537f;
    float e = 5.367655f, f = 0.092809f;
    if (x > e * cut + f)
        return (pow(10.0f, (x - d) / c) - b) / a;
    return (x - f) / e;
}
```

Sony S-Log3

```
float slog3_to_linear(float x) {
    if (x >= 171.2102946929f / 1023.0f)
        return pow(10.0f, (x * 1023.0f - 420.0f) / 261.5f) * 0.19f - 0.01f;
    return (x * 1023.0f - 95.0f) * 0.01125f / (171.2102946929f - 95.0f);
}
```

RED Log3G10

```
float log3g10_to_linear(float x) {
    float a = 0.224282f, b = 155.975327f;
    if (x < 0.0f) return x * 0.01f;
    return (pow(10.0f, x / a) - 1.0f) / b - 0.01f;
}
```

1.2.3.4 Negative Gamma Curves

Cineon (Printing Density) The classic film scan transfer function:

`Linear = (10^((Code - 685) / 300) - 0.0108) / (1.0 - 0.0108)`

ADX (Academy Density Exchange) ACES-standard negative density encoding.

1.2.4 Direction Modes

- **To Negative**: Camera → Digital → Negative Space (for grading)
- **To Digital**: Negative → Digital → Display (for viewing)

1.3 Phi — Primary & Secondary Grading

1.3.1 Purpose

Phi provides a complete color grading toolkit with printer lights emulation, tone mapping, skin processing, and tetrahedral color correction.

1.3.2 Source Code

`/01_OFX/01_Phi/00_Source/Phi.cpp` `/01_OFX/01_Phi/00_Source/PhiKernels.metal`

1.3.3 Mathematical Foundation

1.3.3.1 Printer Lights

Film-style color correction using multiplicative RGB scaling:

```
// Printer light: 2^(exposure/3) scaling
rgb.r *= pow(2.0f, printerR / 3.0f);
rgb.g *= pow(2.0f, printerG / 3.0f);
rgb.b *= pow(2.0f, printerB / 3.0f);
```

Each unit = 1/3 stop, matching traditional lab printer light values.

1.3.3.2 Sigmoid Contrast

Piecewise power function centered on pivot point:

```
float sigmoidContrast(float x, float contrast, float pivot) {
    if (x <= 0.0f) return 0.0f;
    if (x >= 1.0f) return 1.0f;

    // Scale x relative to pivot
    float t = x / pivot;
    float p = contrast;

    // Sigmoid: t^p / (t^p + (1-t)^p)
    float tP = pow(t, p);
    float omtP = pow(1.0f - t, p);
    return pivot * tP / (tP + omtP);
}
```

1.3.3.3 Smoothstep Blending

C1-continuous blending for smooth transitions:

```
float smoothstep(float edge0, float edge1, float x) {
    float t = clamp((x - edge0) / (edge1 - edge0), 0.0f, 1.0f);
    return t * t * (3.0f - 2.0f * t);  // Hermite interpolation
}
```

1.3.3.4 Skin Detection & Processing

Biophysically-inspired skin tone processing using melanin and hemoglobin simulation:

```
// Kubelka-Munk model approximation
float melanin_absorption = melanin * (rgb.r * 0.1f + rgb.g * 0.3f + rgb.b * 0.6f);
float hemoglobin_response = hemoglobin * (rgb.r * 0.7f - rgb.g * 0.3f);

// Apply skin tone modification
rgb.r += melanin_absorption * skinDensity;
rgb.g += hemoglobin_response * skinRichness;
```

1.3.3.5 Tetrahedral HSV Correction

Six-vector color correction in tetrahedral space (Red, Green, Blue, Cyan, Magenta, Yellow):

```
// Determine which tetrahedron contains the color
if (r >= g && g >= b) {
    // Red-Yellow-White tetrahedron
    apply_red_yellow_correction(rgb, redHSV, yellowHSV);
} else if (g > r && r >= b) {
    // Yellow-Green-White tetrahedron
    apply_yellow_green_correction(rgb, yellowHSV, greenHSV);
}
// ... and so on for all 6 primary/secondary hues
```

1.4 Helix — Texture & Detail

1.4.1 Purpose

Helix enhances image texture through clarity, micro-contrast, and multi-scale spatial equalization.

1.4.2 Source Code

`/01_OFX/02_Helix/00_Source/Helix.cpp` `/01_OFX/02_Helix/00_Source/HelixKernels.metal`

1.4.3 Mathematical Foundation

1.4.3.1 Golden Angle Sampling

Fibonacci spiral pattern for artifact-free spatial sampling:

```
const float GOLDEN_ANGLE = 2.39996323f;  // (3 - √5)

for (int i = 0; i < numSamples; i++) {
    float angle = GOLDEN_ANGLE * (float)i;
    float radius = sqrt((float)i / (float)numSamples);
```

```
    samples[i].dx = cos(angle) * radius;
    samples[i].dy = sin(angle) * radius;
}
```

1.4.3.2 Clarity (Local Contrast)

Unsharp mask in luminance channel with controlled radius:

```
float clarity = pixel_lum - local_average_lum;
output_lum = pixel_lum + clarity * amount;
```

The local average is computed using a weighted blur kernel at the specified radius.

1.4.3.3 Micro Contrast

Fine detail enhancement using high-frequency extraction:

```
// Extract fine detail at small radius
float fine_detail = pixel - blur_at_small_radius(pixel);

// Apply micro contrast enhancement
output = pixel + fine_detail * microAmount;
```

1.4.3.4 Spatial Equalizer (6-Band)

Multi-scale frequency decomposition with independent control:

Band	Description	Typical Radius
Z1	Ultra Fine	1-2 px
Z2	Fine	4-8 px
Z3	Medium	16-32 px
Z4	Coarse	64-128 px
Z5	Very Coarse	256-512 px
Z6	Ultra Coarse	1024+ px

Each band applies:

```
float band_detail = blur_at_radius[n] - blur_at_radius[n+1];
output += band_detail * band_gain[n];
```

1.5 Omega — Film Stock Emulation

1.5.1 Purpose

Omega renders the complete photochemical film look: negative stocks, dye processes, print stocks, grain, and halation. All stock parameters derived from manufacturer sensitometric data.

1.5.2 Source Code

`/01_OFX/04_Omega/00_Source/OmegaPlugin.mm` `/01_OFX/04_Omega/00_Source/OmegaKernel.metal` `/01_OFX/04_Omega/03_Data/spectral_data.h` `/01_OFX/04_Omega/03_Data/film_stocks.h`

1.5.3 Mathematical Foundation

1.5.3.1 H&D Curve (Hurter-Driffield)

The characteristic curve maps scene luminance to film density:

```
Density = f(log (Exposure))
```

Omega models this as a parametric sigmoid:

```
float hd_curve(float logE, float gamma, float shoulder, float ceiling, float black) {
    // Toe region
    float toe = black + (logE + offset) * toe_slope;

    // Linear region
    float linear = (logE - midpoint) * gamma;

    // Shoulder region (soft clip)
    float shoulder_val = ceiling - (ceiling - linear) * exp(-shoulder * (logE - shoulder_start));

    // Blend regions smoothly
    return blend_regions(toe, linear, shoulder_val, logE);
}
```

1.5.3.2 Spectral Dye Density

Each film stock has three dye layers (cyan, magenta, yellow) with wavelength-dependent absorption:

```
// From manufacturer spectral data
struct SpectralDensity {
    float wavelength[81];  // 380nm to 780nm, 5nm steps
    float cyan[81];
    float magenta[81];
    float yellow[81];
};
```

Color reproduction is computed by integrating the product of: - Scene spectral power distribution - Film sensitivity at each wavelength - Dye transmission at each wavelength

1.5.3.3 Film Stocks (42 Negatives, 19 Prints)

1.5.3.3.1 Motion Picture Negatives **Kodak Vision3 5219 500T** (2007)

```
ISO: 500
Balance: 3200K (Tungsten)
Gamma: 0.503
R/G/B Ceiling: [1.030, 0.996, 1.010]
R/G/B Multiplier: [1.034, 1.000, 0.906]
RMS Granularity: 5.08
```

Fuji Eterna 500T (2006)

```
ISO: 500
Balance: 3200K (Tungsten)
Exposure Base: 2 (not 10)
MTF at 50 lp/mm: ~0.35
Distinctive: Cooler palette, less saturation
```

1.5.3.3.2 Print Stocks **Kodak 2383 Vision Print** (1998)

```
LAD Values: [1.09, 1.06, 1.03]
Gamma: ~2.6 (theatrical projection)
D-min: [0.05, 0.05, 0.06]
D-max: [4.1, 4.2, 4.1]
```

1.5.3.4 Dye Processes (10 Options)

Process	Description
Neutral	No additional processing
Dye Transfer (Neg)	Technicolor IB from negative
Dye Transfer (K)	Kodachrome-style dye imbibition
Dye Transfer (Slide)	Transparency dye transfer
Radiance	Luminance-emphasized dye blend
Technicolor IV	1930s-1950s process
Technicolor V	1955-1975 process
Ilfochrome M	Cibachrome metallic
Ilfochrome P	Cibachrome pearl

1.5.3.5 Grain Model

Density-dependent grain using RMS measurements from manufacturer data:

```
// RMS varies with density (more grain in midtones)
float rms_at_density(float density, float* rms_curve, float* density_curve) {
    return interpolate(density, density_curve, rms_curve);
}

// Apply grain
float grain = gaussian_noise() * rms_at_density(pixel_density);
output = pixel + grain * grain_amount;
```

Film gauge affects grain size: | Gauge | Grain Scale | |——-|————-| | 16mm | 1.5× | | 35mm | 1.0× | | 65mm | 0.7× |

1.5.3.6 Halation Model

Light scatter through film base, computed as exponential falloff blur:

```
// Separate highlights above threshold
float3 highlights = max(rgb - threshold, 0.0f);

// Apply exponential falloff blur
float3 halation = blur_with_kernel(highlights, halation_radius);

// Composite with film-base coloring (typically red-orange)
float3 halation_color = float3(1.0f, 0.4f, 0.1f);  // From anti-halation dye
output = rgb + halation * halation_color * amount;
```

Three halation methods: 1. **Physical** — Yedlin-style emulsion scatter model 2. **Proosa** — Additive blend (faster) 3. **Minuth** — Frequency separation approach

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1.6 Film Stock Tasting Notes

1.6.1 Motion Picture Negatives

1.6.1.1 Kodak Vision3 (2007–present)

5203 50D — ISO 50, Daylight *Character:* Crisp, clinical, modern. Finest grain in the Vision3 line. Exceptionally smooth highlight roll-off. *Best for:* High-end commercial, beauty, automotive.

5207 250D — ISO 250, Daylight *Character:* Balanced, versatile. ~14 stops dynamic range. The daylight workhorse. *Best for:* General narrative, documentary.

5213 200T — ISO 200, Tungsten *Character:* Warm, smooth. Creamy skin tones under tungsten. *Best for:* Studio work, tungsten-lit interiors.

5219 500T — ISO 500, Tungsten *Character:* Gritty, alive. Shadows retain detail, colors stay saturated. *Best for:* Night exteriors, available light.

1.6.1.2 Kodak ECN-II Historical (1974–2000s)

5247 II 100T — ISO 100, Tungsten, 1974 *Character:* Classic Hollywood warmth. Rich reds, deep blues. *Best for:* Period pieces (1970s-1990s).

5293 200T EXR — ISO 200, Tungsten, 1992 *Character:* The definitive 1990s film look. Warm but not orange. *Best for: Heat*, *Seven*, *Fight Club* era.

1.6.1.3 Kodak ECN-I Historical (1950–1974)

5247 100T — ISO 100, Tungsten, 1950 *Character:* Soft, pastel. The original Eastman Color look. *Best for: The Searchers*, *Rear Window*, *Vertigo* era.

1.6.2 Still Photography

1.6.2.1 Kodak Portra

Portra 160 — ISO 160, Portrait *Character:* Creamy, natural. Flattering skin tones. *Best for:* Portrait, wedding, fashion.

Portra 400 — ISO 400, Portrait *Character:* Versatile, warmer than 160. *Best for:* All-purpose professional photography.

Ektar 100 — ISO 100, Saturated *Character:* Punchy, vivid. Finest grain in consumer line. *Best for:* Landscape, product, travel.

1.6.2.2 Fuji Professional

Pro 400H — ISO 400, Portrait *Character:* Cool, ethereal. Pastel highlights. *Best for:* Wedding, editorial.

Eterna 500T — ISO 500, Motion Picture *Character:* Cool, clean. Less saturated than Kodak. *Best for:* Modern digital-era cinema aesthetic.

1.6.3 Reversal / Slide

Kodachrome 64 — ISO 64, K-14 *Character:* Rich, timeless. Unique dye-transfer colors. *Best for:* The National Geographic look.

Velvia 50 — ISO 50, E-6 *Character:* Hyper-saturated, contrasty. Legendary for landscapes. *Best for:* Nature when reality isn't colorful enough.

Provia 100F — ISO 100, E-6 *Character:* Natural, accurate. Faithful skin tones. *Best for:* Professional transparency work.

1.6.4 Print Stocks

Kodak 2383 — Vision Print (1998) *Character:* Contrasty, saturated. The theatrical reference. *Gamma:* ~2.6

Kodak 5381 — Color Print (1983) *Character:* Classic theatrical. Less contrast than 2383. *Best for:* 1980s-1990s theatrical aesthetic.

1.7 Pipeline Integration

1.7.1 Recommended Order

```
Alpha (input transform) →
Phi (primary grade) →
Omega Negative (film emulation) →
Helix (texture refinement) →
Omega Print (final look) →
Alpha (output transform)
```

1.7.2 Color Space Flow

1. **Alpha**: Camera log/gamut → ACEScct AP1
2. **Phi**: Grade in ACEScct (exposure-linear feel)
3. **Omega**: Emulate in linear AP1
4. **Helix**: Detail work in log space
5. **Alpha**: AP1 → Display (Rec.709/P3/2020 with gamma)

1.8 Technical Notes

1.8.1 GPU Acceleration

All plugins support Metal (macOS) and OpenCL acceleration: - **Metal**: Preferred on Apple Silicon, uses buffer-based OFX standard - **OpenCL**: Cross-platform fallback

1.8.2 Data Sources

- Spectral sensitivity: Manufacturer datasheets
- H&D curves: Published sensitometric data
- Dye densities: Spectrophotometer measurements
- Grain RMS: Manufacturer technical publications
- Matrix coefficients: ACES CTL transforms

1.8.3 References

- Kodak Essential Reference Guides for Sensitometry
- Fujifilm Professional Motion Picture Product Data
- ARRI Camera Color Science Documentation
- ACES Technical Documentation (Academy)
- Steve Yedlin ASC, “Display Prep Demo” and “Color Science for Filmmaking”

Aletheia Film Tools v1.0 All film stock data derived from manufacturer specifications and published research.