Pseudo-Spectral Imaging

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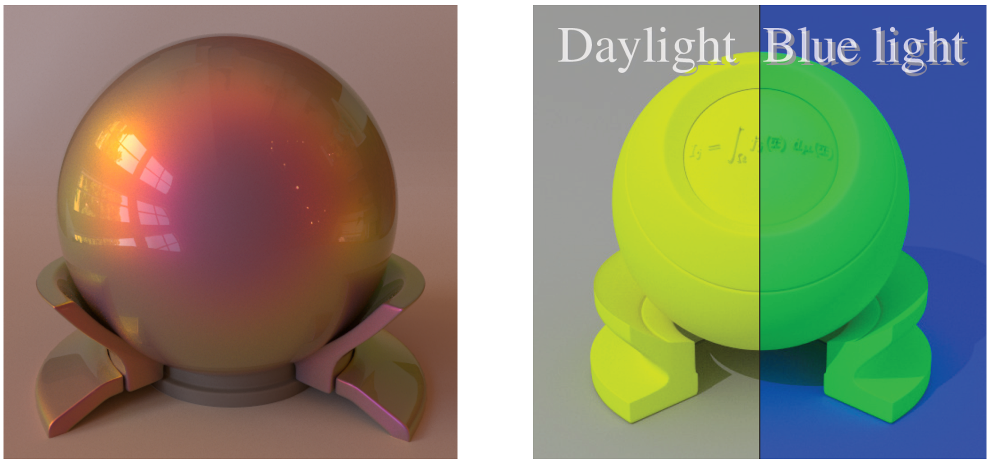

Figure 1: Left: an iridescent material [Fourneau et al., 2024] under environment lighting. Right: a fluorescent material [Belcour et al., 2025] under two typical illuminants. In both cases, RGB rendering is sufficient to achieve accurate results compared to spectral references.

1 Context

In Computer Graphics, there are two main classes of rendering engines. RGB rendering is the most common and is based on RGB colors emitted by light sources, reflected by objects according to their materials, and absorbed by sensors. This is clearly an approximation of physical light transport, since the properties of interest should not be colors but spectra; only at the very end of the rendering process should spectra be converted to colors. The other main class of rendering engine is thus spectral: it is not only much more costly in terms of computation and memory resources, but also makes asset capture (i.e., textures, environments) much more tedious. Yet it remains the solution of choice when it comes to produce physically-realistic (even predictive) images: it properly accounts for a variety of complex effects such as metamerism, iridescence, fluorescence, etc.

2 Objectives

In recent years, research has been done in our team to handle materials with complex spectral effects in RGB rendering engines, with a focus on iridescence [Belcour and Barla, 2017, Fourneau et al., 2024, Fourneau et al., 2025]. Even more recently, we have shown that fluorescence, an optical property of materials thought to be only achievable through spectral rendering, could be closely approximated in a modified RGB rendering engine [Fichet et al., 2024, Belcour et al., 2025]. Now our goal is to generalize this approach to the measurement, modeling and rendering of spectral effects in a non-spectral framework, which we call Pseudo-Spectral Imaging (PSI). Depending on the interest of the candidate, two different sets of objectives may be pursued: pseudo-spectral measurements of real materials and lighting environments; or pseudo-spectral rendering using material and lighting models.

Pseudo-spectral measurements First, we will study to which extent pseudo-spectral material properties (reflectance, fluorescence) may be captured using a limited amount of measurements. We anticipate that as few as three color measurements under three known but arbitrary illuminants should be sufficient in the simplest case. However, more accurate results may be achieved using controlled lighting and additional measurements. Analytical material models may then be fitted to the measured material properties for editing and rendering. Second, we will evaluate to which extent spectral environment (i.e., distant) lighting may be approximated by pseudo-spectral captures made with a consumer-grade camera of known sensitivity functions. Here again, we will investigate whether more accurate results may be achieved using a controlled setup, for instance using color charts or color filters on the camera. Known spectral lighting models (e.g., of clear or overcast skies) may also be used as apriori to refine the pseudo-spectral approximation.

Pseudo-spectral rendering We will start by revisiting our existing RGB iridescence material models in the context of PSI to evaluate whether their accuracy compared to spectral rendering may be improved. A particular case of interest will be accuracy in multiple scattering scenarios, where RGB approximations are prone to show the strongest approximations. We will then explore how additional effects such as metamerism or vathochromism [6] might be achieved within the PSI framework. The idea will be to let artists control the colors potentially reflected by different illuminants, or potentially transmitted through thick colored transparent objects, all without resorting to spectral representations. These developments will require implementing dedicated light transport solutions, which may be of two kinds: either based on real-time rendering (e.g., using Godot [7]) with support of live pseudo-spectral material editing; or based on off-line rendering (e.g., using Mitsuba [8]) with adapted importance sampling strategies.

3 Required skills

Scientific computation in Python, Computer graphics techniques.

For pseudo-spectral measurements: familiarity with physical measurements and experimental setups is welcome; specific knowledge in radiometric measurements and computer vision would be a plus.

For pseudo-spectral rendering: GLSL shader programming; knowledge in path tracing would be a plus.

References

[Belcour and Barla, 2017] Belcour, L. and Barla, P. (2017). A Practical Extension to Microfacet Theory for the Modeling of Varying Iridescence. *ACM Transactions on Graphics*, 36(4):65.

[Belcour et al., 2025] Belcour, L., Fichet, A., and Barla, P. (2025). A Fluorescent Material Model for Non-Spectral Editing & Rendering. In *SIGGRAPH Conference Papers 2025 -: Special Interest Group on Computer Graphics and Interactive Techniques Conference Conference Papers*, pages 1–9, Vancouver BC, Canada. ACM.

[Fichet et al., 2024] Fichet, A., Belcour, L., and Barla, P. (2024). Non-orthogonal reduction for rendering fluorescent materials in non-spectral engines. *Computer Graphics Forum*, 43(4).

[Fourneau et al., 2025] Fourneau, G., Barla, P., and Pacanowski, R. (2025). Efficient Modeling and Rendering of Iridescence from Cholesteric Liquid Crystals. In *EGSR 2025 - 36th Eurographics Symposium on Rendering*, Copenhagen, Denmark. Eurographics Association.

[Fourneau et al., 2024] Fourneau, G., Pacanowski, R., and Barla, P. (2024). Interactive Exploration of Vivid Material Iridescence using Bragg Mirrors. *Computer Graphics Forum*, 43(2).