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Addressing Grazing Angle Reflections in Phong Models

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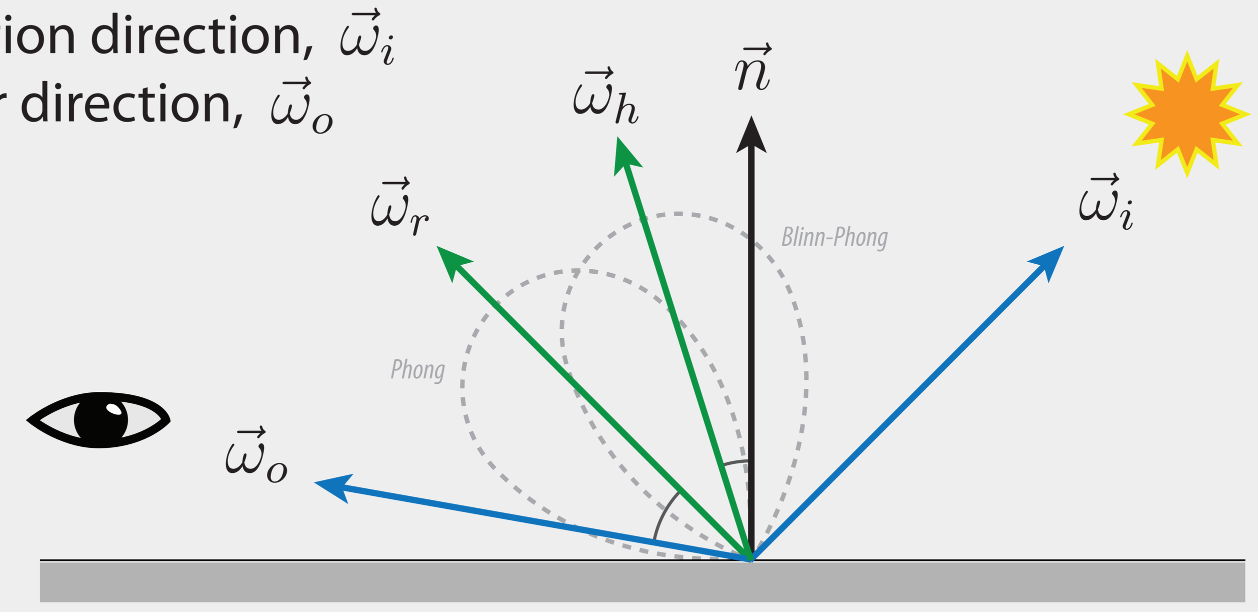
Bidirectional Reflectance Distribution Functions

In this work, we fit Phong models to the BRDFs measured by Matusik et al. [2], but in contrast to previous work we focus on the difficult grazing angles. Our result is a new Phong variant that fits better to a broader range of materials.

- Reflection vector, $\vec{\omega}_r = 2(\vec{\omega}_i \cdot \vec{n})\vec{n} - \vec{\omega}_i$
- Half vector, $\vec{\omega}_h = (\vec{\omega}_i + \vec{\omega}_o)/|\vec{\omega}_i + \vec{\omega}_o|$

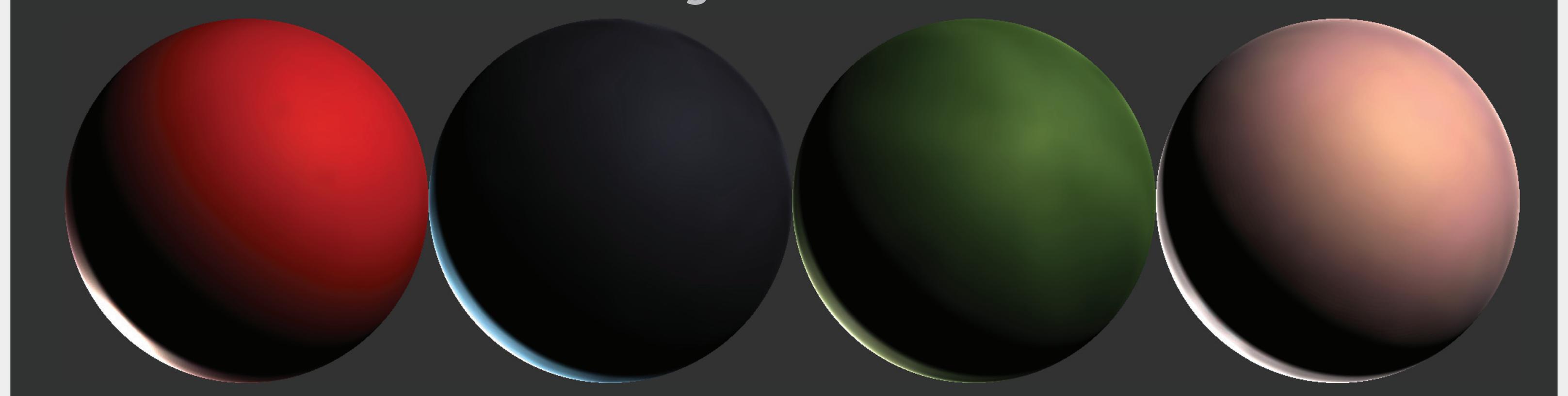
- Surface normal, $\vec{n}$
- Illumination direction, $\vec{\omega}_i$
- Observer direction, $\vec{\omega}_o$



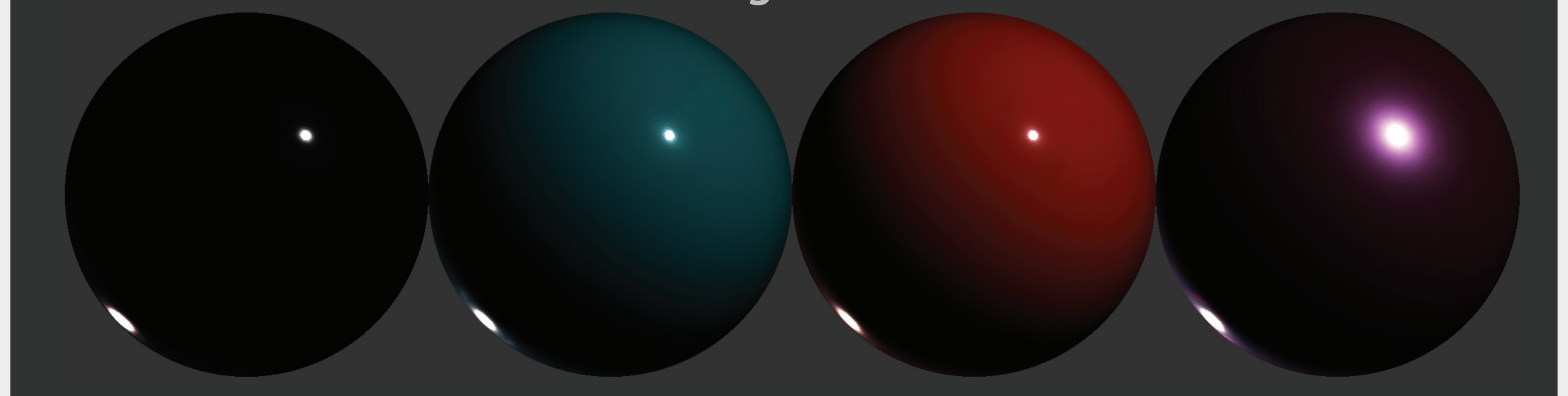
Observations from the MERL database

Inspecting the MERL database of measured BRDFs reveals that some materials exhibit Phong-like and others Blinn-Phong-like behaviour, alhough only Blinn-Phong is assumed physically plausible.

Phong-like Behavior:



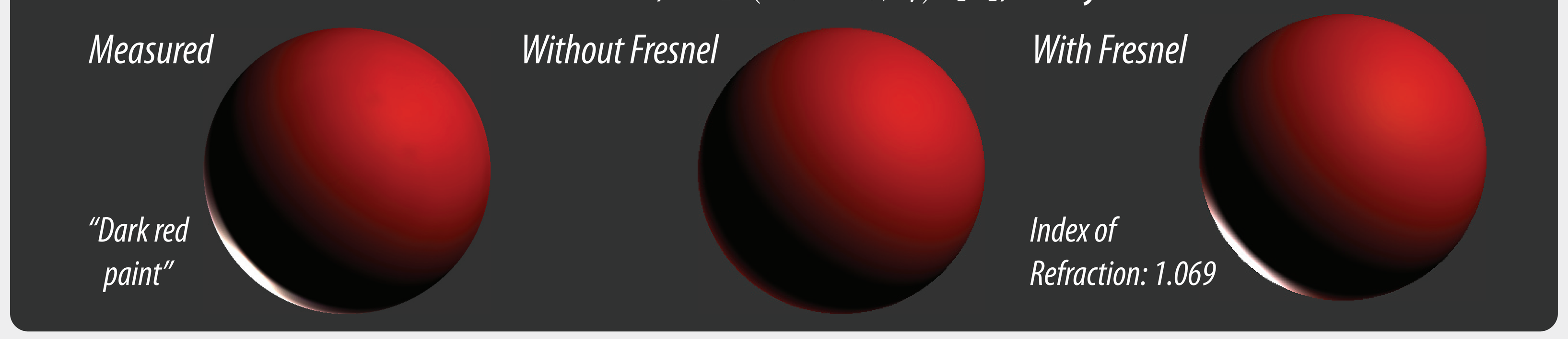
Blinn-Phong-like Behavior:



We suspect the Phong-like behavior is caused by sub-surface scattering in the materials.

Fresnel Coefficient

Compared to many MERL-BRDFs, the intensity of grazing angle reflectance in Phong-models is way too low. In order to boost the intensity at grazing angles, the Fresnel reflectance coefficient, $R_F(\vec{\omega}_i \cdot \vec{\omega}_h, \eta)$ [1], may be used.



Fitting to MERL

Fitting analytical models to densely sampled BRDFs is not trivial [3]. We have found that the following procedure results in good convergences for all materials in the MERL database.

1) Optimize only ρ_d and k_s
2) Optimize only s and α (and η)
3) Optimize s, α and k_s (and η)

Vi minimize the L¹-norm as this corresponds to fitting to the base of the specular peaks.

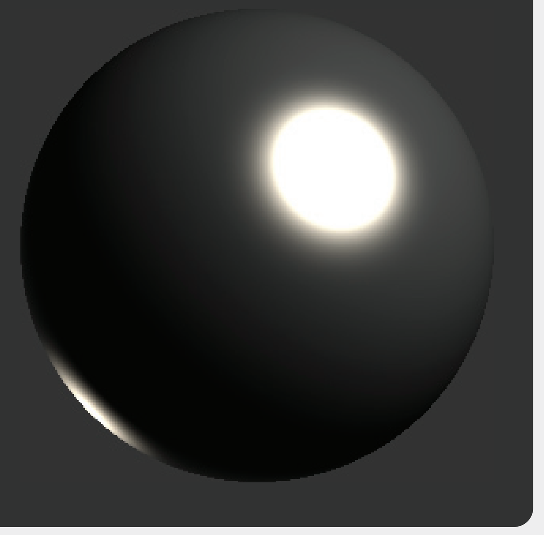
Phong Model [1]

$$f_r^{\mathrm{P}}(\vec{\omega}_i, \vec{\omega}_o) = \frac{\rho_d}{\pi} + \rho_s \frac{s+2}{2\pi}(\vec{\omega}_r \cdot \vec{\omega}_o)^s$$

- Elongated highlight at glancing angles
- Wide highlight at grazing angles
- Claimed non-physical

Blinn-Phong Model [1]

$$f_r^{\mathrm{BP}}(\vec{\omega}_i, \vec{\omega}_o) = \frac{\rho_d}{\pi} + \rho_s \frac{s+8}{8\pi}(\vec{\omega}_h \cdot \vec{n})^s$$



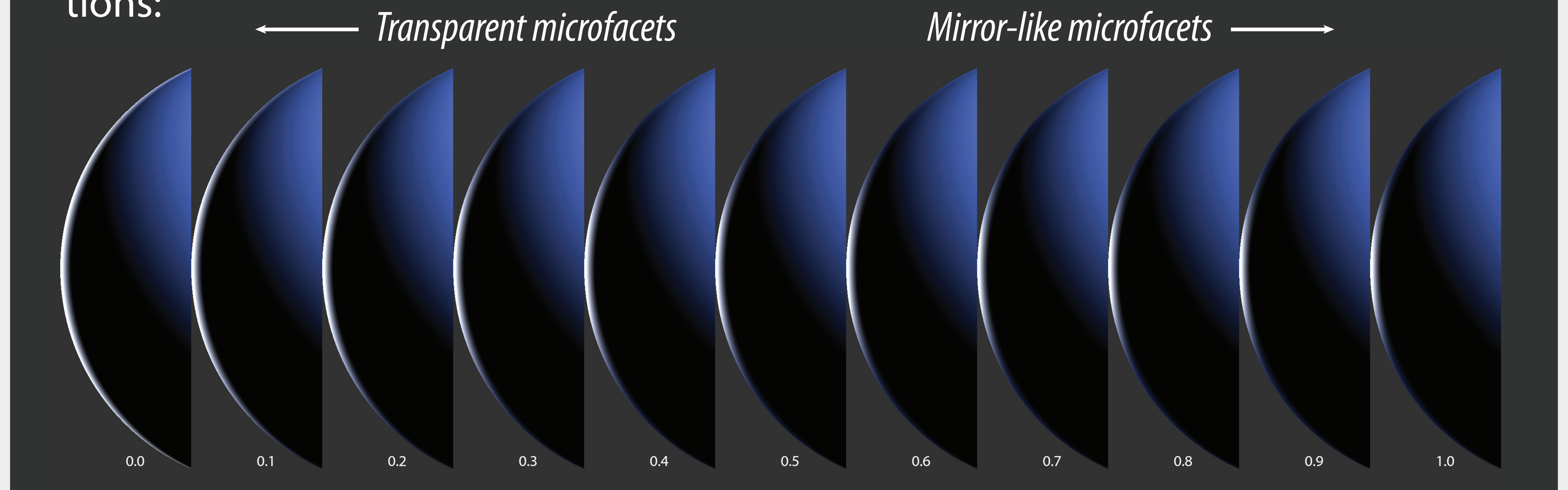
- Circular highlight at glancing angles
- Condenced highlight at grazing angles
- Supported by microfacet theory

Combining Phong and Blinn-Phong

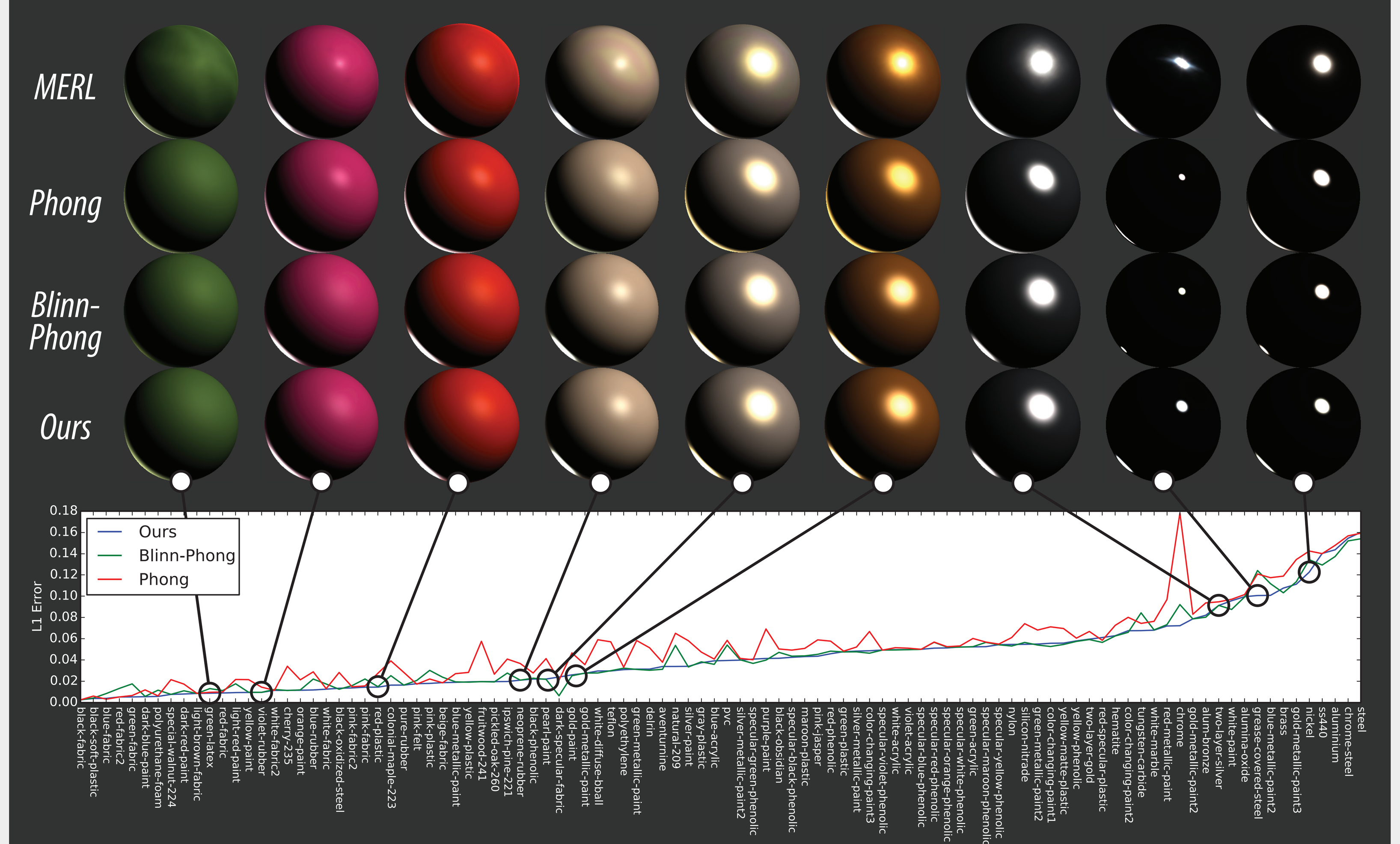
In order to obtain a BRDF-model capable of producing both broad and narrow grazing angle reflections, we propose an interpolation of the two simple BRDF models:

$$f_r^{\mathrm{new}}(\vec{\omega}_i, \vec{\omega}_o) = \frac{\rho_d}{\pi} + k_s\big((1-\alpha)(\vec{\omega}_r \cdot \vec{\omega}_o) + \alpha(\vec{\omega}_h \cdot \vec{n})^4\big)^s$$

With α being an interpolation coeficient, interpolating between the Phong and Blinn-Phong cosines. Effectively this allows shaping of the grazing angle reflections:



Results



[1] AKENINE-MÖLLER, T., HAINES, E., AND HOFFMAN, N. 2008. *Real-Time Rendering*, third ed. A K Peters, Natick, MA.

[2] MATUSIK, W., PFISTER, H., BRAND, M., AND MCMILLAN, L. 2003. A data-driven reflectance model. *ACM Transactions on Graphics (Proc. of ACM SIGGRAPH 2003)* 22, 3, 759–769.

[3] NGAN, A., DURAND, F., AND MATUSIK, W. 2005. Experimental analysis of BRDF models. *In Rendering Techniques 2005 (Proc. of Eurographics Symposium on Rendering)*, 117–126.