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Modeling Light Transport in Fog for Computational Imaging

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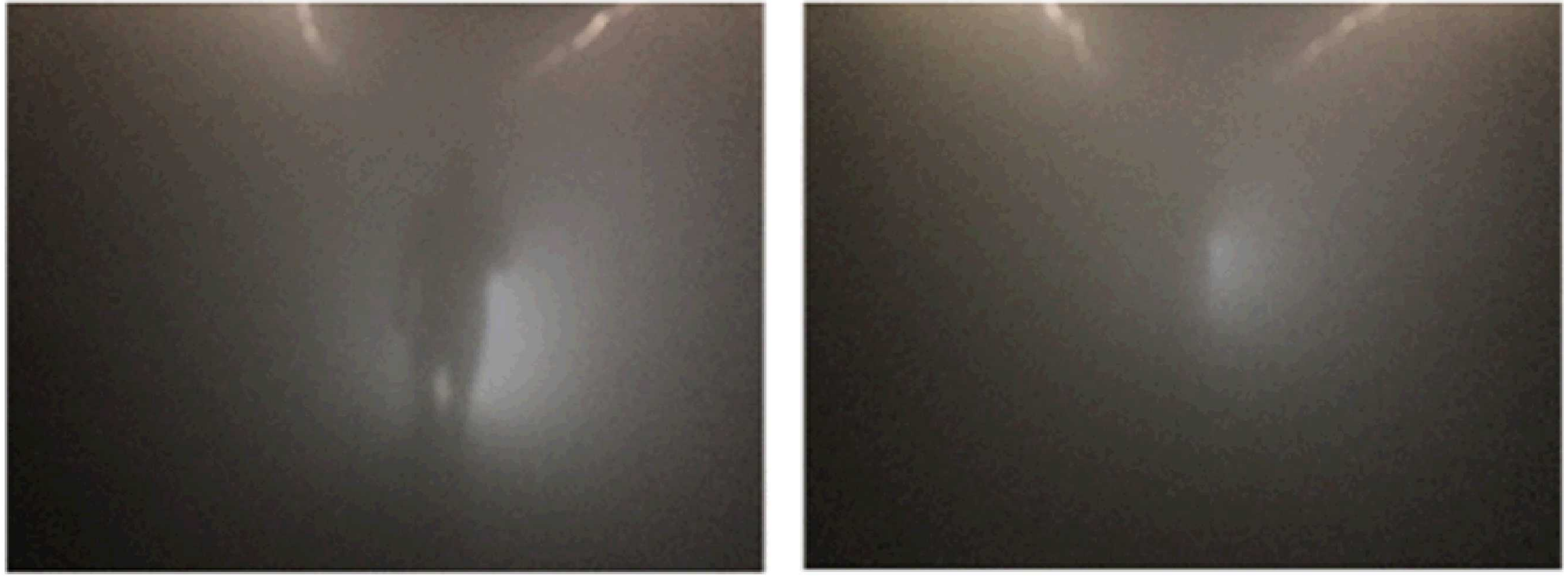

Simulated degraded visual environment at the Sandia Fog Chamber Facility

[5]

Introduction

- Light scattering through a medium can be modeled as photons or particles
- The paths can be visualized like billiard balls

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Introduction

- A Galton board shows the trend of the particles traveling from a light source

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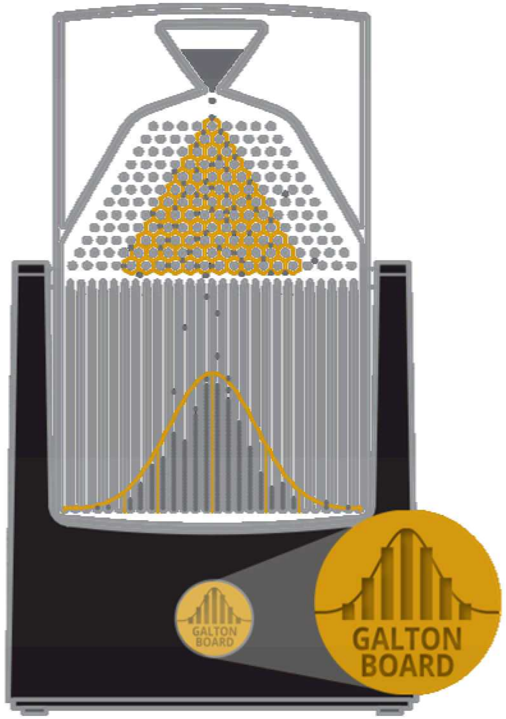

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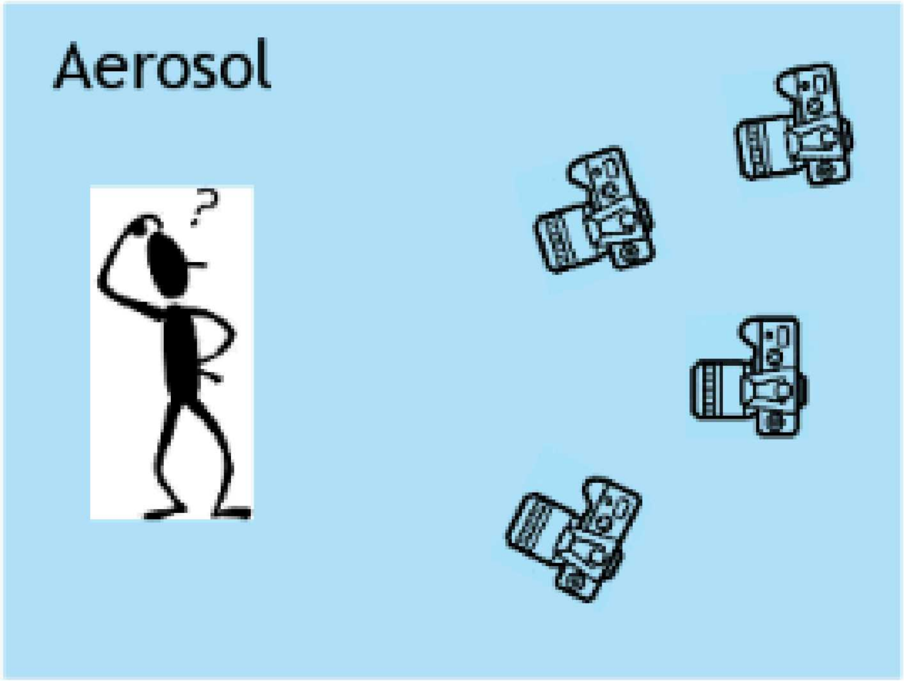
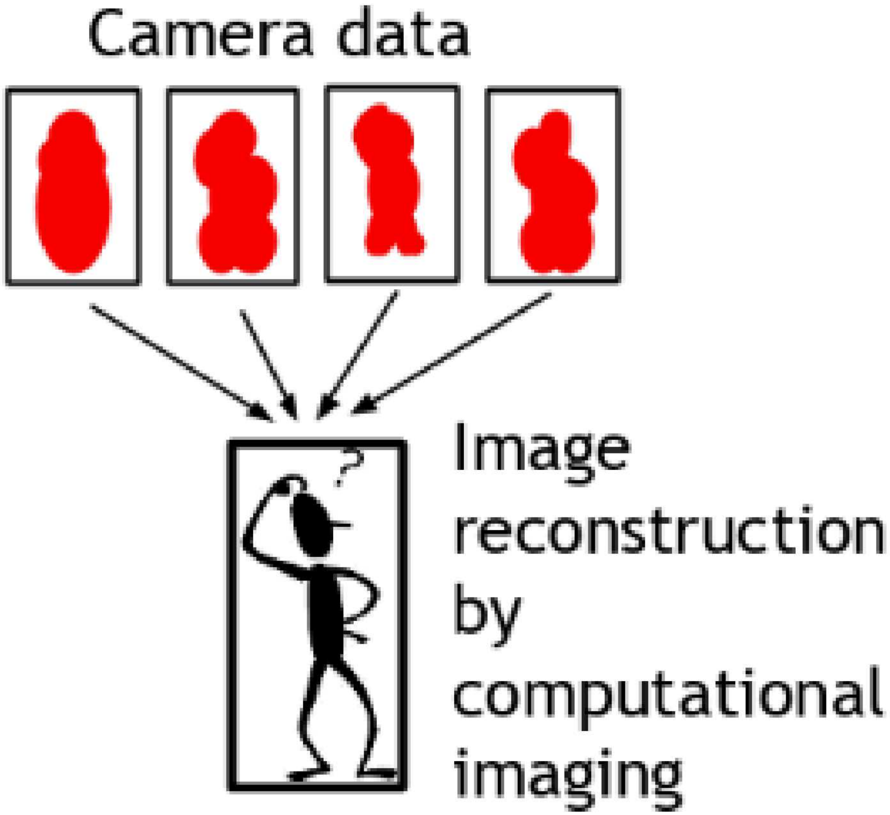
Motivation

- Possible imaging of objects in fog where cameras are not usable





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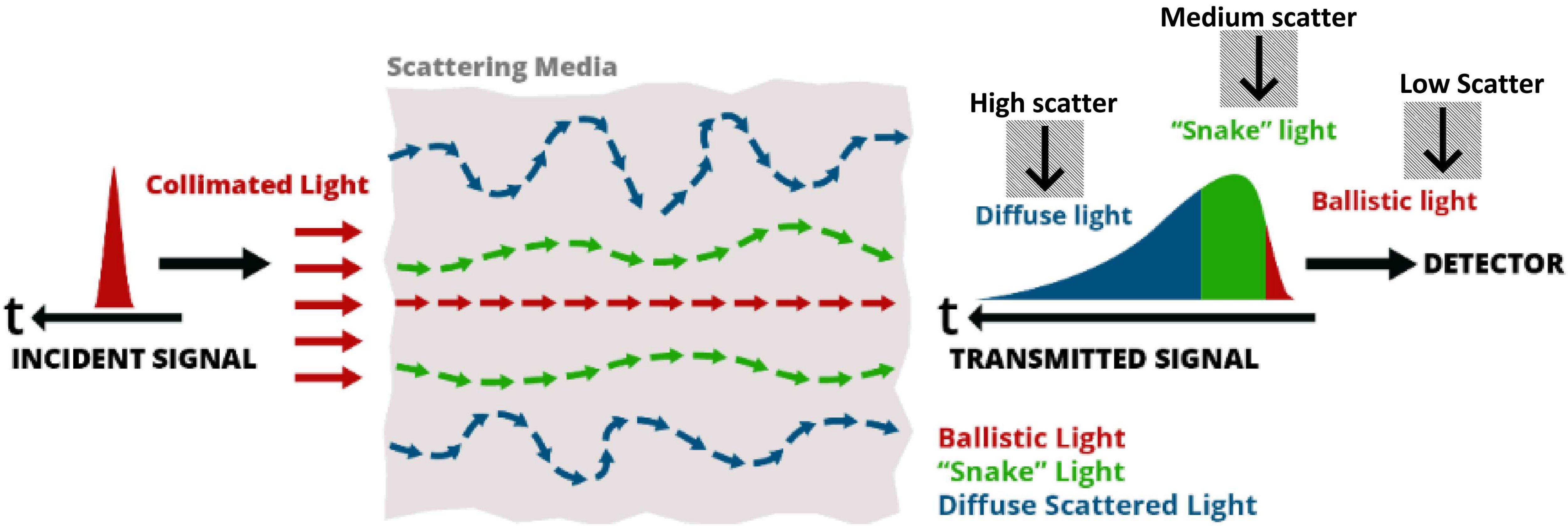
Motivation



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Methods

- The full transport model (radiative transport equation) is computationally cumbersome

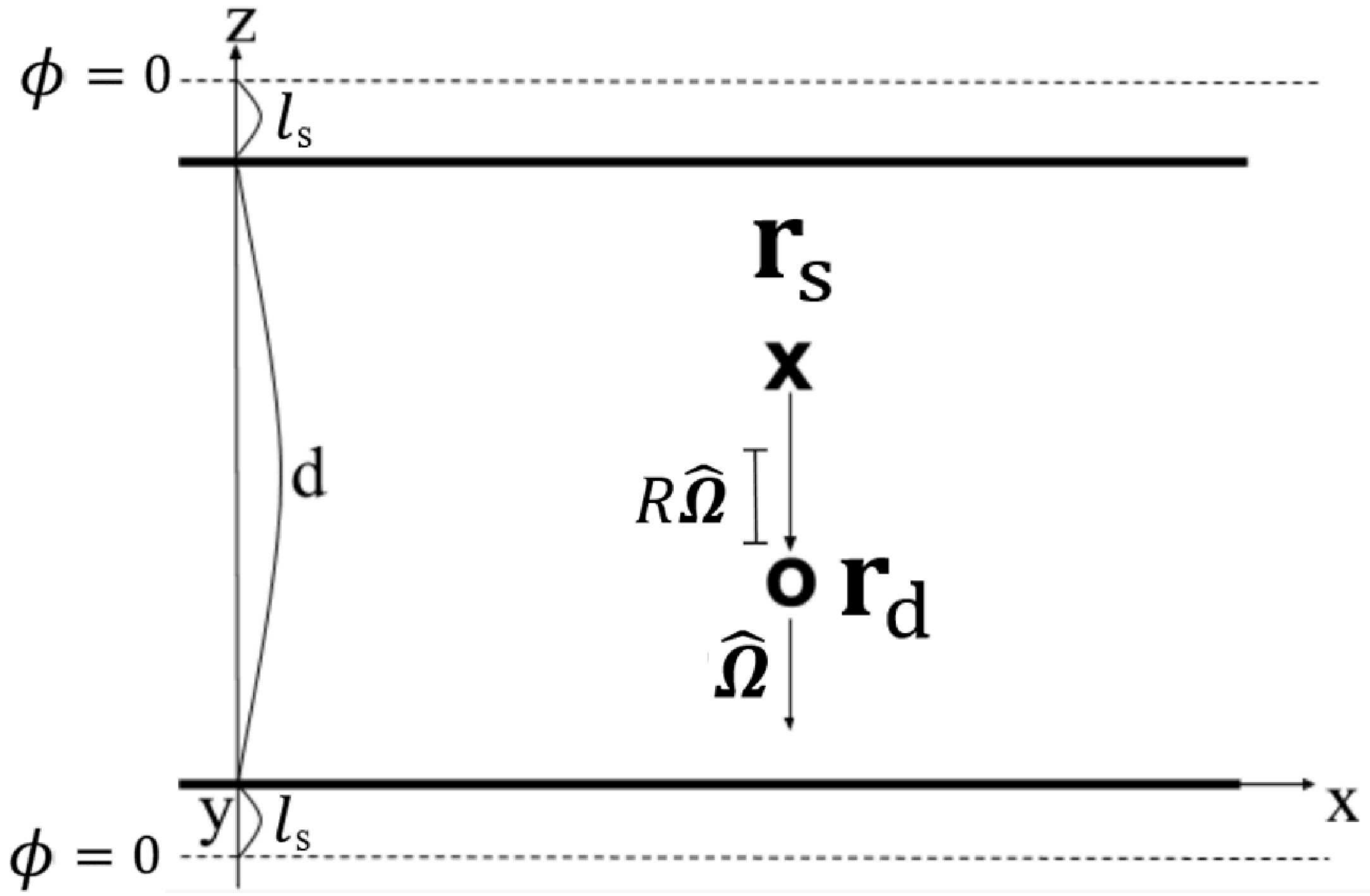
Full Transport Model

$$\frac{1}{\mathrm{c}}\frac{\partial}{\partial t}I(\mathbf{r}.t,\widehat{\mathbf{\Omega}}) + \widehat{\mathbf{\Omega}}\cdot\nabla I(\mathbf{r},\mathrm{t},\widehat{\mathbf{\Omega}}) + (\mu_a+\mu_s)I(\mathbf{r}.t,\widehat{\mathbf{\Omega}}) = \mu_s\int_{4\pi}\mathrm{d}\widehat{\mathbf{\Omega}}' f(\widehat{\mathbf{\Omega}}'\rightarrow\widehat{\mathbf{\Omega}})I(\mathbf{r},\mathrm{t},\widehat{\mathbf{\Omega}}) + \mathrm{Q}(\mathbf{r}.t,\widehat{\mathbf{\Omega}})$$

- Simplifying assumptions must be made based on the level of scatter in the medium

Methods

- Simplifying Assumptions: Anisotropic Source and weak angular dependence for a homogeneous semi-infinite slab



Weak Angular Approximation

$$I(\boldsymbol{r}, t, \widehat{\boldsymbol{\Omega}}) = \frac{1}{4\pi}\,\phi(\boldsymbol{r}, t) + \frac{3}{4\pi}\boldsymbol{J}(\boldsymbol{r}, t) \cdot \widehat{\boldsymbol{\Omega}}$$

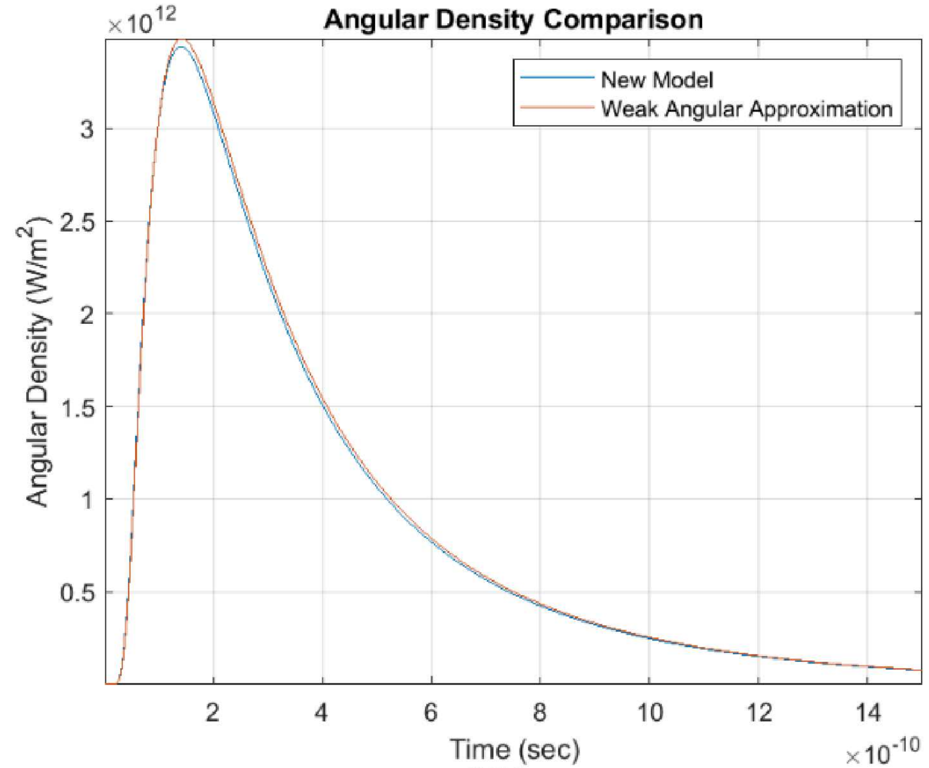
New Model

$$I(\boldsymbol{r}, t, \widehat{\boldsymbol{\Omega}}) = \frac{1}{4\pi}\int_0^\infty dR\, exp[-(\mu_a + \mu_s)R][\phi(\boldsymbol{r}_d - R\widehat{\boldsymbol{\Omega}}, t - \frac{R}{v}) + 3g\boldsymbol{J}\left(\boldsymbol{r}_d - R\widehat{\boldsymbol{\Omega}}, t - \frac{R}{v}\right) \cdot \widehat{\boldsymbol{\Omega}}]$$

Results

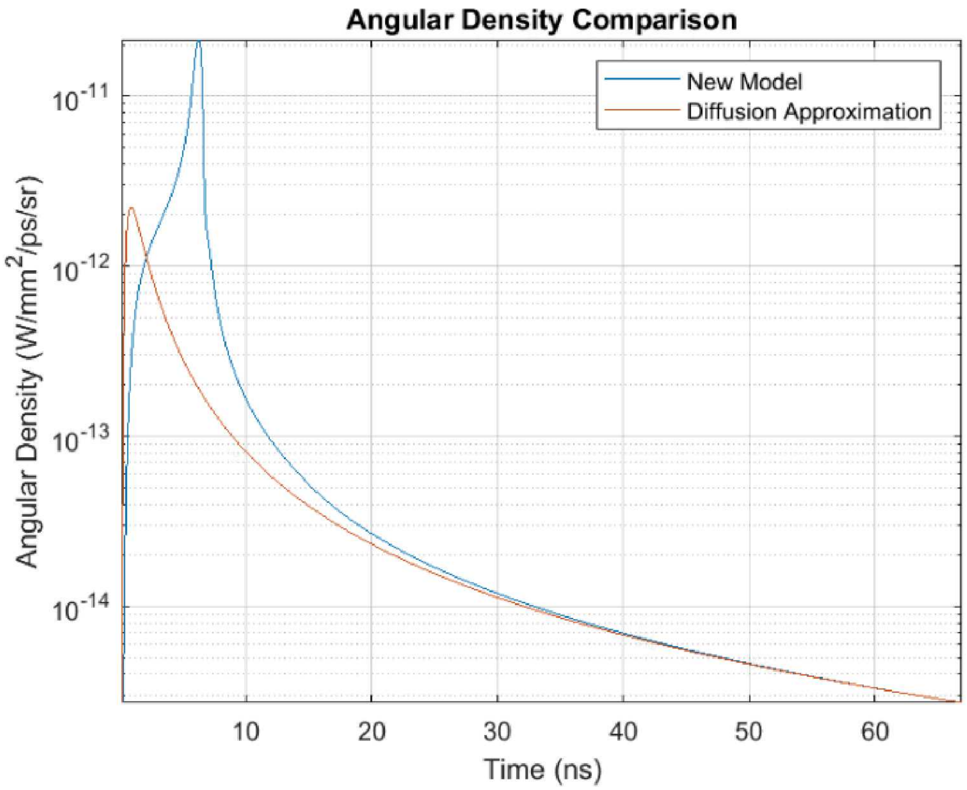
New model and weak angular approximation for a homogeneous semi-infinite slab

Tissue Radiance



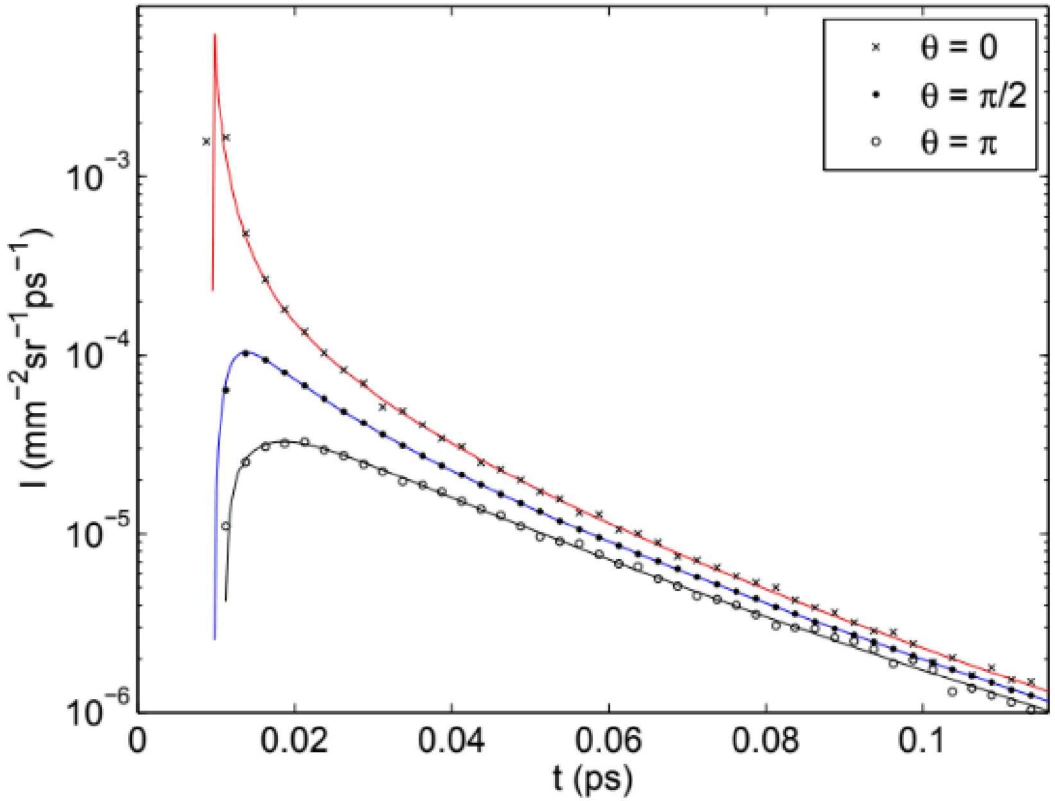
[3]

Fog Radiance



Results

Simulated Medium Anisotropic Scatter Medium



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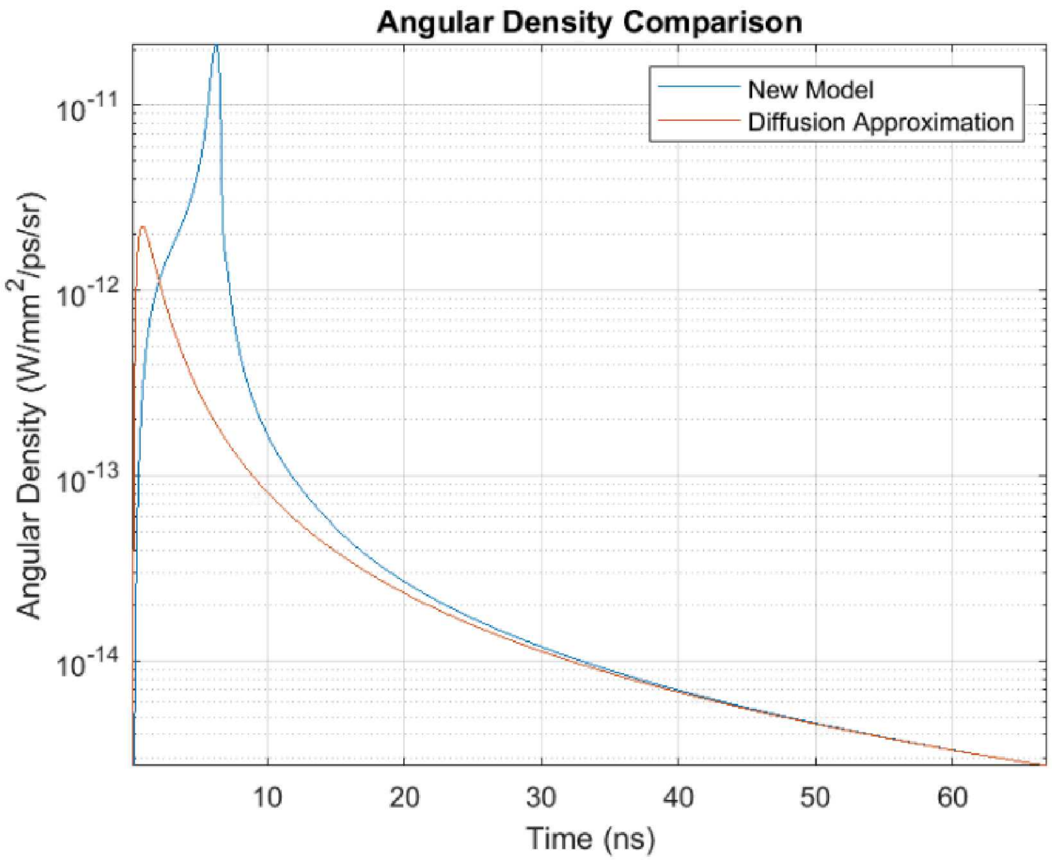
Fog Radiance



Conclusions

- Moderately scattered or “snake” light described by model
- Next step is to compare with experimental data from the Sandia fog chamber

Acknowledgements

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