EGSR DELFT 2023
THE 34TH EUROGRAPHICS SYMPOSIUM ON RENDERING

A Practical and Hierarchical Yarn-based Shading Model for Cloth

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Why Cloth Rendering?

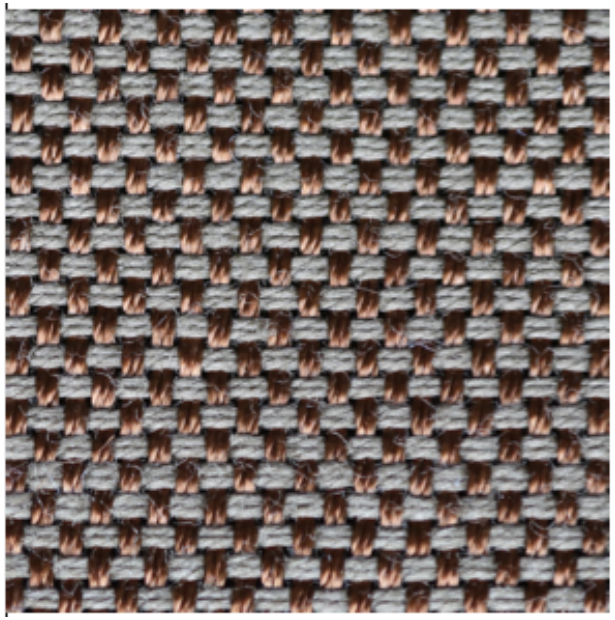
Entertainment

Virtual Reality

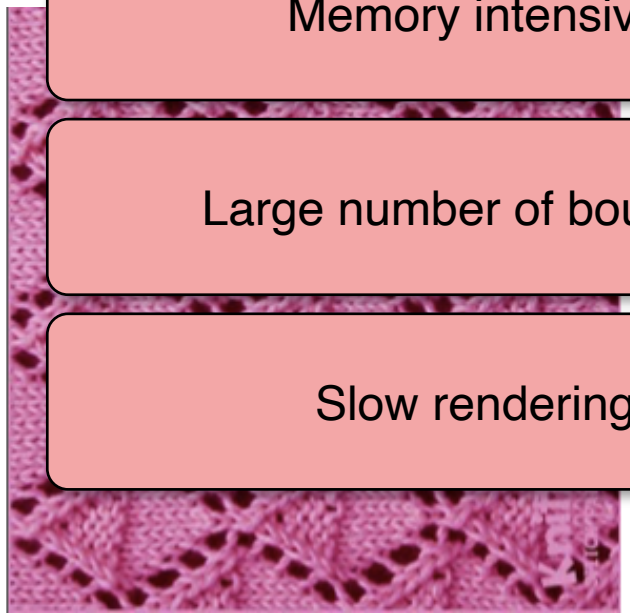
Online retail

Cloth Rendering is Difficult!

Challenge: Geometry



Woven sample



Knitted sample

Memory intensive!

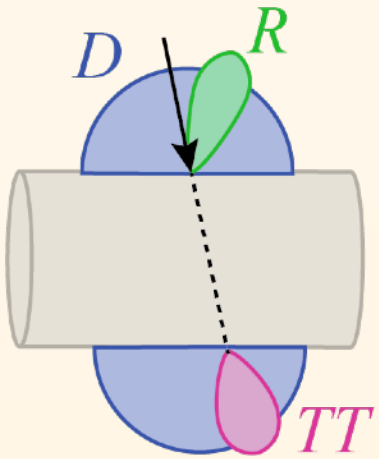
Large number of bounces!

Slow rendering!

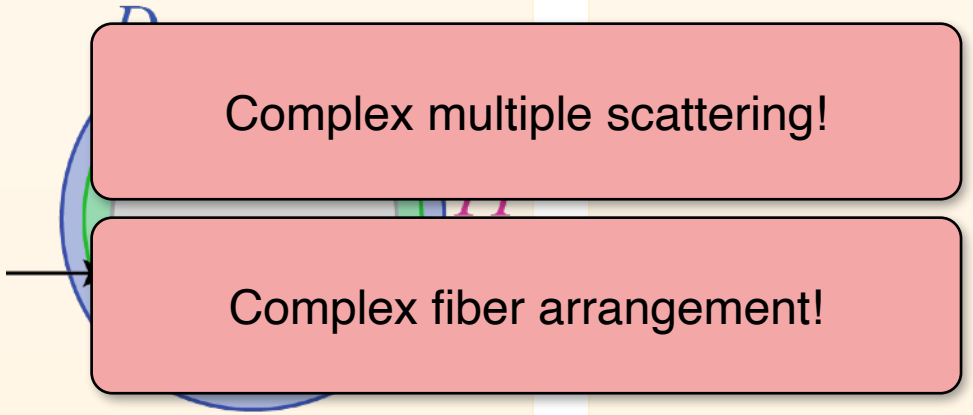
arn Ply Fiber

Cloth Rendering is Difficult!

Challenge: Shading



Longitudinal



Azimuthal

Fiber shading model

?

Yarn shading model

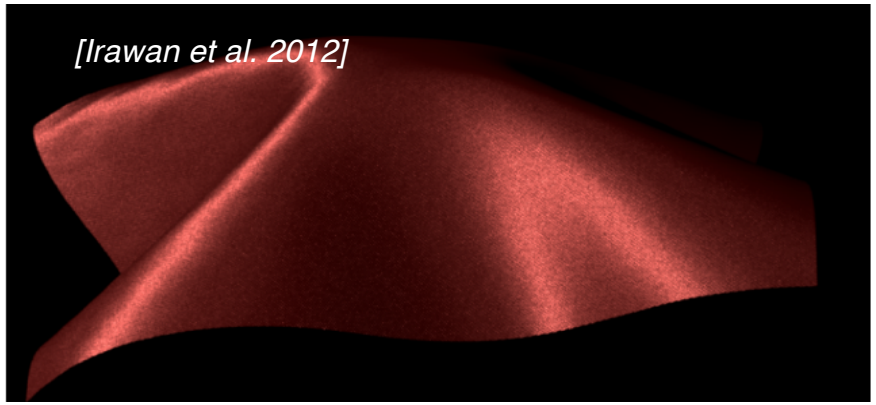
Background

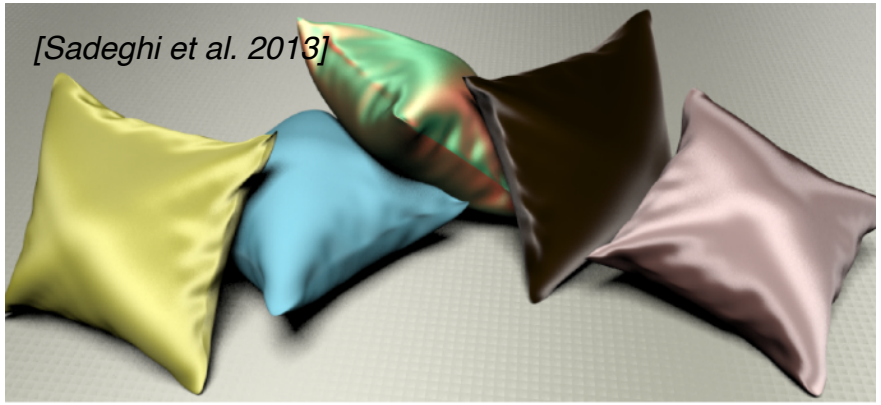
Surface-based Methods

Memory and time efficient!

Not real enough!

Only woven!



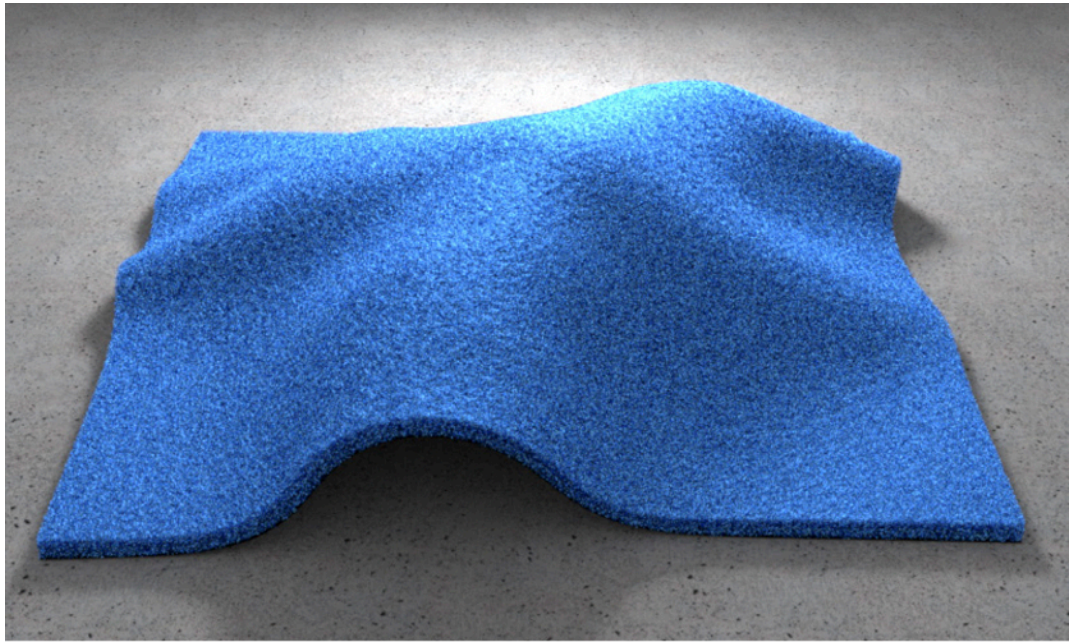


Micro-appearance Methods

Accurate and realistic!

Memory and time inefficient!

[Zhao et al. 2016]



[Khungurn et al. 2015]

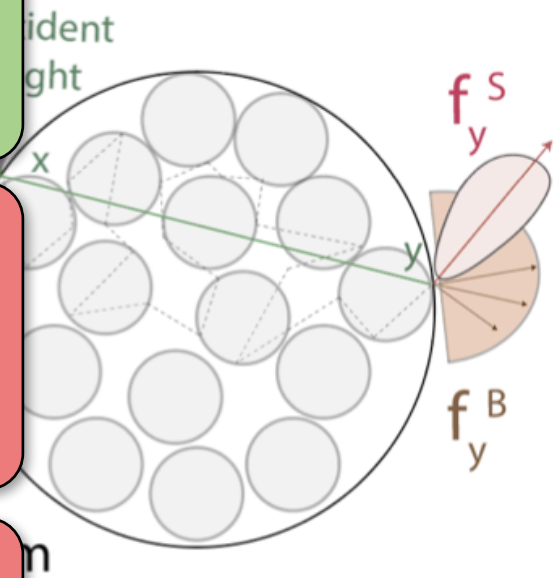
Ply-based method

[Montazeri et al. 2020]

Fast rendering!

Artist driven

Inefficient for multi-ply



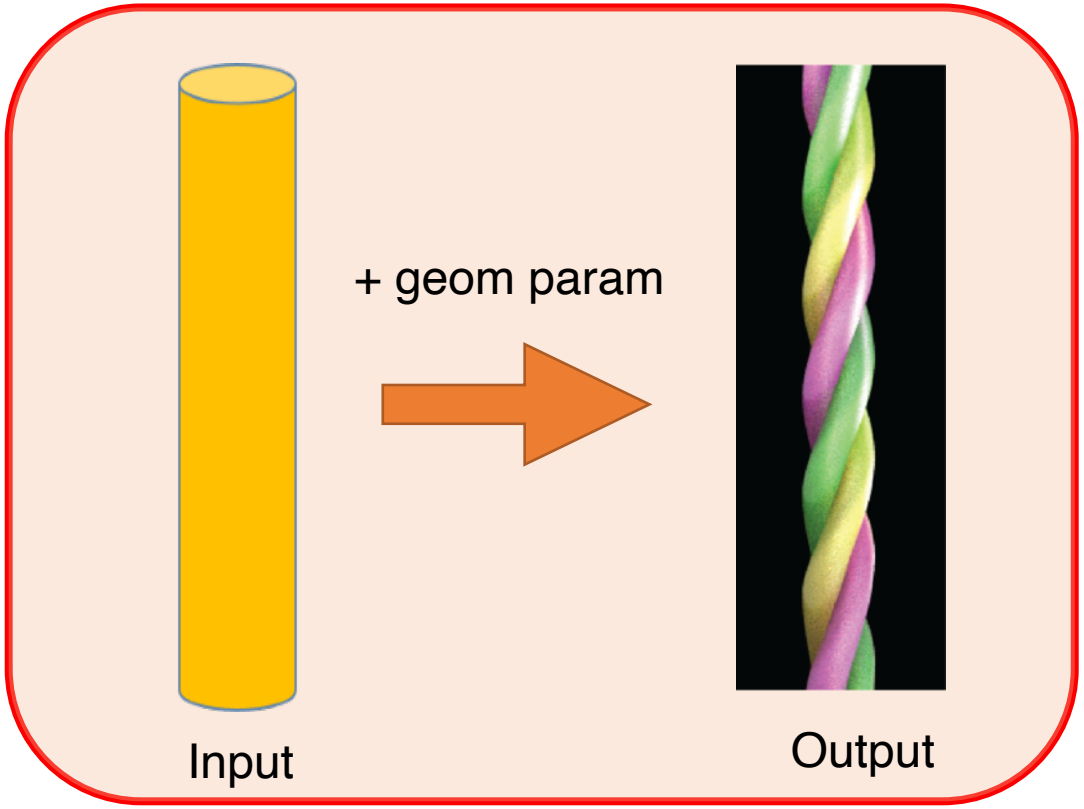
So What?

Accurate and realistic!	Fast rendering!	Memory efficient!
Physically-based!	General model!	Easy to edit!

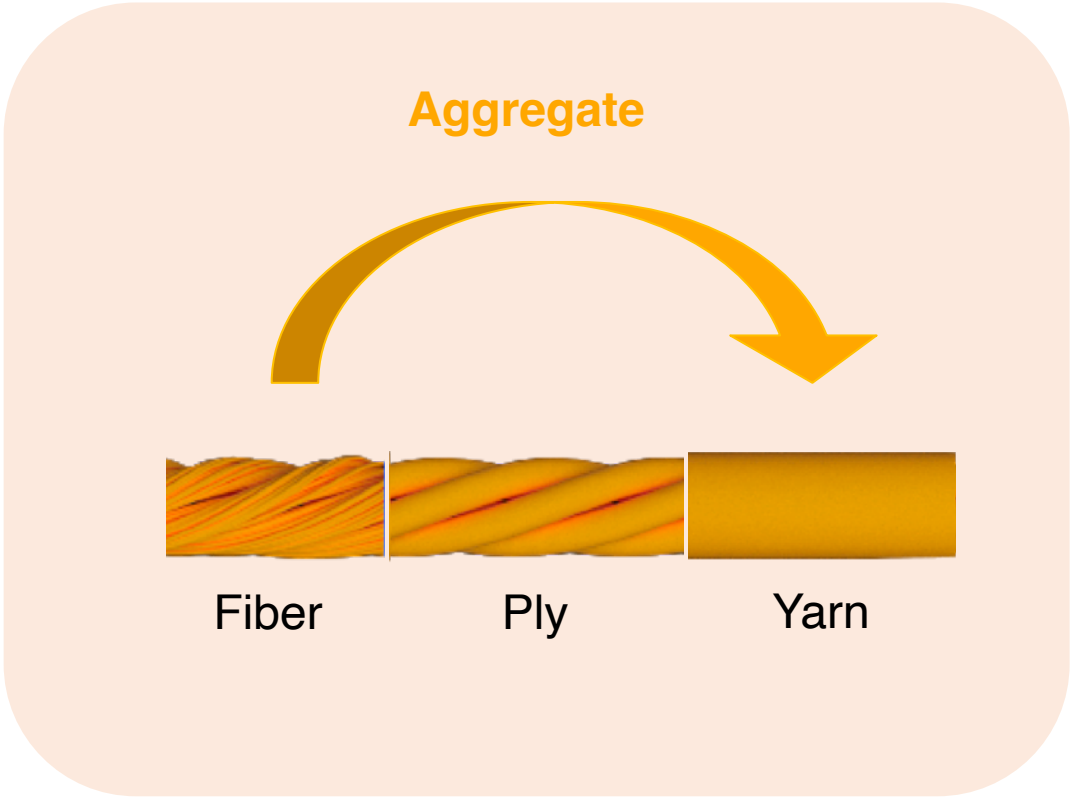
Our Method

Avatar: The Way of Water, Weta Digital, 2023

Overview

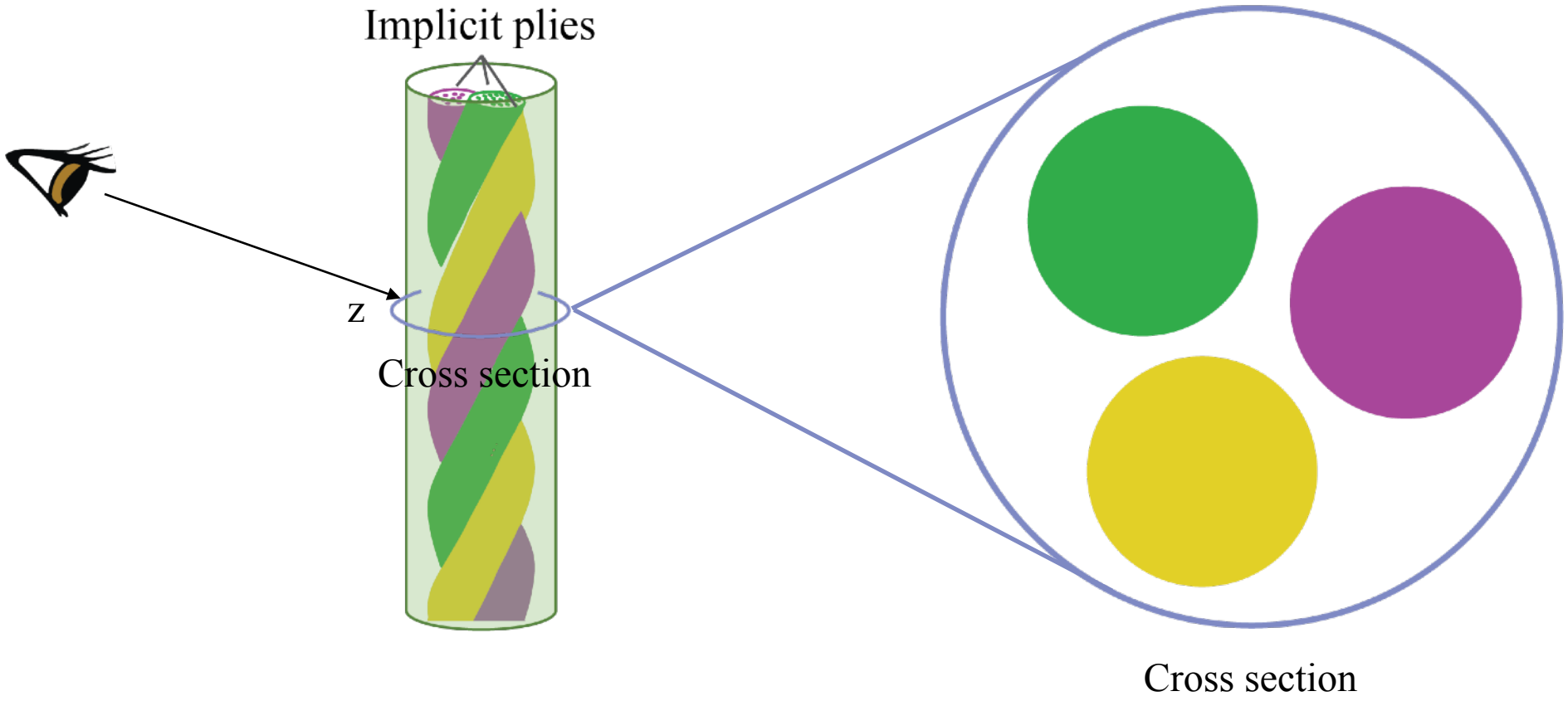


Geometric representation

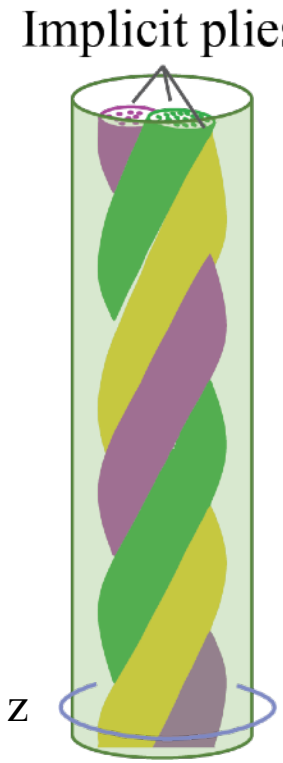


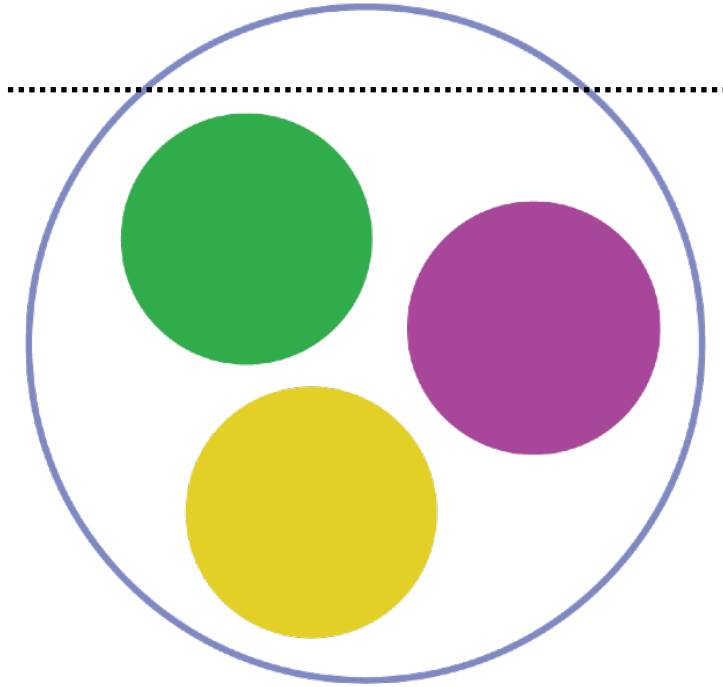
Shading

Our geometric representation



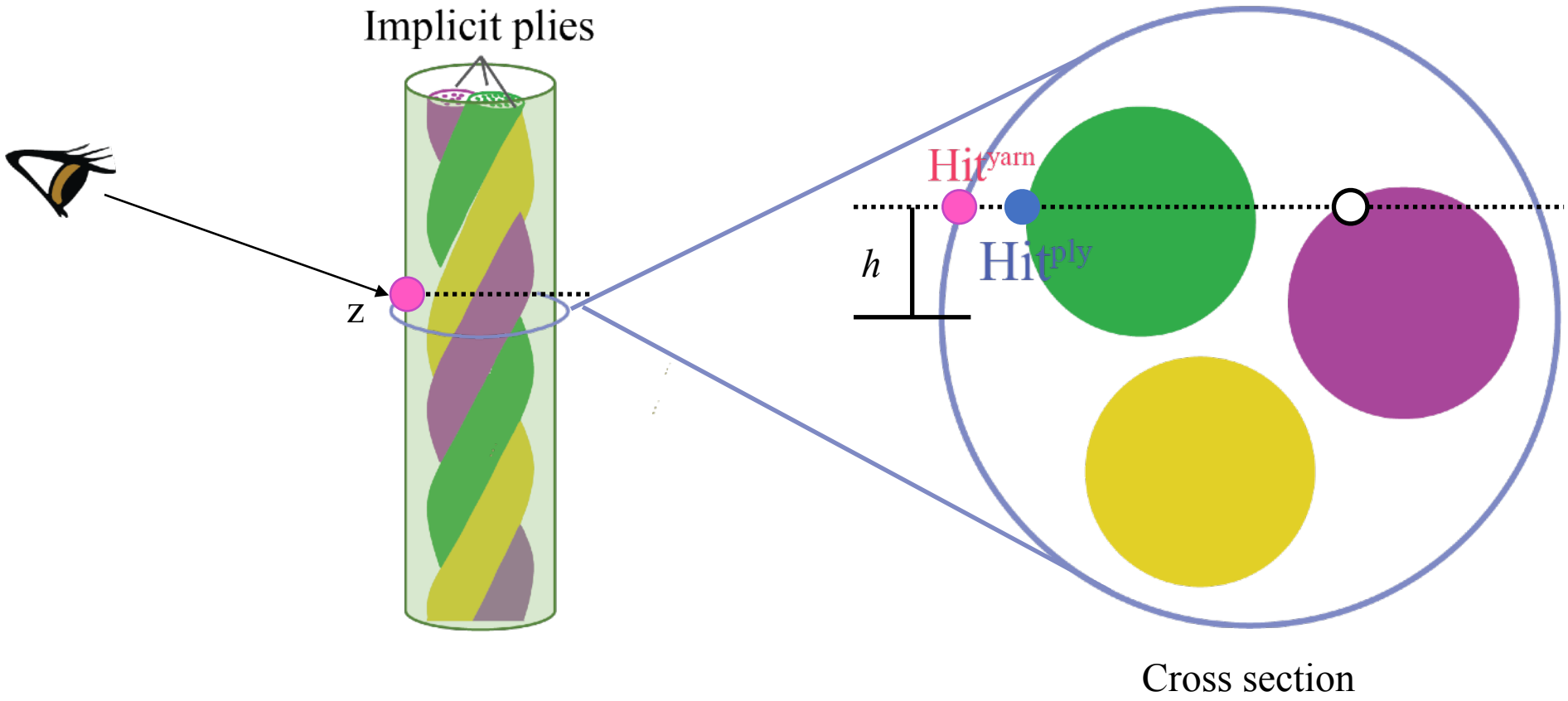
Our geometric representation



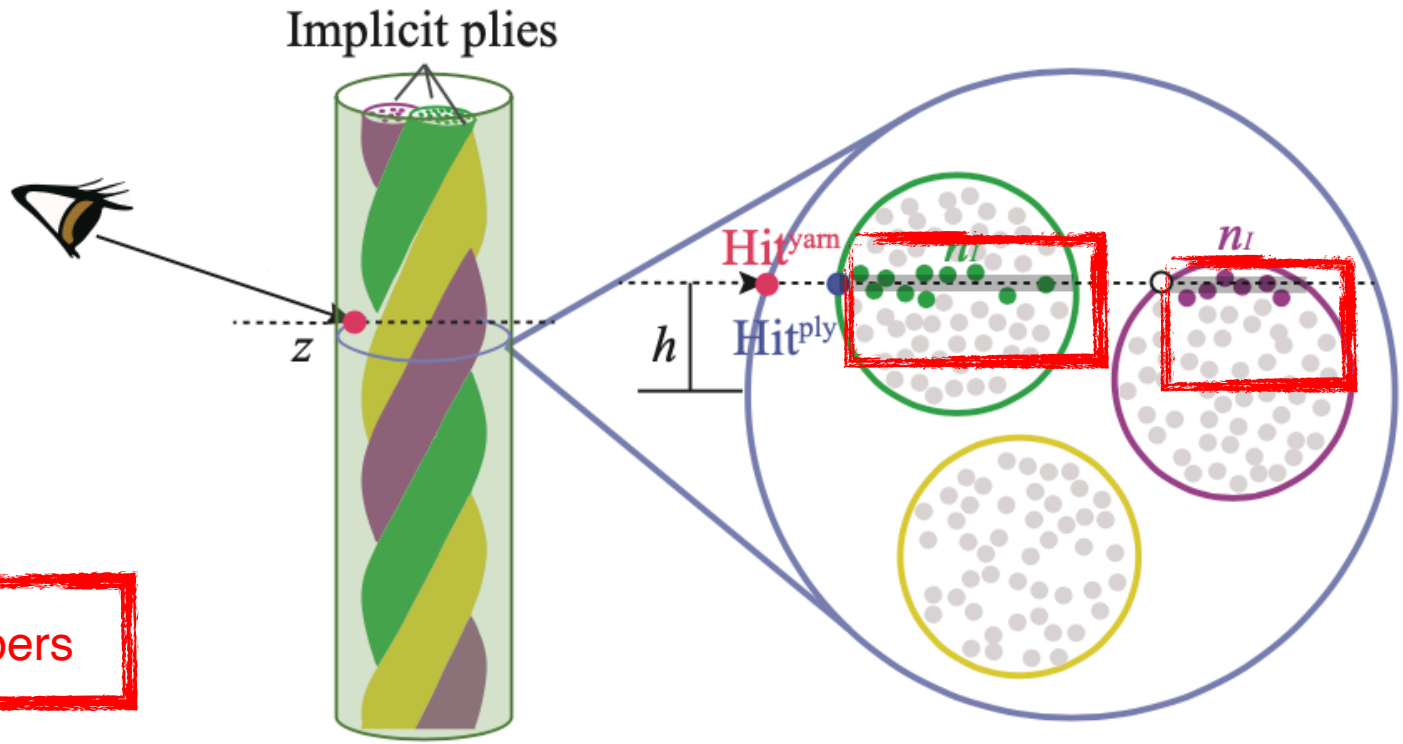


Cross section

Our geometric representation



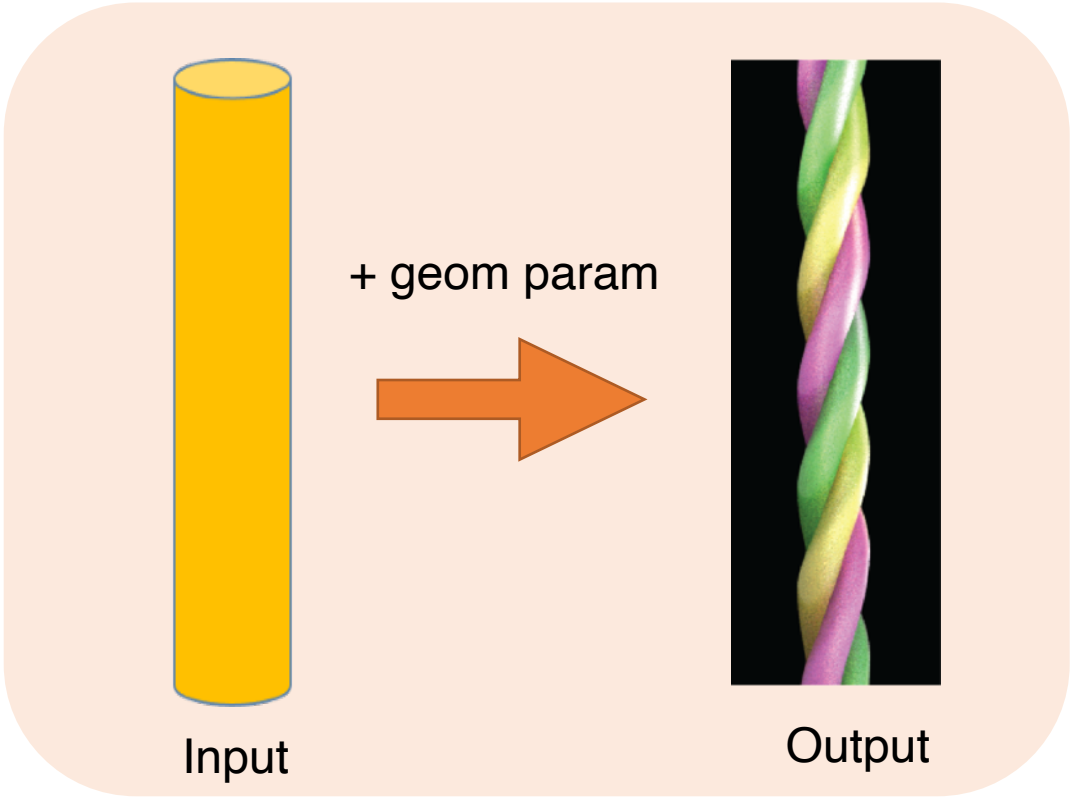
Our geometric representation



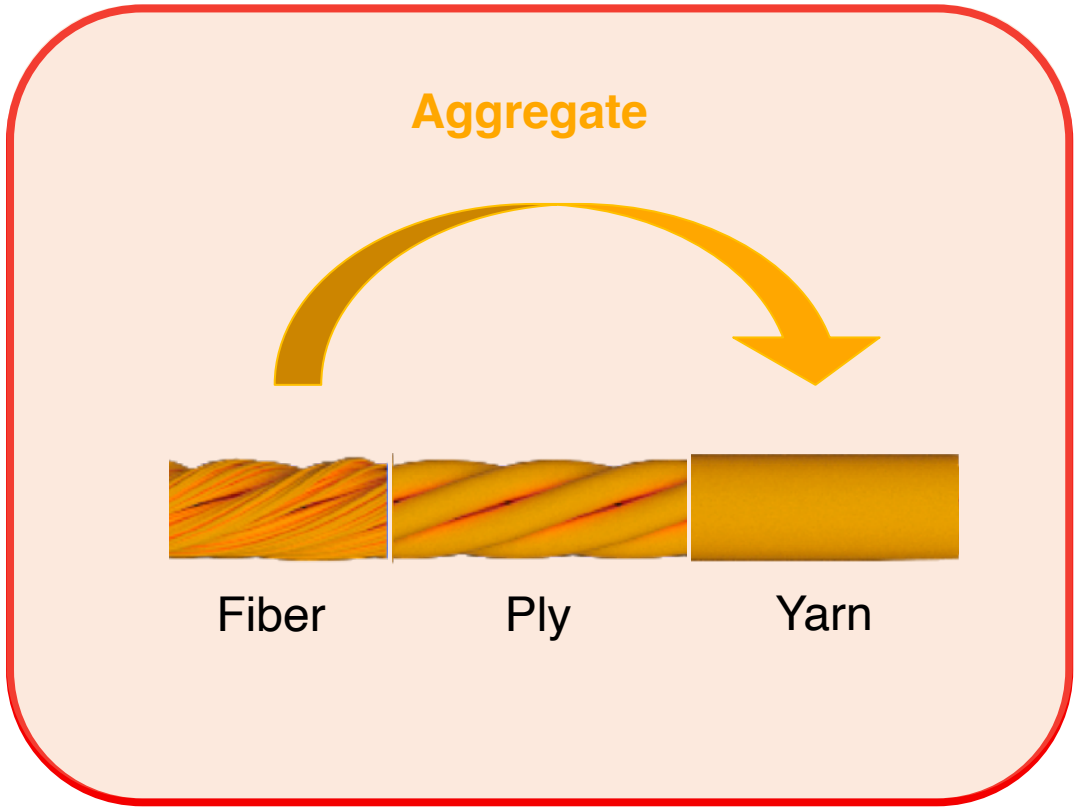
Intersected fibers

Cross section

Overview

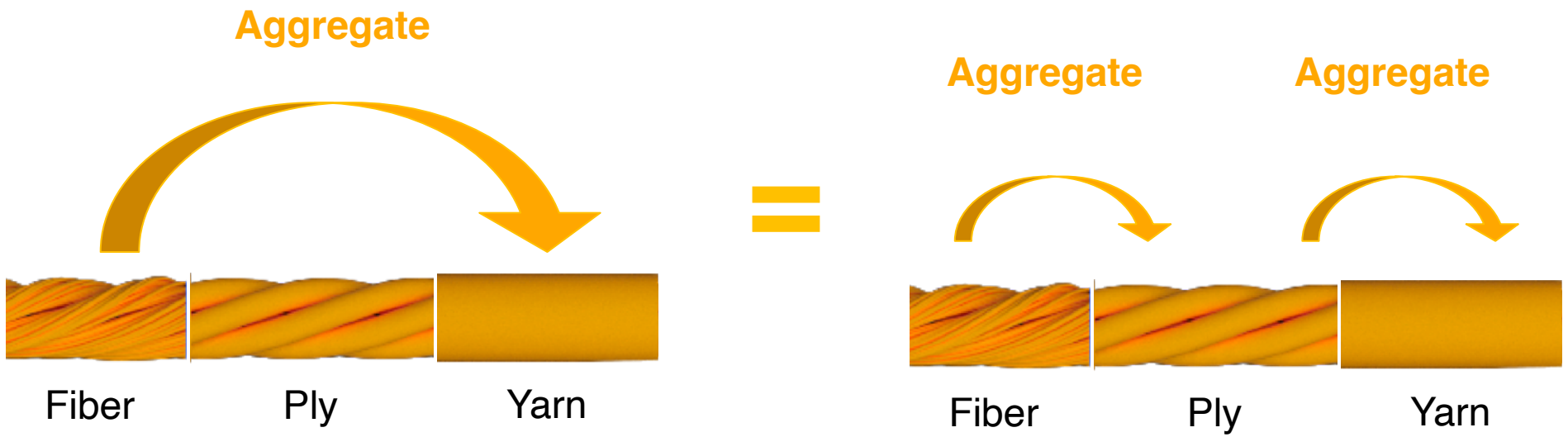


Geometric representation

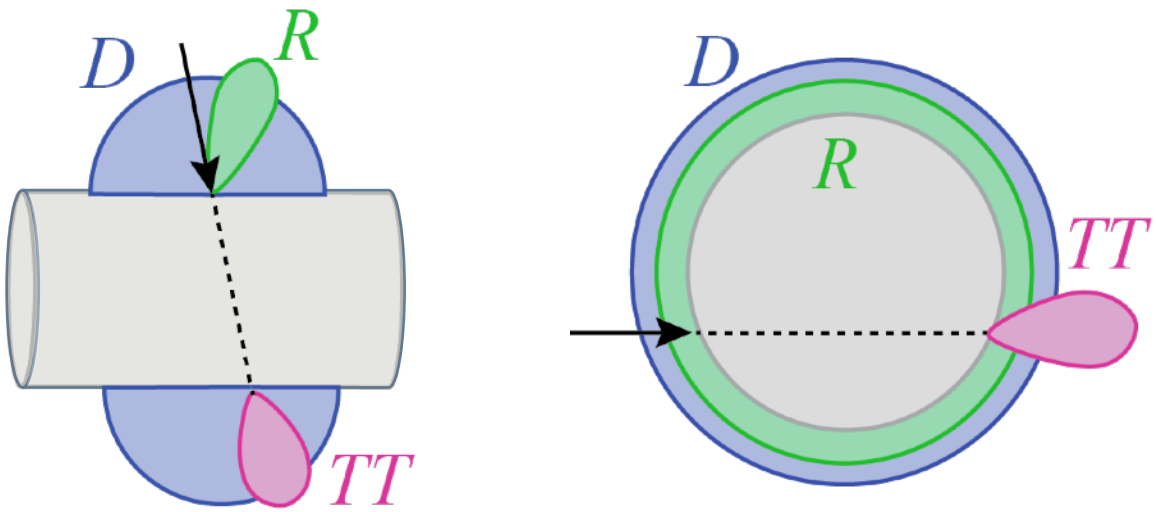


Shading

Our Hierarchical Shading Model



Fiber-level Shading Model



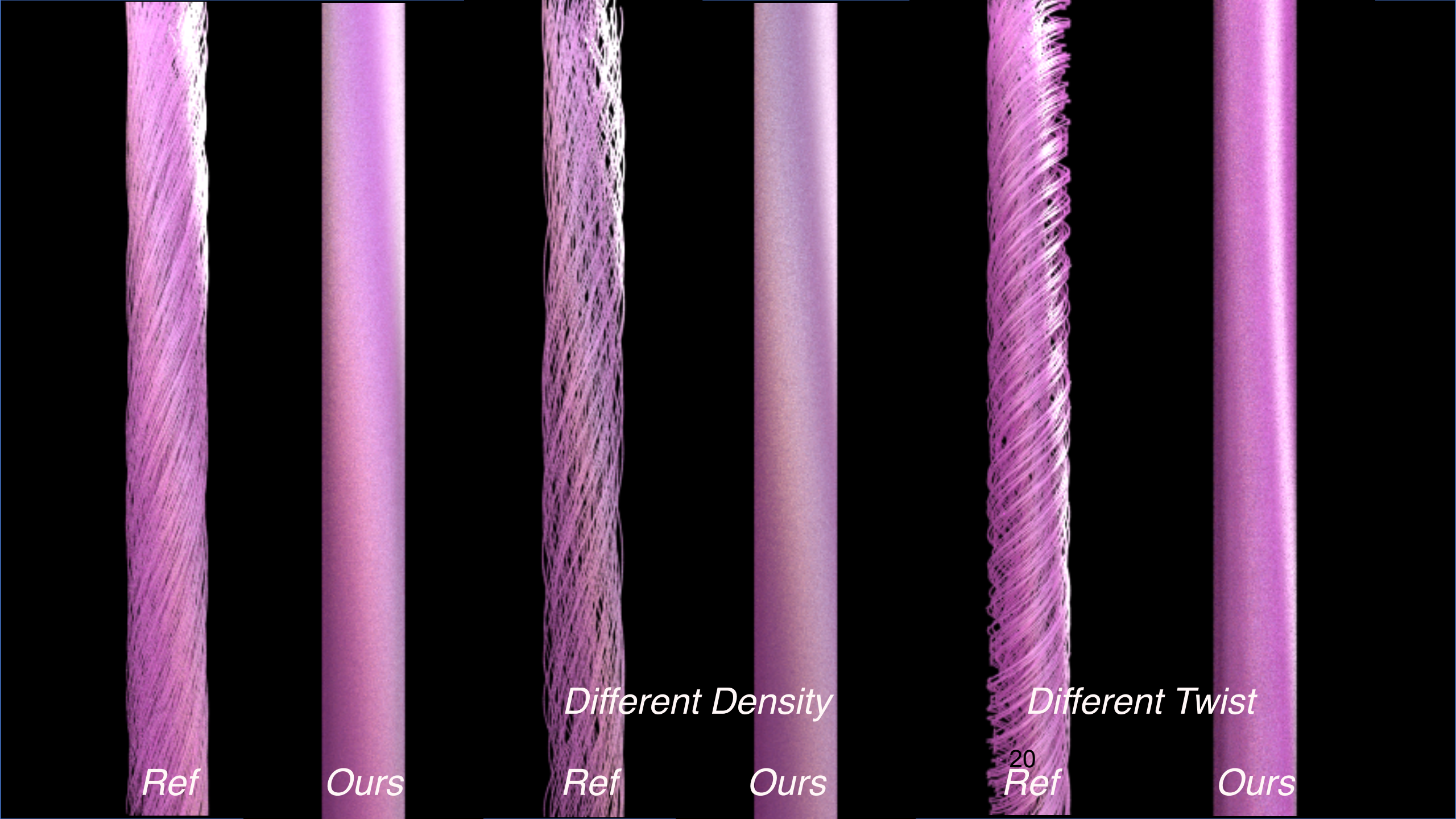
longitudinal

azimuthal

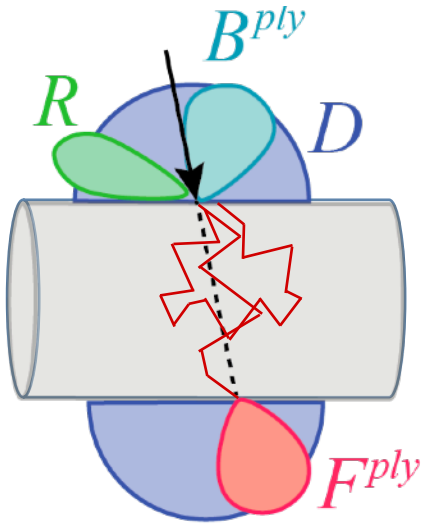
More realistic!

Wider range of material!

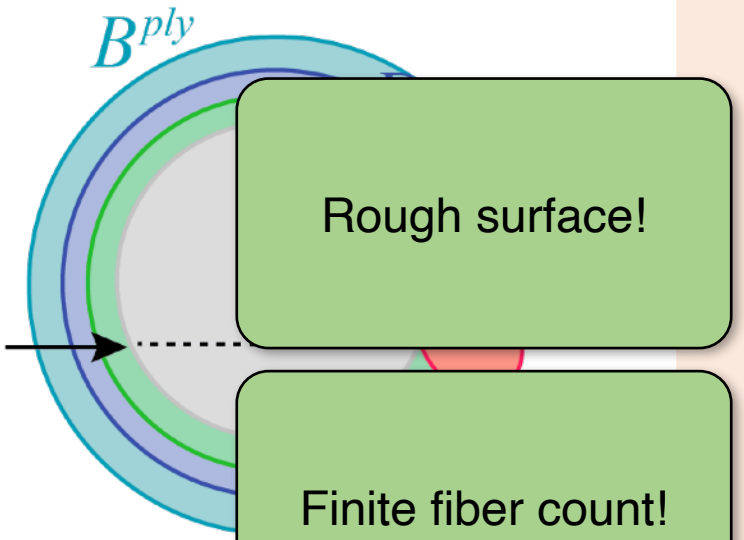
R: reflection term
TT: transmission term
D: diffuse term


Different Density
Different Twist
Ref
Ours
Ref
Ours
Ref
Ours

Ply-level Shading Model



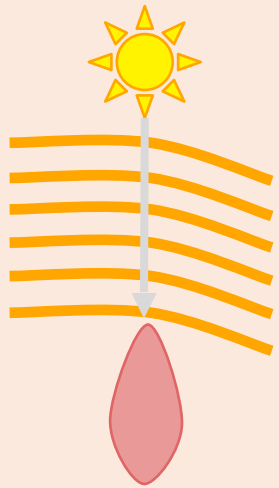
longitudinal



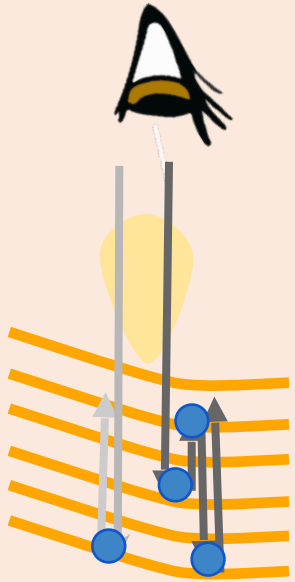
azi

Rough surface!

Finite fiber count!



Forward scattering

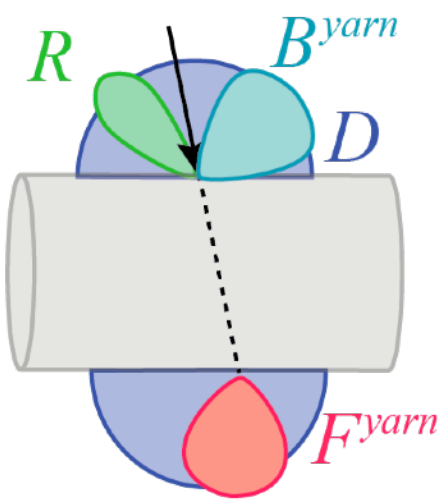


Backward scattering

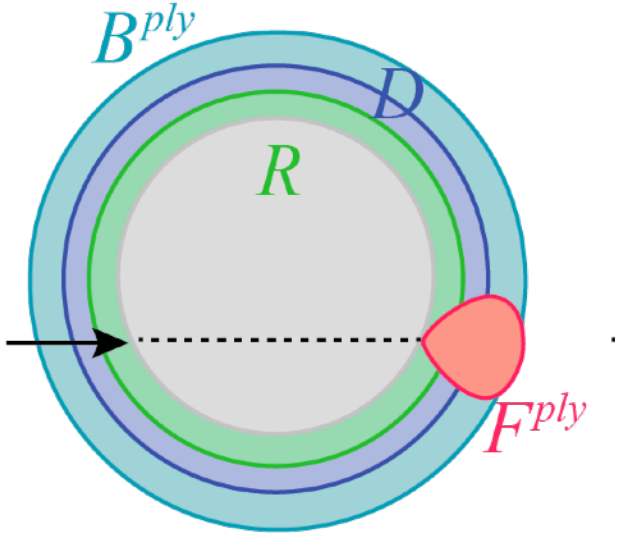
Extended dual scattering


Different Density
Different Twist
Ref
Ours
Ref
Ours
Ref
Ours

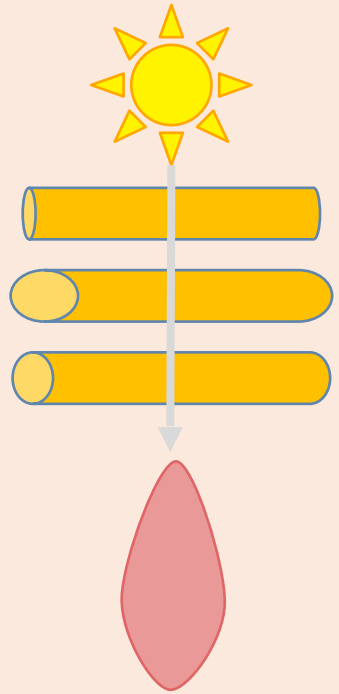
Yarn-level Shading Model



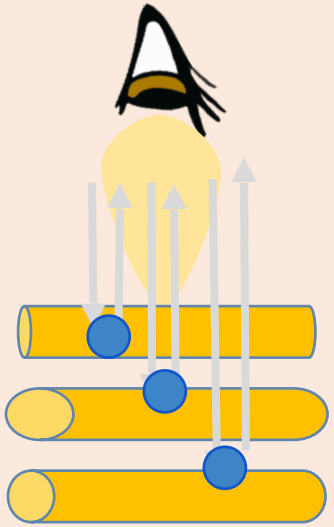
longitudinal



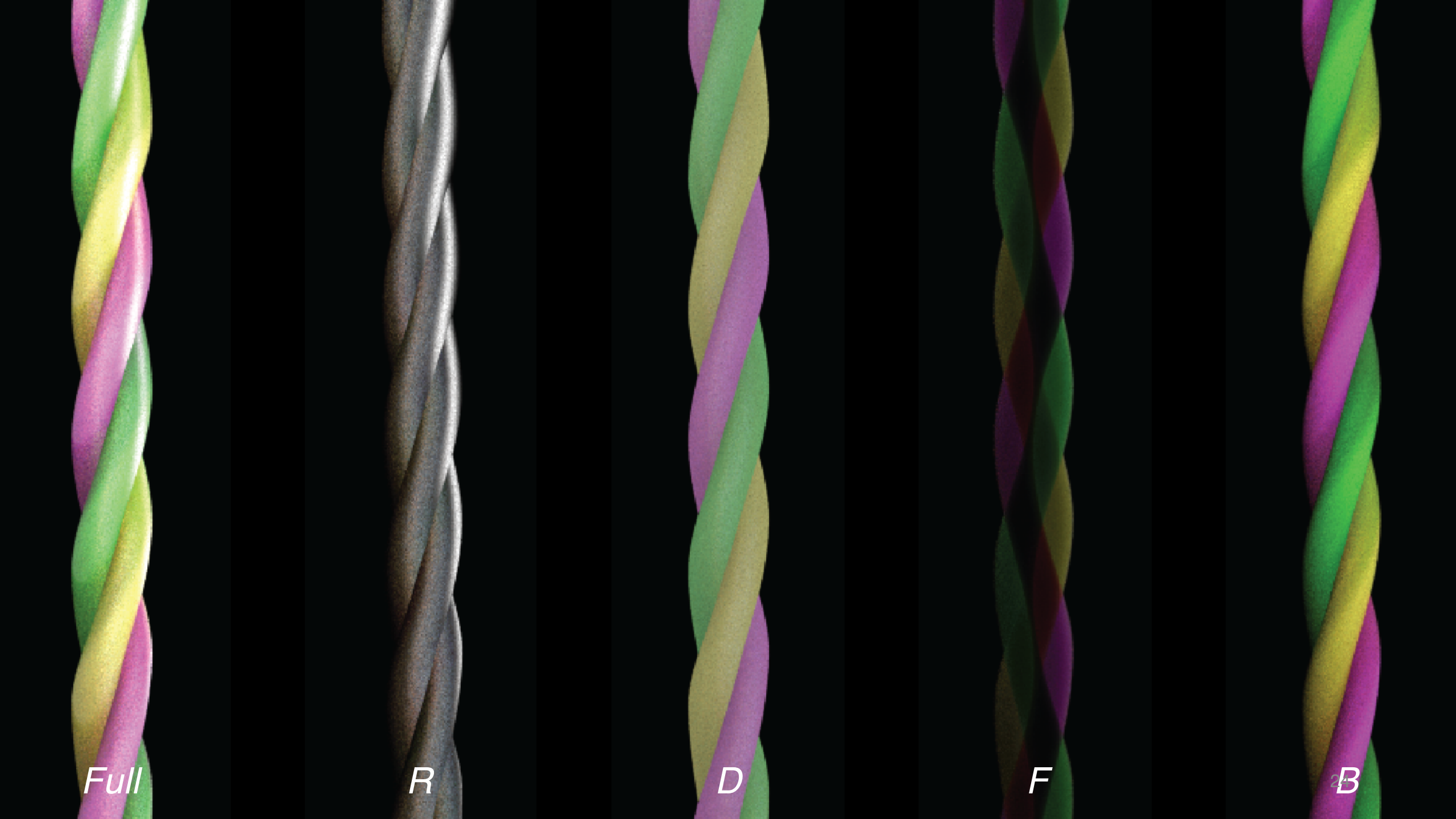
azimuthal



Forward scattering

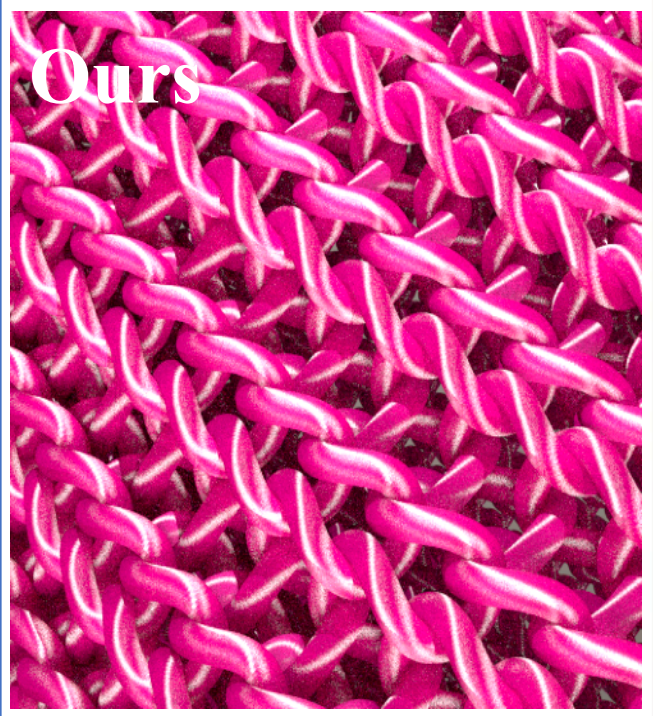


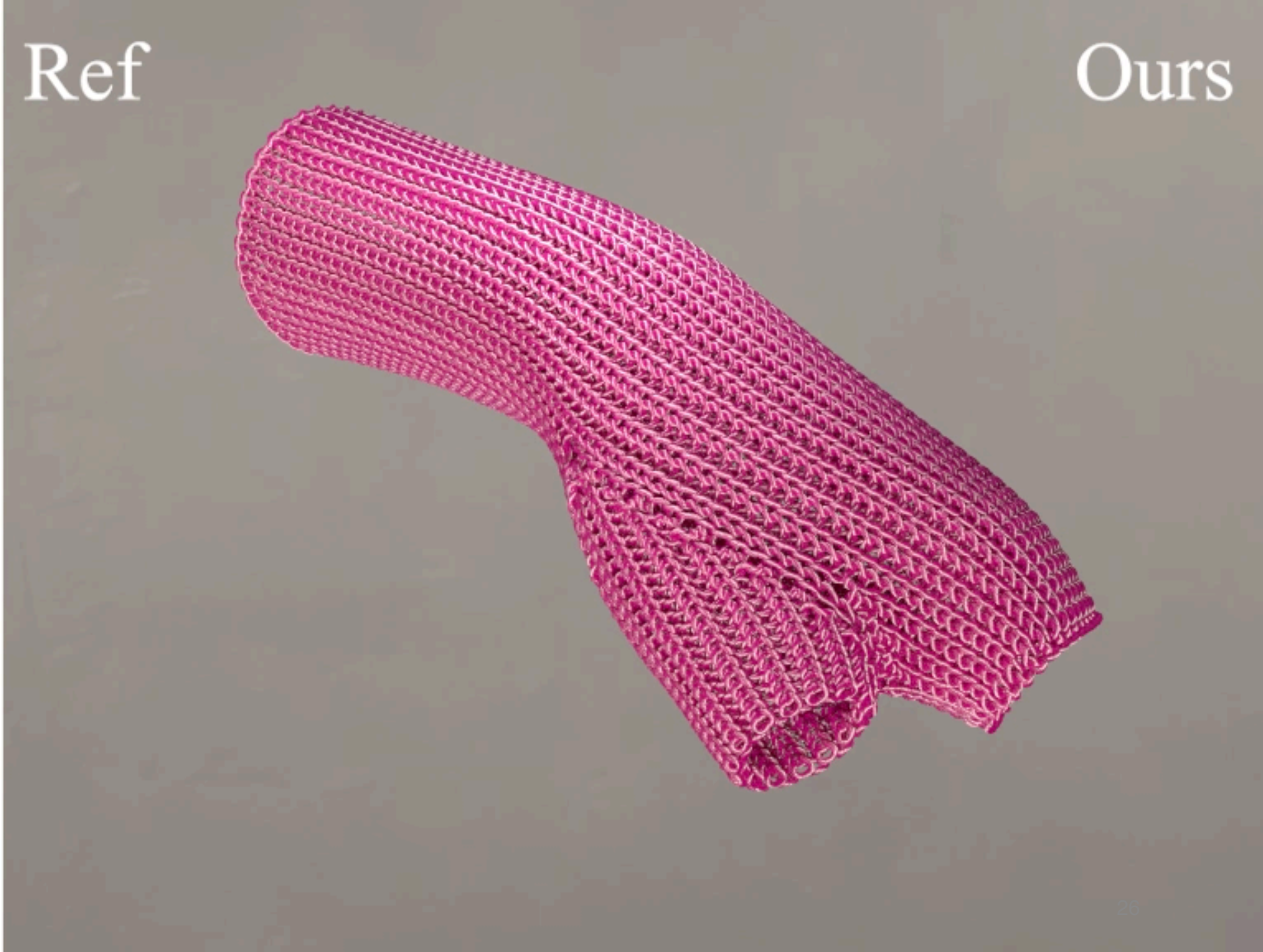
Backward scattering


Full
R
D
F
B

Results


Ref


Ours


Ref
Ours

Single Yarn

Changing fiber twist
(5° - 60°)

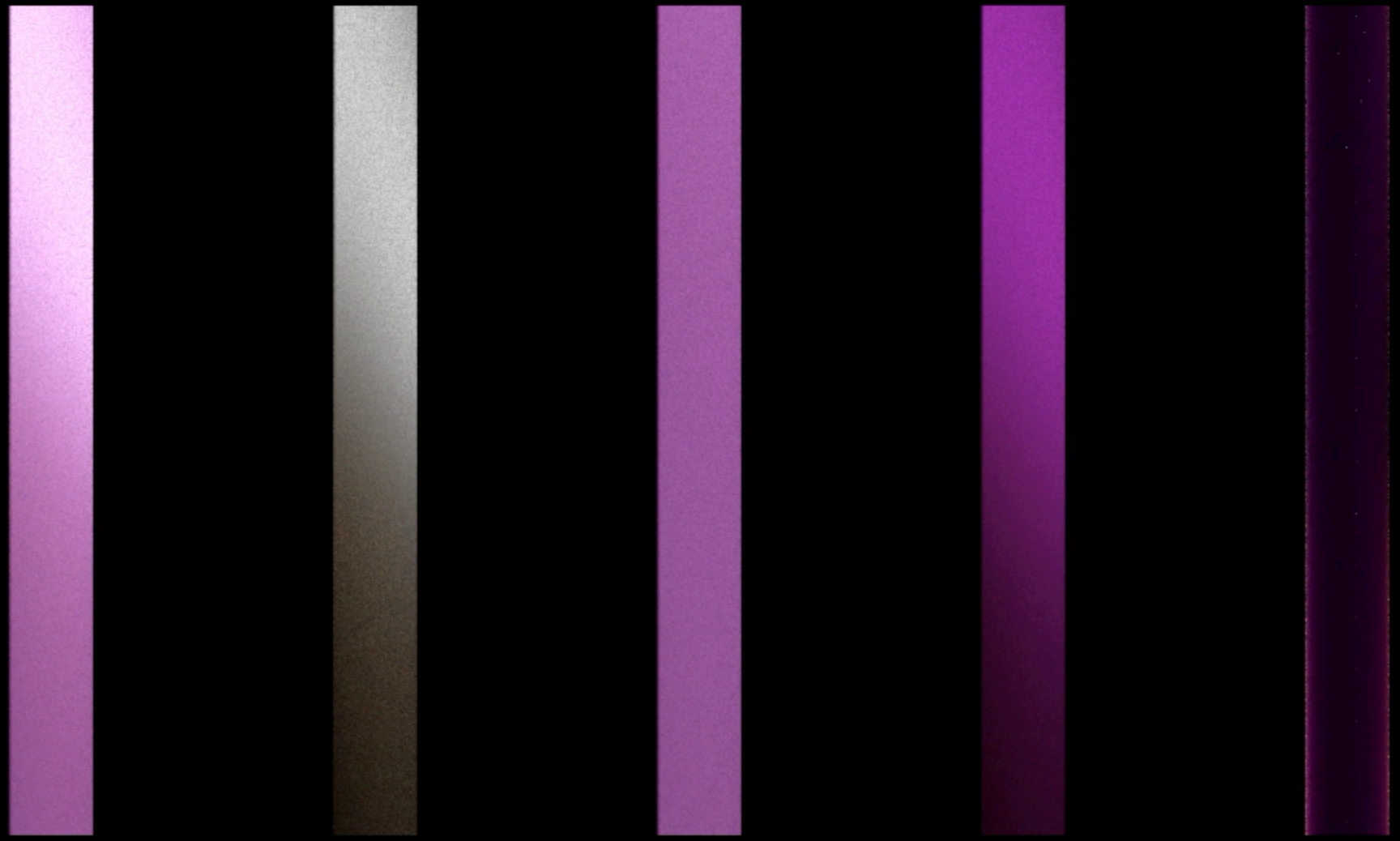
Ours: 32 SPP
Ref: 256 SPP

Increasing fiber twist

Ours

Ref

Increasing fiber twist



Ours R D B F

Increasing fiber numbers

Ours

Ref

Knitted Glove

Temporal stability
(Moving Light)

32 SPP

Point light

Knitted Glove

Temporal Stability
(Zooming in/out)

32 SPP

Point light + Env light

Performance

	Time (s)		Memory (MB)		#Bounce	
	Ref		Ours		Ref	Ours
Fig. 6.a	187		**1.8**		12.4	**1.6**
W/ twice fibers	265		**1.8**		17.4	**1.6**
Fig. 6.b	343		**4.0**		16.5	**3.2**
W/ twice fibers	547		**4.0**		21.3	**3.2**
Fig. 1	519		**4.0**		26.4	**4.2**

7x speedup!

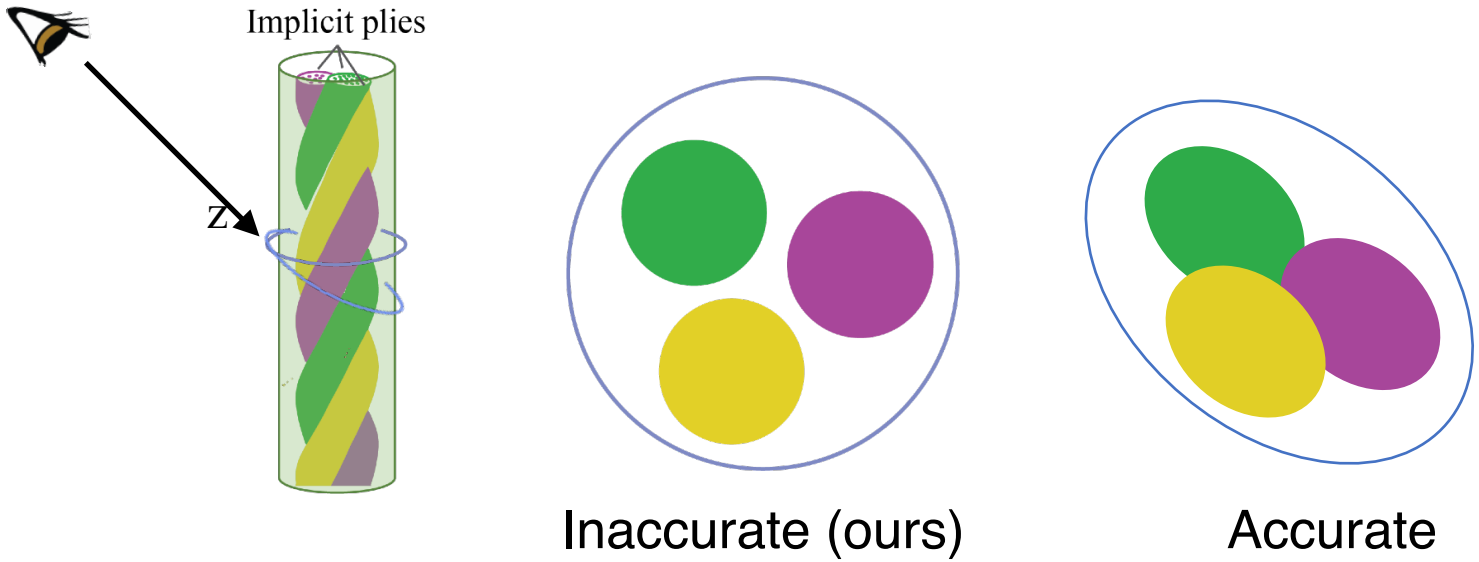
3% memory!

Conclusion

- Efficient and accurate yarn-based shading model
- Represent single and multiple scattering of light
- Yarn-based representation with ply-level geometries
- General application to render woven and knitted fabrics
- Independent to the ply count

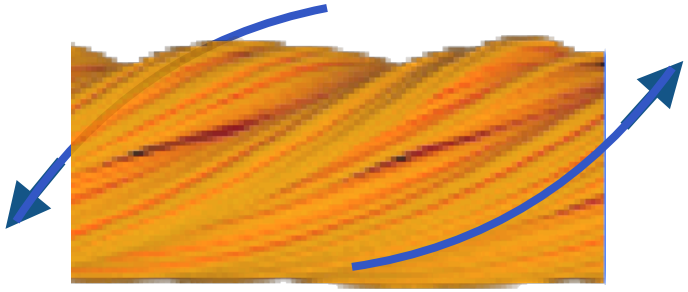
Limitations

- Perpendicular ray assumption: inaccurate at grazing angles.



Limitations

- Perpendicular ray assumption: inaccurate at grazing angles.
- Uniform fiber distribution assumption: inaccurate scattering events



Limitations

- Perpendicular ray assumption: inaccurate at grazing angles.
- Uniform fiber distribution assumption: inaccurate scattering events
- Not considered fly-away fibers

w/o flyaway

w/ flyaway

[Montazeri et al. 2020]

From Alex Alvarado

Future Work

- Implementing BCSDF model for real-time rasterization-based applications.
- Extending the method with multi-resolution for efficient level-of-detail rendering.

Acknowledgement

- Anonymous reviewers
- Marc Droske
- Gifted Grants: Adobe, Intel, Meta and XVerse
- Weta Digital

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Thank you!

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