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Modelling Rayleigh Scattering Loss in Arbitrary Profile Fibers

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Contents

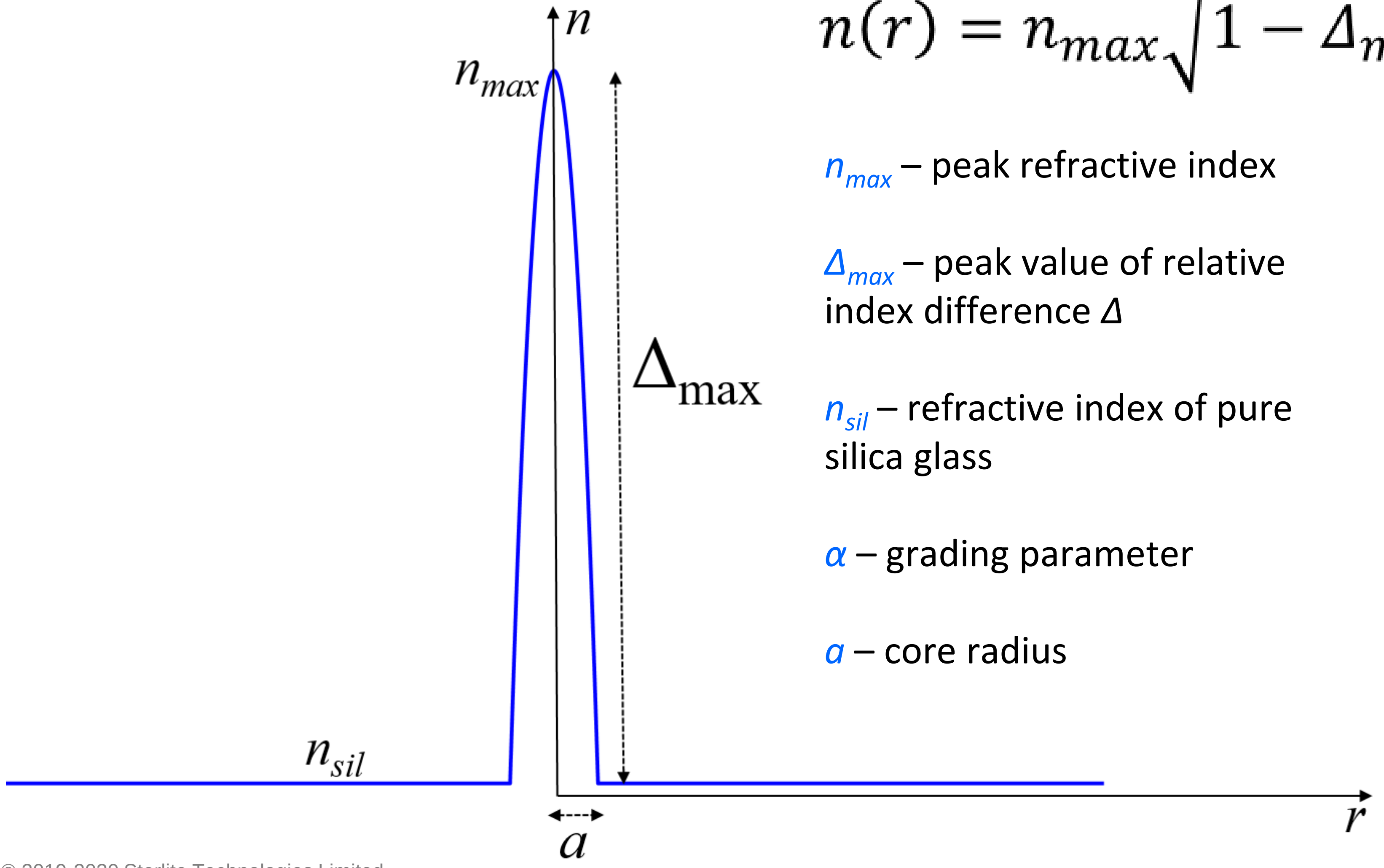
Introduction

- Rayleigh scattering loss (RSL) contributes almost 80% to fiber attenuation
- Modern optical fibers have ultra-low attenuation with the limit being set by RSL
- RSL arises from random microscopic inhomogeneities which is directly proportional to dopant concentration
- Hence prediction of RSL is needed from designer’s point of view
- Here we model RSL for arbitrary profile fiber with graded-index fiber as an example

Theory and Computations

Graded refractive index profile

Definition and profile parameters



$$n(r) = n_{max}\sqrt{1 - \Delta_{max}\left(\frac{r}{a}\right)^{\alpha}}$$

n_{max} – peak refractive index

Δ_{max} – peak value of relative index difference Δ

n_{sil} – refractive index of pure silica glass

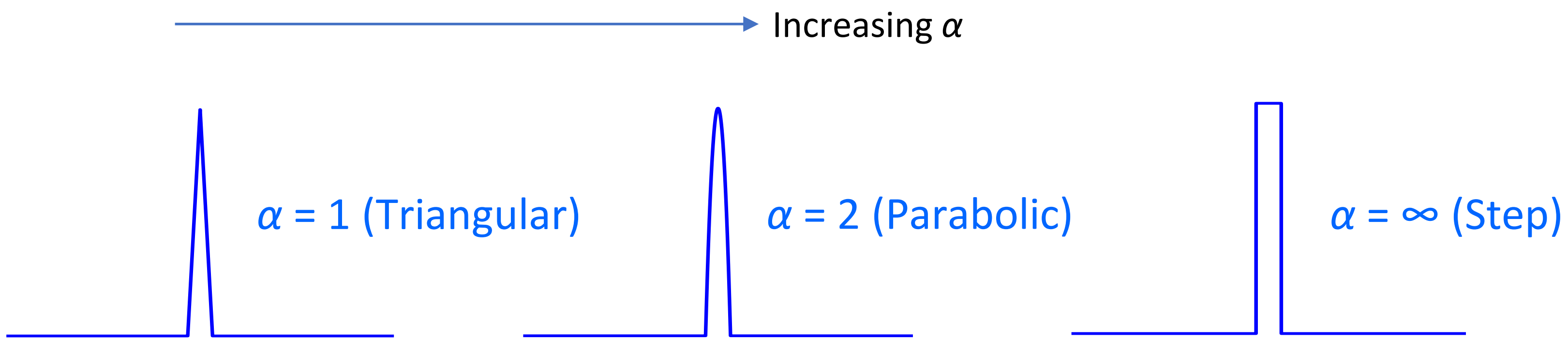
α – grading parameter

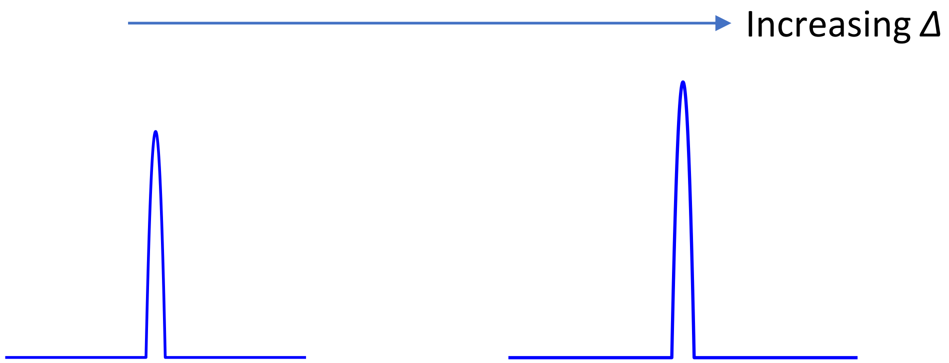
a – core radius

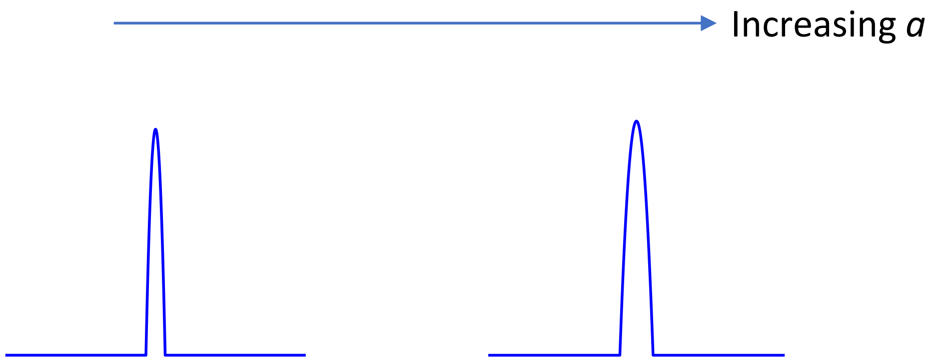
Relative index difference:

$$\Delta(r) = \left(n(r)^2 - n_{sil}^2\right)/(2n(r)^2)$$

Varying the profile parameters







Theory

- RSL is proportional to (1/λ^4), where λ is the light wavelength
- RSL is proportional to the light power profile P(r)
- Finally, RSL is proportional to the Rayleigh scattering coefficient A(r) [1]

- Thus RSL in the fiber core is given by:

RSC   Light power

$$\alpha_R = \frac{1}{\lambda^4}\int_0^a A(r)P(r)rdr \Big/ \int_0^a P(r)rdr$$

Light wavelength

- RSC of GeO_2-doped silica is given as [2]:

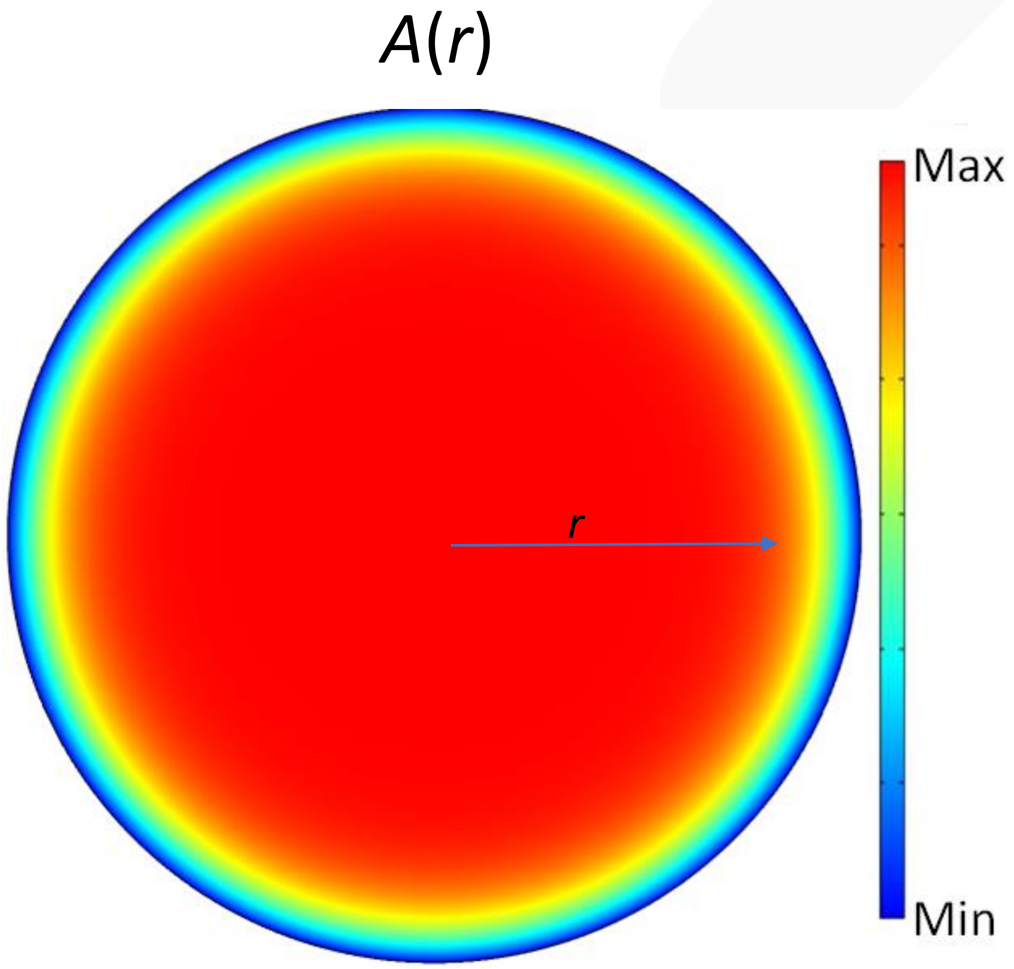
RSC of pure silica = 0.8 dB/km.μm^4

$$A(r) = A_0(1 + 44|\Delta(r)|)$$

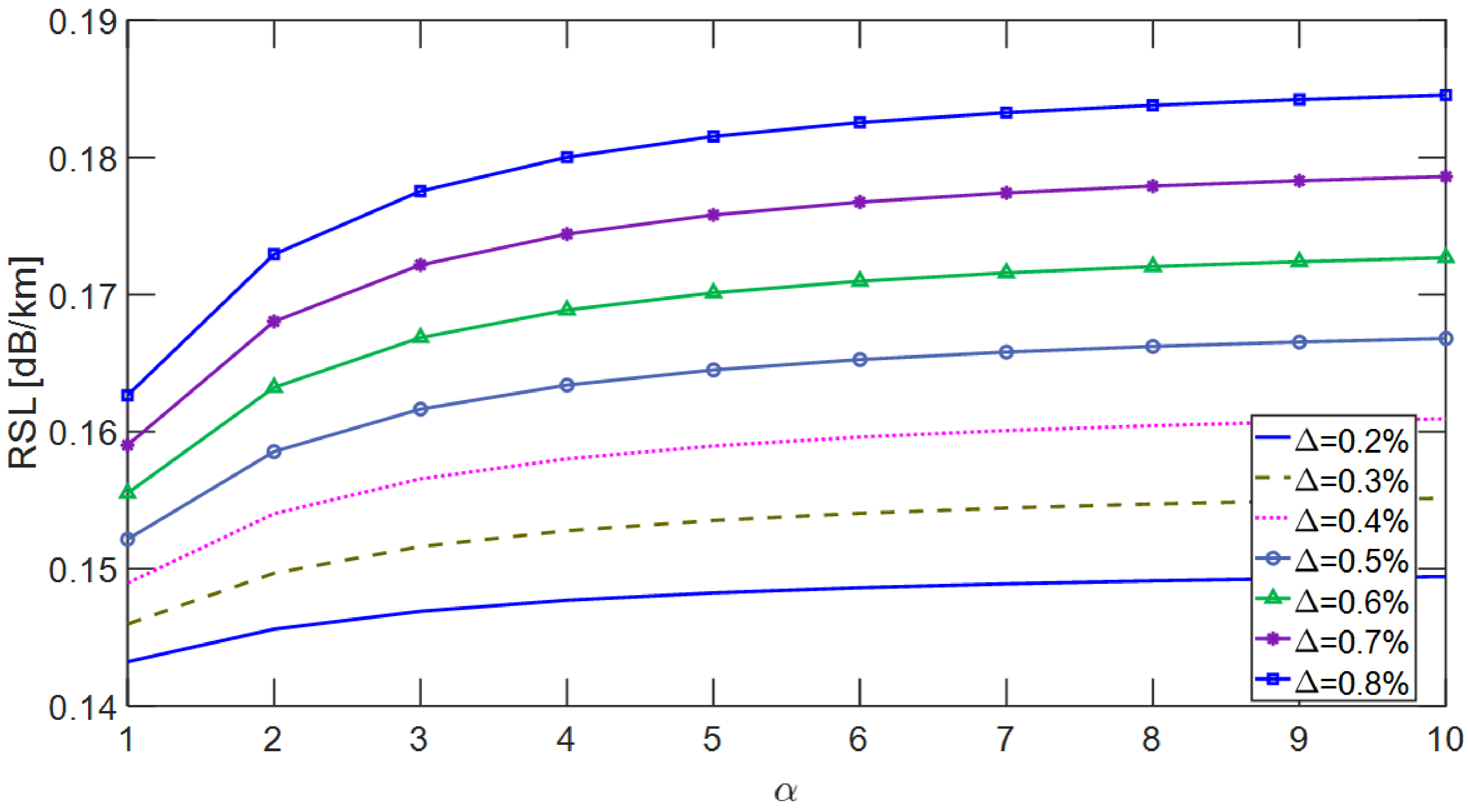
[1] M. Ohashi *et. al.*, "Optical loss property of silica-based single-mode fibers," *J. Lightw. Technol.*, 10, pp. 539 – 543 (1992)
[2] W. Zhi *et. al.*, "Loss properties due to Rayleigh scattering in different types of fiber," *Opt. Exp.*, 11, pp. 39 – 47 (2003)

Computation in Comsol

- *n*(*r*) is defined
- Hence *Δ*(*r*) is calculated
- Thereby, *A*(*r*) is calculated. Surface plot of *A*(*r*) is shown at the right
- λ was set to 1.55 μm
- **Mesh:** maximum mesh element size set to 0.25μm in the core and 'normal' otherwise
- Wave equations were solved using the 'Wave Optics module'
- This gives the light power profile *P*(*r*)



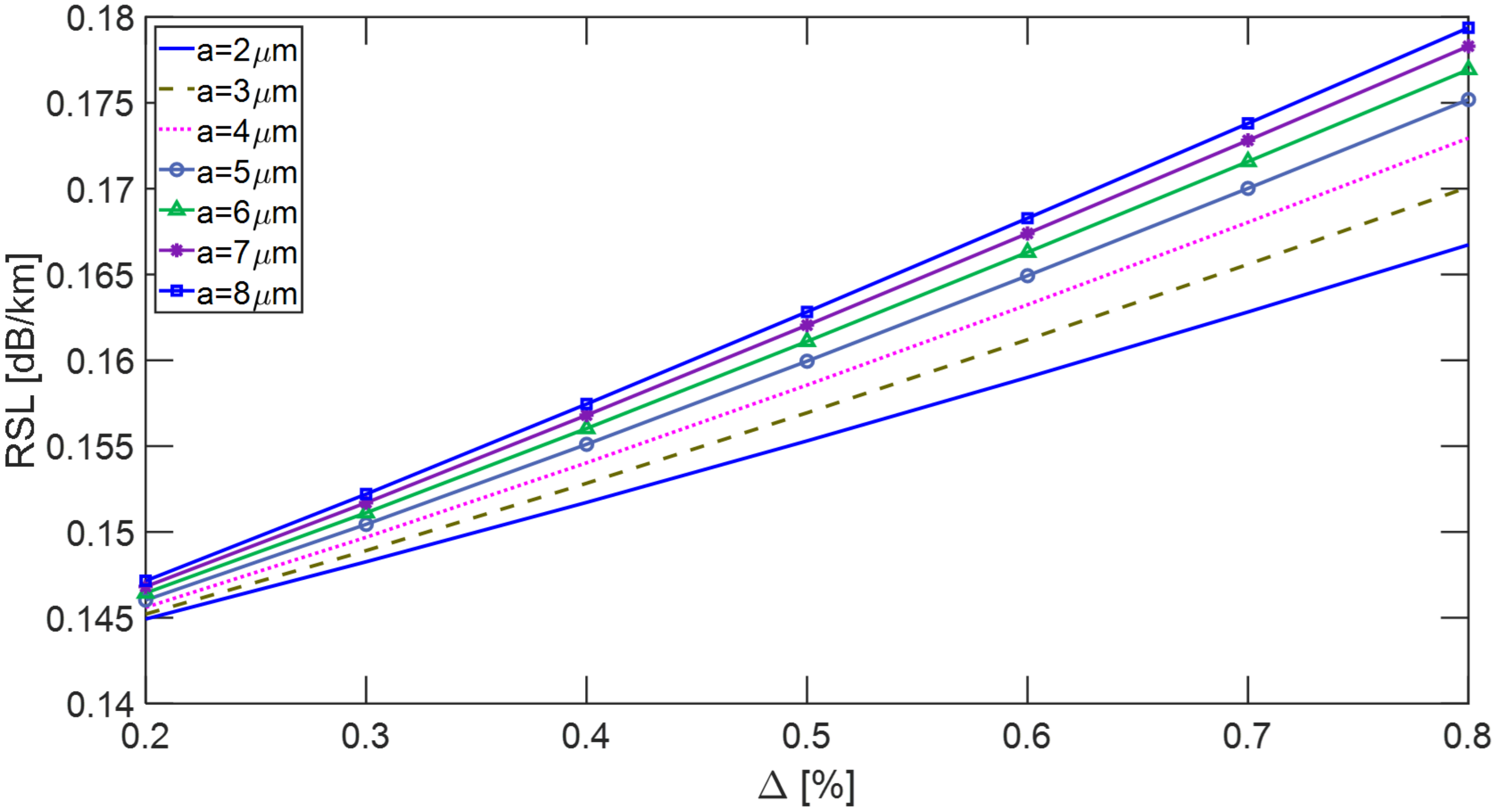
Results (1)



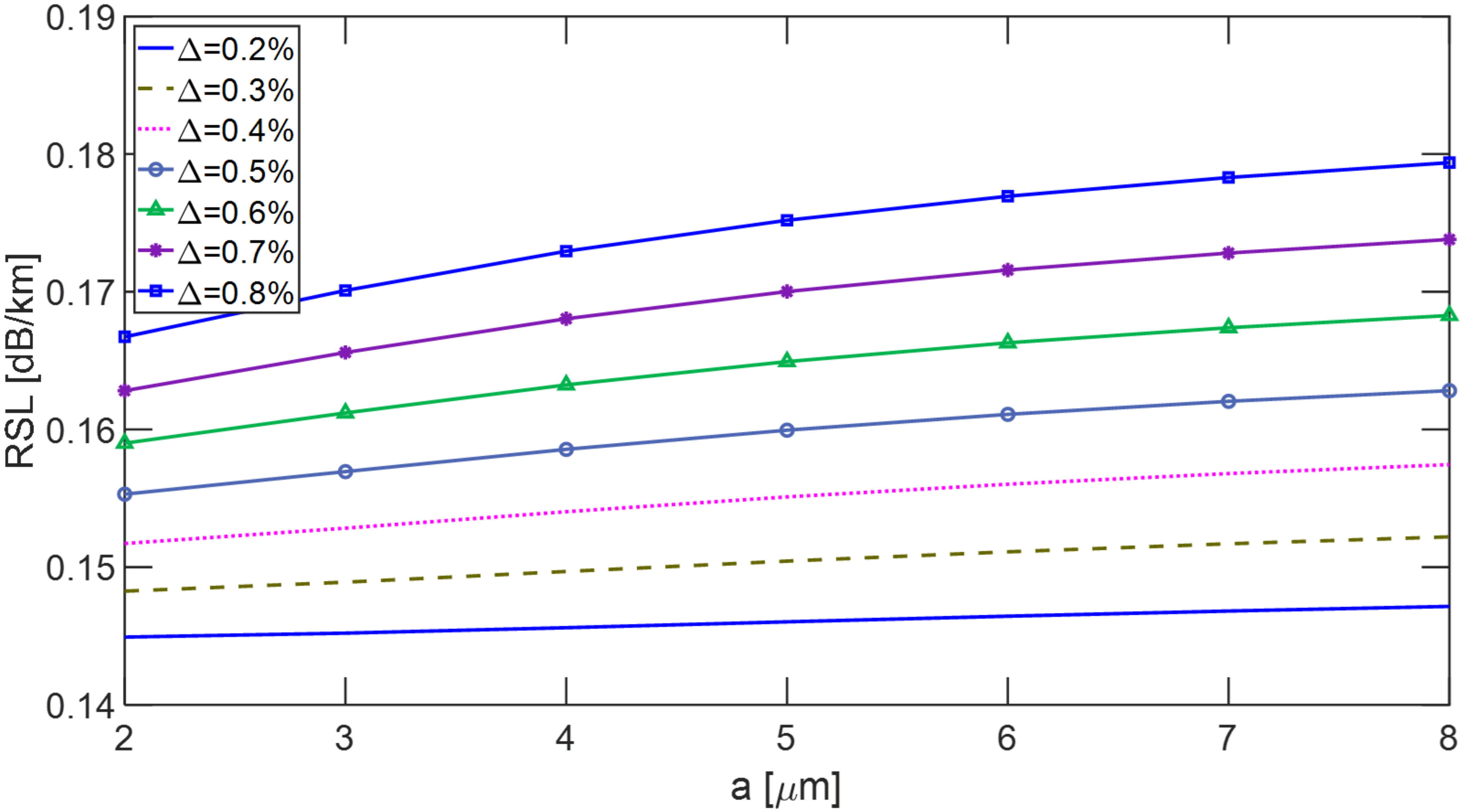
- RSL was calculated as a function of *α* for different *Δ*s.
- Core radius was set to the standard 4μm
- Plot suggests RSL increases when *α* and/or *Δ* increases

Results (2)

- RSL was calculated as a function of *Δ* for different core radii.
- Plot suggests RSL increases when *Δ* and/or core radius increases

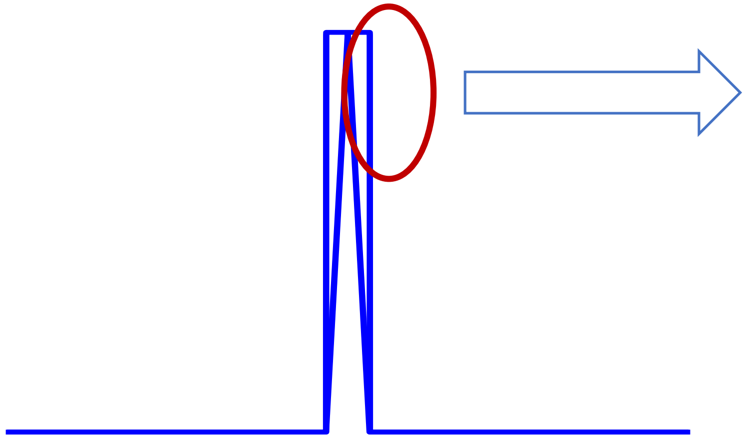


Results (3)



- RSL was calculated as a function of *Δ* for different core radii.
- Plot suggests RSL increases when *Δ* and/or core radius increases

Explanation



more GeO_2 concentration, more scattering centers, RSL increases !!

Similar explanation holds for the cases of increasing *Δ* and core dimension

Conclusion

- Till date, there exists model for step-index or equivalent profiles in literature
- We have presented a COMSOL model to calculate RSL of arbitrary profile fiber with graded index fiber as an example
- This model can be useful for predicting fiber attenuation from a designer's perspective

Thank You !!

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