# Mode-Dependent Characterization of Rayleigh Backscattering in Ring-Core Fibers

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## Abstract

The mode-dependent characteristic of Rayleigh backscattering in a ring-core fiber is theoretically and experimentally demonstrated. Compared to few-mode fiber, the Rayleigh backscattering of high-order orbital momentum mode supported by ring-core fiber bears much resemblance.

## Introduction

In this paper, we theoretically and experimentally characterize the mode-dependent Rayleigh backscattering of high-order orbital angular momentum (OAM) mode groups (MGs) with topological charge |*l*| = 1, 2, 3 in an RCF. Both the theoretical and experimental results show that very similar Rayleigh backscattering characteristic can be found when OAM MG |*l*| = *i* (*i*=1, 2, 3) is excited and OAM MG |*l*| = *j* (*j*=1, 2, 3 and *j* ≠ *i*) is backscattered on the transmitting side of RCF, which are quite different from that in the FMFs in and could be resulted from the single radial-order limitation of the RCF.

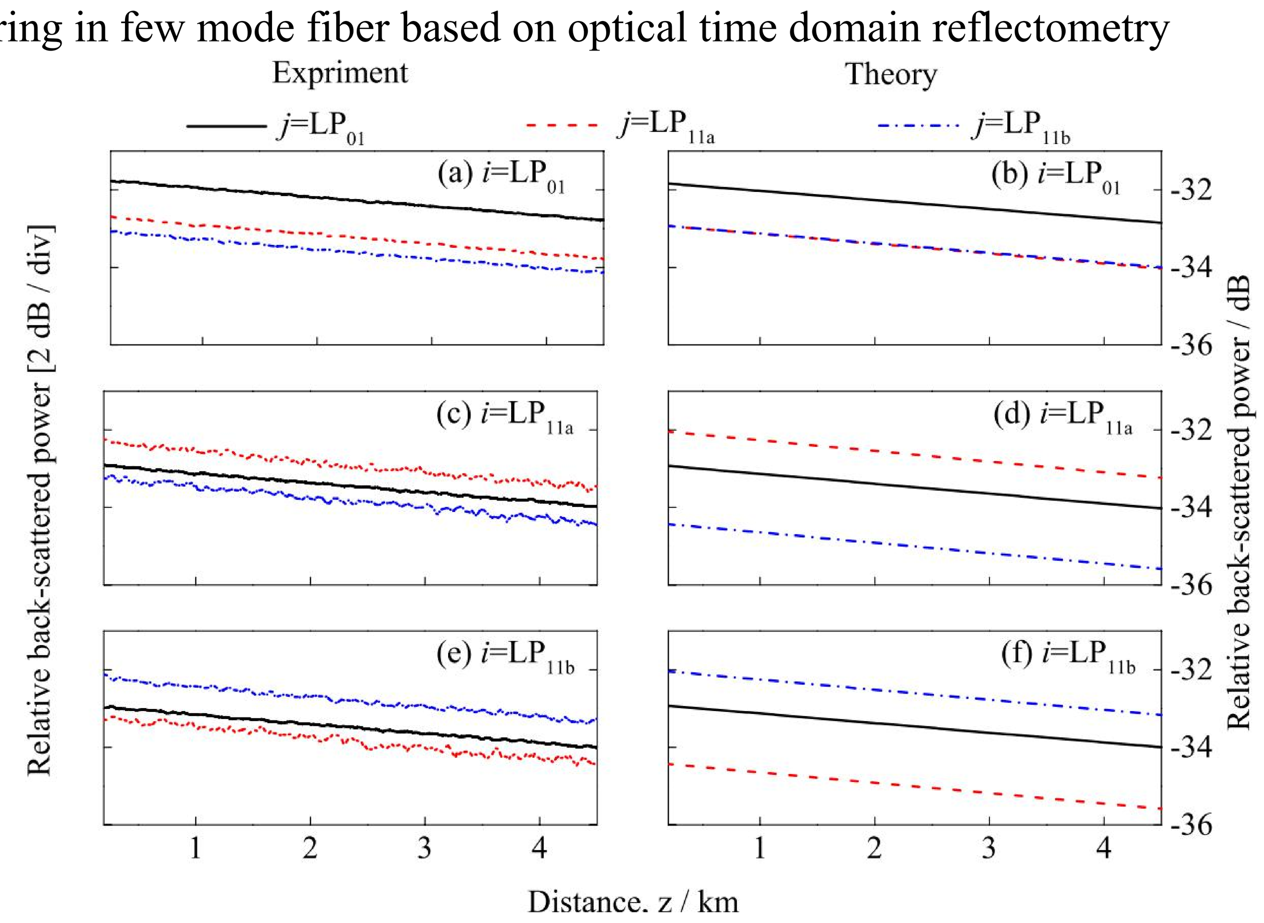
## Background

- Existing theory of Rayleigh backscattering in multimode mode fibers(MMF):

  Rayleigh backscattering light is found to equally propagate among all the guided modes in strong-coupled MMF

- Existing characterization of Rayleigh backscattering in few mode fiber based on optical time domain reflectometry

  - In absence of coupling between the guiding modes in few-mode fibers, an excitation in certain forward-guiding mode can generate Rayleigh backscattering in other backward-guiding modes.




Zhen W, et al., Sci Rep., **6**, 1-8 (2016).

However, Rayleigh backscattering in RCFs, which could show different mode-dependent characteristic from FMFs due to radially limited refractive-index profile, has not been evaluated yet.

## Theory analysis of Rayleigh backscattering in ring-core optical fiber

Assuming that an optical pulse with the temporal width of $\Delta T$ and a constant power of $P_0$ was launched into OAM MG | MG |*l*| = *i* (*i*= 0, 1, 2, 3) :

- the power of Rayleigh backscattering in OAM MG | MG |*l*| = *j* (*j* = 0, 1, 2, 3) :

$$P_{ij}^{BS}(t) = \frac{v_{gi}v_{gj}}{v_{gi}+v_{gj}} P_0 \alpha_s B_{ij} \Delta T e^{-(\alpha_i+\alpha_j)\frac{v_{gi}v_{gj}}{v_{gi}+v_{gj}}t}$$

approximation

$$P_{ij}^{BS}(t) = P_0 \alpha_s B_{ij} \bar{v} e^{-2\bar{\alpha}\bar{v}t}$$

the logarithmic form of above equation is the basis of theoretical Rayleigh backscattering curves

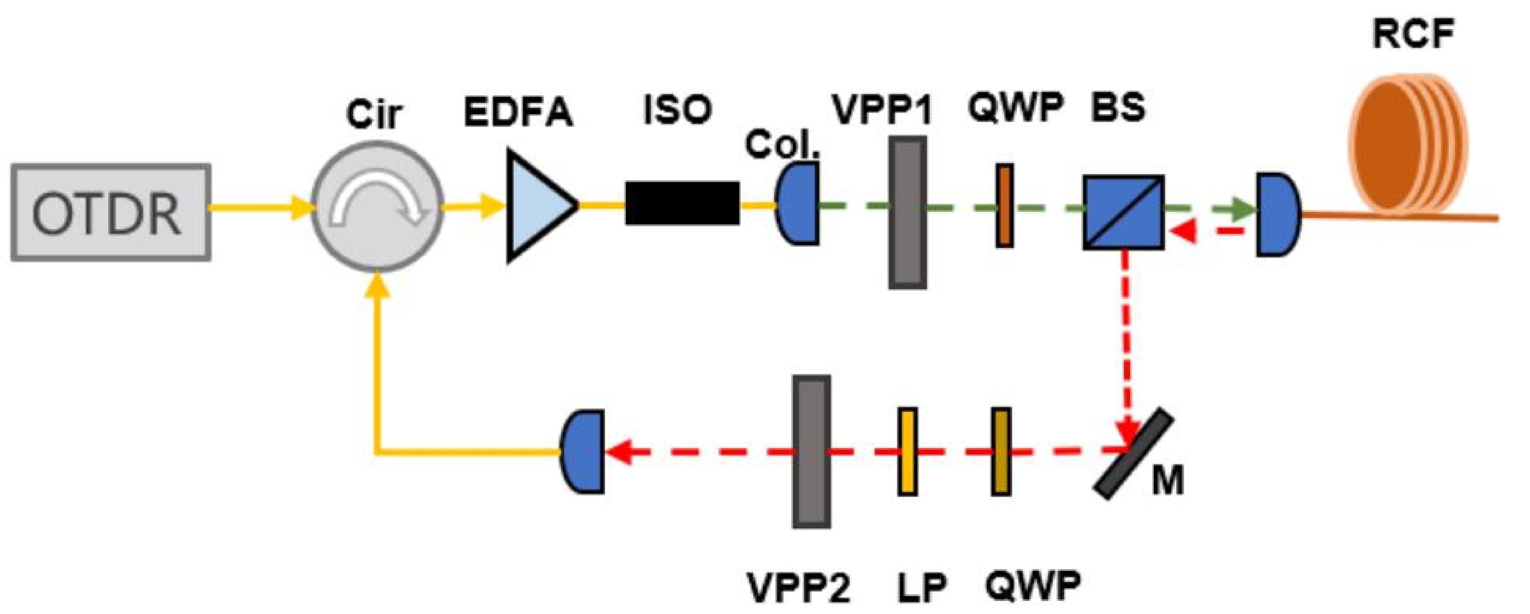
- the overall capture fraction power $B_{ij}$ at a specific position ($R$, φ) in the coordinate system:

$$B_{ij} = \frac{3\pi}{2(kan)^2} \frac{\int_0^\infty \int_0^{2\pi} \psi_{Ni}^2(R,\phi) \int_0^{2\pi} \psi_{Nj}^2(R,\phi)\, d\phi R dR}{\int_0^\infty \int_0^{2\pi} \psi_{Ni}^2(R,\phi)\, d\phi R dR \int_0^\infty \int_0^{2\pi} \psi_{Nj}^2(R,\phi)\, d\phi R dR}$$

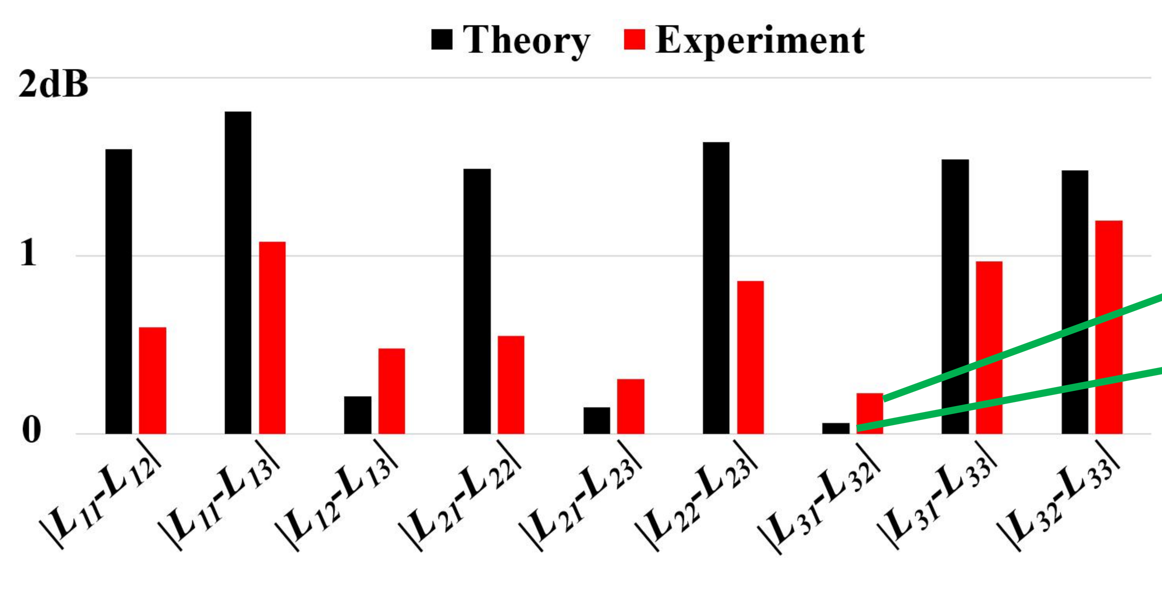
the ratio of the backscattered power into OAM MG |*l*| = *j* to the total scattered power

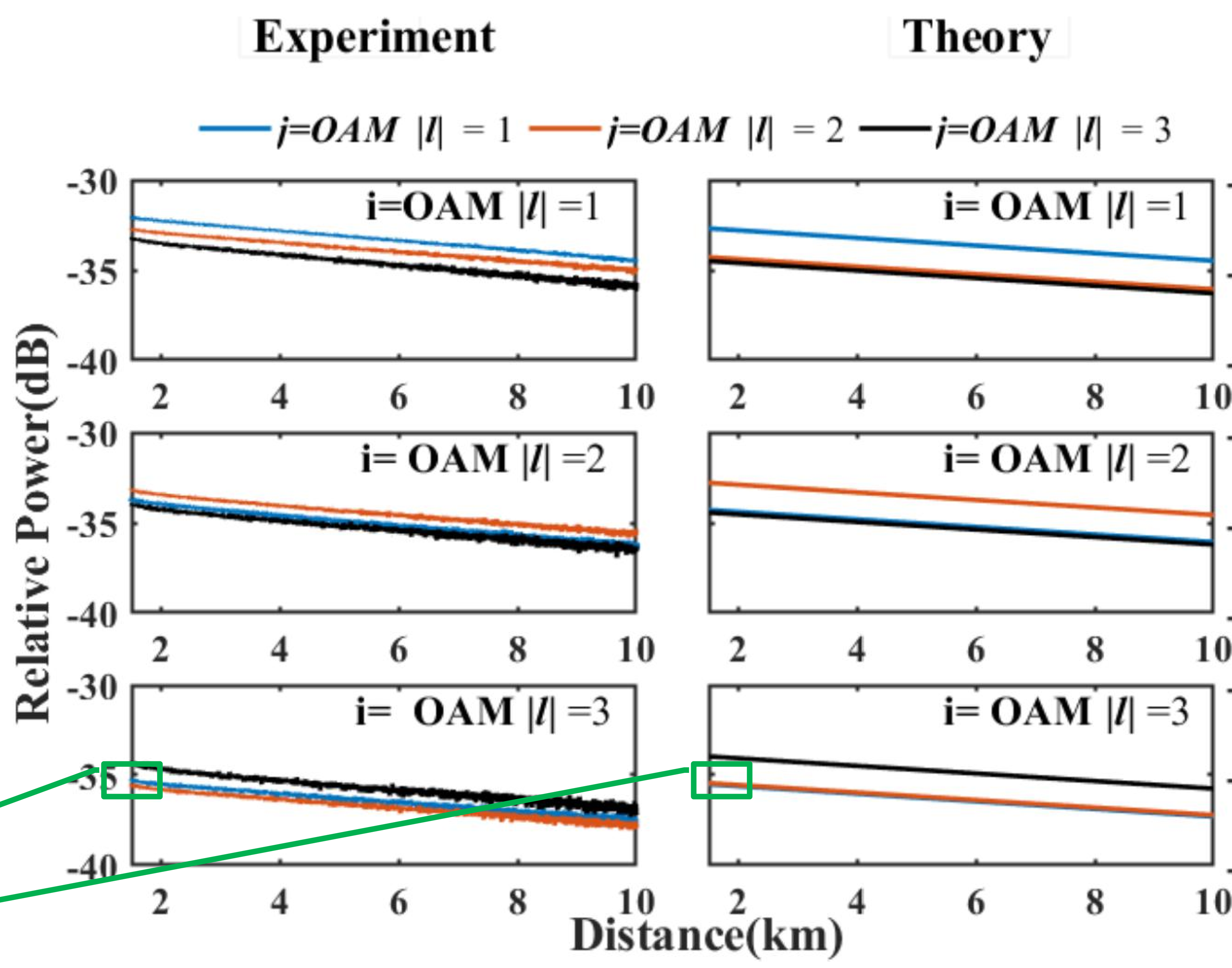
## Experimental setup and results

◆ experimental setup for measuring Rayleigh backscattering curves




◆ comparison between the intercepts of experimental and theoretical curves




◆ experimental measured curves and the corresponding theoretical curves

## Conclusions

- A good agreement is obtained between the experimental and theoretical results.
- Different from that in FMFs, the Rayleigh backscattering in RCF shares high similarities when OAM MG |*l*| = *i* (*i*=1, 2, 3) is excited and OAM MG |*l*| = *j* (*j*=1, 2, 3 and *j* ≠ *i*) is backscattered due to the single radial-order limitations.

## Acknowledgements

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