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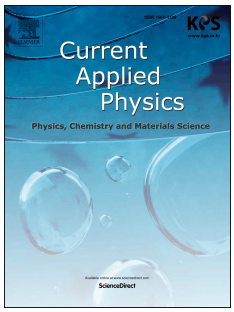

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PII: S1567-1739(18)30237-2

DOI: 10.1016/j.cap.2018.08.015

Reference: CAP 4821

To appear in: *Current Applied Physics*

Received Date: 2 June 2018

Revised Date: 14 August 2018

Accepted Date: 28 August 2018

Please cite this article as: C. Song, H.S. Park, K.Y. Song, B.Y. Kim, Acousto-optic generation of orbital angular momentum states of light in a tapered optical fiber, *Current Applied Physics* (2018), doi: 10.1016/j.cap.2018.08.015.

Acousto-optic Generation of Orbital Angular Momentum States of Light in a Tapered Optical Fiber

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Abstract

We demonstrate an acousto-optic mode converter based on a tapered optical fiber to efficiently generate orbital angular momentum states of light. In our scheme an acoustic wave is deployed to the waist of tapered optical fiber where two degenerate HE_{21} modes leading to +1 and -1 orbital angular momentum eigen-modes are resonantly excited. The excitation of TM_{01} and TE_{01} modes is suppressed by enlarging the intermodal index difference between near-degenerate spatial modes. Numerical calculation for optimization of the taper diameter is provided. The experimental characterization of generated states is performed by analyzing the output far-field pattern and the spatial interference fringes with a uniform reference beam.

Keywords : orbital angular momentum, acoustooptic couplers, multiplexing, optical fiber communication, optical fiber applications.

1. Introduction

Orbital angular momentum (OAM) states of light are currently one of the key elements of advanced optical sensors and optical communication technologies [1, 2]. The spiral-phase structure of the OAM states can yield a ring-type beam shape for optical tweezers [3], and enables quantized momentum transfer during light-matter interactions [4]. High-dimensional optical communications also benefit from the OAM states both in free-space [5] and through optical fibers [6]. The practicability of all those applications critically depends on efficient generation of multiple OAM states.

Spatially structured light can be straightforwardly created based on holographic media such as spatial light modulators and q-plates [7, 8], but with high optical loss due to multiple orders of diffraction and mode field size mismatch [9]. Techniques based on coherent coupling between a fundamental mode and higher-order modes are free from such loss factors and provide inherently high efficiency [10-16]. In-line coherent generation of OAM modes in few-mode fibers have been demonstrated using long-period fiber gratings [10-13], acousto-optic (AO) mode converters [14, 15] or fused mode selective coupler [16]. To ensure mode selectivity among adjacent spatial modes with almost the same effective refractive indices, a specialty fiber having a ring-type core has been used [10] or precise control of acoustic and optical polarizations has been incorporated [14]. In this work, we propose and demonstrate a novel approach based on tapering a conventional few-mode fiber with a step index profile in order to separate almost degenerate modes for enhanced selectivity instead of using dedicated ring core fiber or precisely controlling of acoustic polarizations. A conventional fiber AO transducer producing a flexural acoustic wave [17] excites OAM states inside the tapered region while suppressing the coupling to unwanted TE and TM modes within the spectral region of interest. This enhances the applicability of OAM modes to the existing optical fiber sensor and space-division-multiplexed communication technologies.

2. Acousto-optic excitation of OAM modes