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Widely-Tunable Single-Notch Acousto-optic Filter using Two-mode Photonic Crystal Fiber

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Abstract

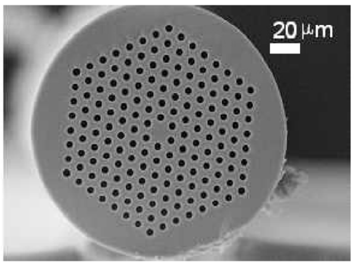
We demonstrate a novel acousto-optic filter using a two-mode photonic crystal fiber. Thanks to endless two-mode operation of the fiber, single notch over a whole spectrum is obtained with tuning range of > 1000 nm.

Introduction

All-fiber acousto-optic tunable filters (AOTF) employing two-mode fibers (TMFs) have been investgated for applications to a wavelength filter, an optical switch/router, a dynamic optical add-drop multiplexer, and a dynamic gain equalizer [1-4]. They have advantages such as fast tuning speed, low insertion loss, and relatively wide tuning range. However, their tuning range is limited within ~200 nm because of finite two-mode operation region in conventional TMFs. In a single mode region, there appear multiple notches corresponding to multiple cladding modes, which is not desirable in most of applications. In order to extend their tuning range, we incorporated an endless two-mode photonic crystal fibers (TM PCFs), which supports two spatial modes over the whole low-loss silica window (from 400 to 1800 nm) for AOTF. In this paper, we demonstrate a novel all-fiber AOTF incorporating a TM PCF with a single notch whose wavelength is tunable from below 700 to 1700 nm.

Experiments

The cross-section of the PCF used in our experiment is shown in Figure. 1. The PCF structure consists of three parts– a silica core, a holey cladding, and an outer silica region. The holey cladding region has seven rows of air-holes surrounding the silica core with hexagonal symmetry. The average value of the relative hole-diameter (d/Λ) and the spacing between the holes are measured to be 0.492 and 9.689 μm, respectively. Mode properties were calculated by using a freely available simulation package adapting the plane-wave basis method that is designed to find mode characteristics in a general photonic crystal structure [5]. The second-order mode cut-off wavelength was calculated to be about 3400 nm. Therefore, the PCF in our work shows two-mode operation in the optical wavelength region of below 1800 nm which we are interested in. Coupling efficiencies between the LP_{01} and three lowest-order LP_{0l} modes were also calculated. The result showed that couplings from the LP_{01} to higher-order LP_{0l} ($l \geq 2$) modes are negligible as compared to that of the LP_{01} and the LP_{11} modes due to the weak field intensity of higher-order LP_{0l} ($l \geq 2$) modes in the core region.



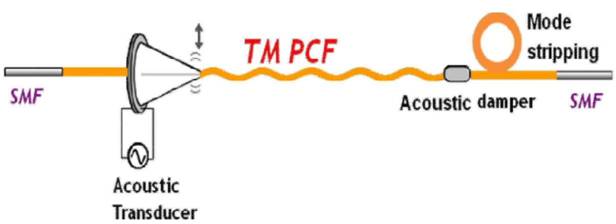


Figure. 1. Cross-section of the TM PCF *Figure. 2. Schematic of the proposed device*

The set-up for the AOTF with the TM PCF is described in figure 2. The device consists of an acoustic transducer and a TM PCF. The LP_{01} mode from the light source is launched to the TM PCF and a specific wavelength component of the incident light that satisfies the phase matching condition is converted to the LP_{11} mode by acoustic flexural wave. The AO interaction length is 15.5 cm and the range of the applied acoustic frequency is from 0.571 to 3.3 MHz. The acoustic wave is absorbed at an acoustic damper at the end of the interaction region. The coupled LP_{11} mode is removed by bending the TM PCF after the interaction region and the remaining LP_{01} mode is coupled to the single-mode fiber (SMF) and measured by the optical spectrum analyzer (OSA).

Figure 3.(a) show the output spectrum of the AOTF. Only one notch by coupling between the LP_{01} and LP_{11} core modes was shown in the transmission spectrum as expected. The position of the resonant peak was repeatedly measured with changing the applied acoustic frequency from 2.1 to 3.3 MHz. The resonant notch was tuned from 1200 to 1650 nm as shown in the figure. The tuning range of the device was limited only by the spectral range of the broadband source and the efficiency of the acoustic transducer. The beatlength between the LP_{01} and the LP_{11} core modes as a function of optical wavelength is summarized in figure 3. (b). The straight line is given from the calculation and the dots are obtained from the experiment. Both results match well with each other.

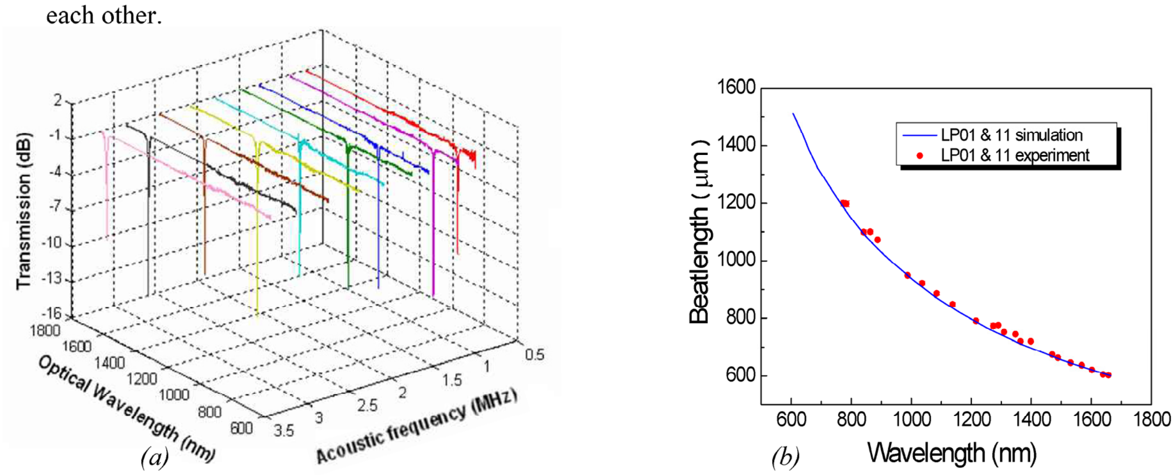


Fig. 3. (a) Resonant peak change in the transmission spectrum with respect to the applied acoustic frequency. (b) Beatlength as a function of optical wavelength. Lines (calculation) and symbols (experiment).

Conclusions

We demonstrated a novel all-fiber AOTF employing a TM PCF. The tuning range of the device was from below 700 to 1700 nm at a given acoustic frequency region from 0.571 to 3.3 MHz. We expect that this work will allow extremely broadband wavelength-tuning devices to be developed.

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