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Tilted fiber Bragg grating assisted nonlinear effects in Carbon nanotube-coated optical fibers

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Single-wall carbon nanotubes (SWNTs) have attracted much interest in the field of optical communications in recent years, due to their ultrafast nonlinear properties in the near IR. Their potential applications in optics include noise suppression in long-haul transmission systems, wavelength conversion and passive mode-locking [1]. In order to maximize their interaction with the light, SWNTs have been integrated in optical devices in numerous ways, such as thin films on substrates, polymer composites, or deposition on fiber ends. In all cases, these options involve breaking the guided structure. We present a novel solution where an optical fiber is coated by a SWNT layer, and the interaction of the in-core transmitted light with the SWNT coating is provided by a tilted fiber Bragg grating (TFBG). These gratings enhance the coupling of light from core mode to cladding modes resonances, and they have found many uses in sensing applications [2].

Light propagating through a TFBG-written fiber can couple to a counter-propagating cladding mode if its wavelength matches a cladding-mode resonance. The many cladding modes resonances of standard fibers result in a multi-notch transmission response as shown in Fig. 1 a). The transverse mode profile of cladding modes spreads to the cladding of the fiber and interacts with the outer medium interface. Therefore cladding mode resonance frequencies depend on the refractive index of the outer medium in addition to other parameters [2]. If we apply a nonlinear layer on the fiber surface, the outer refractive index depends on the light intensity and an intensity-dependent TFBG transmission response is obtained. In our case, the nonlinear layer is a coating of SWNTs deposited on the fiber surface. Fig. 1 b) depicts the structure of the device.

Fig. 1 a) Linear transmission response of the nanotube-coated tilted fiber Bragg grating. b) Nanotube-coated TFBG structure. Light for which the wavelength matches a cladding mode resonance couples to a cladding mode when injected to the grating, interacting with the outer SWNT layer. c) Nonlinear amplitude and phase responses of the SWNT-coated TFBG, of an un-coated regular 4 deg TFBG and of a standard fiber.

To demonstrate nonlinear effects, a 2 cm-long 4 degree TFBG was written using the phase mask method. For the SWNTs deposition, a floating SWNT thin film on water was prepared [3]. The fiber was immersed in the tray and the SWNT film was wrapped around the fiber. The SWNT coating was examined by SEM imaging and Raman spectroscopy. Nonlinear effects were measured with a pump-probe phase-sensitive set-up described in [4]. The pulsed light injected to the TFBG had -3.5 dBm, 1535 nm and 1 ps of average power, wavelength and pulse duration respectively, providing 22.5 W of peak power in the fiber. The 1 ps duration determines the measurement resolution. Fig. 1 c) shows the nonlinear responses of the SWNT-coated TFBG, a regular TFBG without coating, and regular fiber. These results demonstrate that interaction of the pump with the nonlinear cladding, as mediated by the TFBG, is sufficient to modulate the amplitude of the probe by more than 6% (12% in intensity) on a picosecond time scale. We have also checked that the magnitude of the effect depends on the relative spectra of the TFBG and of the probe light, indicating possible optimization strategies.

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