Polarization Control for Optical Nanofibers

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Abstract: We present the first method allowing to resolve the uncertainty about the polarization in single-mode nanofiber waveguides. The method is based on probing of the evanescent field at the nanofiber waist by means of the second nanofiber crossed with the first one. We demonstrate how the polarization transformation occurred before the nanofiber waist can be reversed with the fidelity higher than 99%. Our method for near-field polarization control shall provide the desired level of precision to numerous applications of optical nanofibers.

Nanofiber waveguides have numerous applications in near-field optics, sensing, optomechanics, experimental quantum and atomic physics, studies of whispering gallery modes, etc. [1, 2]. Despite being such a powerful tool, the nanofiber has a major flaw: it does not maintain the polarization of guided light. So far there is no technique for determining the polarization states (besides the trivial horizontal and vertical ones) at the waist of a nanofiber waveguide. To address this non-trivial problem, we have developed a two-step method which allows for a compensation of polarization transformations by any object free of dichroism. Once the compensation is achieved, an arbitrary polarization state can be delivered to the point of interest unperturbed. Our method is based on mapping of two non-orthogonal states from the input to the point of interest by means of a free-space compensator consisting of two waveplates and a variable retarder.

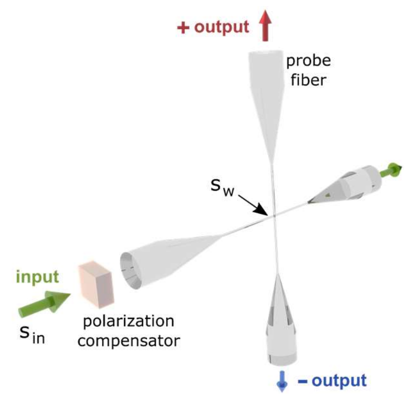

Fig. 1. Sketch of the crossed-nanofiber directional coupler. The input laser beam with the polarization state $\mathbf{s}_{\mathrm{in}}$ is launched into a single-mode tapered optical fiber crossed with a near-identical fiber at right angles. By adjusting the free-space compensator while monitoring the optical power exiting the '+' and '-' pigtails, we achieve the complete polarization control in the input nanofiber, so that $\mathbf{s}_{\mathrm{w}} = \mathbf{s}_{\mathrm{in}}$ for an arbitrary $\mathbf{s}_{\mathrm{in}}$.

Adiabatic nanofibers are indeed free of dichroism. Thus, in principle, they can be polarization-compensated using our method. However, one still has to detect a pair of non-orthogonal states at the nanofiber waist. We achieved this by crossing the nanofiber under study with a near-identical nanofiber at right angles, see Fig. 1. The resultant directional coupler enables one to unambiguously distinguish two required states based on two independent effects – the induced asymmetric dipolar emission and the quantum spin-Hall effect of light [4] – both of which contribute to measurable breaking of the system's mirror symmetry. Although only two states are mapped, the compensation ensures maintenance of an arbitrary polarization, and thus provides the sought complete control. We expect our results to have a major impact on the wide range of experiments and applications involving nanofiber waveguides, and perhaps beyond, into the areas of integrated photonics and chiral light-matter interactions.

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