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Optical sensing of nanoparticles in the infrared by use of silica nanowires

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Abstract We numerically investigate an optical sensor in the infrared based on a Mach–Zehnder interferometer (MZI) assembled with two single-mode silica nanowires immersed in acetonitrile. We propose to use acetonitrile as the detecting solution because, in contrast to water which has very high losses in the infrared, it has negligible losses at important wavelengths of 1,300 and 1550 nm. By solving for the fundamental mode of a three-layer nanowire, we calculate the propagation constant difference between the sensing and reference arms at the output of the MZI optical sensor. For nanoparticles with a size of 12 nm and an index of refraction of 1.4, the sensitivity of the optical sensor becomes a maximum for a wire diameter of 1.23 μm. An optical sensor operating at a wavelength of 325 nm and using water as the detecting solution requires nanowires with a diameter of 240 nm, which is much more difficult to implement.

Keywords Infrared · Optical sensor · Organic solvent · Silica nanowire · MZI

1 Introduction

Optical sensors have been receiving increased attention in recent years and are used for a variety of applications including measurement of temperature, strain, and liquid refractive index. Various optical structures have been investigated as refractive index sensors such as long-period and Bragg fiber gratings (Liang et al. 2005; Fang et al. 2010; Bhatia and Vengsarkar 1996), step-index fibers with micro-channel (Lee et al. 2011), photonic crystals (Wu et al. 2008), silica-air photonic crystal fibers (Jha et al. 2009; Phan et al. 2007; Rindorf and Bang 2008; Wu et al. 2009; Han et al. 2010), and fiber-assisted surface Plasmon resonances (Allsop et al. 2007; Ma et al. 2009). In long-period fiber gratings, the resonance wavelength between the core and cladding modes is shifted by a change in the refractive index of the surroundings of the fiber. Long-period gratings can be realized in step-index

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