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PHOTONIC CRYSTAL FIBRE WGM RESONATORS FOR MAGNETIC FIELD SENSING

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Whispering gallery mode (WGM) micro-resonators are remarkable optical devices whose small modevolumes and high Q-factors make them attractive for a wide range of applications such as filters, lasers, modulators and sensors [1]. WGMs can be excited in dielectric structures with circular symmetry, such as microspheres, micro-disks, and optical fibres, and can be imagined as closed-trajectory rays confined within the cavity by almost total reflections from the curved surface of the resonator. The spectral positions of the WGM resonances are highly sensitive to the geometrical dimensions of the resonator and refractive indices of both the resonator itself and its surrounding medium [2].

Polarization maintaining photonic crystal fibres (PM-PCF) containing micron-sized air holes can be used as cylindrical WGM resonators whose effective refractive index can be altered by infiltrating them with various materials. In this work we propose a novel magnetic field sensor based on a short section of PM-PCF infiltrated with a ferrofluid, a highly stable magnetic colloidal suspension consisting of well-dispersed single domain ferromagnetic nanoparticles in water with the assistance of suitable surfactants. The effective dielectric constant and refractive index of the ferrofluid are dependent on the orientation state of the magnetic nanoparticles [3]. As a result, the effective refractive index and extinction ratio of the WGM spectrum produced by such a resonator varies in the presence of magnetic field and thus the spectral shift of the WGM resonances can be related to the magnitude of the field. We studied WGMs in a cylindrical micro-resonator based on a 1 cm-long section of PM-PCF-1500 fibre, tapered to a waist diameter of 50 μm to improve sensitivity and then infiltrated with a water based ferrofluid (CYTODIAGNOSTICS) which utilised 5-nm-diameter Fe_3O_4, ferromagnetic nanoparticles, with a concentration of 5 mg/ml and typical magnetization >25 emu/g. WGMs were excited by evanescent coupling of a guided mode of a ~1 μm waist diameter fiber taper to the micro-resonator PM-PCF fiber resonator. Excitation of WGMs causes a series of dips in the transmission spectrum of the fiber taper. Fig. 1 illustrates the WGM spectra without a magnetic field and in the presence of magnetic fields of up to 26.9 mT. As can be seen from the figure, application of magnetic field results in the decrease of extinction ratio and a red shift of the WGM spectrum with an estimated sensitivity of ~52.8 pm/mT as shown in Fig. 2. The proposed sensor offers advantages of good sensitivity, small size and ease of fabrication.

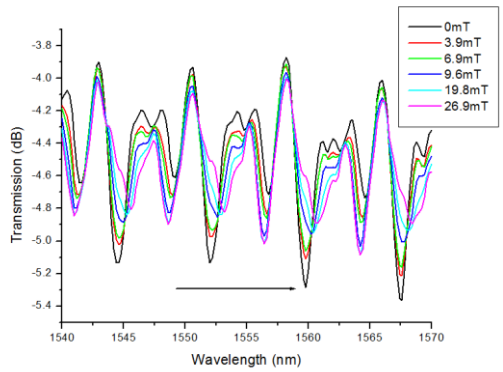

Fig. 1. WGM spectra under different applied magnetic fields.

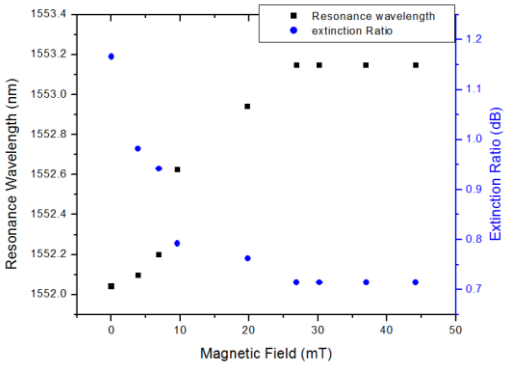

Fig. 2. Resonant wavelength and extinction ratio vs. magnetic field for a selected resonance of 1552 nm.

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