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Integrating hetero-core fiber optics sensor in intelligent technological textiles

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ABSTRACT

In the context of the emerging Industry 4.0 paradigm, smart fabric sensors have been representing a novel addition to the textile industry. The proposed sensors utilize macro-bending techniques with varying fiber optic core sizes. The study involved the construction and testing of macro-bending sensors using single-mode (9 μm) and hetero-core (50–9–50 μm) fibers, configured into seven sinusoidal loops. The experiment was further extended to different types of elastic textiles. Spandex demonstrated superior linearity compared with jersey and rubber bands. The integration with the DOIT ESP32 DevKit facilitated real-time monitoring of respiratory rates. The results from the experiment indicated that the macro-bending sensor, fabricated using hetero-core optical fiber, exhibited superior sensitivity in comparison to the sensor assembled from single-mode optical fiber, with respective sensitivity values of 1.72 and 1.30 dB/cm. The designed sensors displayed closely aligned behavior during forward and reverse loading, indicating the reversibility of the fiber optic sensor. Given its simplistic design and low fabrication cost, the proposed sensor holds significant potential for practical applications.

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1. INTRODUCTION

Fiber optic sensors (FOS) can be categorized into four distinct groups based on their operational principles: intensity modulation (including micro bending, transmission-based, reflection-based, and macro-bending FOS), phase modulation (comprising Mach–Zehnder interferometers, Michelson interferometers, Fabry–Perot interferometers, and Sagnac interferometers), wavelength modulation (incorporating Bragg gratings, fluorescent-based sensors, and blackbody sensors), and polarization modulation. The research community has been focusing on the development of cost-effective and easy-to-fabricate sensors. Among them, macro-bending sensors have emerged as viable alternatives with applications in various domains such as displacement, pressure, temperature, and liquid detection [1], [2]. Displacement sensors, in particular, hold promise for healthcare monitoring and structural health monitoring [3], [4]. Conventional methods for movement detection have also been extensively researched [5].

Recent years have witnessed a substantial increase in the enthusiasm for incorporating sensors into fabrics [6]. Shen *et al.* [7] have successfully created wearable macro-bending optical sensors that can detect small body vibrations resulting from heartbeat and breathing. These sensors can capture and document cardiac and respiratory activities, thus providing an all-encompassing health monitoring solution. Considerable progress has also been achieved in incorporating FOS into textiles, as propelled by a multitude of researchers [8]–[11].