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Integrated optical fiber devices

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Abstract: Integrating functional materials, photonic structures and circuits in an optical fiber platform provides opportunities for a range of novel applications. Recently, Yuan TT et al presents a comprehensive review on the development of in-fiber photonic integrated devices and systems, including historic background, methods of integration, structures and materials, functionalities and performances, as well as applications in sensing, communications, signal manipulation and processing, medical diagnosis and treatment. The review also includes insightful analysis and discussion of future research directions.

Keywords: optical fiber; optical fiber sensor; photonic integration in fiber; in-fiber photonic; integration

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Photonic integration, which incorporates multiple passive and/or active photonic components such as waveguides, modulators, lasers and detectors to form a functional circuity on a single chip, has experienced exciting development. It enables manipulation of light with enhanced functionality, reduced form factor, and increased efficiency over the bulky optical systems, and has potential for a wide range of applications in telecommunications, sensing, artificial intelligence, and quantum systems[1,2].

In parallel, there are also active research on photonic integration in an optical fiber platform. Optical fibers have been the backbone of our information society for several decades[3] and yet the field of fiber-optics is continuingly developing. In additional to the recent development of novel photonic crystal, photonic bandgap and anti-resonant optical fibers[4], one area of significant development is the integration of novel structures and materials into optical fibers to achieve more functionalities for more widespread applications. Examples are the lab-in-fiber or lab-on-fiber technologies for biomedical applications[5,6], and integration of two-dimensional and gas-phase materials with optical fibers for light manipulation[7,8], and semiconductor materials for nonlinear photonic applications[9].

Recently, a review paper on three-dimensional integrated optical fiber devices is published in *Opto-Electronics Technology*[10]. The review starts with a brief discussion of the concept and historic background of photonic integration in optical fibers, followed by expansion of functionality by two and three dimensional structural modifications and materials integrations, and a summary and future outlook. It includes different methods of structural modifications and integrations such as direct fiber-drawing, side and end-face polishing, chemical etching, thermal splicing, diffusion, tapering and twisting, femtosecond laser micro-machining, assembly of microdevices and meta surfaces, and so on.

The review also discusses many applications of the integrated optical fiber devices, including three-dimensional shaping sensing, refractive index sensing, chemical and biochemical sensing, polarizers and modulators, broadband photodetectors, beaming focusing and manipulation, OCT imaging, spectral filtering, vortex beam generation, and optical microfluidic devices.

The field of integrated optical fiber devices is still developing. As pointed out in the review, the future development may include miniaturization of three-dimensional optical devices that may be embedded in different applications systems, distributed sensing units that can be seamlessly integrated with optical fiber systems, optoelectronic hybrid chip and fiber integration, integrating multifunctional photonic components into a slender optical fiber for biomedical applications, indicated in Fig. 1.

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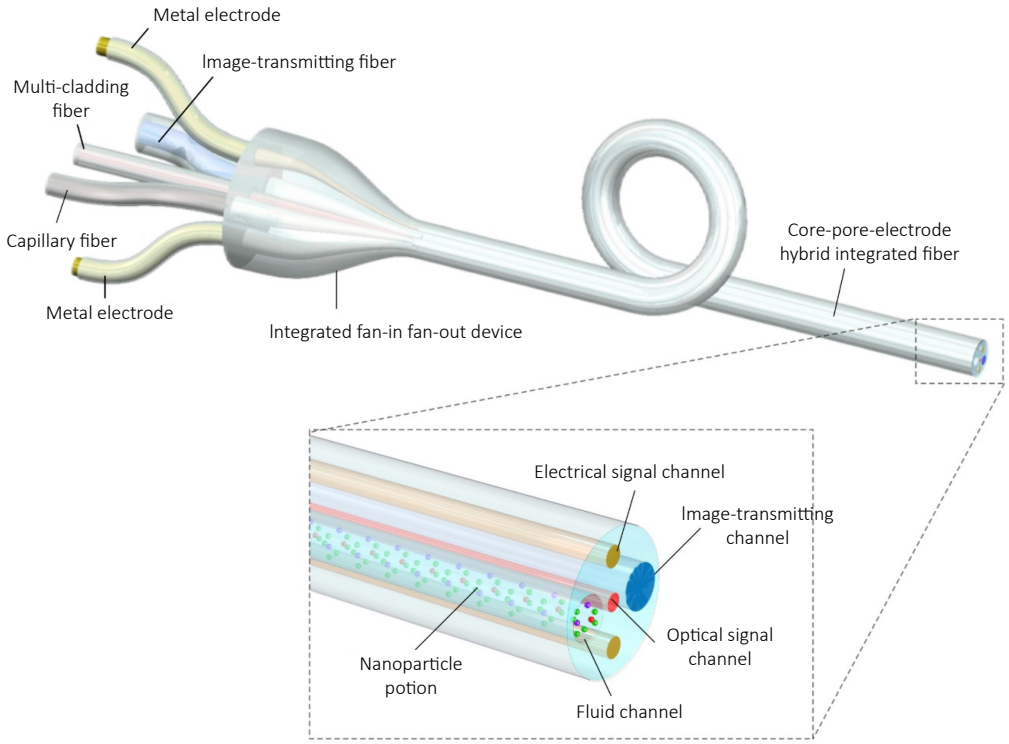

Fig. 1 | Schematic of a multifunctional modular optical fiber probe capable of integrating sensing, diagnosis, and therapy with a single optical fiber[10].

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