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All optically powered chip-on-tip microcamera for surgical guidance

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Abstract: We present an all-optical powered 6 Fr microcamera based chip-on-tip endoscope system. The optical powering is achieved by fiber illuminating a customized multisegmented photovoltaic cell. The powering system produces 10 mW of electrical power sufficient to power microcamera. We demonstrated the performance of the system on calcification tissue-mimicking phantoms.

1. Introduction

The realm of modern surgery has witnessed a paradigm shift with the advent of innovative technologies that enhance precision, minimize invasiveness, and improve patient outcomes. Among these technological advancements, endoscopy has played a pivotal role by enabling surgeons to access and visualize intricate anatomical structures through minimally invasive procedures [1,2]. However, the efficacy of endoscopic interventions is intrinsically linked to the quality of imaging and size of endoscopes that enable surgeon's to navigate within the surgical field. The next-generation chip on tip surgical endoscopes requires robust in performance and resistance to electromagnetic interference noise of other medical devices, a small footprint (3-6 Fr), hyperspectral imaging for multi-biomarker quantification and a higher frame rate to reduce motion artefacts. These innovations demand for all optical powered and higher data rates which is not possible by using conventional electrical cables. There is a need to develop novel communication and powering platforms tailored to enable chip-on-tip endoscopes to probe deep within the body. Laser-to-laser power conversion is demonstrated in the literature [3]. There are no literature on optically powered endoscope systems for biomedical application.

In this work, we present an all-optical powered 6 Fr microcamera based chip-on-tip endoscope system. The optical powering is achieved by illuminating a customized multi-segment photovoltaic (PV) cell with a multimode fiber. The powering system operates at its maximum efficiency point which supplies 10 mW of electric power sufficient to power microcamera. We demonstrated the performance of the system on calcification tissue-mimicking phantoms.

2. Material and methods, Results

Fig. 1a shows the schematic layout of an optically powered microcamera system. Fig. 1b shows the experimental arrangement of the optical powering unit. The 808 nm laser light from a fiber was coupled to powering fiber (core diameter 200 µm). The powering fiber is placed at an optimal distance to generate a 250 µm beam profile to maximize illumination on the PV cell. The power conversion efficiency is around 47.8 %. The output of the PV cell is connected to a microcamera (AMS NanEYE RGB micro-camera, with a field-of-view (FOV) of 90° and F# 2.7). The frame rate of the microcamera is controlled by varying the illumination of the light on the PV cell. The images taken by the camera by read out using custom-made readout board (BAP Image Systems, Ergolding, Germany). A multi-wavelength illumination source in the range of 400-980 nm from broadband supercontinuum (Fianium SC 450) is coupled to illumination fiber to enable multi-spectral imaging. The wavelength selection was made using custom Pellin Broca prism based optics [4].

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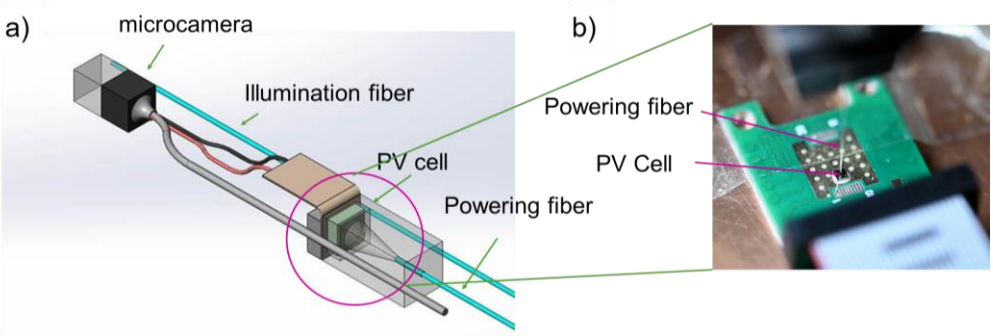

Fig.1 a) schematic layout of optically powered microcamera system b) experimental setup of PV cell optical powering unit.

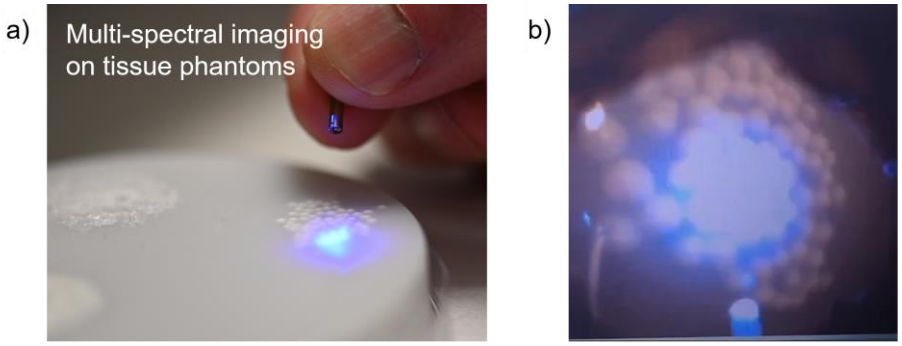

Fig2. a) 6Fr optically powered endoscope on the topic of tissue-mimicking phantom, b) calcification phantom captured by endoscope at 405 nm (video file).

Tests on tissue-mimicking phantom were performed to understand the performance of the endoscope for surgical guidance application. A multi-layer tissue phantom with varying top layer thickness (0.5, 1 mm) with hydroxyapatite calcification in the bottom layer was used. Fig 2a, shows the optically powered endoscope imaging from top of calcification tissue mimicking phantom. Phantom also has calcification of difference which is used to probe the resolution of the endoscope system to image the smallest calcification. Fig. 2b shows the 1 mm calcification as imaged by the microcamera. Specular reflection of the fiber illumination is seen in the middle of the phantom this can be reduced by using multi-illumination methods [5].

We demonstrate the first-of-its-kind optically powered 6 Fr endoscopic microcamera system for biomedical applications. The system performance was tested on calcification tissue-mimicking phantoms to simulated surgical guidance. Our work forms the basis for the next generation of all optically powered chip-on-tip endoscopic systems for small-footprint medical applications.

3. References

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