

# Elasticity Difference Detection of Silicone Tissue Models and Biological Tissue by SPS Endoscopic ESPI

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Investigations on elasticity difference detection of silicone tissue models and biological tissue by spatial phase shifting endoscopic Electronic Speckle Pattern Interferometry (SPS Endoscopic ESPI) have been carried out. The results of the investigations show the applicability of SPS Endoscopic ESPI in combination with a reproducible tissue stimulation.

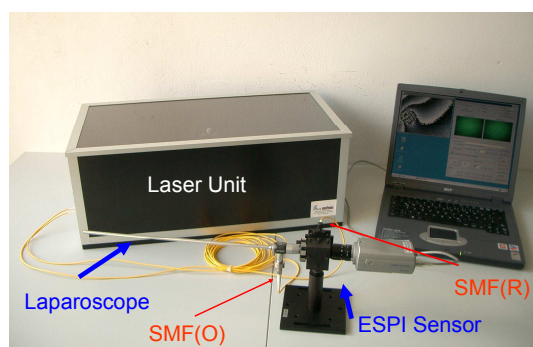
## 1 MOTIVATION

Spatial phase shifting endoscopic ESPI (SPS Endoscopic ESPI) is a method for quantitative detection of displacements and movements in biological cavities [1]. In combination with reproducible tissue stimulation SPS Endoscopic ESPI opens up new perspectives for biomedical applications, e. g. tumor recognition by the detection of elasticity differences of biological tissue.

Investigations on silicone tissue models with areas of locally decreased elasticity have been carried out by application of SPS Endoscopic ESPI in combination with different methods of tissue stimulation in order to determine the detection limit of the method. Results of in vitro investigations on a biological specimen demonstrate the method's applicability.

## 2 METHOD

The investigations are carried out by application of a modular SPS Endoscopic ESPI system that is depicted in Fig. 1.



**Fig. 1** Modular SPS Endoscopic ESPI system consisting of a laser unit, an endoscopic ESPI module and a notebook-computer for image processing. SMF(O): single mode fiber for object illumination; SMF(R): single mode fiber for the reference wave.

The modular system consists of a laser unit, an endoscopic ESPI sensor and a notebook-computer for image processing. The coherent light source is a frequency doubled Nd:YAG-laser ( $\lambda=532$  nm, 100 mW). The investigated area is imaged by commercial endoscopes (Karl Storz GmbH & Co. KG). The laser light for object illumination and reference wave is guided by single mode optical fibers. For the detection of tissue movements, the speckle-interferograms of different object states are recorded by a progressive scan CCD sensor with IEEE1394 interface (Sony XCD X700, resolution: 1024 x 768 pixels).

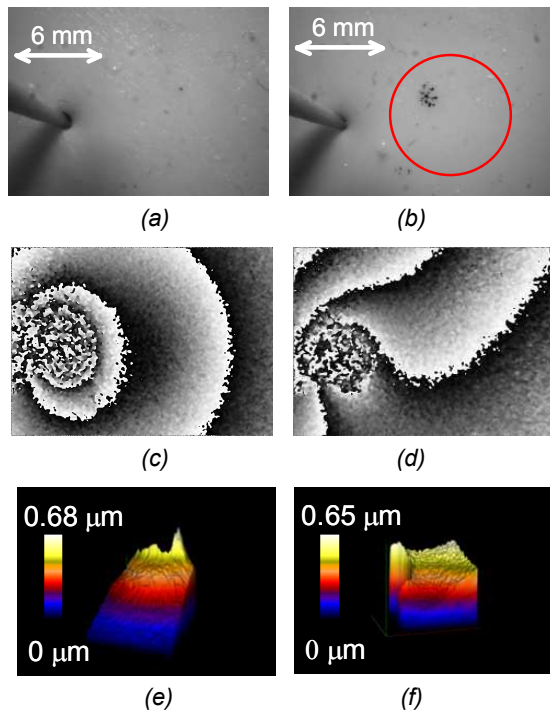
Stroboscopic visualization of tissue surface movements by correlation fringe patterns near video repetition rate is possible. A spatial phase shifting method is applied for quantitative analysis of object movements [2].

## 3 RESULTS

Fig. 2 shows exemplarily a result of investigations on silicone tissue models with different elasticity distributions. The specimens are stimulated by a piezo translator (stimulation frequency  $f \approx 1.5$  Hz, amplitude:  $\approx 3.5$   $\mu$ m). Figs. 2(a), (c) and (e) show results obtained from investigations on a homogeneous model (left column) in comparison to a model with an embedded silicone sphere (right column, red circle) of different elasticity ( $\varnothing = 6$  mm, depth = 2.6 mm) beneath the visible surface (see Figs. 2(b), (d) and (f)).

For the homogenous reference model, concentric phase difference fringes around the stimulation center are observed (Fig. 2(c)), while the stimulation of the tissue model with a disturbance results in distributions of parallel fringes (Fig. 2(d)).

Tab. 1 shows results of systematic investigations on silicone tissue models with disturbances of different materials and size.



**Fig. 2** Investigations on silicone tissue models: (a), (b) White light images; (c), (d) smoothed phase difference distributions mod  $2\pi$  (stimulation with piezo translator); (e), (f) Pseudo-3D-Plots of the displacement.

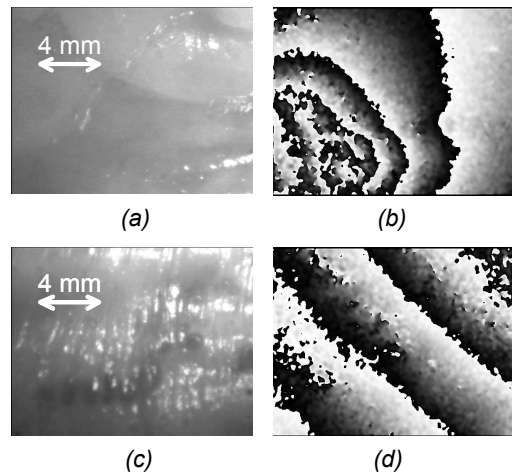
The models are stimulated by a piezo translator (stimulation frequency  $f \approx 1.5$  Hz, amplitude:  $\approx 3.5$   $\mu\text{m}$ ) to determine the detection limit of the method.

disturbance	$\varnothing = 1.3$ mm	$\varnothing = 3$ mm	$\varnothing = 6$ mm
metal sphere	1 mm	2.5 mm	5.8 mm
silicone sphere	--	1.4 mm	3.8 mm

**Tab. 1** Detection limit of SPS Endoscopic ESPI for investigations on silicone tissue models with disturbances of different materials and size.

In a further experiment, in vitro investigations on an intestinal specimen with carcinoma stimulated by an endoscopic ultrasonic tube (single pulse, amplitude: 200  $\mu\text{m}$ ) have been carried out (see Fig. 3).

Figs. 3(a) and 3(c) show the white light images of the investigated areas for tissue without pathological findings (a) as well as for a tumorous part of the tissue (c). Exemplary results of the depicted smoothed phase difference distributions mod  $2\pi$  of the relaxation process are shown in Figs. 3(b) and 3(d).



**Fig. 3** In vitro investigations on a human intestinal specimen: (a), (c) White light images of a tissue part without pathological findings (a) and of the tumorous tissue (c); (b), (d) smoothed phase difference distributions mod  $2\pi$ .

Similar to the results obtained from investigations on the silicone tissue models, the phase difference shows concentric fringes for the tissue part without pathological findings (Fig. 3(b)) and a parallel fringe distribution for the hardened tumorous tissue (Fig. 3(d)). Thus, the tissue part without pathological findings can be distinguished from the tumorous tissue of diminished elasticity.

#### 4 DISCUSSION

The results of the investigations on silicone tissue models with areas of diminished elasticity demonstrate the detection of disturbances up to a diameter of 1.3 mm. Furthermore, the results of in vitro investigations on an intestinal specimen show that SPS Endoscopic ESPI in combination with a reproducible stimulation technique is applicable for the detection of elasticity differences of biological tissue.

#### 5 Acknowledgement

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#### Literature

- [1] W. Avenhaus, B. Kemper, S. Knoche, D. Domagk, C. Poremba, G. von Bally, W. Domschke: „Dynamic holographic endoscopy: ex vivo investigations of malignant tumours in the human stomach“ in *Laser in Medical Science* **19**: 223-228 (2005).
- [2] B. Kemper, J. Kandulla, D. Dirksen, G. von Bally: „Optimization of spatial phase shifting in endoscopic electronic speckle pattern interferometry“ in *Optics Communications* **217**: 151-160 (2003).