080 **SHEAR MODULUS MICROSCOPY USING DISPLACEMENT VECTOR MEASUREMENT.**

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**Abstract.** We have been developing several ultrasound (US) strain tensor measurement methods and several shear modulus reconstruction methods for the differential diagnosis of diseases. Recently, we also started to perform other applications of the shear modulus reconstructions (e.g., on normal physical motions of arms, legs, etc, and cultured tissues, iPS cell). In this context, we started to develop the microscope of shear modulus using 100 MHz US. Perform of a 3-dimensional (3D) displacement vector measurement enables our developed shear modulus reconstruction methods to deal with an arbitrary mechanical source (e.g., gravity, and internal, external, spontaneous or extracorporeal ones). Thus, for a skin, normal and artificial deformations in an arbitrary direction will be dealt with. Various clinical applications can also be considered (e.g., cultured cardiac tissue). In this report, using Field II, US point spread functions (PSFs) were calculated for 3.5 and 105 MHz lateral modulation. The same modulation frequencies are set as those of the US frequencies. A prototype microscope using a concave aperture transducer (100 MHz) was also used to obtain a US image (however, nonmodulated image).

## I. Introduction

We have been developing several ultrasound (US) strain tensor measurement methods [1,2] and several shear modulus reconstruction methods [3–5] for the differential diagnosis of diseases. Recently, we also started to perform other applications of the shear modulus reconstructions (e.g., on normal physical motions of arms, legs, etc [6], and cultured tissues, iPS cell). In this context, we started to develop the microscope of shear modulus using 100 MHz US.

For instance, the microscope can be used for the evaluations of the skin shear moduli (i.e., those of the epidermis, dermis, subcutaneous tissue) of various body parts, e.g., face, arm, leg, abdomen, breast. Last year, the preliminary measurement results of the aging effect on a facial skin obtained using 7.5 MHz US were reported [7]. Such a low frequency macroscopic and high frequency microscopic evaluations will lead to developments of various techniques (e.g., using medicines, cosmetics, equipment) for skin care and culture (e.g., dry skin, crack, oily skin, sun burn etc) as well as diagnosis of diseases.

Perform of a 3-dimensional (3D) displacement vector measurement enables our developed shear modulus reconstruction methods to deal with an arbitrary mechanical source (e.g., gravity, and internal, external, spontaneous or extracorporeal ones). Thus, for a skin, normal and artificial deformations in an arbitrary direction will be dealt with. Various clinical applications can also be considered (e.g., cultured cardiac tissue).

In this report, US point spread functions (PSFs) were calculated for 3.5 and 105 MHz lateral modulation using Field II. The same modulation frequencies are set as those of the US frequencies. Isotropic Gaussain envelopes of the PSFs are designed (axial, $\sigma_x$ = lateral $\sigma_y$). The apodization functions for the respective modulations are calculated by Fraunhofer approximation [2]. We refer to the modulation as the lateral Gaussain envelope cosine modulation (LGECM). A prototype microscope using a concave aperture transducer (100 MHz) was also used to obtain a US image (however, nonmodulated image).

## II. Simulations

Linear array type transducers were modeled for 3.5 and 105 MHz. The specifications of the respective transducers were shown in Fig. 1 together with the correspondingly calculated point spread functions (PSFs) using (Field II). The reduced scale factor of the images is 30. However, as shown, PSF of 105 MHz has a large lateral width. That is, obtained US image will have a low lateral resolution. Interestingly, PSF is not effected by the US element width (i.e., not reduced, 0.43 mm vs 0.014 mm).

Next, for comparison with the PSF calculated for the linear array type transducer (US and modulation frequencies, 105 MHz), PSFs of concave aperture transducers with the same frequency and different R (= 0.286; 0.273; 0.250) were calculated. As shown in Fig. 2, concave transducers were able to yield smaller PSFs than the linear array type transducer. In Fig. 3a, a US image is shown. Specifically, to acquire 3D rf signals, the specimen was mechanically scanned using a concave aperture transducer (100 MHz, diameter, 2.4 mm; focus, 3.2 mm). As shown in Fig. 3b, the focus position can also be controlled in the axial direction. That is, if necessary, during the echo data acquisition, the focus position is also changed in the axial direction. The specimen was a sponge for skin culture (Johnson & Johnson). For instance, the tension may be applied such that the specimen elongates in the lateral direction. Thus, the configurations of the concave transducers shown in Fig. 4 should be realized in our elasticity microscope. The configurations realize the crossed beams (US simultaneously transmitted), i.e., coherent superposition (lateral modulation) [2]. Alternatively, mechanically steered beams can also be superimposed to realize the lateral modulation (US respectively transmitted). However, because any lateral modulations were not performed here, only the axial displacement and axial strain can be measured accurately.

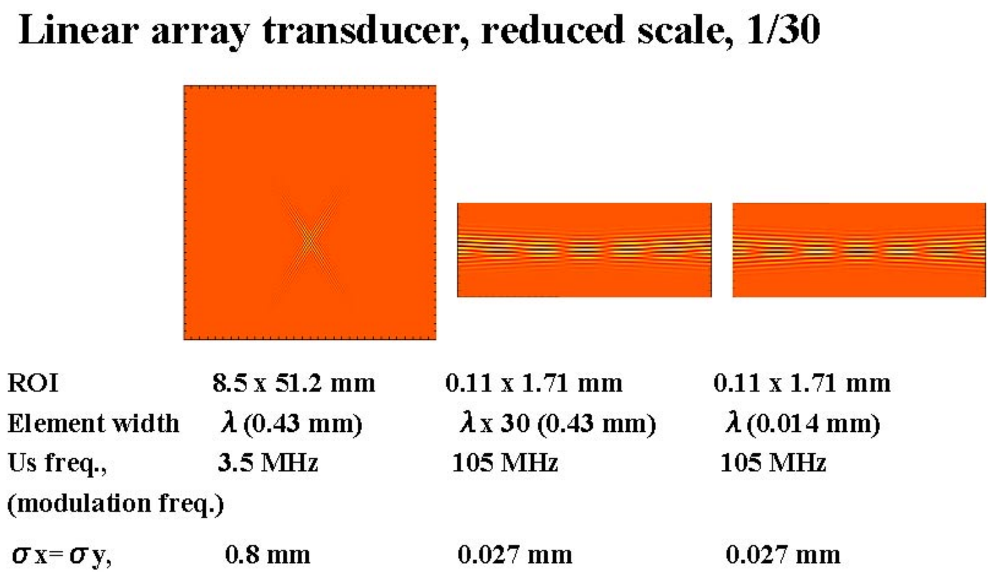


Fig. 1. Point spread functions (PSFs) calculated for linear array type transducers with US frequencies 3.5 and 105 MHz (Field II). The reduced scale factor of the images is 30.

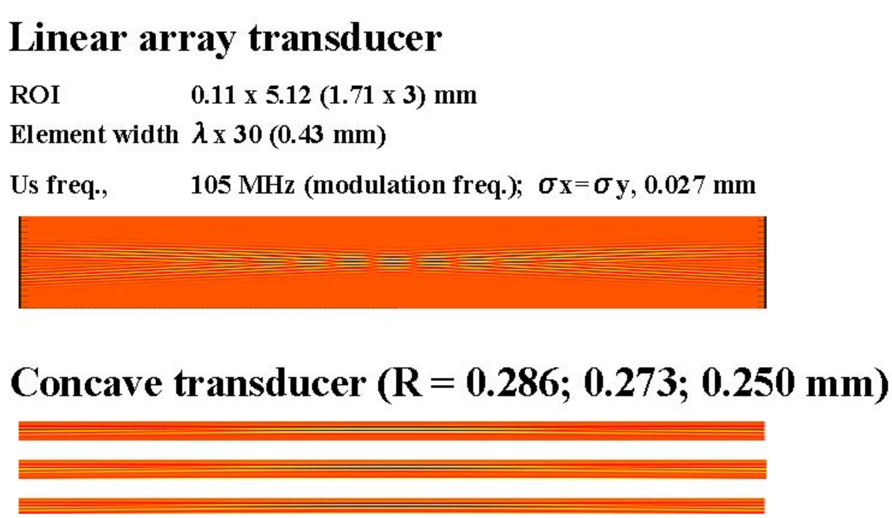


Fig. 2. Point spread functions (PSFs) calculated for linear array type and concave aperture transducers with a US frequency, 105 MHz.

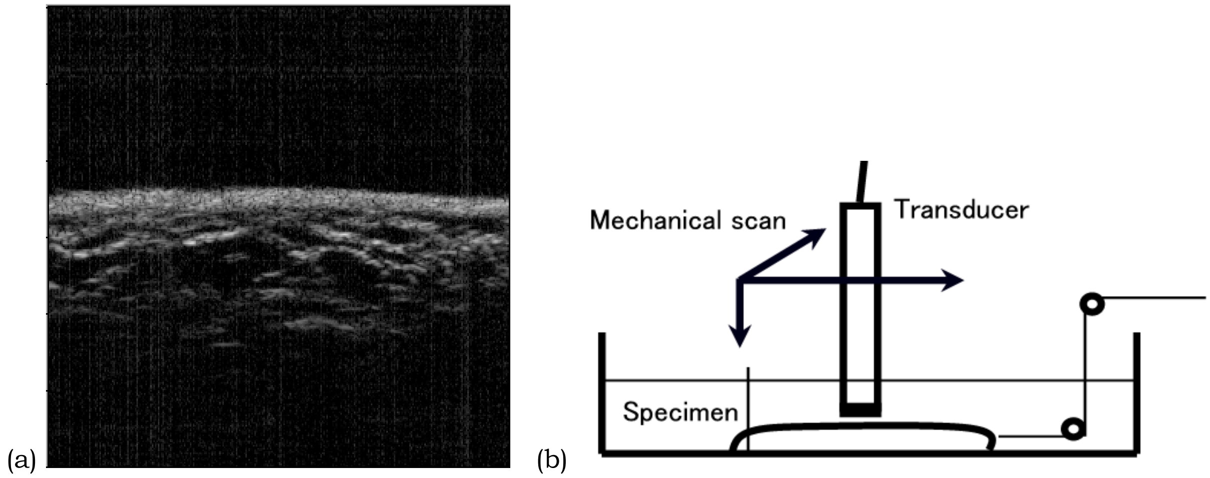


Fig. 3. (a) B-mode image obtained on a sponge using a prototype microscope (HONDA ELECTRONICS CO., LTD, Japan, 100 MHz). (b) Schematic of the mechanical scan system.

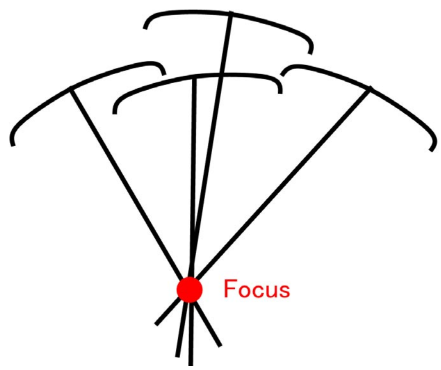


Fig. 4. Schematic of lateral modulation using concave transducers in elasticity microscope. Four beams are crossed. Coherent superposition can also be performed by mechanical steering of a concave transducer.

**III. Conclusions**

By using the proposed configurations of the concave transducers, the accuracy of the displacement vector measurement achievable will be clarified. The most proper lateral modulation will also be used to obtain accurate 3D displacement vector measurement and accurate 3D shear modulus reconstruction. By shortening the data acquisition time, a viscous shear modulus and a micro flow parameter can also be measured. That is, a viscous shear modulus microscope and micro flow meter can also be realized. If possible, arrays of concave apertures will also be used (US respectively transmitted or symmetrically, simultaneously transmitted). The evaluations of anisotropic mechanical properties are also our targets.

**References**

[1] C. Sumi et al., “Fine elasticity imaging on utilizing the iterative rf-echo phase matching method,” IEEE Trans UFFC, 46, 158-166, 1999.

[2] C. Sumi et al., “Displacement vector measurement using instantaneous ultrasound signal phase — Multidimensional autocorrelation and Doppler methods,” IEEE Trans UFFC, 55, 24-43, 2008.

[3] C. Sumi et al., “Usefulness of ultrasonic strain measurement-based shear modulus reconstruction for diagnosis and thermal treatment,” IEEE Trans UFFC, 52, 1670-1689, 2005.

[4] C. Sumi et al., “Reconstructions of shear modulus, Poisson’s ratio and density using approximate mean normal stress $\lambda\varepsilon_{\alpha\alpha}$ as unknown,” IEEE Trans UFFC, 53, 2416-2434, 2006.

[5] C. Sumi et al., "Effective shear modulus reconstruction obtained with approximate mean normal stress remaining unknown," IEEE Trans UFFC, 54, 2394-2403, 2007.

[6] C. Sumi, "Ultrasonic axial strain measurement for lateral tissue deformation," UMB, 33, 1830-1837, 2007.

[7] C. Sumi et al., "Preliminary study on human skin shear modulus reconstruction," Proc. of 6th Int Conf Ultrason Meas Imag Tissue Elasticity, p. 41, 2007.

[8] C. Sumi et al., "Beamforming for realizing designed point spread function," IEEE 2007 Int Ultrason symp, 1557-1562, 2007.