NOVEL PUSHES MAKE COMPLEX SHEAR WAVES FOR ELASTICITY IMAGING

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Disclosure

I, have the following relevant financial interests, arrangements, or affiliations with a commercial interest.

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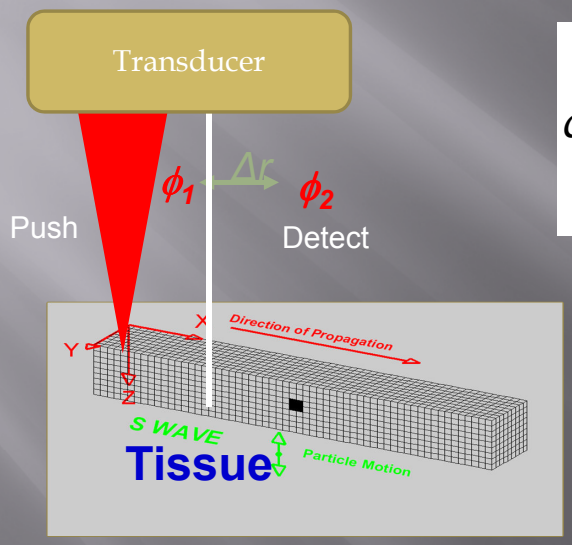
Outline

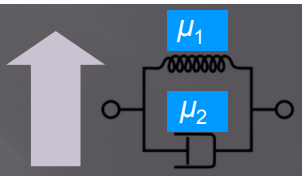
- What is Shear wave dispersion ultrasound velocimetry?
- Shear waves are induced by radiation force produced by ultrasound beams
- Four different classes of ultrasound push beams are available.
- Push beams have different bandwidths, depths of focus and penetration depths.

Ultrasound Induced Shear Waves Are Used to Characterize Tissue Mechanical Properties



$$c_s(\omega) = \sqrt{\frac{2\left(\mu_1^2 + \omega^2\mu_2^2\right)}{\rho\left(\mu_1 + \sqrt{\mu_1^2 + \omega^2\mu_2^2}\right)}}$$

Voigt model



$$\nabla^2\phi = \frac{1}{c_p^2}\frac{\partial^2}{\partial t^2}\phi$$

$$\nabla^2\underline{\psi} = \frac{1}{c_s^2}\frac{\partial^2}{\partial t^2}\underline{\psi}$$

$$c_s(\omega) = \frac{\omega \cdot \Delta r}{\phi_2 - \phi_1}$$

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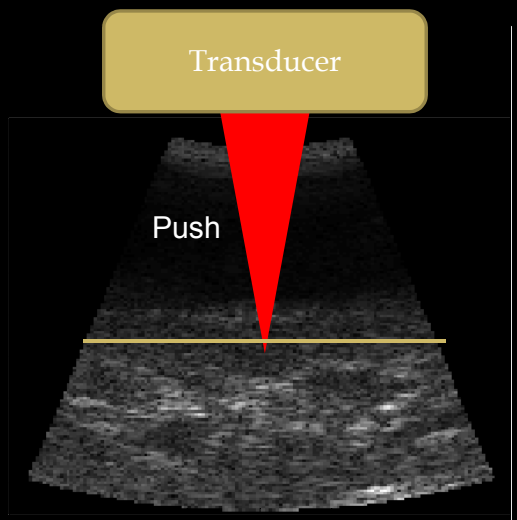
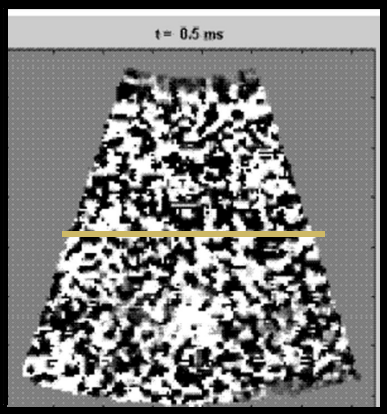
Kidney Experiment





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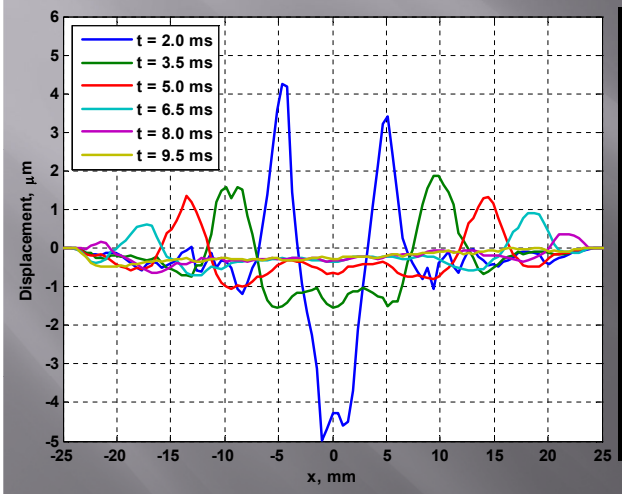
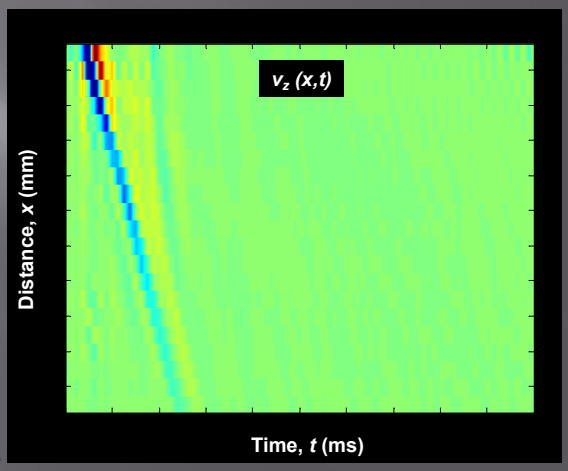
Tissue Displacement Velocity





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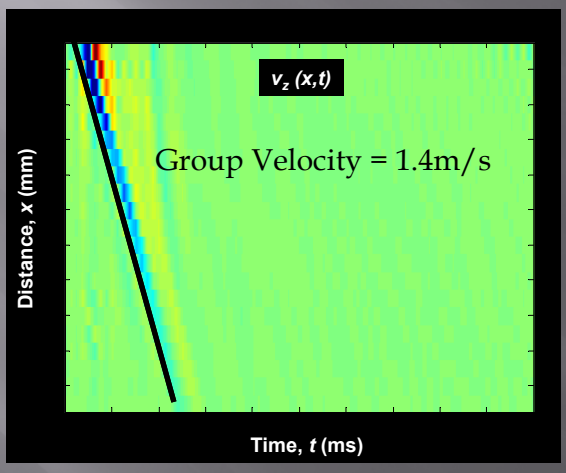
Group Velocity

Modulus (effective) = $\{V_g\}^2$ @f= ? Hz



$$H(k,f)=\sum_{m=-\infty}^{+\infty}\sum_{n=-\infty}^{+\infty}v_z(x,t)e^{-j2\pi(kmx+fnt)}$$

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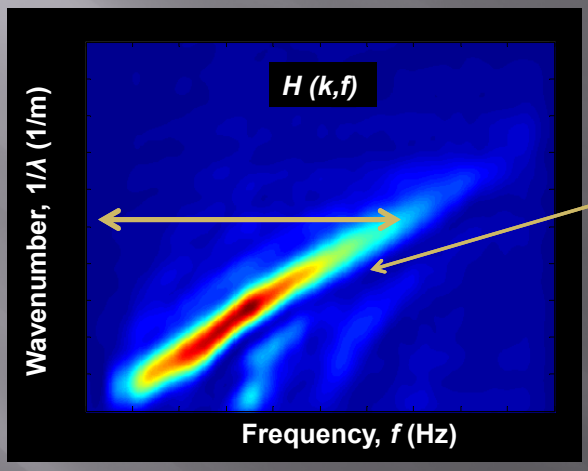
$$H(k,f)=\sum_{m=-\infty}^{+\infty}\sum_{n=-\infty}^{+\infty}v_z(x,t)e^{-j2\pi(kmx+fnt)}$$



Information Content
Of the Shear Wave

$$c=\lambda f$$

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How Do The Geometry And Time Course Of The Push Beam Affect The Information Content Of The Shear Wave?

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Specs for Push Beams

- **Transducer**: Philips L7-4
- **Push beam center frequency**: 5 MHz
- **Push beam duration**: ~600 microseconds for all push methods
- **Detect beam center frequency**: 5 MHz
- **F-number = 1.5** is fixed for all SSI and focused push tests
- **SSI Mach#** = 15.5
- **Frame rate** = 3125 Hz
- **Image resolution** = 0.308 mm (both lateral and axial)
- **Phantom elasticity**: ~ 2.25 kPa (~1.5 m/s shear wave speed)

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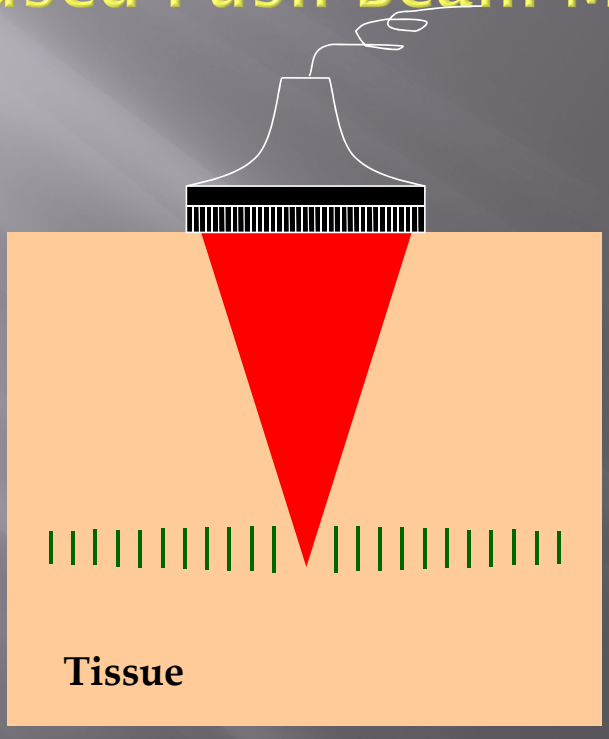
Focused Push Beam Method



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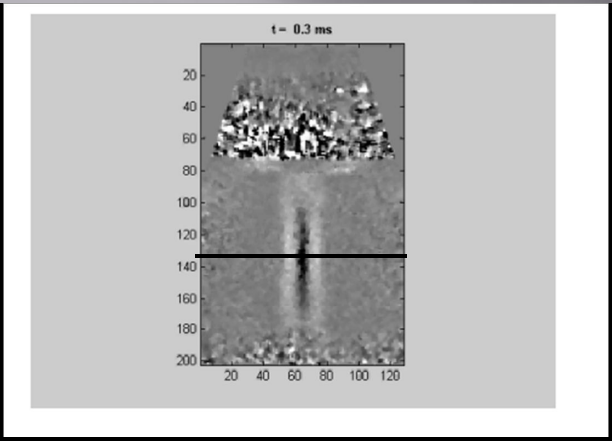
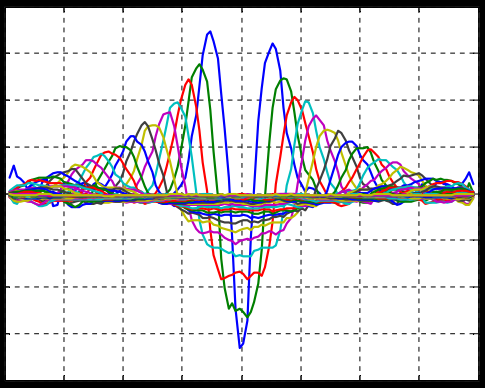
Focused Push in Gelatin Phantom





100–500 µs step function push

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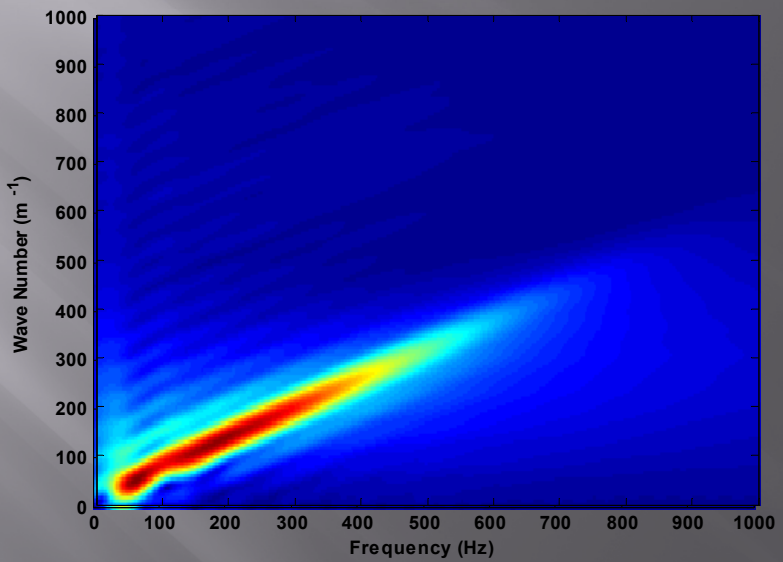
K- space for Focused Push at 20 mm



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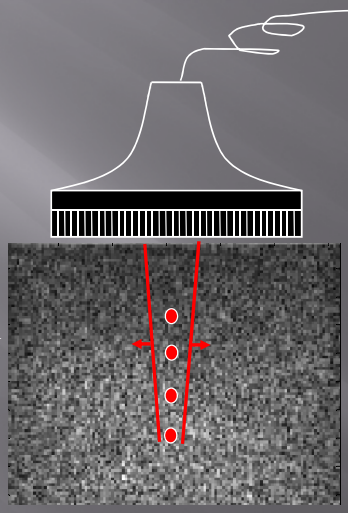
Super Sonic Push

- 4-point SSI (15, 20, 25, 30 mm)
- Fixed F/# = 1.5
- PRF = 3125 Hz
- Spatial Resolution = 0.308 mm
- Phantom #2



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Supersonic Shear Wave

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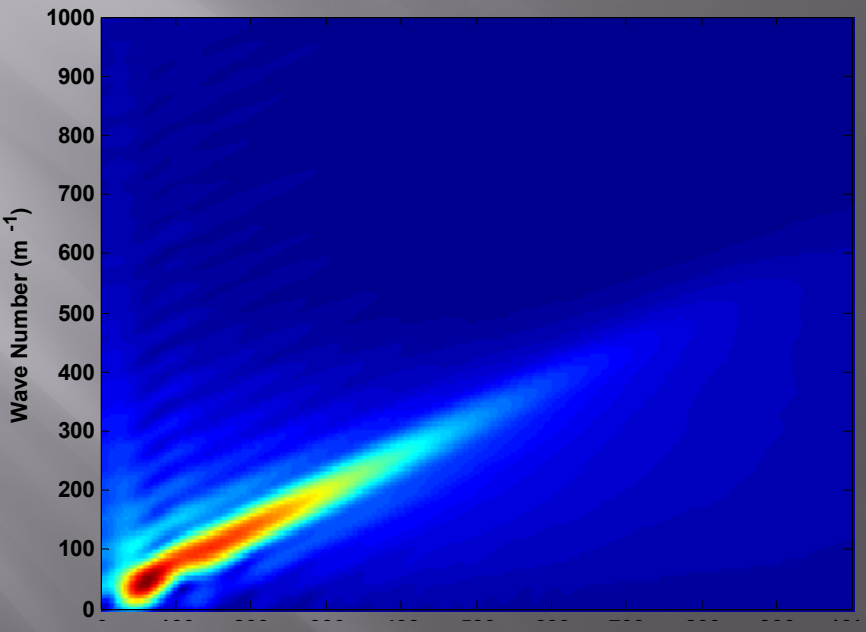
K-space for Super Sonic Push at 20mm



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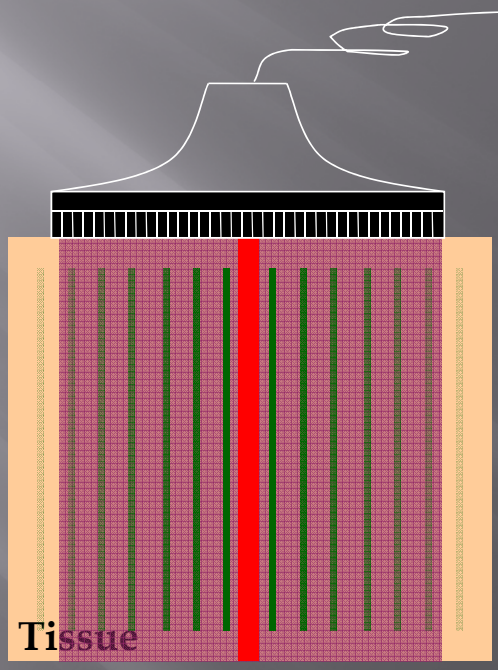
Unfocused Push Beam



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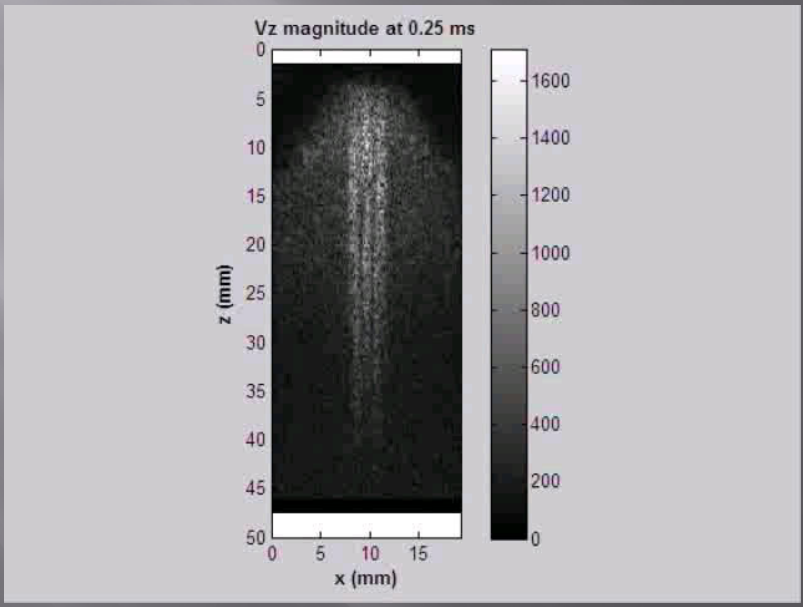
Unfocused Push Beam

- Verasonics imaging system: 4 kHz flash imaging
- L7-4: 16 elements. Push: 5 MHz, 600 μs.



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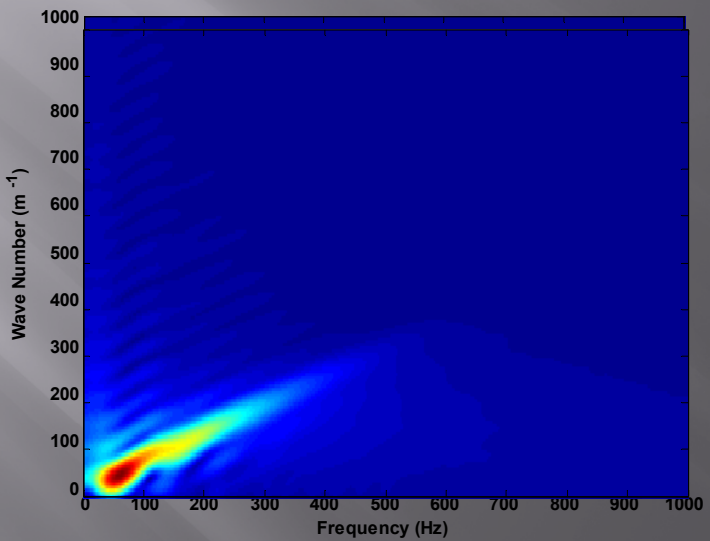
K-space of Unfocused Push at 20 mm



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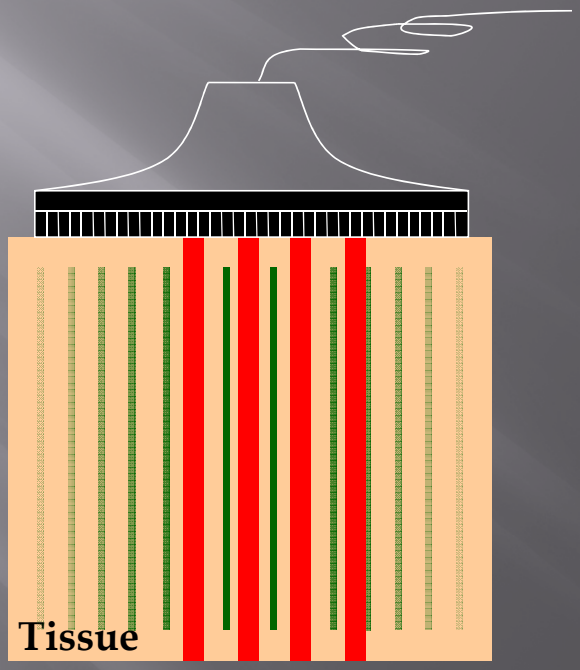
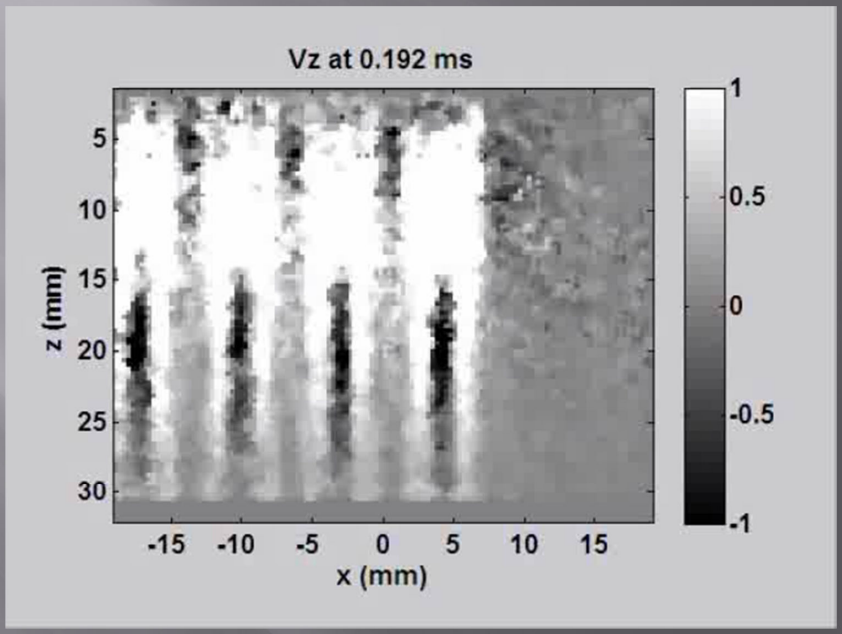
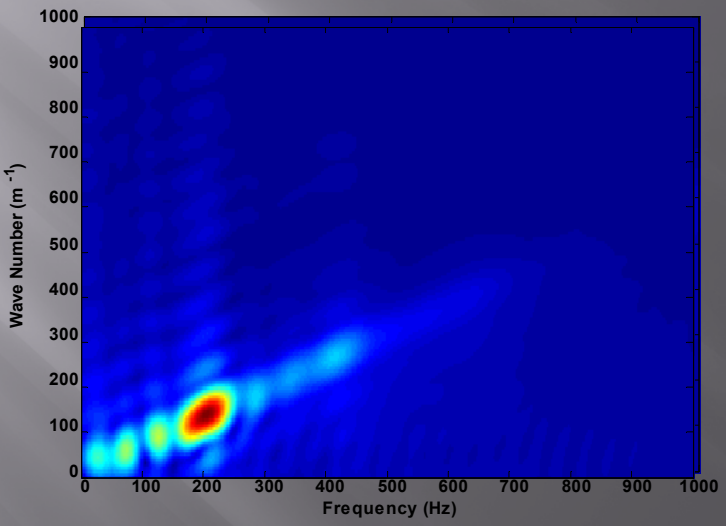
Comb Push Beam



Four Tooth Comb Push



K-space of Comb Push at 20 mm



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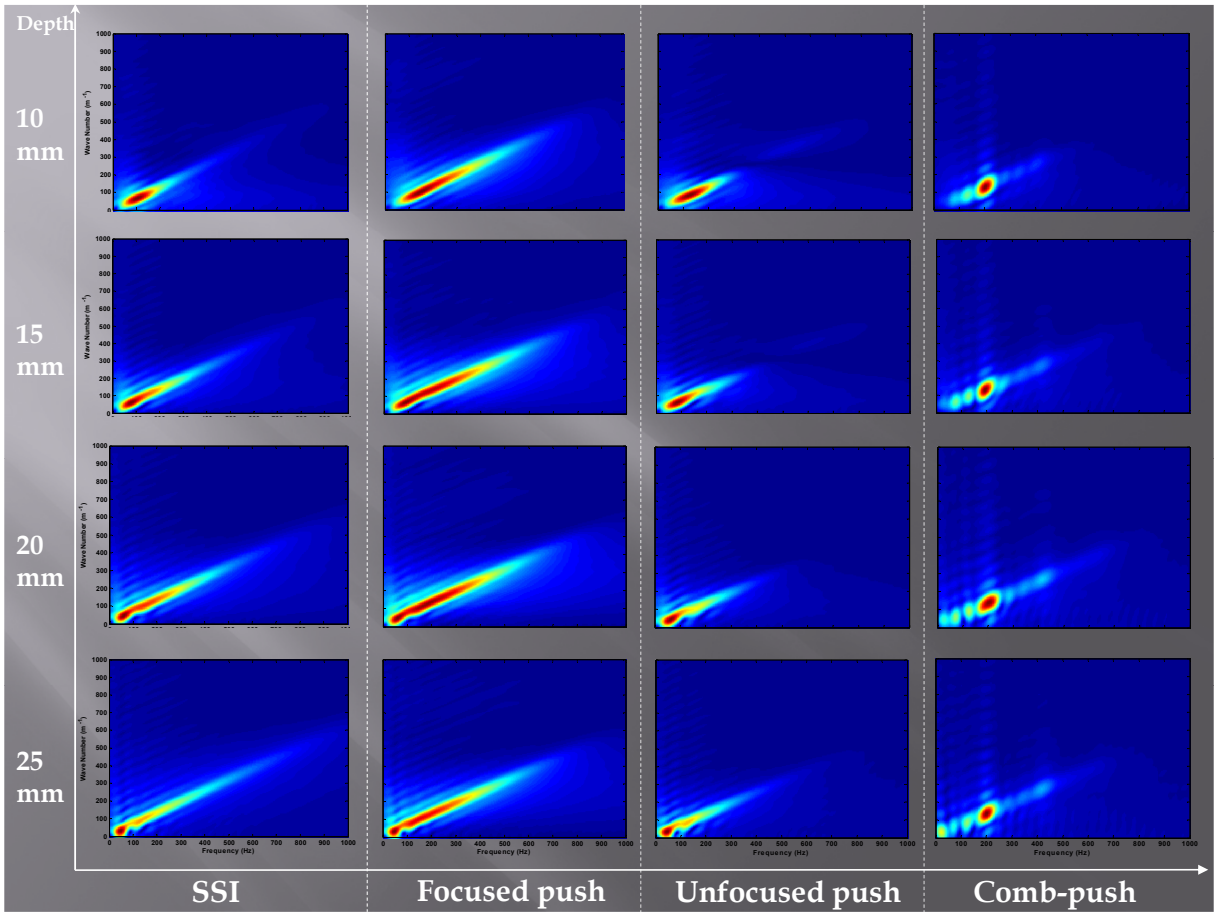
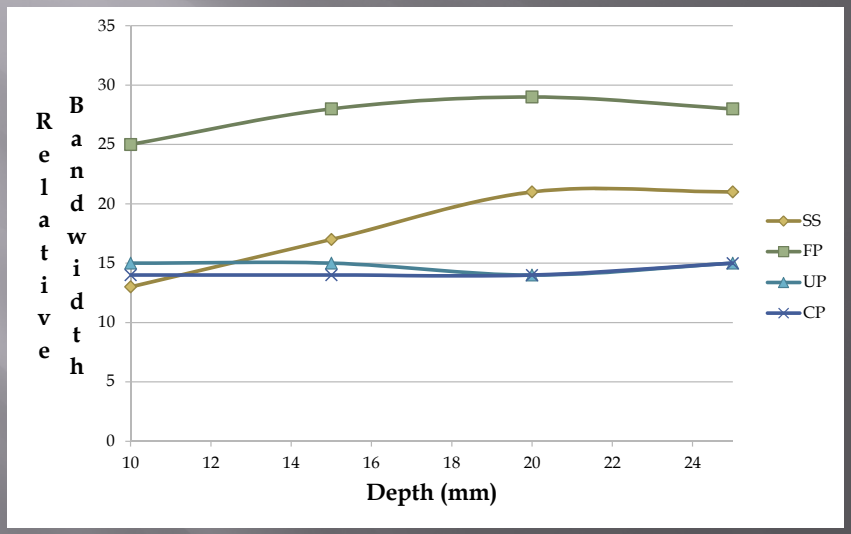


Relative Bandwidth vs Push Beam Type



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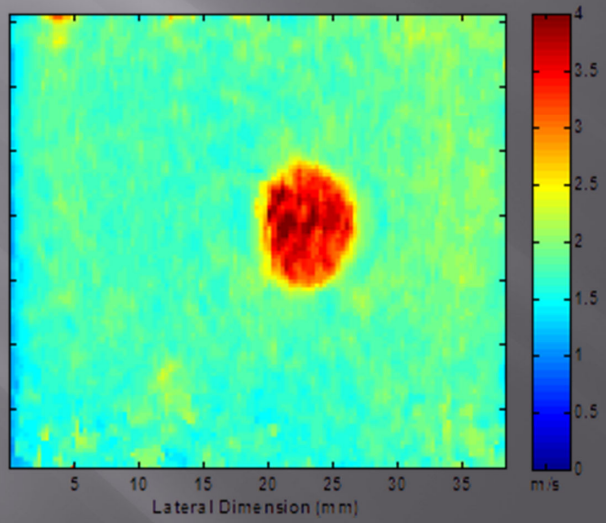
Comb Push Image of Group Velocity at ~200 Hz

Phantom with inclusion (m/s)

Length of acquisition 35ms



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Summary

- Broadest bandwidth is produced by Focused Beam
- Deepest Depth also by Focused Beam
- Deepest Depth of field is by Unfocused Beam
- Super Sonic Beams better deeper
- Comb push has high degree of freedom for various applications.