DEVELOPMENT OF NOVEL 3D ACOUSTIC BOREHOLE INTEGRITY MONITORING SYSTEM

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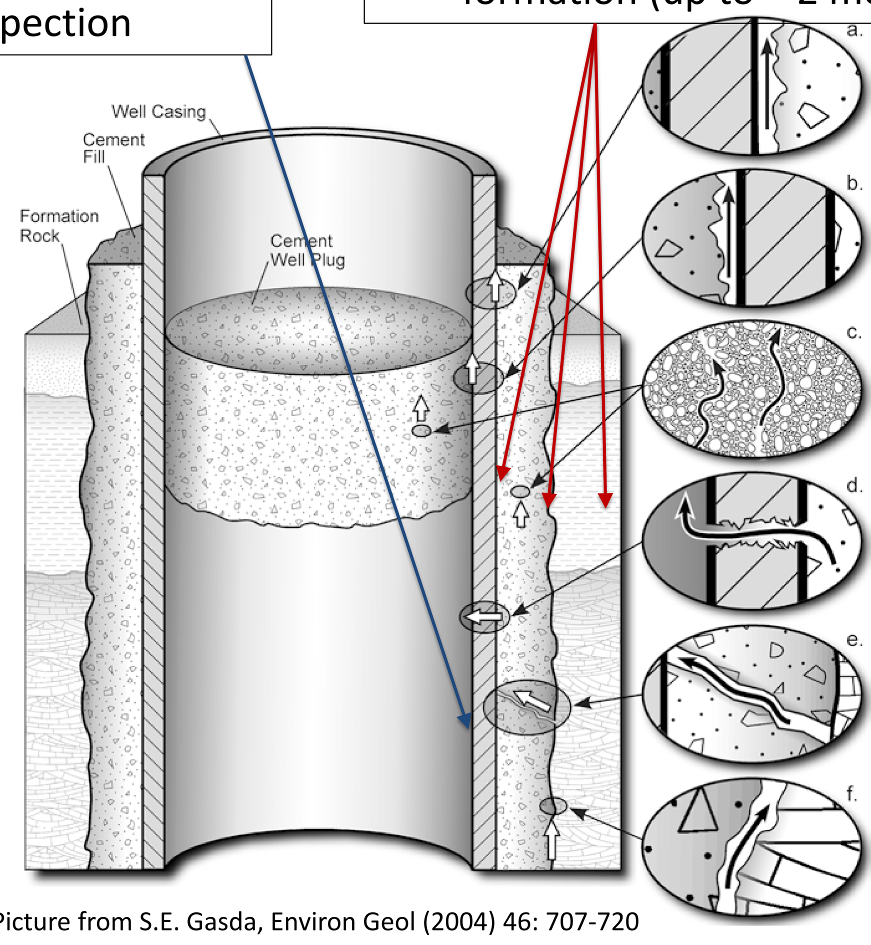
Introduction

- **Primary goal**: fill the existing technology gap between conventional sonic tools and long range sonic imaging tools in providing a robust ability to image the near-borehole environment.

Existing ultrasonic tools work well for casing inspection

We plan to extend applicability to (1) casing-cement interface, (2) cement-formation interface, and (3) out in the formation (up to ~ 2 meters).



* Picture from S.E. Gasda, Environ Geol (2004) 46: 707-720

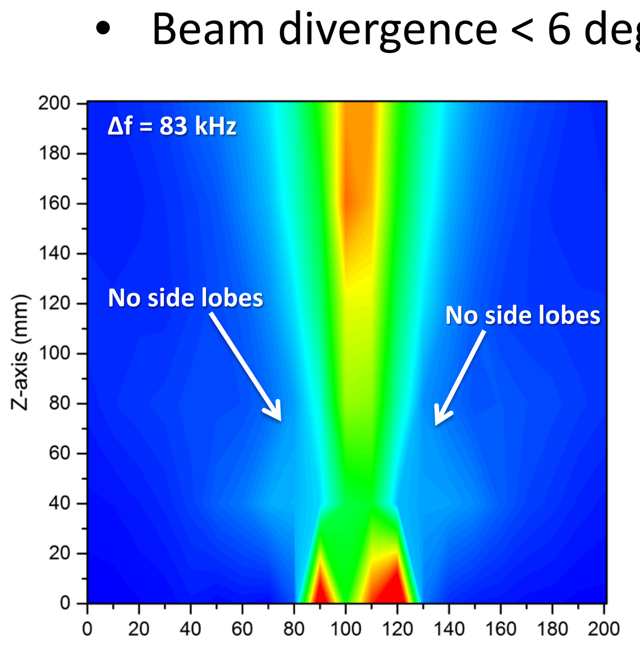
- **Main objective**: develop a *novel acoustic source* that provides directional, low but broad frequency range (10-150 kHz), and highly collimated (< 6 degrees) beam to produce 3D acoustic images of the environment outside the borehole, 360 degrees around the borehole axis, in an annular region of a few meters from the center of the borehole in either open or cased holes.

- **Expected outcome**: a laboratory demonstration of our technology through 3D mapping of the cement area consisting of fractures and other defects outside a simulated borehole casing.

Acoustic Source

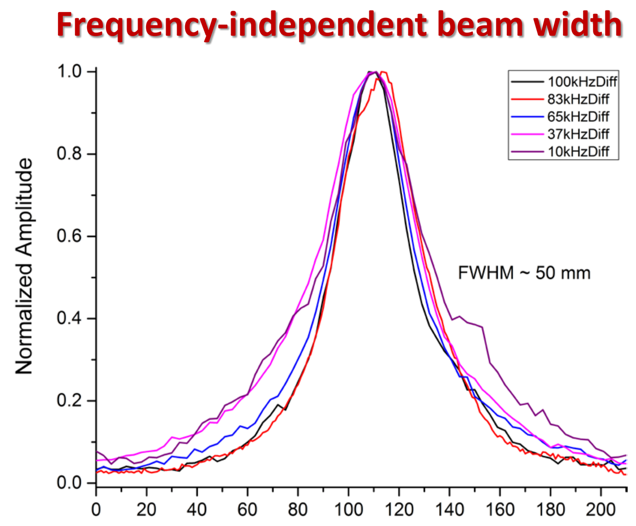
Improved and adapted directional, low frequency, broadband (10-150 kHz), collimated acoustic source based on our patented technology. This includes two different concepts, a parametric source approach and a Bessel beam approach. These approaches provide complementary information and we will explore the feasibility of combining both approaches into a single source.

- **Collimated Acoustic Beam**:
  - Low frequency (10-150 kHz)
  - Large bandwidth (140 kHz)
  - Frequency-independent beam width
  - No side lobes
  - Beam divergence < 6 degrees



83 kHz difference frequency beam profile in H_2O

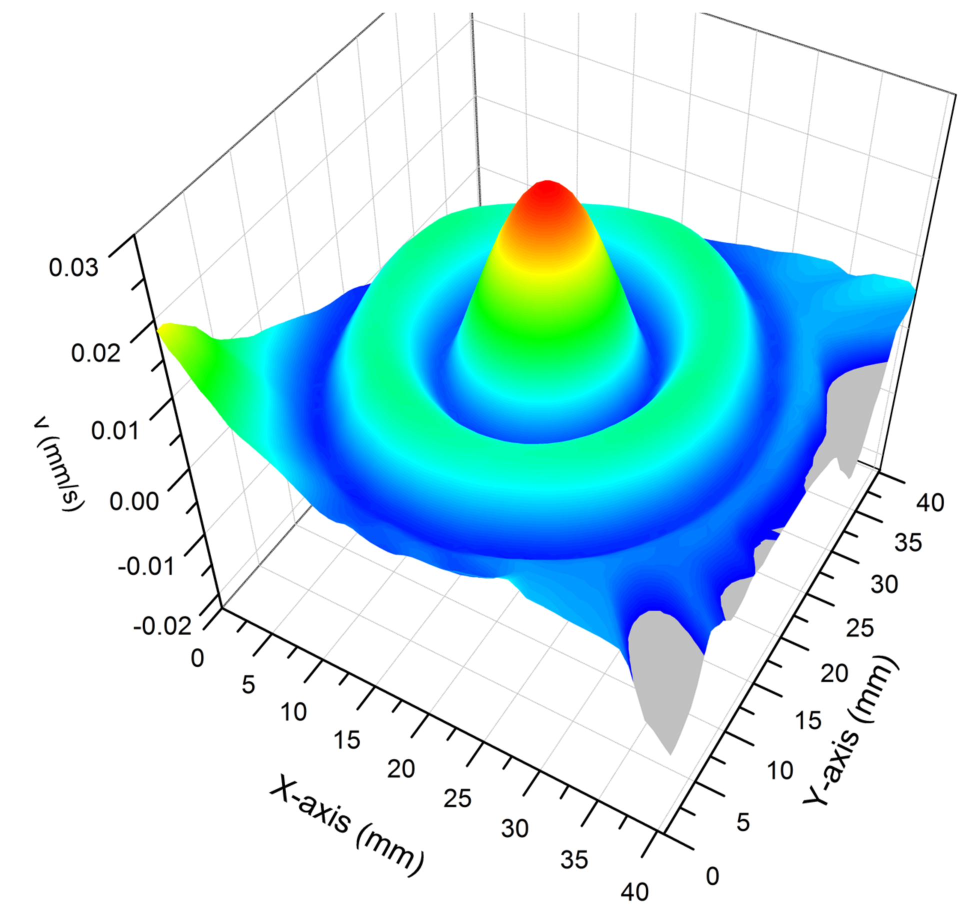
Frequency-independent beam width



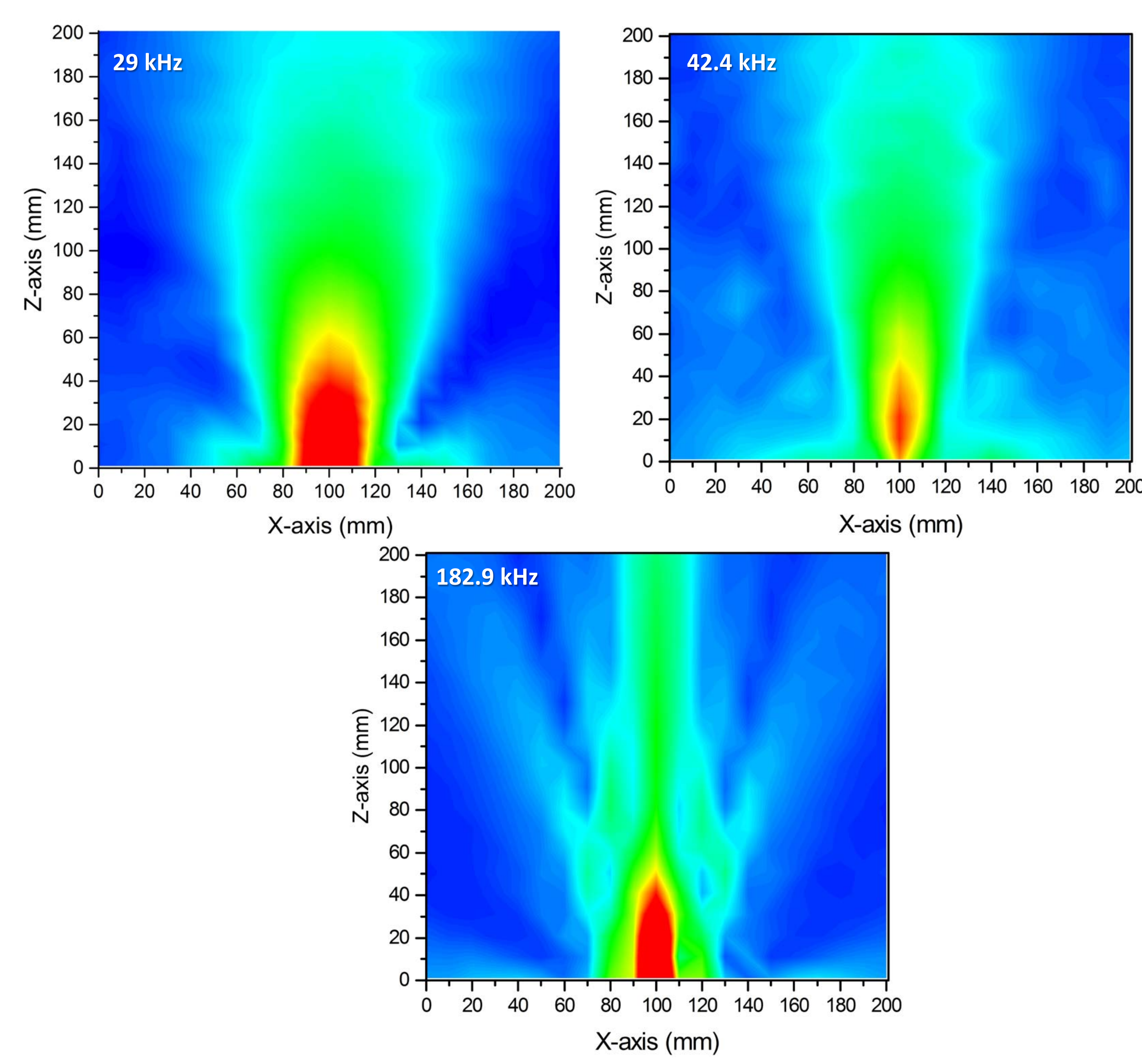
Scans of beam widths at 110 mm from transmitter in H_2O

Acoustic Source Development (cont.)

- **Bessel-type beam**:
  - Low frequency (10-150 kHz)
  - Large bandwidth (140 kHz) – *needs additional improvement for flatter frequency response*
  - Frequency-independent beam width
  - Limited diffraction during propagation
  - Reduced side lobes – *needs additional improvement*

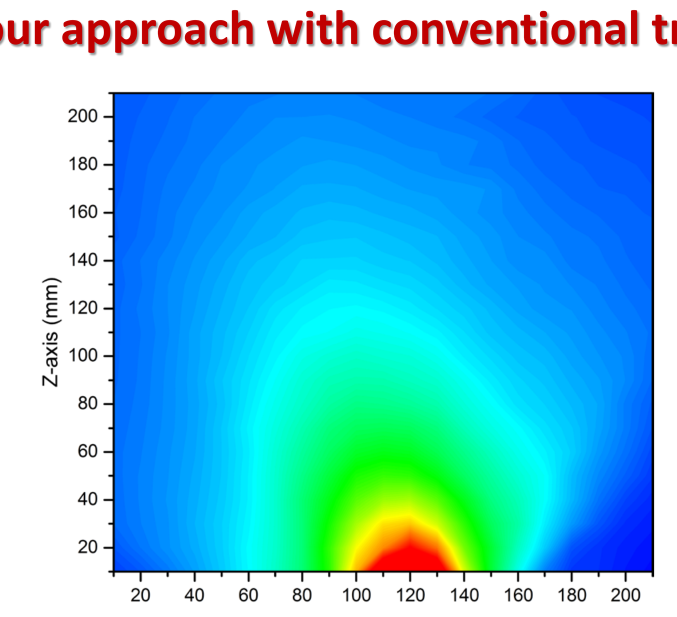


Transducer surface profile of a Bessel-type transducer



Some examples for low-frequency beam profiles in H2O for a Bessel-type transducer

Compare our approach with conventional transducer:



Beam profile in H2O for a conventional transducer , at 100 kHz excitation

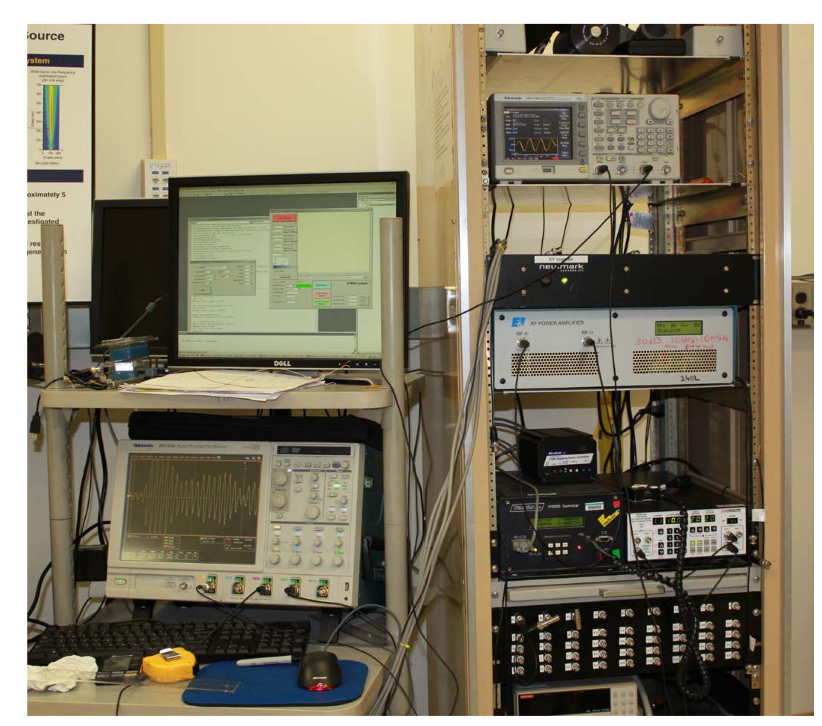
Used a particular-case Bessel beam source that is very simple to build and can be very rugged. The tests show that this Bessel beam has relatively broad bandwidth, similar collimation with the original parametric source, and produces significantly higher intensity sound beam than our original collimated beam source.

Simulated borehole

Designed and built a simulated borehole using metal casing embedded in cement. Various types of defects and fractures will be created in the cement area at various distances from the casing.

Measurement System

Configured a measurement system based on equipment available in our laboratory. This will allow a host of measurements, such as reflection seismology, guided wave propagation in the casing, and other acoustic propagation methods to provide a complete 3D measurement capability in 360 azimuthal direction.



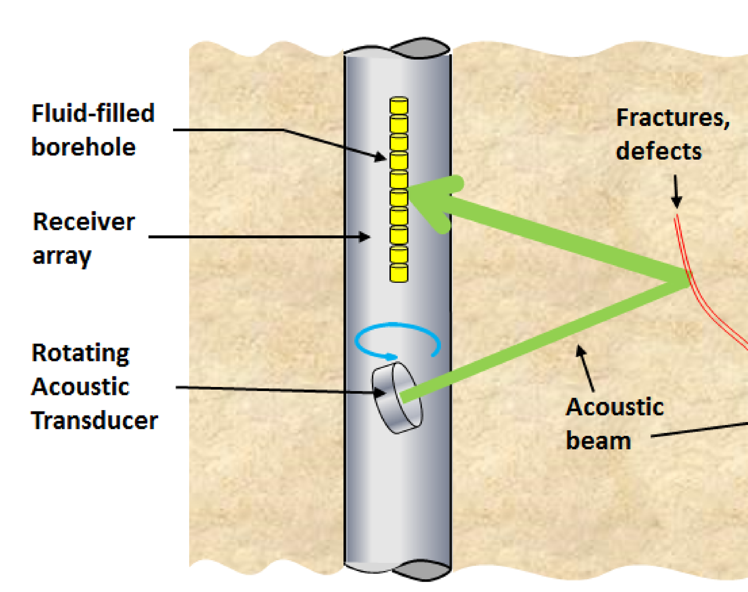
Near-term plans

- **Demonstration of proof of concept in laboratory**

Conduct comprehensive measurements and analyze the data to evaluate its full capability and identify any limitations of the technology. This will allow us to provide recommendations for enhancements and refinements of the proposed technology.

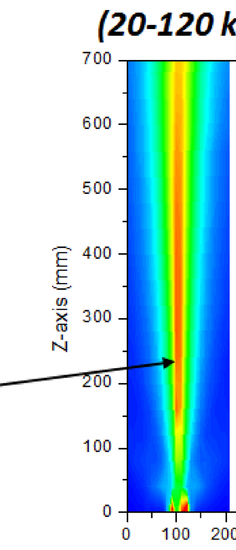
Long-term plans

Develop a commercially deployable technology for well integrity monitoring, based on our novel acoustic source and novel image reconstruction, in collaboration with ORNL (Oak Ridge National Lab), NETL (National Energy Technology Lab) and SNL (Sandia National Lab).



360 degree imaging

Wide band, low frequency Collimated beam (20-120 kHz)



No side-lobes