Time-domain HIFU field measurements by ruggedized hydrophone and reciprocity techniques

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INTRODUCTION - The growing use of high intensity focused ultrasound (HIFU) for therapy has led to a need to characterize HIFU-transducer fields. Acoustic fields do not scale linearly with intensity; nonlinearities appear at therapeutic intensities and contribute to the therapeutic effect. Therefore, measuring the fields at the intensities of the intended applications is critically important. Common thin-film hydrophones can be damaged at high intensities. Recently, Onda Corp. (Sunnyvale CA USA) has introduced model HNA-0400 ruggedized needle hydrophone. Evaluations of this hydrophone have been limited to manufacturer whitepapers. Here we compare the time-domain field characterization ability of the HNA-0400 hydrophone to the reciprocity technique (based on the Helmholtz-Rayleigh acoustic reciprocity theorem).

METHODS - The acoustic field was produced by a Sonic Concepts (Bothell WA USA) annular-array, 5-element, spherical-cap, PZT therapy transducer having a 35-mm focal length, 33-mm aperture, and 14-mm diameter central hole. A single element was excited with a 2-cycle, 5.25-MHz excitation pulse to produce a peak acoustic power of approximately 100 W. The therapy transducer was attached to a three-axis, linear-motion, servomotor controller, and the transducer was immersed in a 3-l Pyrex beaker filled with degassed water. The HNA-0400 hydrophone was affixed vertically at the bottom of the beaker. In the reciprocity technique, the hydrophone tip served as a passive reflector. The therapy transducer was connected to the receive channel of a pulser/receiver. The pulser/receiver output was acquired with an 8-bit digitizer with sampling frequencies of 250 MS/s to 1 GS/s. In the hydrophone technique, the hydrophone was connected directly to the digitizer. Scan planes were formed from sets of uniformly spaced, parallel scan lines; scan volumes were formed from sets of uniformly spaced, parallel scan planes. A characteristic (such as peak negative pressure) of each scan line was selected, reducing the volume to a single transverse or axial plane intersecting the acoustic focal region.

RESULTS - The hydrophone method provides considerably more spatial detail than the reciprocity method, revealing the beam's transverse side lobes, which are not visible in the reciprocity images. In addition, it exhibits a signal-to-noise ratio of 39 dB under the conditions studied, compared to the reciprocity signal-to-noise ratio of 36 dB. We also note that field strength can be estimated directly with the hydrophone technique, whereas the reciprocity technique, without supplemental measurements, provides only relative values.

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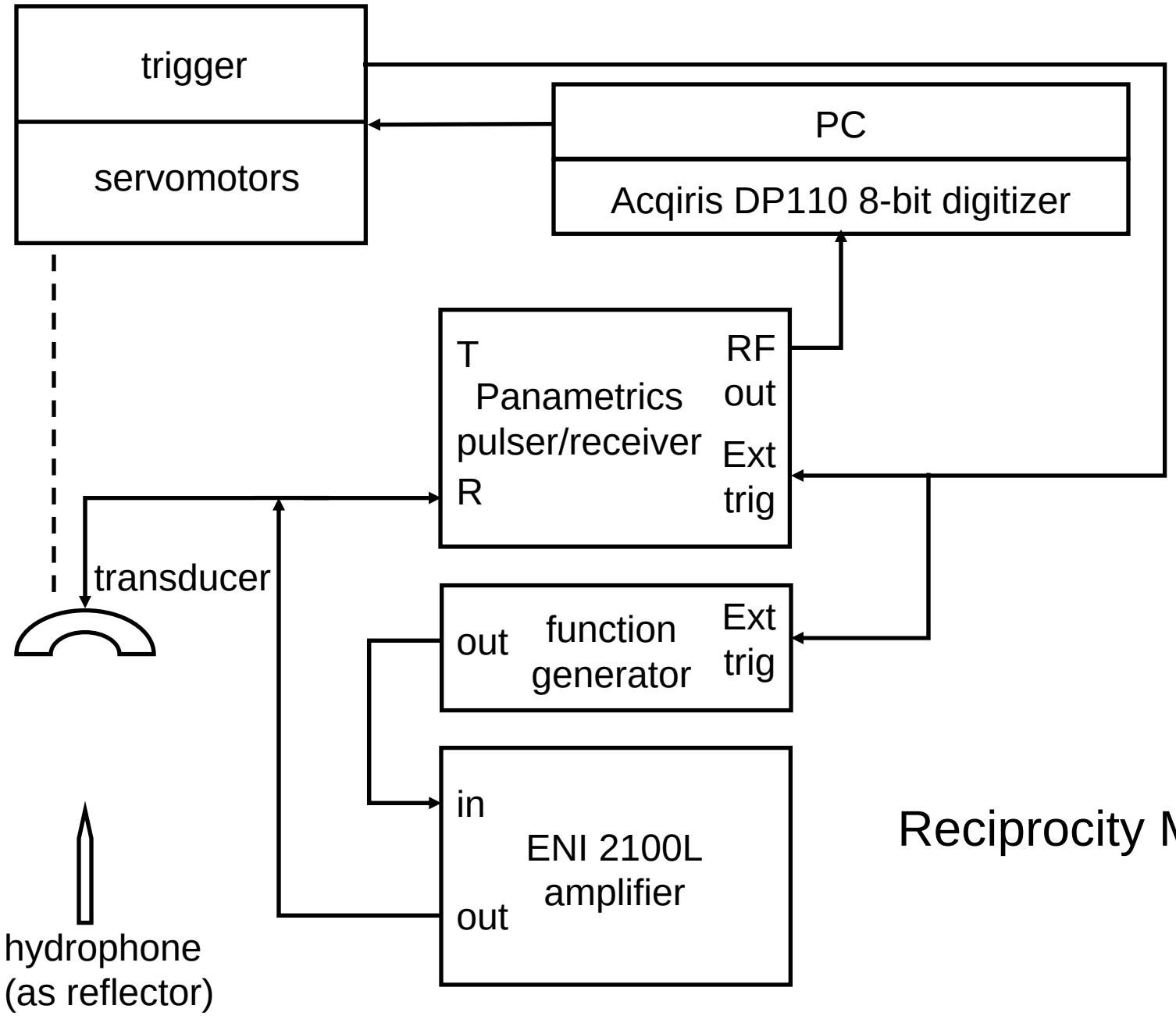
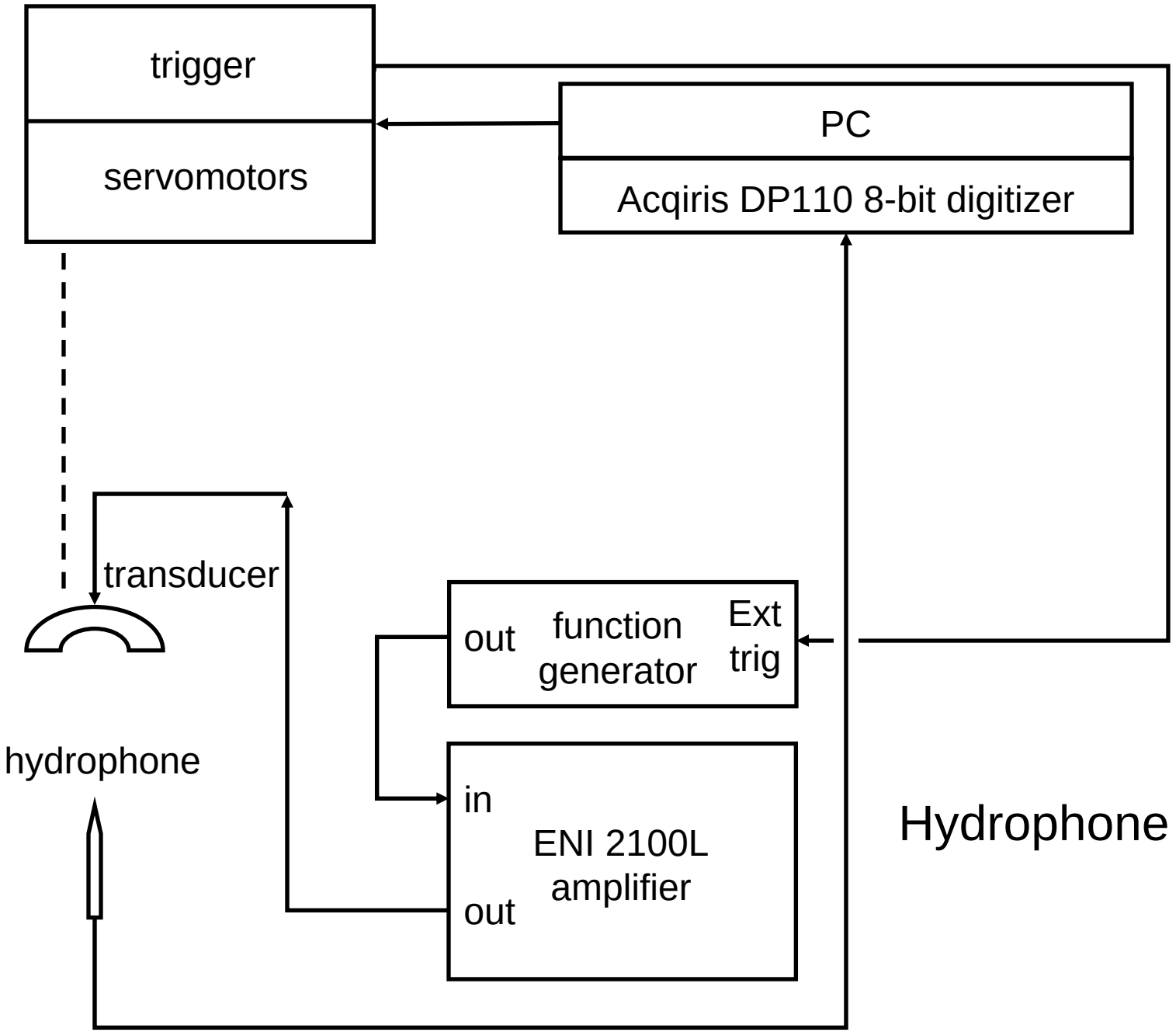


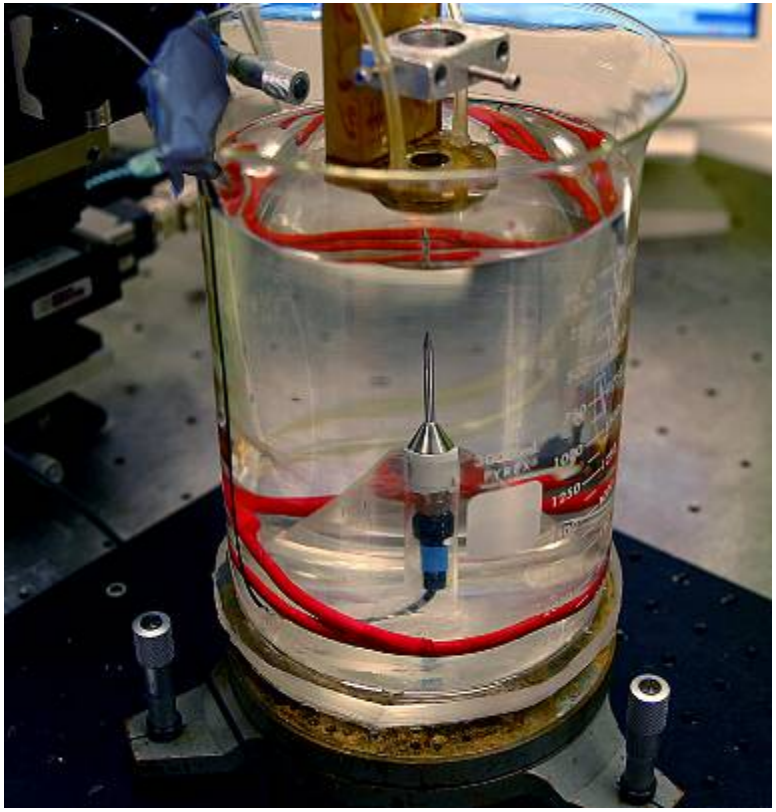
Reciprocity Method



Hydrophone Method

Onda Corp. HNA-0400 Hydrophone

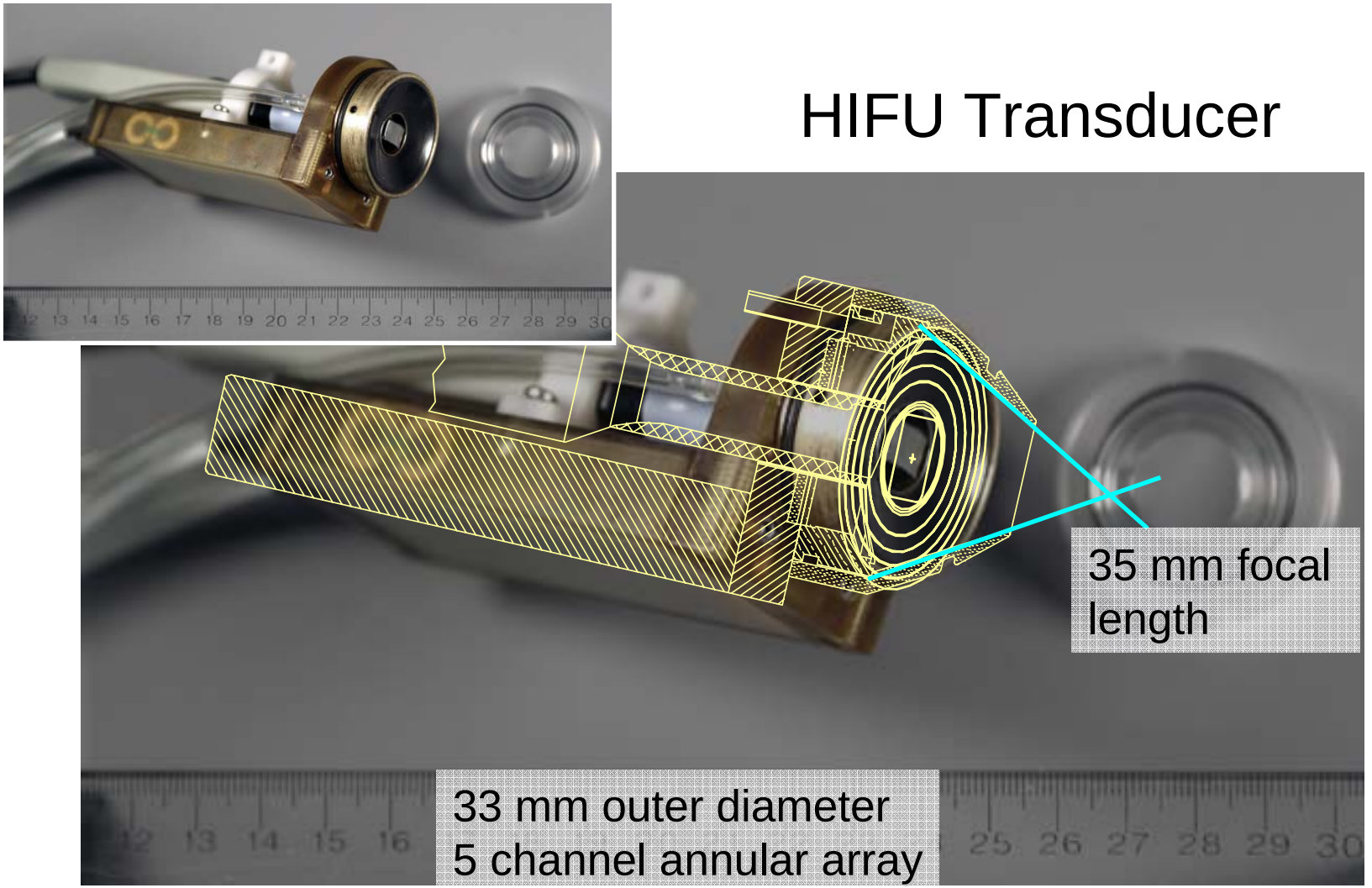
manufacturer specs:
400 μm tip
1 - 10 MHz (full width half power)
-265 dB_{1V} / μPa



36 mm

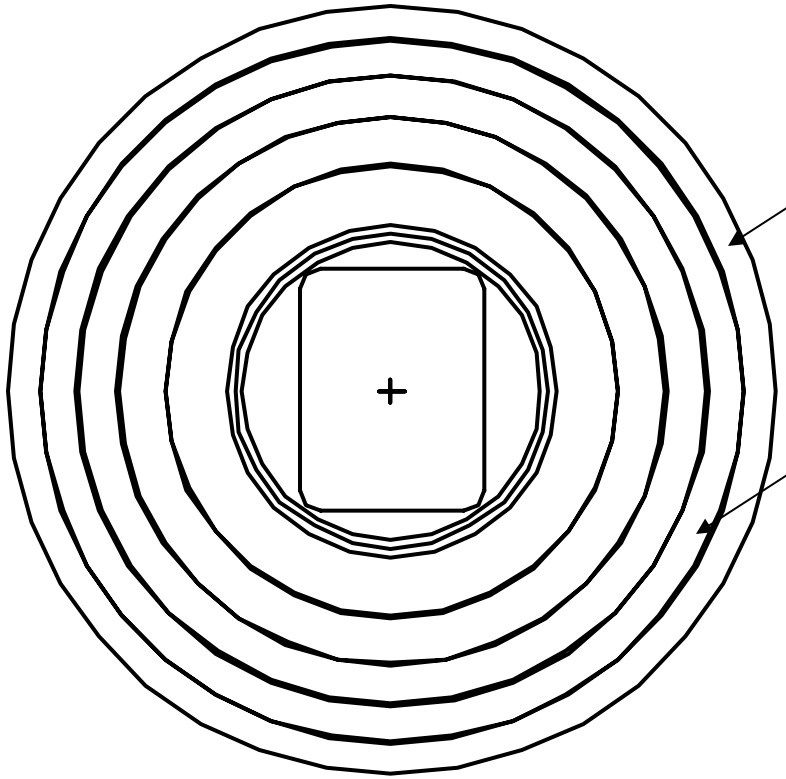
SMA connector

HIFU Transducer



Sonic Concepts, Bothell WA USA

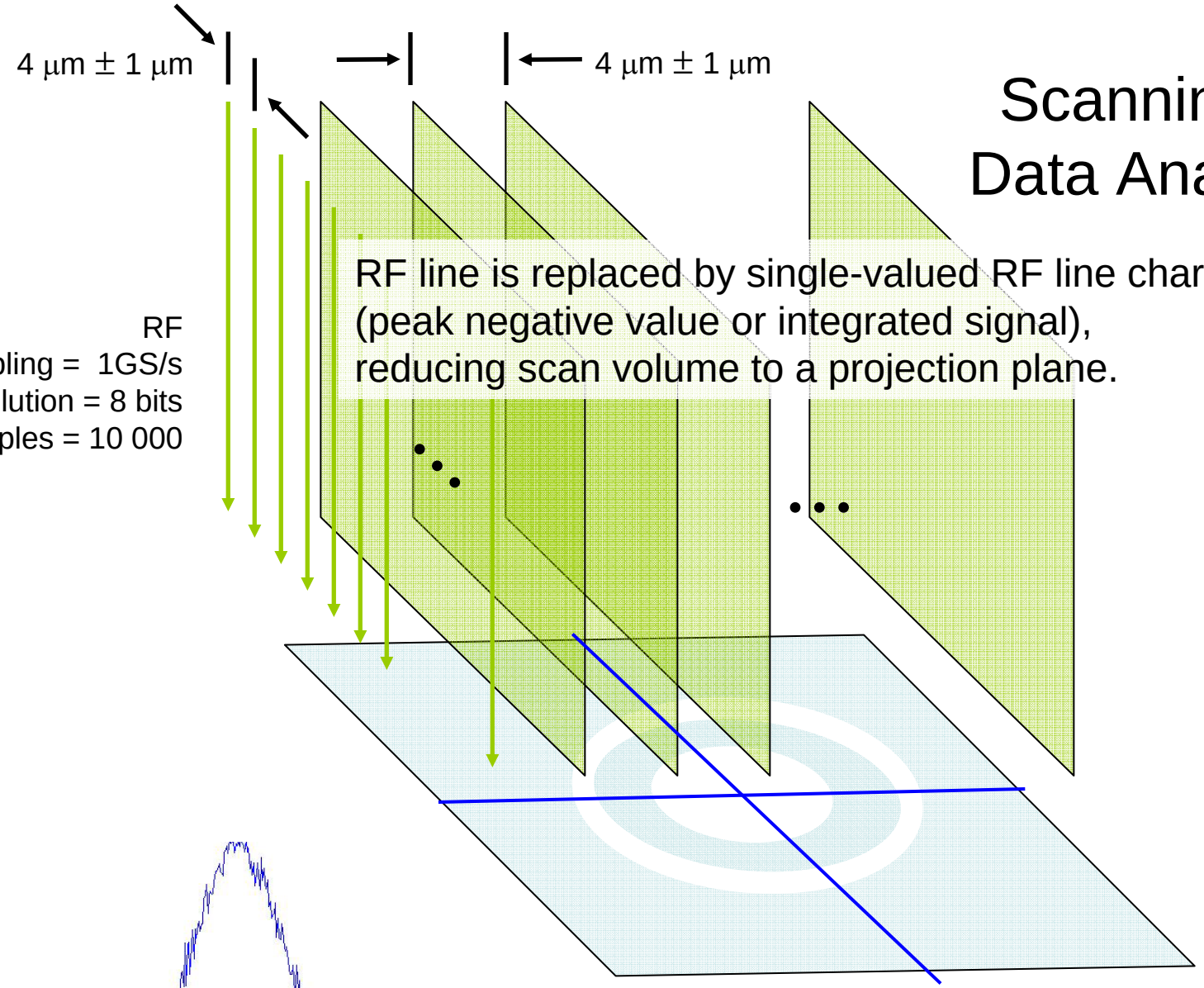
HIFU transducer geometry



annulus 5
outer diameter = 32.9 mm
inner diameter = 30.3 mm

annulus 4
outer diameter = 30.1 mm
inner diameter = 27.1 mm

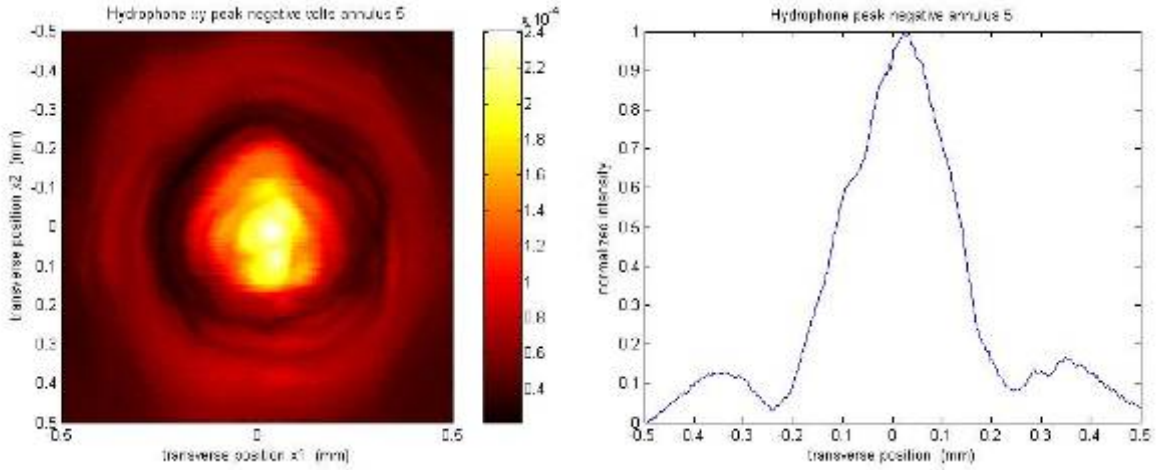
Scanning & Data Analysis



RF
Sampling = 1GS/s
Resolution = 8 bits
Samples = 10 000

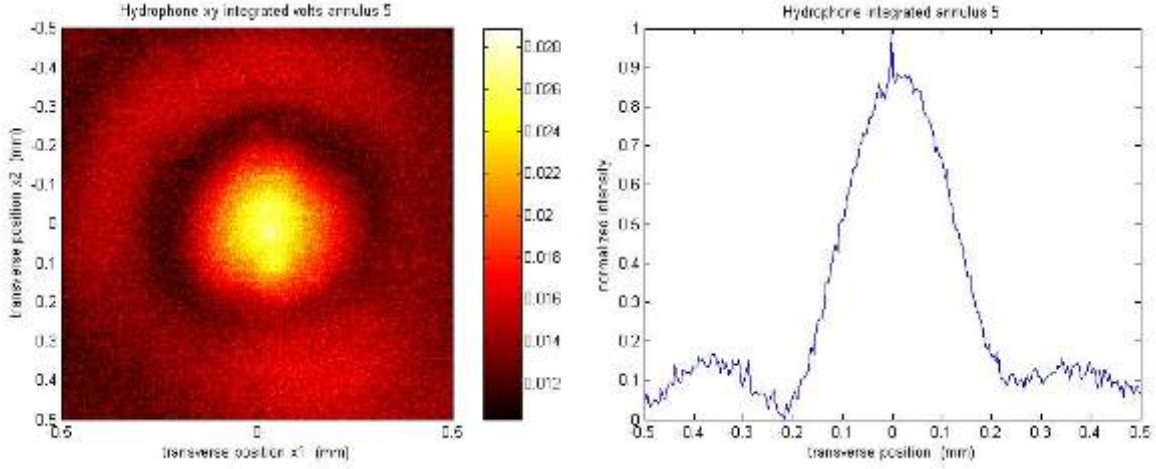
RF line is replaced by single-valued RF line characteristic (peak negative value or integrated signal), reducing scan volume to a projection plane.

Projection plane is sliced (12x at 15° intervals) and slices are averaged.

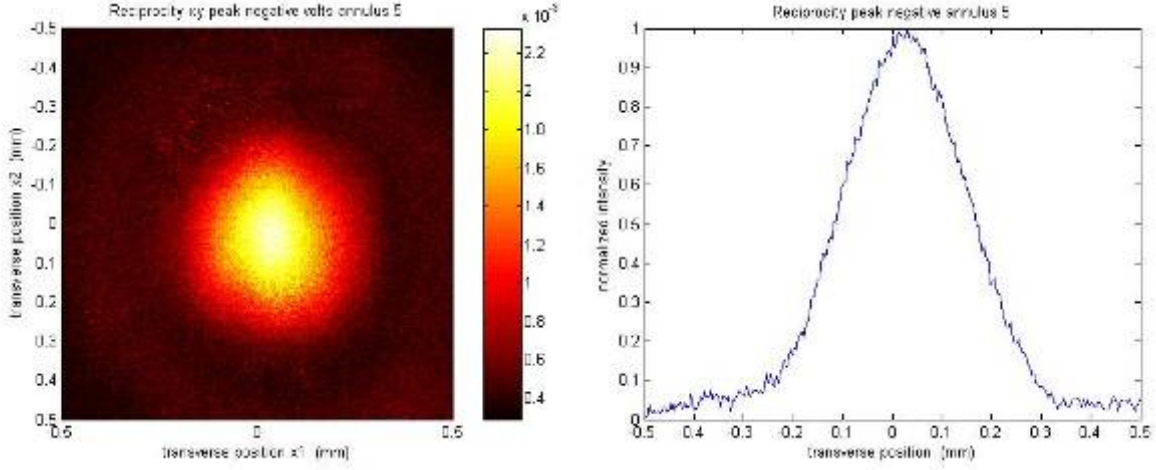


Annulus 5

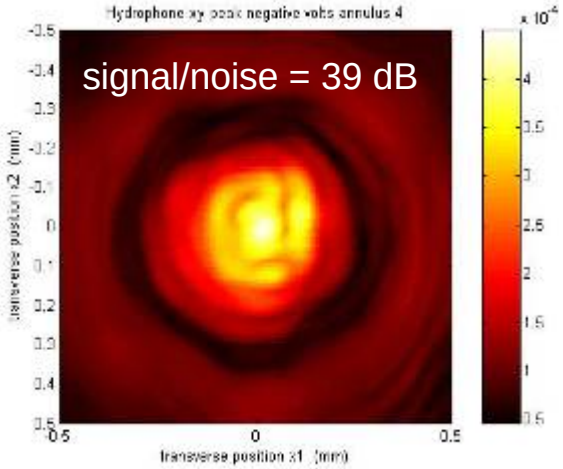
Hydrophone peak negative

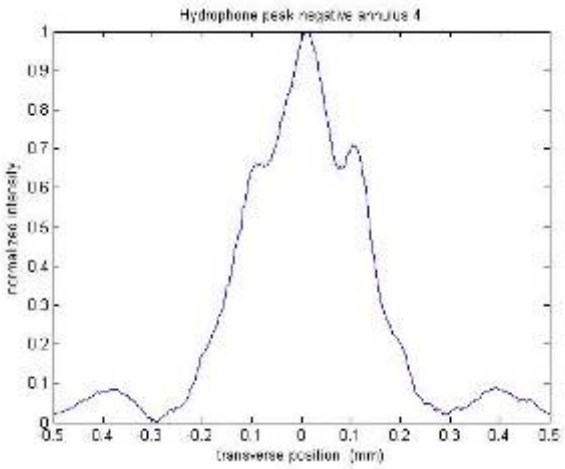


Hydrophone integrated



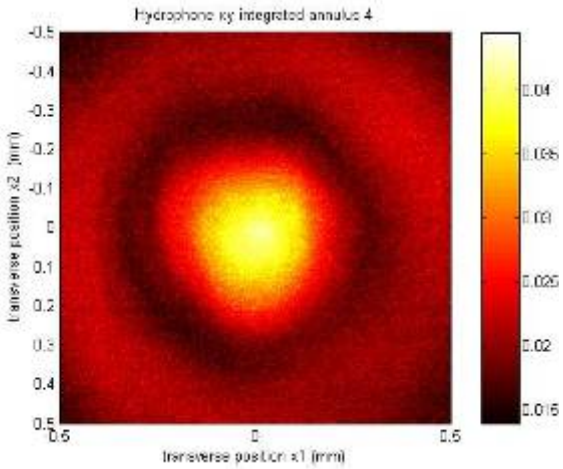
Reciprocity peak negative

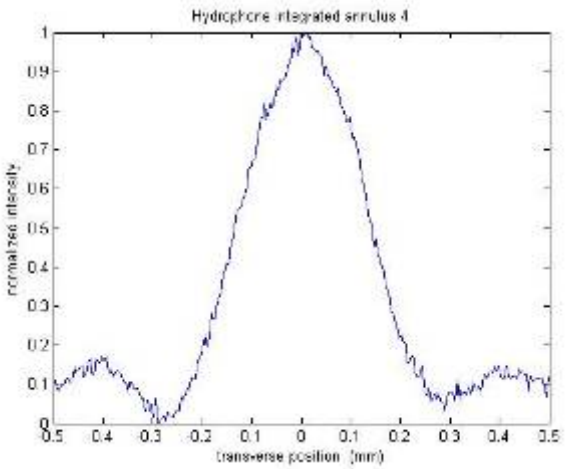




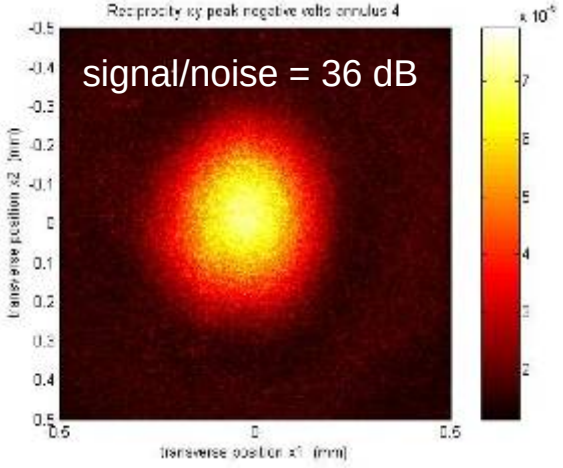
Annulus 4

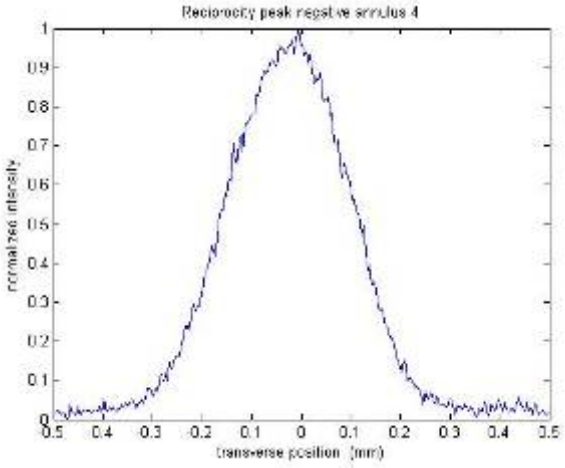
Hydrophone
peak negative





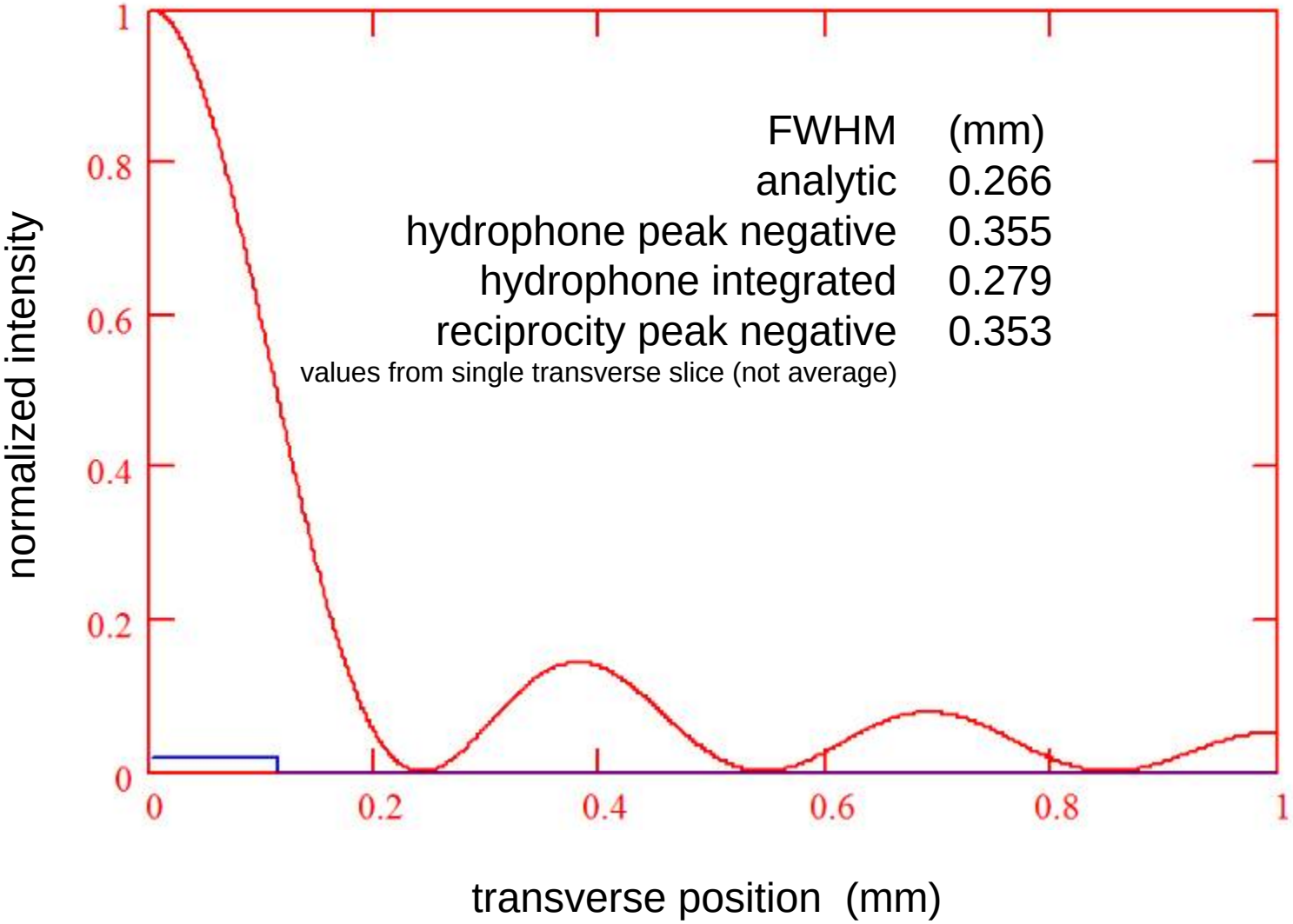
Hydrophone
integrated



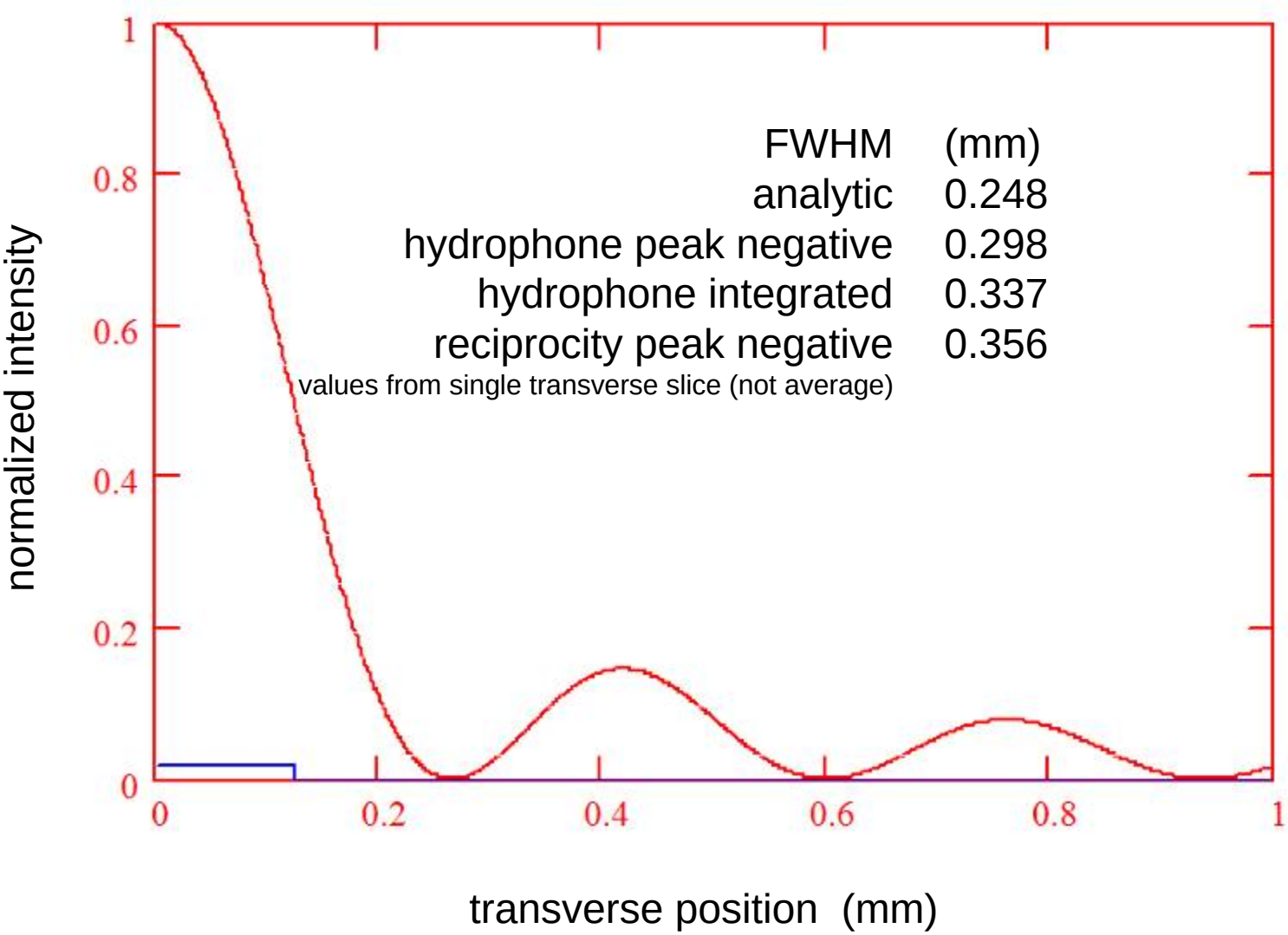


Reciprocity
peak negative

Analytic solution – annulus 5



Analytic solution – annulus 4



FWHM	(mm)
analytic	0.248
hydrophone peak negative	0.298
hydrophone integrated	0.337
reciprocity peak negative	0.356

values from single transverse slice (not average)

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Further Information

http://www.rri-usa.org/biomed.php?r=publications