

# Nick Bottenus

nick.bottenus@duke.edu — (908) 414-0724  
Duke University - Department of Biomedical Engineering  
259 Hudson Hall, Durham, NC 27708

Google Scholar: <https://scholar.google.com/citations?user=j67iR84AAAAAJ&hl=en>

ORCID: <http://orcid.org/0000-0002-4080-2310>

ResearcherID: <http://www.researcherid.com/rid/C-3208-2016>

## Education

Ph.D.	2011-2017	<b>Duke University, Pratt School of Engineering</b> Department of Biomedical Engineering GPA 4.0/4.0 Title: Ultrasound Beamforming Methods for Large Coherent Apertures
B.S.E	2007-2011	<b>Duke University, Pratt School of Engineering</b> Department of Biomedical Engineering Department of Electrical and Computer Engineering GPA 3.99/4.0 - Ranked 1 of 254 students, <i>summa cum laude</i>

## Research Experience

**Visiting Assistant Professor** 2019–Jan 2020  
*University of Colorado at Boulder, Department of Mechanical Engineering, Boulder, CO*

**Research Scientist** 2017–Present  
*Duke University, Department of Biomedical Engineering, Durham, NC*  
Diagnostic ultrasound imaging research for improving image quality through advances in signal and array processing. Clinical translation and evaluation of beamforming methods.

**Chief Science Officer** 2018–Present  
*MicroElastic Ultrasound Systems, Durham, NC*  
Leading algorithm development and pre-clinical research for a new ultrasonic elasticity device. Participating in development and prototyping of the low-cost, portable device based on radiation force excitation.

**Pre-doctoral Fellow** 2011–2017  
*Duke University, Department of Biomedical Engineering, Durham, NC*  
Studied diagnostic ultrasound imaging. Developed and published research on synthetic aperture imaging, spatial coherence, displacement estimation, and image quality. Advised by Gregg Trahey.

## Student Intern/Co-op

2013–2014

*Siemens Healthcare, Mountain View, CA*

Performed commercial ultrasound scanner image optimization and software development. Researched synthetic aperture and spatial coherence imaging methods.

## Undergraduate Independent Study

2010–2011

*Duke University, Department of Biomedical Engineering, Durham, NC*

Implemented an implantable battery charging circuit for use with brain-machine interface device. Advised by Patrick Wolf.

## Awards and Honors

### External

- 2016 IEEE International Ultrasonics Symposium Student Travel Support
- 2015 SPIE Medical Imaging Robert F. Wagner Best Student Paper Award Finalist
- 2015 SPIE Medical Imaging Cum Laude Poster Award
- 2013 NSF Graduate Research Fellowship Program - Honorable Mention

### Internal

- 2017 Duke BME Award for Outstanding Doctoral Dissertation
- 2016 Duke BME PhD Teaching Assistant of the Year Award
- 2015 Duke Imaging Tech Fair “Most Exciting New Imaging Technology” Poster Award
- 2014 Duke Imaging Tech Fair “Most Exciting New Image Processing Tech.” Poster Award
- 2011–2014 Duke Medical Imaging Training Program Pre-doctoral Fellowship
- 2013 Duke BME Teaching Assistant of the Year Award - Honorable Mention
- 2011 James B. Duke Graduate Fellowship (Duke University)
- 2011 Graduation with Departmental Distinction (Duke University)
- 2011 Pratt School of Engineering Senior Class Awards (Duke University)
  - Walter J. Seeley Award for highest academic standing
  - da Vinci Award for highest academic standing
  - Howard G. Clark Award for independent research and presentation

## Grant Activity

**Funding source:** Duke-Coulter Translational Partnership. **Amount:** \$92,530

Role: Research Scientist, 50% time (PI: Trahey)

Project title: Intrapulse Spatial Compounding

Funding period: Sep 2017 – Aug 2018

Description: Clinical translation of beamforming methods from my sole-author paper, “Recovery of the complete data set from focused transmit beams”, for applications in cardiac imaging

**Funding source:** Duke-Coulter Translational Partnership, seed funding. **Amount:** \$30,000

Role: Research Scientist, 64.3% time (PI: Trahey)

Project title: Intrapulse Spatial Compounding

Funding period: Feb 2017 – Aug 2017

Description: Development of beamforming methods from my sole-author paper, “Recovery of the complete data set from focused transmit beams”

## Teaching Experience

### **Instructor**

Semester	Number	Level	Title
2018 Fall	MP 734	Graduate	Non-ionizing Medical Imaging (co-instructor)
2017 Fall	MP 734	Graduate	Non-ionizing Medical Imaging (co-instructor)

### **Guest Lectures**

Semester	Course	Lecture Title
2018 Spring	BME 844	Synthetic Aperture Ultrasound Imaging
2017 Fall	BME 354	Introduction to Microcontrollers

### **Mentoring**

Period	Program	Description
2018	BME	Technical mentor for two first year engineering design teams
2013 – 2014	Pratt Fellows	Trisha Lian - Swept synthetic aperture imaging

### **Graduate Teaching Assistant**

Semester	Number	Level	Title
2015 Fall/2016 Spring (2 semester class)	BME 790	Graduate	Medical Device Hardware and Software Design <i>BME PhD TA of the Year</i>
2015 Spring	BME 844	Graduate	Advanced Ultrasonic Imaging
2014 Fall	BME 464	Undergrad	Medical Instrument Design
2013 Spring	BME 354	Undergrad	Introduction to Medical Instrumentation <i>BME TA of the Year honorable mention</i>
2012 Fall	BME 464	Undergrad	Medical Instrument Design
2012 Spring	BME 153	Undergrad	Biomedical Electronic Measurement I

### **Undergraduate Grader Teaching Assistant**

Semester	Number	Level	Title
2009–2011	ECE 52	Undergrad	Introduction to Digital Systems (5 semesters)
	BME 154	Undergrad	Biological Electronic Measurement II (2 semesters)
	ECE 54	Undergrad	Introduction to Signals and Systems

## Peer-Reviewed Publications

Long, W.; **Bottenus, N.**; Trahey, G.; “Lag-One Coherence as a Metric for Ultrasonic Image

Quality”. *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, vol. 65, no. 10, pp. 1768–1780. Oct. 2018

**Bottenus, N.** “Comparison of virtual source synthetic aperture beamforming with an element-based model”. *Journal of the Acoustical Society of America*, vol. 143, pp. 2801–2812. May 2018

**Bottenus, N.;** Long, W.; Morgan, M; Trahey, G.; “Evaluation of large aperture imaging through the ex vivo human abdominal wall”. *Ultrasound in Medicine and Biology*, vol. 44, no. 3, pp. 687–701. Mar. 2018

**Bottenus, N.;** “Recovery of the complete data set from focused transmit beams” *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 65, no. 1, pp. 30–38. Jan. 2018

Jakovljevic, M.; **Bottenus, N.;** Kuo, L.; Kumar, S.; Dahl, J.; Trahey, G. “Blocked Elements in 1-D and 2-D Arrays Part II: Compensation Methods as Applied to Large Coherent Apertures”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 64, no. 6, pp. 922–936, Jun. 2017

Heyde, B.; **Bottenus, N.;** D’hooge, J.; Trahey, G.; “Evaluation of the transverse oscillation technique for cardiac phased-array imaging: A theoretical study”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 64, no. 2, pp. 320–334, Feb. 2017

**Bottenus, N.;** Long, W.; Zhang, H.K.; Jakovljevic, M.; Bradway, D.P.; Boctor, E.M.; Trahey, G.E.; “Feasibility of Swept Synthetic Aperture Imaging”. *IEEE Transactions on Medical Imaging* vol. 35, no. 7, Jul. 2016

Zhang, H.K.; **Bottenus, N.;** Cheng, A; Guo, X.; Trahey, G.E.; Boctor, E.M.; “Synthetic Tracked Aperture Ultrasound (STRATUS) Imaging: Design, Simulation, and Experimental Evaluation”. *Journal of Medical Imaging* vol. 3, no. 2, Apr. 2016

**Bottenus, N.;** Trahey, G.E.; “Evaluation of the transverse oscillation method using the Cramer-Rao Lower Bound”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 11, pp. 2009–2017, Nov. 2015

Hollender, P.; **Bottenus, N.;** Trahey, G.; “A multi-resolution approach to shear wave image reconstruction.” *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 8, pp.1429–1439, Aug. 2015

**Bottenus, N.;** Ustuner, K.F.; “Acoustic reciprocity of spatial coherence in ultrasound imaging”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 62, no. 5, pp.852–861, May 2015

**Bottenus, N.;** Trahey, G.E.; “Equivalence of time and aperture domain additive noise in ultrasound coherence”. *Journal of the Acoustical Society of America*, vol. 137, pp.132–138, Jan. 2015

**Bottenus, N.;** Byram, B.C.; Dahl, J.J.; Trahey, G.E.; “Synthetic aperture focusing for short-lag spatial coherence imaging”. *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency*

Conference Presentations and Posters (\* indicates no proceedings)

**Bottenus, N.;** “REFoCUS: Ultrasound focusing for the software beamforming age.” *2018 IEEE International Ultrasonics Symposium*, October 2018

**Bottenus, N.;** Long, W.; Long, J.; Trahey, G.; “A real-time lag-one coherence tool for adaptive imaging.” *2018 IEEE International Ultrasonics Symposium*, October 2018

**Bottenus, N.;** Kakkad, V.; Long, W.; Flint, K.; Bradway, D.; Lefevre, M.; Trahey, G.; “Cardiac image quality reflected by spatial and temporal coherence.” *2018 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2018

**Bottenus, N.;** “Synthetic recovery of the complete harmonic data set”. *SPIE Medical Imaging 2018: Ultrasonic Imaging and Tomography*, February 2018

**Bottenus, N.;** “Recovery of the complete data set from ultrasound sequences with arbitrary transmit delays”. *174th Meeting of the Acoustical Society of America*, December 2018

\***Bottenus, N.;** Long, W.; Morgan, M.; Trahey, G.; “Swept synthetic aperture study of large aperture imaging through ex vivo human abdominal wall”. *2017 IEEE International Ultrasonics Symposium*, September 2017

\***Bottenus, N.;** Long, W.; Morgan, M.; Pinton, G.; Trahey, G.; “Simulated and ex vivo large aperture imaging through human abdomen”. *2017 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2017

**Bottenus, N.;** “A method for intrapulse spatial compounding”. *2016 IEEE International Ultrasonics Symposium*, September 2016

**Bottenus, N.;** Pinton, G.; Trahey, G.; “Large coherent apertures: improvements in deep abdominal imaging and fundamental limits imposed by clutter”. *2016 IEEE International Ultrasonics Symposium*, September 2016

\***Bottenus, N.;** Long, W.; Trahey, G.; “Transmit beamforming strategies for Swept Synthetic Aperture imaging”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

**Bottenus, N.;** Long, W.; Bradway, D.; Trahey, G.E.; “Phantom and in vivo demonstration of swept synthetic aperture imaging”. *2015 IEEE International Ultrasonics Symposium*, 21-25 October 2015

**Bottenus, N.;** Trahey, G.E.; Ustuner, K.F.; “Ultrasound coherence imaging using hardware receive beamforming and broad transmit beams”. *Proc. SPIE 9419, Medical Imaging 2015: Ultrasonic Imaging and Tomography*, February 23, 2015 – **Cum Laude Poster Award**

**Bottenus, N.**; Jakovljevic, M.; Boctor, E.M.; Trahey, G.E.; “Implementation of swept synthetic aperture imaging”. *Proc. SPIE 9419, Medical Imaging 2015: Ultrasonic Imaging and Tomography*, February 22, 2015 – **Robert F. Wagner Best Student Paper Award Finalist**

\***Bottenus, N.**; Trahey, G.E.; “Time and aperture domain noise equivalence in coherence imaging”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

**Bottenus, N.**; Dahl, J.J.; Trahey, G.; “Apodization schemes for short-lag spatial coherence imaging”. *2013 IEEE International Ultrasonics Symposium*, pp.1276-1279, 21-25 July 2013

\***Bottenus, N.**; Byram, B.C.; Dahl, J.J.; Trahey, G.E.; “Synthetic-aperture image quality study of short-lag spatial-coherence imaging”. *2013 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2013

**Bottenus, N.**; Byram, B.C.; Trahey, G.E.; “A synthetic aperture study of aperture size in the presence of noise and in vivo clutter”. *Proc. SPIE 8675, Medical Imaging 2013: Ultrasonic Imaging, Tomography, and Therapy*, 86750S, March 29, 2013

**Bottenus, N.**; Hyun, D.; Dahl, J.; Trahey, G.; Byram, B.; “Application of synthetic aperture focusing to short-lag spatial coherence”. *2012 IEEE International Ultrasonics Symposium*, pp.2262-2265, 7-10 Oct. 2012

## Invited Talks

“REFoCUS: No-compromise focusing for the software beamforming age”. *Siemens Healthineers*, Mountain View, California. May 4, 2017

“REFoCUS: Ultrasound beamforming for the undecided and unknown”. *Stanford University*, Stanford, California. May 2, 2017

“Ultrasound beamforming methods for large coherent apertures”. *Vanderbilt University*, Nashville, Tennessee. April 28 2017.

“Applied synthetic aperture methods: summed receive signal coherence and swept synthetic aperture imaging”. *Technical University of Denmark*, Lyngby, Denmark. June 11 2015.

## Other Presentations

**Bottenus, N.**; Long, W.; Bradway, D.; Trahey, G.E.; “Phantom and in vivo demonstration of swept synthetic aperture imaging”. *Duke Imaging Technology Fair 2015*, October 2015 – **“Most exciting new imaging technology” poster award**

**Bottenus, N.**; “Large swept synthetic aperture imaging”. *Artimino Conference on Medical Ultrasound 2015*, June 2015

**Bottenus, N.**; Jakovljevic, M; Kuo, L.; Kumar, S; Boctor, E.M; Trahey, G.E.; “Swept Syn-

thetic Aperture Ultrasound Imaging”. *Duke Imaging Technology Fair 2014*, October 2014 – “**Most exciting new image processing technology**” poster award

**Bottenus, N.**; Hyun, D.; Dahl, J.; Trahey, G.; Byram, B.; “Application of synthetic aperture focusing to short-lag spatial coherence”. *2012 NIBIB Training Grantees Meeting*, June 2012

### Conference Presentations By Co-authors (\* indicates no proceedings)

Ali, R.; Dahl, J.; **Bottenus, N.**; “Regularized inversion method for frequency-domain recovery of the full synthetic aperture dataset from focused transmissions.” *2018 IEEE International Ultrasonics Symposium*, October 2018.

Long, J.; Long, W.; **Bottenus, N.**; Pinton, G.; Trahey, G.; “Implications of lag-one coherence on real-time adaptive frequency selection.” *2018 IEEE International Ultrasonics Symposium*, October 2018.

Flint, K.; **Bottenus, N.**; Long, W.; Bradway, D.; McNally, P.; Ellestad, S.; Trahey, G.; “Implementation and clinical evaluation of a fetal ALARA ultrasound system.” *2018 IEEE International Ultrasonics Symposium*, October 2018.

Caenen, A.; Hollender, P.; **Bottenus, N.**; Segers, P.; Trahey, G.; Palmeri, M.; “Investigating the degree of shear wave speed anisotropy as a function of studied ventricular zone.” *2018 IEEE International Ultrasonics Symposium*, October 2018.

\*Long, W.; **Bottenus, N.**; Nelson, R.; Trahey, G.; “Characterization of B-mode image quality using lag-one coherence (LOC)”. *2018 IEEE International Ultrasonics Symposium*, October 2018.

Dahl, J.; Hyun, D.; Li, Y.; Jakovljevic, M.; Bell, M.; Long, W.; **Bottenus, N.**; Kakkad, V.; Trahey, G.; “Coherence Beamforming and Its Applications to the Difficult-To-Image Patient”. *2017 IEEE International Ultrasonics Symposium*, September 2017.

Hollender, P.; **Bottenus, N.**; Bradway, D.; Trahey, G.; “Single Track Location Comb-Push Ultrasound Shear Elastography (STL-CUSE)”. *2017 IEEE International Ultrasonics Symposium*, September 2017.

\*Trahey, G.; **Bottenus, N.**; Pinton, G.; “Beamforming methods for large aperture imaging”. *17th Meeting of the Acoustical Society of America*, June 2017

\*Morgan, M.; **Bottenus, N.**; Trahey, G.; “Beamforming challenges in swept synthetic aperture imaging”. *2017 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2017

Heyde, B.; **Bottenus, N.**; Trahey, G.; D’hooge, J.; “Impact of Beamforming Strategies and Regularisation on Ultrasound Displacement Estimation Using RF-Based Image Registration”. *2017 IEEE International Symposium on Biomedical Imaging*, April 2017

\*Heyde, B.; **Bottenus, N.**; D’hooge, J.; Trahey, G.; “Impact of beamforming on deformation

imaging with phased arrays: a comparison of transverse oscillations and traditional focused beamforming”. *2016 IEEE International Ultrasonics Symposium*, September 2016

Ramirez Jr., J; **Bottenus, N.**; Trahey, G; Krolik, J.L; “Synthetic Aperture Imaging with Thinned Linear Sensor Arrays for Medical Ultrasound”. *IEEE Sensor Array and Multichannel Signal Processing Workshop*, July 2016

\*Heyde, B.; **Bottenus, N.**; D’hooge, J; Trahey, G.; “Benefits and limitations of the transverse oscillation technique for phased-array imaging”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

\*Jakovljevic, M.; **Bottenus, N.**; Kuo, L; Kumar, S; Dahl, J; Trahey, G; “Detection of and Compensation for Blocked Elements using Large Coherent Apertures: Ex Vivo Studies”. *2016 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2016

\*Zhang, H.K.; **Bottenus, N.**; Cheng, A.; Trahey, G.E.; Boctor, E.M.; “Synthetic-tracked aperture ultrasound imaging using robotic guidance”. *2015 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2015

\*Jakovljevic, M.; **Bottenus, N.**; Trahey, G.E.; “Ex-vivo measurements of ultrasonic wavefront distortion using large synthetic apertures across ribs and abdomen”. *2015 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2015

\*Li, Y.L.; Cook, M.; **Bottenus, N.**; Dahl, J.J.; “Coherent flow imaging: detecting slow flow signal with backscatter spatial coherence”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

\*Trahey, G.E.; Jakovljevic, M; **Bottenus, N.**; Boctor, E. “Swept Array Synthetic Aperture Imaging (SASAI)”. *2014 Ultrasonic Imaging and Tissue Characterization Symposium*, June 2014

Hollender, P.J; **Bottenus, N.**; Trahey, G.E.; “Robust Shear Wave Velocity Reconstruction From Multi-Resolution Time-of-Flight Estimates”. *Twelfth International Tissue Elasticity Conference*, October 2013

Dahl, J.J.; **Bottenus, N.**; Lediju Bell, M.A.; Cook, M.J.; “Coherent flow imaging: A power Doppler imaging technique based on backscatter spatial coherence,”. *2013 IEEE International Ultrasonics Symposium*, pp.639-642, 21-25 July 2013

## Patents

Peter Hollender, **Nicholas Bottenus**. “Methods, Systems and Computer Program Products for Multi-resolution Imaging and Analysis,” US patent No. (not yet provided)

Kutay F. Ustuner, **Nicholas Bottenus**, “Coherence Ultrasound Imaging with Broad Transmit Beams,” US patent No. 10,064,602.



Emad M. Boctor, Gregg Trahey, **Nicholas Bottenus**, Haichong Zhang. “Synthetic Aperture Ultrasound System,” US patent No. (not yet provided)

## Patent applications

Gregg Trahey, Willie Long, Peter Hollender, David Bradway, Vaibhav Kakkad, **Nicholas Bottenus**. “Methods, Systems, and Computer Program Products for Triggering Ultrasound Data Acquisition,” in review, Application 16/113,497

**Nicholas Bottenus**, Gregg Trahey. “Systems and Methods for Intra-Beam Compounding for Ultrasound Imaging,” in review, PCT/US2018/040015.

## Professional Service

Reviewer for:

- IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control
- IEEE Transactions on Medical Imaging
- Ultrasonic Imaging
- Nature Communications
- Science Advances

2017, 2018	Session chair for Ultrasonic Imaging and Tissue Characterization Symposium
2009–2011	BME curriculum committee undergraduate student representative

## Outreach

2018	Duke TIP Scholar Weekend teaching assistant - Biomedical Engineering
2016	Jordan High School Science Fair judge

## Professional Memberships

2017 – 2018	ASA
2017 – 2018	AIUM
2014 – 2018	IEEE (Ultrasonics, Ferroelectrics and Frequency Control)