

TYLER S. RALSTON, PH.D.

CONTACT

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CURRENT EMPLOYMENT

Butterfly Network, Inc.
Co-founder and Team Lead of Signal Processing and Imaging Group

Guilford, CT
12/11 –present



- **Organizational leadership:** Direct fast-paced, high-performing teams
 - Employ a distributed daily journal for high-bandwidth communication and record keeping, thus increasing IP discovery and simplifying logistics.
 - Drive cross-functional alignment across technical and commercial teams to identify objectives, and achieve key results.
- **\$100M fund raising:** Led technical coordination to build proof-of-concept prototypes, implemented risk-reduction demonstrations for real-time visualizations in 3D, IP portfolio management, hired top-tier talent for core technological areas, advised CEO on business plan and market opportunities, facilitated integration with cloud and deep learning.
 - **National Press:** MIT Tech Review, Wired, Forbes, World Economic Forum, Fox News, Tech Republic.
 - **4Catalyzer Fellow:** (09/2015) Granted an honorary title and honorarium in recognition of extraordinary merits within Butterfly Network and 4Catalyzer. The 1st and only Fellow commendation to present date.
- **Real-time transmission ultrasound system:** (8852103, 9155521, 9033884, 9028412, 9022936, 20150247921, 20140243614, 20140180093, 20140180113, 20140180094, 20140180100, 20140180112, 20140180088, 20140180099, 20140180092, 20140180095)
- **3D ultrasound system on a semiconductor:** MEMs (20140264660, 20140219062), digital and analog ASIC and FPGA for sequencing and processing (20150301165, 20150297193, 20150080724, 20140288428), end-to-end signal processing chain (20140180096, 20140180097)
- **Image-guided high-intensity focused ultrasound:** (20140180176, 20140180177)
- **Coordination with Key Opinion Leaders, Key Technical Leaders and Scientific Advisory Board:** Arranged the *Next-generation of Medical Imaging Workshop at Carnegie Mellon University* with top-tier researchers in ultrasound, magnetic resonance, optical, x-ray and computed tomography imaging.
- **Ultrasound acquisitions and reconstructions:** Created and validated sequences for 2-D and 3-D imaging in various modes (B-mode, M-mode, spectral and PW- Doppler, coded-aperture, coded-waveform, harmonic imaging, and more)
- **Ultrasound signal processing:** MATLAB, Python, C++, and GPU: plenoptic operators, Fourier-domain and time-domain beamformers, calibrators, signal conditioners, filters, correlators, interpolators, bounded optimizers, and more.
- **3D visualization tools:** Tuvok, WebGL, Mayavi2: Real-time voxel-based rendering, 2D transfer functions, iso-surfaces, remap functions, auto-leveling, histograms, denoising, segmentations, and integration into holographic and stereo displays.

PREVIOUS APPOINTMENTS

Lawrence Livermore National Laboratory
Technical Staff/PI in Adaptive Optics & Signal/Image Processing Group

Livermore, CA
11/10 –12/11



- **3D gamma ray imaging:** Constructed a gamma ray imaging toolbox with metrics for automated 2D/3D shape classification using shape descriptors, e.g. orientation (PCA), shape bases (spherical harmonics), shape histograms, concavity, crinkliness, spherical extent functions, slice-oriented feature detectors, wavelets, and more.
- **Radioisotope nuclide detection:** Developed the radionuclide analysis toolkit, and a networked multi-sensor detector. Code and algorithm development included, Bayesian network propagation and evaluation, branch-and-bound optimization, high-energy spectral detector resampling methods, and system I/O dev.
- **3D x-ray CT micro-laminography:** Image processing in computed tomography, denoising for increased SNR using wavelets, digital filtering, and contrast equalization.



Massachusetts Institute of Technology Lincoln Laboratory
Technical Staff/Program lead/PI in Aerospace Sensor Technology Group

Boston, MA
4/07 –11/10




- **Multi-sensor Fusion Program**^{18,24,25,28,30} (Lead - CLASSIFIED)
 - Maintained DOD Air Force sponsorship and relationship with regular detailed reports and presentations.
 - Inverse Synthetic Aperture Radar and electro-optical backprojection for 3D incoherent composite imaging.
 - 3D Interferometric ISAR image processing algorithms for reconstructions from multiple baselines.
 - Research and development of computer vision algorithms for model building from 2D and 3D imagery.
 - **Real-time through-wall radar imager**^{29,31} (Co-Principal Investigator)
 - Successfully won award for proposal and presentation to Advanced Concepts Committee.
 - Built signal chain architecture and real-time signal processing subsystem (C++ & GPU).
 - Coordinated the designs for antenna, analog circuit, and mechanical structure.
 - Received National Press: CNN, BBC, FOX, ABC, NBC, MIT, Slate, Wired, Wall Street Journal, Slashdot...
 - **Next-generation Radar Operating System Architecture (ROSA II) for all DOD imaging radars**
 - Engineered pulse integration routine for interpolating equally spaced angles from equally spaced times whereby one can adjust the coherent integration by adjusting the resampling window size.
 - Designed modules for the second-generation real-time ROSA II which accounted for the refraction of the atmosphere and accounted for antenna biasing for monopulse calculations.
 - Constructed Kalman filters for tracking, simulated scenarios of sensors for tracking space objects.
 - **Space Fence Performance Evaluation System**⁵⁰
 - Multi-GPU (Nvidia) computing for the propagation of satellites in orbits using SGP4 standard propagation.
- Massachusetts Institute of Technology:** Professional Program in Graphics Cards for Technical Computing


RESEARCH EXPERIENCE

Beckman Institute for Advanced Science and Technology <i>Postdoctoral Research Associate for the <u>Optical Science Group</u> and the <u>Biophotonics Imaging Laboratories</u>, at UIUC in Electrical and Computer Engineering</i> <i>Fellow/Graduate Research Assistant for <u>Nanoelectronics & Biophotonics Laboratory</u></i>	Urbana, IL 11/06 – 3/07 8/02 – 10/06	 
<ul style="list-style-type: none">• Time-domain OCT system¹: Optical setup for heterodyning of broadband Ti:Sa source with UHNA fiber. Designed detection and scanning with dual balanced detector and Fourier optics (RSOD), respectively. Created a digital design for a FPGA (Virtex II), which acquired data, controlled galvanometer waveforms and digitally down converted signal using a Harvard processing architecture. Programmed both a DSP (TI C6701) and a computer (C++) to calculate and display structural and Doppler images.• Spectral-domain (SD) OCT system^{3,6,12}: Optical design, theoretic based software acquired axial scans at 29 kHz, and dispersion and beam diffraction (ISAM^{8,10,12}) were both corrected in real-time at 2.25 frames/sec.• SD-optical coherence and multi-photon microscope (OCM-MPM)^{5,7}: Designed detection optics & software.• Theory: Developed inverse scattering solutions for resolution improvements⁸⁻¹². Developed hardware and software solutions to increase processing efficiency.• Analysis: Signal analysis for resampling methods (linear, cubic-B splines, non-uniform FFTs, and prolate-spheroidal), boundary conditions, resolution expectations, phase stability measures and corrections⁹. Signal conditioning (wavelets⁴⁰, regularizations^{2,4,8-12}, entropy measures^{2,4})• Biological applications: Developmental biology³, neural imaging^{1,†}, cellular matrices, cellular spectroscopic scattering⁷, cancer tissues^{3,12}, and contrast agents^{21,22}.		

TEACHING EXPERIENCE

University of Illinois Urbana-Champaign Graduate Teaching Assistant <i>Teaching Assistant for <u>Biomedical Instrumentation Lab</u> and <u>Digital Signal Processing</u></i>	Urbana-Champaign, IL 8/01 – 5/03	
<ul style="list-style-type: none">• Teaching and preparing lab, generating and grading lab reports, office hours.• Proctoring exams, teaching, office hours (140+ in section), grading homework.		

INDUSTRY EXPERIENCE

Battelle <i>Full-Time Employee, Electrical/Computer Engineer</i>	Columbus, OH 5/98 – 8/01	
<ul style="list-style-type: none">• ThinPrep® Imaging System (pap screener) (2001) - R&D 100 Award - Automated microscope station for analyzing and identifying cancerous cells from pap tests. Programmed automation and detection in C++, Rhapsody, and assembly.• White blood cell classification (2000) – Microscope for pattern/image recognition of blood cells/platelets using mathematical 3-D computer vision techniques such as Optimal Infinite Impulse Response Edge Detectors, ellipse fitting by solving the generalized eigenvalues, convolutions, derating models. Programming in Matlab, C, and Matrox Imaging Library. *Earned “Key Contributor” award for this project.• Enteral feeding pump (1999) - Embedded and computer-controlled system, micro-controller, and liquid crystal display selection, assessment, and programming.• Neoprobe Neo2000® (radiation detector) (1998) - R&D 100 Award - Gamma ray detection console with audible surgical guidance. Programmed boot loaders and system drivers. Debugged DSP pipeline. Verified console interface.		

HONORS

- **Best Paper Award** MSS Tri-services 2010
- ***Key Contributor Award** from Battelle for proven feasibility of a medical microscope that differentiates white blood cell types.
- **†Beckman Fellowship** for research on "Mapping neural activity through optical scattering changes using real-time SD-OCT"
- Newport Spectra-Physics **Research Excellence Award**
- Milton Chang OSA Annual Meeting Travel Grant 2005
- SPIE Photonics West Travel Grant 2006
- ECE Graduate College Travel Grant 2005 & 2006
- Incubic Travel Award for Frontiers in Optics 2006
- CSX Employee Scholarship
- Ohio American Legion Scholar
- Golden Key National Honor Society
- University of Dayton Presidential Scholarship
- Dean's List
- Lewis/Morgan Scholarship Recipient
- NAECON Scholarship

ACTIVITIES, INTERESTS, AND MEMBERSHIPS

- Institute of Electronics & Electrical Engineers (IEEE)-*Computer Chair* at UIUC
- Society for Optical Engineering (SPIE)-*Committee Aide* for Early Career Professionals (ECPs)
- Optical Society of America (OSA)-*President, Vice President, Treasurer, and Graduate Advisor* at UIUC
- OSA Frontiers in Optics conference *presider* for the “**Diagnostics in Microscopy**” session.
- Reviewer for Journals: *Optics Letters, Electronic Letters, Optics Communications, Optics Express, Journal of Biomedical Optics, IEEE Transactions on Medical Imaging, IEEE Phased Array, and Nature Photonics*
- Association for Computing Machinery (ACM)
- IEEE Biomedical Engineering Society (EMBS)
- Eta Kappa Nu Honorary ECE Society
- Golden Key National Honor Society
- Engineers Foundation of Ohio
- Ohio Society of Professional Engineers
- Engineers Leadership Institute
- Engineers Supporting Peers
- National Society of Professional Engineers
- Institute of Artificial Intelligence
- Reviewer for conferences: *SPIE Photonics West, OSA Frontiers in Optics, IEEE Radar Symposium*

COMPUTER SKILLS

Organizational: MS Project, Asana, JIRA, Confluence, Crucible, Slack
Programming: Matlab/Octave, C, C++, iPython, Python, OpenCL, CUDA, Java, Verilog, VHDL (Xilinx/Altera), TMS320C6701(TI DSP ASM/C), System Generator(FPGA design & sim), Simulink(model based control, comm, DSP

system-level design), Matrox Imaging Library, HTML, assembly languages (Spim/MIPS, IBM 370, DSP), WinBatch(scripting), Visual Basic, Mathematica, Maple, OCAML, Prolog, TI-92 (CAS), LaTeX, Rhapsody, Intel Math Kernel Library, OpenSceneGraph, OpenCV, k-wave, Field II
Software: LabView, Code Composer Studio (TI DSP), Quartus, Questa, Xilinx ISE 5.1i, Vivado, ModelSim SE (VHDL sim), LogiCore, Pspice(electronics sim), Scanalytics (image processing), AutoCAD/Autodesk, SketchUp, Visio, PhotoShop/Framemaker/Premiere, MS Office, Repositories: Github, Mercurial, SVN, CVS, Rendering: Enthougt VTK, Mayavi2, Amira, Slicer Dicer, ImageVis3D, Tuvok, Seg3D, WebGL, Osirix, ImageJ
Operating Systems: DOS, Windows (8/7/Vista/ME/2000/NT/XP/Server), MacOS X, iOS, Linux (Red Hat/Fedora/Ubuntu/Debian), Unix, VAX, Sun Solaris.

EDUCATION **University of Illinois at Urbana-Champaign (UIUC), M.S., Ph.D.** Urbana-Champaign, IL
Electrical and Computer Engineering (ECE), M.S., Ph.D. 8/01 – 10/06

PH.D. DISSERTATION: **Ralston TS.** “Interferometric Synthetic Aperture Microscopy.” Open to public, Beckman Institute for Advanced Science and Technology. Preliminary Examination: December 19, 2005. Final Defense: September 20, 2006.
 • \$1.3M raised for a startup to commercialize my Ph.D. thesis technology ([Diagnostic Photonics](#)).
 • Ph.D. qualifying exam: (controls, signal processing, logic, computer architecture, acoustics, bioengineering, data structures and algorithms, electromagnetics, analog circuits, solid state, probability, and electro-mechanical devices)
 • Designed, tested, and debugged broad-bandwidth interferometric optical systems (hardware and software).

MASTERS THESIS: **Ralston TS,** “A real-time optical coherence tomography system utilizing an acquisition and signal processing architecture implemented on a field programmable gate array”

University of Dayton, B.S. Dayton, OH
Bachelor of Science in Computer Engineering 8/96 – 12/00

GRANTS **OSA Activity Grant,** University of Illinois Urbana-Champaign (2005). Grant application for “*Photons After Dark,*” a weekly interdepartmental graduate student seminar series in optical science.
OSA Annual Meeting, Milton-Chang travel grant. (2005)
SPIE Photonics West, conference travel grant. (2006)
ECE Graduate College, conference travel grant. (2005)
OSA Frontiers in Optics, Incubic travel grant. (2006)
UIUC Graduate College, conference travel grant. (2006)
Beckman Fellowship Grant, salary and travel grant.
National Health Institute, R21 phase grant contribution, “Interferometric Synthetic Aperture Microscopy”
Diagnostic Photonics \$1.3M raised to commercialize my Ph.D. dissertation technology
MIT Lincoln Laboratory ACC & NTL, \$1M raised for real-time through-wall radar system

SCIENTIFIC CONTRIBUTIONS *Author and/or co-author of 36 Patents, 50 Papers with 1300+ citations, 3 Book chapter contributions. 42 presentations at international conferences, and 18 invited presentations. Work covered by the press media in numerous articles.*

*PATENTS:
 * PATENTS.JUSTIA.COM*

1. Architecture of Single Substrate Ultrasonic Imaging Devices, Related Apparatuses, and Methods
Application number: 20150301165
Abstract: Aspects of the technology described herein relate to ultrasound device circuitry as may form part of a single substrate ultrasound device having integrated ultrasonic transducers. The ultrasound device circuitry may facilitate the generation of ultrasound waveforms in a manner that is power- and data-efficient.
Type: Application
Filed: April 17, 2015
Issued: October 22, 2015
Assignee: Butterfly Network, Inc.
Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Andrew J. Casper

2. Ultrasonic Imaging Compression Methods and Apparatus
Application number: 20150297193
Abstract: To implement a single-chip ultrasonic imaging solution, on-chip signal processing may be employed in the receive signal path to reduce data bandwidth and an output data module may be used to move data for all received channels off-chip as a digital data stream. The digitization of received signals on-chip allows advanced digital signal processing to be performed on-chip, and thus permits the full integration of an entire ultrasonic imaging system on a single semiconductor substrate. The on-chip digitization of received signals also enables the on-chip integration of ultrasound processing and/or pre-processing to reduce the burden on off-chip computing. Data compression architectures are disclosed to facilitate the transfer of data off-chip as a digital data stream in accordance with the bandwidth requirements of standard commercially-available output interfaces.
Type: Application
Filed: April 17, 2015
Issued: October 22, 2015
Assignee: Butterfly Network, Inc.
Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Andrew J. Casper

3. Transmissive imaging and related apparatus and methods
Patent number: 9155521
Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.
Type: Grant
Filed: February 27, 2014

Issued: October 13, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

4. Image-guided high intensity focused ultrasound and related apparatus and methods

Patent number: 9149255

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Grant

Filed: February 27, 2014

Issued: October 6, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

5. COMPLEMENTARY METAL OXIDE SEMICONDUCTOR (CMOS) ULTRASONIC TRANSDUCERS AND METHODS FOR FORMING THE SAME

Application number: 20150251896

Abstract: Complementary metal oxide semiconductor (CMOS) ultrasonic transducers (CUTs) and methods for forming CUTs are described. The CUTs may include monolithically integrated ultrasonic transducers and integrated circuits for operating in connection with the transducers. The CUTs may be used in ultrasound devices such as ultrasound imaging devices and/or high intensity focused ultrasound (HIFU) devices.

Type: Application

Filed: May 13, 2015

Issued: September 10, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

6. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20150247921

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: May 13, 2015

Issued: September 3, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

7. Microfabricated ultrasonic transducers and related apparatus and methods

Patent number: 9067779

Abstract: Micromachined ultrasonic transducers integrated with complementary metal oxide semiconductor (CMOS) substrates are described, as well as methods of fabricating such devices. Fabrication may involve two separate wafer bonding steps. Wafer bonding may be used to fabricate sealed cavities in a substrate. Wafer bonding may also be used to bond the substrate to another substrate, such as a CMOS wafer. At least the second wafer bonding may be performed at a low temperature.

Type: Grant

Filed: March 2, 2015

Issued: June 30, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Susan A. Alie, Keith G. Fife, Nevada J. Sanchez

8. Complementary metal oxide semiconductor (CMOS) ultrasonic transducers and methods for forming the same

Patent number: 9061318

Abstract: Complementary metal oxide semiconductor (CMOS) ultrasonic transducers (CUTs) and methods for forming CUTs are described. The CUTs may include monolithically integrated ultrasonic transducers and integrated circuits for operating in connection with the transducers. The CUTs may be used in ultrasound devices such as ultrasound imaging devices and/or high intensity focused ultrasound (HIFU) devices.

Type: Grant

Filed: December 5, 2014

Issued: June 23, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

9. Transmissive imaging and related apparatus and methods

Patent number: 9033884

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Grant

Filed: February 27, 2014

Issued: May 19, 2015

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

10. Transmissive imaging and related apparatus and methods

Patent number: 9028412

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive

ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Grant

Filed: February 27, 2014

Issued: May 12, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

11. Transmissive imaging and related apparatus and methods

Patent number: 9022936

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Grant

Filed: February 27, 2014

Issued: May 5, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

12. COMPLEMENTARY METAL OXIDE SEMICONDUCTOR (CMOS) ULTRASONIC TRANSDUCERS AND METHODS FOR FORMING THE SAME

Application number: 20150084053

Abstract: Complementary metal oxide semiconductor (CMOS) ultrasonic transducers (CUTs) and methods for forming CUTs are described. The CUTs may include monolithically integrated ultrasonic transducers and integrated circuits for operating in connection with the transducers. The CUTs may be used in ultrasound devices such as ultrasound imaging devices and/or high intensity focused ultrasound (HIFU) devices.

Type: Application

Filed: December 5, 2014

Issued: March 26, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

13. MONOLITHIC ULTRASONIC IMAGING DEVICES, SYSTEMS AND METHODS

Application number: 20150087977

Abstract: To implement a single-chip ultrasonic imaging solution, on-chip signal processing may be employed in the receive signal path to reduce data bandwidth and a high-speed serial data module may be used to move data for all received channels off-chip as digital data stream. The digitization of received signals on-chip allows advanced digital signal processing to be performed on-chip, and thus permits the full integration of an entire ultrasonic imaging system on a single semiconductor substrate. Various novel waveform generation techniques, transducer configuration and biasing methodologies, etc., are likewise disclosed. HIFU methods may additionally or alternatively be employed as a component of the "ultrasound-on-a-chip" solution disclosed herein.

Type: Application

Filed: December 5, 2014

Issued: March 26, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

14. INTERCONNECTABLE ULTRASONIC TRANSDUCER PROBES AND RELATED METHODS AND APPARATUS

Application number: 20150080724

Abstract: Ultrasound devices and methods are described, including a repeatable ultrasound transducer probe having ultrasonic transducers and corresponding circuitry. The repeatable ultrasound transducer probe may be used individually or coupled with other instances of the repeatable ultrasound transducer probe to create a desired ultrasound device. The ultrasound devices may optionally be connected to various types of external devices to provide additional processing and image rendering functionality

Type: Application

Filed: December 5, 2014

Issued: March 19, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Nevada J. Sanchez, Gregory L. Charvat, Gregory Corteville

15. INTERCONNECTABLE ULTRASONIC TRANSDUCER PROBES AND RELATED METHODS AND APPARATUS

Application number: 20150032002

Abstract: Ultrasound devices and methods are described, including a repeatable ultrasound transducer probe having ultrasonic transducers and corresponding circuitry. The repeatable ultrasound transducer probe may be used individually or coupled with other instances of the repeatable ultrasound transducer probe to create a desired ultrasound device. The ultrasound devices may optionally be connected to various types of external devices to provide additional processing and image rendering functionality

Type: Application

Filed: July 22, 2014

Issued: January 29, 2015

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Nevada J. Sanchez, Gregory L. Charvat, Gregory Corteville

16. Transmissive imaging and related apparatus and methods

Patent number: 8852103

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and

ultrasound imaging, are also described.

Type: Grant

Filed: October 17, 2012

Issued: October 7, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

17. MONOLITHIC ULTRASONIC IMAGING DEVICES, SYSTEMS AND METHODS

Application number: 20140288428

Abstract: To implement a single-chip ultrasonic imaging solution, on-chip signal processing may be employed in the receive signal path to reduce data bandwidth and a high-speed serial data module may be used to move data for all received channels off-chip as digital data stream. The digitization of received signals on-chip allows advanced digital signal processing to be performed on-chip, and thus permits the full integration of an entire ultrasonic imaging system on a single semiconductor substrate. Various novel waveform generation techniques, transducer configuration and biasing methodologies, etc., are likewise disclosed. HIFU methods may additionally or alternatively be employed as a component of the "ultrasound-on-a-chip" solution disclosed herein.

Type: Application

Filed: March 13, 2014

Issued: September 25, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

18. COMPLEMENTARY METAL OXIDE SEMICONDUCTOR (CMOS) ULTRASONIC TRANSDUCERS AND METHODS FOR FORMING THE SAME

Application number: 20140264660

Abstract: Complementary metal oxide semiconductor (CMOS) ultrasonic transducers (CUTs) and methods for forming CUTs are described. The CUTs may include monolithically integrated ultrasonic transducers and integrated circuits for operating in connection with the transducers. The CUTs may be used in ultrasound devices such as ultrasound imaging devices and/or high intensity focused ultrasound (HIFU) devices.

Type: Application

Filed: March 13, 2014

Issued: September 18, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

19. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140243614

Abstract: Ultrasound imaging devices and heads up displays, as well and systems utilizing both are described. In some embodiments, ultrasound data or images may be displayed on a heads up display, which may be a head-mounted display. One or more users may manipulate the images. Image capture devices and sensors may also be implemented.

Type: Application

Filed: February 26, 2014

Issued: August 28, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Gregory L. Charvat, Nevada J. Sanchez, Alexander Magary

20. CMOS ULTRASONIC TRANSDUCERS AND RELATED APPARATUS AND METHODS

Application number: 20140217478

Abstract: CMOS Ultrasonic Transducers and processes for making such devices are described. The processes may include forming cavities on a first wafer and bonding the first wafer to a second wafer. The second wafer may be processed to form a membrane for the cavities. Electrical access to the cavities may be provided.

Type: Application

Filed: February 4, 2014

Issued: August 7, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

21. CMOS ULTRASONIC TRANSDUCERS AND RELATED APPARATUS AND METHODS

Application number: 20140219062

Abstract: CMOS Ultrasonic Transducers and processes for making such devices are described. The processes may include forming cavities on a first wafer and bonding the first wafer to a second wafer. The second wafer may be processed to form a membrane for the cavities. Electrical access to the cavities may be provided.

Type: Application

Filed: February 4, 2014

Issued: August 7, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Keith G. Fife, Gregory L. Charvat, Nevada J. Sanchez

22. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180093

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

23. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180113

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

24. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180094

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

25. IMAGE-GUIDED HIGH INTENSITY FOCUSED ULTRASOUND AND RELATED APPARATUS AND METHODS

Application number: 20140180177

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

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Assignee: BUTTERFLY NETWORK, INC.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

26. VOLUMETRIC IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180097

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

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Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

27. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180100

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

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Assignee: Butterfly Network, Inc.

Inventors: [Tyler S. Ralston](#), Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

28. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180112

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

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Assignee: BUTTERFLY NETWORK, INC.

Inventors: TYLER S. RALSTON, JONATHAN M. ROTHBERG, NEVADA J. SANCHEZ, GREGORY L. CHARVAT

29. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180088

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

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Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

30. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180099

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

31. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180092

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

32. IMAGE-GUIDED HIGH INTENSITY FOCUSED ULTRASOUND AND RELATED APPARATUS AND METHODS

Application number: 20140180176

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

33. TRANSMISSIVE IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180095

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

34. ULTRASOUND IMAGING AND RELATED APPARATUS AND METHODS

Application number: 20140180096

Abstract: Apparatus and methods are described that include ultrasound imaging devices, which may operate in a transmissive ultrasound imaging modality, and which may be used to detect properties of interest of a subject such as index of refraction, density and/or speed of sound. Devices suitable for performing high intensity focused ultrasound (HIFU), as well as HIFU and ultrasound imaging, are also described.

Type: Application

Filed: February 27, 2014

Issued: June 26, 2014

Assignee: Butterfly Network, Inc.

Inventors: Tyler S. Ralston, Jonathan M. Rothberg, Nevada J. Sanchez, Gregory L. Charvat

35. Interferometric synthetic aperture microscopy

Patent number: 7602501

Abstract: Methods and apparatus for three-dimensional imaging of a sample. A source is provided of a beam of substantially collimated light characterized by a temporally dependent spectrum. The beam is focused in a plane characterized by a fixed displacement along the propagation axis of the beam, and scattered light from the sample is superposed with a reference beam derived from the substantially collimated source onto a focal plane detector array to provide an interference signal. A forward scattering model is derived relating measured data to structure of an object to allow solution of an inverse scattering problem based upon the interference signal so that a three-dimensional structure of the sample may be inferred in near real time.

Type: Grant

Filed: July 10, 2007

Issued: October 13, 2009

Assignee: The Board of Trustees of the University of Illinois

Inventors: Tyler S. Ralston, Daniel L. Marks, Paul Scott Carney, Stephen A. Boppart

36. Interferometric Synthetic Aperture Microscopy

Application number: 20080140341

Abstract: Methods and apparatus for three-dimensional imaging of a sample. A source is provided of a beam of substantially collimated light characterized by a temporally dependent spectrum. The beam is focused in a plane characterized by a fixed displacement along the propagation axis of the beam, and scattered light from the sample is superposed with a reference beam derived from the substantially collimated source onto a focal plane detector array to provide an interference signal.

Type: Application

Filed: July 10, 2007

Issued: June 12, 2008

Assignee: The Board of Trustees of the University of Illinois

Inventors: [Tyler S. Ralston](#), Daniel L. Marks, Paul Scott Carney, Stephen A. Boppart

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Ralston TS. "Inverse scattering in optical coherence tomography" *Photons After Dark* - seminar series for optical engineering students. October 6, 2005.

Ralston TS. "Gaussian beam deconvolution in optical coherence tomography." Beckman Institute's Nanoelectronics and Biophotonics Seminar Series. October 10, 2005.

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Ralston TS. "Phase Corrections for Interferometric Synthetic Aperture Microscopy" Optical Society of America Student Chapter Meeting. March 30, 2006.

Ralston TS. "3-D Microscopy Beyond OCT: Interferometric Synthetic Aperture Microscopy (ISAM)" Optoelectronics Research Centre in the Electronic and Electrical Engineering Department at University College Dublin in Ireland, May 11, 2006.

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