14:33:58 OCA PAD AMENDMENT - PROJECT HEADER INFORMATION 10/06/95

Active

Project #: E-21-615 Cost share #: Rev #: 13
Center # : 10/24-6-R6805-0A0 Center shr #: OCA file #:
Work type : RES
Contract#: ECS-8957044 Mod #: ADM. REVISION Document : GRANT
Prime #: Contract entity: GTRC

Subprojects ? : Y CFDA: 47.041
Main project #: PE #:

Project unit: ECE Unit code: 02.010.118
Project director(s):
HUNT W D ECE (404)894-2945

Sponsor/division names: NATL SCIENCE FOUNDATION / GENERAL
Sponsor/division codes: 107 / 000

Award period: 890815 to 960131 (performance) 960430 (reports)

Sponsor amount	New this change	Total to date
Contract value	0.00	311,500.00
Funded	0.00	311,500.00
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: PYI AWARD

PROJECT ADMINISTRATION DATA

OCA contact: Jacquelyn L. Bendall 894-4820

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Security class (U,C,S,TS) : U ONR resident rep. is ACO (Y/N): N
Defense priority rating : N/A NSF supplemental sheet
Equipment title vests with: Sponsor GIT X

Administrative comments -
ISSUED TO REVISE DELIVERABLE SCHEDULE IN ORDER TO COINCIDE WITH PRINCIPAL INVESTIGATOR'S COMMENTS.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 10/16/96

Project No. E-21-615 Center No. 10/24-6-R6805-0A0

Project Director HUNT W D School/Lab ECE

Sponsor NATL SCIENCE FOUNDATION/GENERAL

Contract/Grant No. ECS-8957044 Contract Entity GTRC

Prime Contract No.

Title PYI AWARD

Effective Completion Date 960131 (Performance) 960430 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	N	
Final Report of Inventions and/or Subcontracts	N	
Government Property Inventory & Related Certificate	N	
Classified Material Certificate	N	
Release and Assignment	N	
Other	N	

Comments
LETTER OF CREDIT APPLIES. 98A SATISFIES PATENT REPORT.

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

E-21-615

1

1990-1991 Presidential Young Investigator Program

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices, and Transducers for Biomedical Ultrasound

Investigator: William D. Hunt

Organization: School of Electrical Engineering
Georgia Institute of Technology

Address: School of Electrical Engineering
Georgia Institute of Technology
777 Atlantic Drive, N.W.
Atlanta, Georgia 30332-0250

Telephone: (404) 894-2945

Funding: $62,500.00

Abstract

The work being conducted in this project is divided amongst three areas:

Acoustic Charge Transport (ACT) Devices

High Definition Television (HDTV) or High Definition Systems (HDS), as it is also known, represents a large commercial market for high technology in the United States. It has become a highly politicized area and it is the battleground for arguments over whether or not the government should become involved in industrial policy. While this battle is being waged, researchers such as myself are pressing ahead. The long term goal of our research efforts in ACT devices is to develop a high-speed, high-resolution camera for HDTV. In our approach we will collect charge from an array of avalanche photodiodes (APD) and read this charge out using the ACT phenomena. Along the way towards this goal we anticipate that we will make many technological advancements regarding surface acoustic wave (SAW) propagation through the array and the optimization of the device architecture for acoustic charge transport. We have efforts in place to optimize the ACT channel and investigate SAW waveguide structures which will lead us to an efficient acoustic design for the APD array.

In this project we will nominally employ an APD overlying a heterostructure ACT channel. A vertical bipolar junction transistor will be used to minimize blooming and the overall system architecture will be the frame interline transfer technique developed for CCD imagers. The array will ultimately consist of 1920 (V) x 1080 (H) picture elements with each element being 8 μm x 8 μm. The anticipated frame rate for a two megapixel array will be 170 Hz.

Surface Acoustic Wave (SAW) Devices

SAW devices are in widespread use as vital components in a variety of systems ranging from TV sets to communications systems to electronic test equipment. In our efforts the application we will be working with most closely is digital radio communication. In this research we will be working closely with Bell Northern Research (BNR), a division of Northern Telecom. BNR is employing a 64-QAM (quadrature amplitude modulation) scheme for their microwave systems and the fidelity desired for such a system places stringent requirements on the SAW device components vital to its effective implementation. These stringent requirements lead us to a more detailed investigation of the details of the device physics for the SAW filters and resonators being used. It is on further understanding and analyzing the device physics of the relevant SAW components that we will work. This will involve the use of the laser probe measurement system we have in our laboratory for experimental work and the exploitation of the analysis software we have been developing.

Transducers for Biomedical Ultrasound

A topic of significant interest in vascular research is arteriosclerotic change in the carotid and the implications of this change for the patient's susceptibility to stroke. It has become evident that not only is the severity and extent of the plaque buildup important, but also the texture of the plaque is important. In order to determine the texture of the plaque we have been looking at methods for tissue characterization rather than techniques to enhance ultrasound images from existing biomedical equipment. To achieve this end we are starting with the ultrasound transducer and exploiting microelectronic fabrications techniques to develop a wideband focusing transducer. We will perform both theoretical and experimental investigations into the acoustic design details for this transducer so as to optimize its performance for a specific biomedical application. We will experimentally determine the ultrasonic signatures associated

with various plaque types and will utilize this information to develop signal processing techniques which will allow us to ultrasonically classify the plaque as fibrous, calcific, fatty or ulcerated.

I. Research Summary

The research conducted during the second year of the PYI included the projects described above as well as a modest effort in Surface Transverse Waves in GaAs and Quartz. Ph.D. students who were at one time or another supported by this grant and their accomplishments during this past year are listed below.

1. **Victor M. Bright (Ph.D):** Mr. Bright is working in the area of Surface Transverse Waves in GaAs and Quartz. This includes investigations of the propagation of these waves under metallic gratings, techniques to generate the waves and techniques to measure the propagation characteristics of these waves.
   Research Accomplishments: During this past year he published two more journal articles and has made one conference presentation. He has become adept at device fabrication and is showing signs of becoming a good experimentalist. He has three experiments underway, each of which will probably result in a journal article.
2. **Yoonkee Kim (Ph.D):** Mr. Kim's research is in the area of ACT devices and SAW propagation in the ACT device structure.
   Research Accomplishments: Mr. Kim has developed a computer program to be used in the design of SAW waveguides for ACT devices. He is working to embellish this program to yield waveguide profile predictions for a variety of multilayered device architectures. He has laid out a semiconductor mask and is fairly far along in the planning of experiments. In addition, he is doing some collaborative work with Mr. Bright which appears quite fruitful at this point. During the past year he has published two journal papers and has made one conference presentation.
3. **Michael Z. Sleva (Ph.D):** Mr. Sleva is working on the transducers for medical ultrasound project.

III. Conference Papers

1. Kenney, J. S. and Hunt, W. D., "Synthesis of acoustic matching networks by discrete space Fourier transform method," *IEEE 1990 Ultrasonics Symposium Proceedings*, vol. 1, pp. 581-586, December 1990.
2. Kim, Y. and Hunt, W. D., "A Laguerre polynomial approach to surface acoustic wave propagation in multilayered structures," *IEEE 1990 Ultrasonics Symposium Proceedings*, vol. 1, pp. 179-183, December 1990.
3. Bright, V. M. and Hunt, W. D., "Bleustein-Gulyaev wave propagation under periodic metal gratings," *IEEE 1990 Ultrasonics Symposium Proceedings*, vol. 1, pp. 173-178, December 1990.
4. Sleva, M. Z. and Hunt, W. D., "A PVDF Fresnel lens transducer," *IEEE 1990 Ultrasonics Symposium Proceedings*, vol. 2, pp. 821-826, December 1990.
5. Sleva, M. Z. and Hunt, W. D., "Design and construction of a PVDF ultrasound Fresnel lens," presented at the First Annual University System of Georgia Research Symposium, May 17-18, 1991, Augusta, Georgia.

E-21-615
2

1991-1992 PRESIDENTIAL YOUNG INVESTIGATOR PROGRAM

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices and Transducers for Biomedical Ultrasound

Investigator: William D. Hunt

Organization: School of Electrical Engineering
Georgia Institute of Technology

Address: School of Electrical Engineering
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Funding: $62,500

Abstract

Acoustic Charge Transport (ACT) Devices:

High Definition Television (HDTV) or High Definition Systems (HDS), as it is also known, is a potentially large commercial market for high technology in the United States. It has become a highly politicized area and it is the battleground for arguments over whether or not the government should become involved in industrial policy. While this battle is being waged, researchers such as myself are pressing ahead. The long term goal of our research efforts in ACT devices is to develop a high-speed, high-resolution camera for HDTV. In our approach we will collect charge from an array of superlattice avalanche photodiodes (APD) and read this charge out using the ACT phenomena. Towards this goal we anticipate that we will make many technological advancements regarding surface acoustic wave (SAW) propagation through the array and the optimization of the device architecture for acoustic charge transport. We are working to optimize the ACT channel and investigate SAW waveguide structures which will lead us to an efficient acoustic design for the APD array.

In this project we will nominally employ an APD overlying a heterostructure ACT channel. A vertical bipolar junction transistor will be used to minimize blooming and the overall system architecture will be the frame interline transfer technique developed for CCD imagers. The array will consist of 1920(V) x 1080 (H) picture elements with each element being 8μm x 8μm. The anticipated frame rate for a two megapixel array will be 170Hz. We feel that our

research will provide general improvements for ACT devices used for analog signal processing and communication systems and for fiber optic applications of APDs.

Surface Acoustic Wave (SAW) Devices

SAW devices are in widespread use as vital components in a variety of systems ranging from TV sets to communications systems to electronic test equipment. In this project we are working with SAW devices to be used for digital radio communications. In this research we are be working closely with Bell Northern Research (BNR), a division of Northern Telecom. BNR utilizes SAW devices in a variety of communication systems. These devices include resonators, filters and tapped delay lines for time delay equalization. The quality requirements required for these systems places stringent requirements on the SAW device components. These stringent requirements lead us to a more detailed investigation of the details of the device physics for the SAW filters and resonators being used. We have been doing theoretical and experimental work on the device physics of the relevant SAW components. Most of our efforts to date have been focused on waveguide coupled resonators on ST-Quartz that are to be used for narrow band filters in cellular radios. In our work we will use the laser probe measurement system we have in our laboratory for examining the surface acoustic wave beam profiles in the devices of interest. In addition we have been development software which will assist BNR in their development of new SAW components.

Transducers for Biomedical Ultrasound

A topic of significant interest in vascular research is arteriosclerotic change in the carotid and the implications of this change for the patient's susceptibility to stroke. It has become evident that not only is the severity and extent of the plaque buildup important, but also the texture of the plaque is important. In order to determine the texture of the plaque we have been looking at methods for tissue characterization rather than techniques to enhance ultrasound images from existing biomedical equipment. To achieve this end we are exploiting microelectronic fabrication techniques to develop a wideband focusing transducer. We have been performing both theoretical and experimental investigations into the acoustic design details for this transducer so as to optimize its performance for a specific biomedical application. To this end we are teaming with Professor Mark Allen's group at Georgia Tech which is engaged in the development of micromotors and microsensors. Our ultimate goal is to develop a wideband catheterized acoustic microscope.

I. Research Summary

The research conducted during the third year of the PYI included the projects described above as well as a modest effort on the basic nature of surface transverse waves on GaAs. Ph.D. students who were at one time or another supported by this grant and their

accomplishments during this past year are listed below.

1. Victor M. Bright (Ph.D): Mr. Bright worked in the area of Surface Transverse Waves in GaAs. This includes investigations of the propagation of these waves under metallic gratings, techniques to generate the waves and techniques to measure the propagation characteristics of these waves.

Research Accomplishments: During this past year he published two more journal articles and made one conference presentation. He has become adept at device fabrication and is showing signs of becoming a good experimentalist. Mr. Bright received his Ph.D. during the Winter Quarter 1992 and has accepted a faculty position at the Air Force Institute of Technology in Dayton, Ohio.

2. Yoonkee Kim (Ph.D): Mr. Kim's research is in the area of ACT devices and SAW propagation in the ACT device structure. In addition, he has successfully applied some of his waveguide analysis tools to waveguide-coupled SAW resonators.

Research Accomplishments: Mr. Kim has developed a computer program to be used in the design of SAW waveguides for ACT devices. He is working to embellish this program to yield waveguide profile predictions for a variety of multilayered device architectures. He has conducted a first round of waveguide experiments and based on the data he obtained has laid out a new mask and will begin fabricating these devices within the next month or so. In addition, he has done some collaborative work with Mr. Bright which resulted in a conference paper and a journal article. During the past year he has published two journal papers.

3. Michael Z. Sleva(Ph.D): Mr. Sleva is working on the transducers for medical ultrasound project.

Research Accomplishments: Mr. Sleva has established the process for the fabrication of PVDF transducers in our laboratory and has taught two undergraduates the fabrication methodology. During the past year he has made detailed calculations of the acoustic field profile and the transient acoustic field of various candidate transducers. He is currently putting together a first-rate experimental system for measuring the acoustic sound field emanating from the transducer. This system will be used to evaluate the ultrasonic signature of various plaque types and will assist us in evaluating the acoustic microscope transducers. His progress has been slowed somewhat due to problems in purchasing the experimental apparatus. During the coming months he will complete a series of vital experiments and I expect that he will submit two journal papers during the upcoming year.

4. Steve Kenney(Ph.D): Mr. Kenney is working on the noise properties of ACT devices and is developing experimental and analytical techniques which will enable us to optimize the ACT device structure.

Research Accomplishments: Mr. Kenney only recently joined the group as a full time graduate student. Prior to the Spring quarter of 1992 he was working full time at SPC of America in Atlanta as an RF engineer. He has been working for me for two years while going to graduate

school part time and during that time published one journal paper and one conference paper. In addition, he made considerable headway on the selection and definition of a topic for his dissertation. I expect that he will be very productive over the coming year.

5. Houston Irby(Ph.D.): Mr. Irby joined the group in the Winter of 1992 and will be working on ACT devices. Since he is in his first year of graduate school he is probably a year or so away from defining a research topic.

Research Accomplishments: Mr. Irby has been engaged in the fabrication and testing of ACT devices. Currently his work involved considerable laboratory work and he is showing considerable promise in that area.

6. Brian Meadows(Ph.D): Brian is a Physics graduate student who joined the group in the Fall of 1992. He will also be working on the ACT device project. Again, he is probably a year or so away from defining a research topic.

Research Accomplishments: Mr. Meadows is working on ACT device fabrication and testing. He brings with him considerable industrial experience.

II. Referred Journal Articles

1. Kenney, J.S. and Hunt, W.D., "Synthesis of acoustic matching networks by discrete space Fourier transform method," *Journal of the Acoustical Society of America*, vol. 89, no. 5, pp. 2123-2130, May 1991.

2. Bright, V. M. and Hunt, W. D., "Analysis of Bleustein-Gulyaev wave propagation under thin periodic metal electrodes," *Journal of Applied Physics*, vol. 70, no. 2, pp. 594-602, July 1991.

3. Bright, V. M., Kim, Y., and Hunt, W. D., "Study of surface acoustic waves on the {110} plane of gallium arsenide," *Journal of Applied Physics*, vol. 71, no. 2, pp. 597-605, January 1992.

4. Kim, Y. and Hunt, W. D., "An analysis of surface acoustic wave propagation in a piezoelectric film over a GaAs/AlGaAs heterostructure," *Journal of Applied Physics*, vol. 71, no. 5, pp. 2136-2142, March 1992.

III. CONFERENCE PAPERS

1. Bright, V. M., Kim, Y., and Hunt, W. D., "Surface acoustic waves on the {110} cut of gallium arsenide," presented at the 1991 IEEE Ultrasonics Symposium in Lake Buena Vista, Florida, December 1991.

E21-615
3

1992-1993 PRESIDENTIAL YOUNG INVESTIGATOR PROGRAM

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices and Transducers for Biomedical Ultrasound

Investigator: William D. Hunt

Organization: School of Electrical Engineering
Georgia Institute of Technology

Address: School of Electrical Engineering
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Telephone: (404) 894-2945

FAX: (404) 894-4700

Funding: $62,500

Abstract

Acoustic Charge Transport (ACT) Devices:

High Definition Television (HDTV) or High Definition Systems (HDS), as it is also known, is a potentially large commercial market for high technology in the United States. Under the Clinton administration it seems assured that the research emphasis will continue to shift away from military applications to commercial ones. As such we are well positioned for this change in perspective. We are engaged in an effort to develop a high-speed, high-resolution camera for HDTV. In our approach we will collect charge from an array of superlattice avalanche photodiodes (APD) and read this charge out using the ACT phenomena. In working towards this ultimate goal we have made and will continue to make significant strides in understanding surface acoustic wave (SAW) propagation in these photodiode array structures and in developing an optimal architecture. This has included an extensive study of the SAW properties of a ZnO on GaAs structure as well as an extensive study of the waveguide properties of structures which are similar to the ultimate imager array configuration. In addition, we have progressed well in our modelling of ACT devices and measurement of noise and transport properties.

Surface Acoustic Wave (SAW) Devices:

SAW devices are in widespread use as vital components in a variety of systems ranging from TV sets to communications systems to electronic test equipment. In this

project we are working with SAW devices which are to be used for digital radio communications. In this research we are working closely with Bell Northern Research (BNR), the research arm of Northern Telecom. Though we have been working with BNR for only a short time some of our research has already found its way into BNR products. We have been doing theoretical and experimental work on the device physics of the relevant SAW components. Most of our efforts to date have been focused on waveguide coupled resonators on STX-Quartz that are to be used for narrow band filters in cellular radios. In our work we will use the laser probe measurements system we have in our laboratory for examining the surface acoustic wave beam profiles in the devices of interest. In addition, we have been writing software which will assist BNR in their development of new SAW components.

Transducers for Biomedical Ultrasound:

For the past year we have been working with Dr. David Connuck of the Pediatric Cardiology Group at the Medical College of Georgia to develop an ultrasound methodology which would allow physicians to make better diagnoses and hence better treat infants and children with congenital heart defects. Specifically, we hope to develop a catheter tip transducer and attendant signal processing system to detect the degree of lamination in the pulmonary artery of patients with congenital heart defects. To achieve this we are exploiting microelectronic fabrication techniques to develop a wideband focusing transducer and have explored some non-standard signal processing techniques which have allowed us to demonstrate the validity of our approach. We anticipate a tremendous amount of activity and progress over the next year in our work in this area.

I. Research Summary

The research conducted during the third year for the PYI included the projects described above. Graduate students who were at one time or another supported by this grant and their accomplishments during this past year are listed below. In all eight undergraduate students participated in the research.

1. Yoonkee Kim (Ph.D.): Mr. Kim's research is in the area of ACT devices and SAW propagation in the ACT device structure. In addition, he has successfully applied some of his waveguide analysis tools to waveguide-coupled SAW filters.

Research Accomplishments: Mr. Kim's efforts this past year were concentrated on the study of SAW propagation in ZnO on GaAs substrates. The purpose of this research was to investigate the possibility of using a piezoelectric overlay, such as ZnO, on GaAs substrates so as to enhance the piezoelectric coupling and thereby reduce the RF drive power needed for ACT devices. It was found that DC-Triode Sputtered ZnO films with an intervening layer such as Si_3N_4 between the ZnO and GaAs provides a tremendous enhancement of the piezoelectric properties. Instead of needing 27dBm of RF drive power for the transducer in an ACT device only 8 dBm will be needed. This will decrease the power budget needed for ACT devices in systems and will also increase device lifetime. In addition, measurements of

the slowness surface on the ZnO-GaAs were made using our laser probe and a line-focused-beam acoustic microscope at the National Research Council of Canada by Dr. C.K. Jen. These results are quite interesting and will be submitted for publication soon. They indicate that ZnO film thickness can be used to control the SAW anisotropy of the aggregate structure. During the past year Mr. Kim has publishes one conference paper and has completed his dissertation. He is receiving his Ph.D. during the Spring Quarter 1993.

2. Michael Z. Sleva (Ph.D.): Mr. Sleva is working on the transducers for the biomedical ultrasound project.

Research Accomplishments: Mr. Sleva completed the assembly of the experimental system for the measurement of the acoustic beam profiles from our transducers. In addition, he put together a measurement apparatus which allows us to measure the ultrasonic echo from pressurized vessels. This is a copy of one being used by Professor Ray Vito of the School of Mechanical Engineering at Georgia Tech with whom we are also collaborating. He has made tremendous progress on the fabrication of the transducers and we should have process standardized within the next few months. Mr. Sleva has begun to make tissue ultrasonic impulse response measurements and is close to establishing a rigorous protocol. Mr. Sleva presented a paper at the 1992 IEEE Ultrasonic Symposium.

3. Steve Kenney (Ph.D.): Mr. Kenney is working on the noise properties of ACT devices and is developing experimental and analytical techniques which will enable us to optimize the ACT device structure.

Research Accomplishments: Early during this past year Mr. Kenney selected his research topic and has proceeded steadily in his work. He has developed a good physical model for ACT devices and has corroborated his theory with experiment. In addition, he has lent his considerable expertise in RF system design to the biomedical ultrasound project and has helped that effort considerably. He has published two conference papers and has had a journal paper accepted.

4. Houston Irby (Ph.D.): Mr. Irby has done considerable work on the ACT devices including fabrication, mask design and testing. In addition he has been working on an exploratory project which, if it is successful, will become his thesis topic.

Research Accomplishments: Mr. Irby has been engaged in fabrication and testing of ACT devices and has been instrumental in establishing our fabrication procedures. In addition he has made considerable strides on his exploratory project, planning experiments and designing devices.

5. Erol Yurtkuran (M.S.): Mr. Yurtkuran joined the group in the Winter of 1993 and is working on ACT devices.

Research Accomplishments: At this stage Mr. Yurtkuran has been most heavily involved in engineering tasks in the group. This has included the creation of macros for the EESof program environment which has allowed us to perform device mask layout in this RF

simulation tool environment. Currently he is working on testing of ACT devices. Should he elect to pursue his Ph.D. he will work towards the selection of a thesis topic.

II. Referred Journal Articles

1.Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Mode profiles in waveguide-coupled resonators," accepted for publication in *Journal of Applied Physics* 1993.

2.Kenney, J.S. and Hunt, W.D., "A physically-based small-signal circuit model for heterostructure acoustic charge transport devices," accepted for publication in the *1993 Symposium Issue of IEEE Transactions on Microwave Theory and Techniques*, December 1993.

III. CONFERENCE PAPERS

1.Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Mode profiles in waveguide-coupled resonators," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, pp. 45-49, October 1992

2.Kim, Y., Hunt, W.D., Hickernell, F.S. and Higgins, R.J., "Surface acoustic wave properties of ZnO films on {100}-cut <110>-propagating GaAs substrates,"*Proceedings of the 1992 IEEE Ultrasonics Symposium*, pp. 413-417, October 1992

3.Sleva, M.Z. and Hunt, W.D., "Transient analysis of a PVDF Fresnel zone plate," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, pp. 593-598, October 1992

4.Kenney, J.S. and Hunt, W.D., "A small-signal equivalent circuit model for heterostructure acoustic charge transport devices," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, pp. 215-220, October 1992.

5. Kenney, J.S., Hunt, W.D., and May, G.S., "Yield prediction of acoustic charge transport transversal filters," to be presented at the *15th IEEE/CHMT International Electronics Manufacturing Technology Symposium*, 1993.

6. Kenney, J.S. and Hunt, W.D., "A physically-based small-circuit model for heterostructure acoustic charge transport devices," to be presented at the *IEEE MTT-S International Microwave Symposium*, June 1993.

7.Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Transverse and longitudinal mode profiles in waveguide-coupled resonators," *to be presented at the IEEE MTT-S International Microwave Symposium*, June 1993.

IV. Patents and Invention Disclosures

W.D. Hunt, K.F. Brennan and C.J. Summers, "An acoustic charge transport imager," #5,162,885, awarded November 10, 1992.

E-21-615
#4

1993-1994 PRESIDENTIAL YOUNG INVESTIGATOR PROGRAM

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices and Transducers for Biomedical Ultrasound

Investigator: William D. Hunt
Associate Professor

Organization: School of Electrical and Computer Engineering
Georgia Institute of Technology

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Funding: $62,500

Abstract

Acoustic Charge Transport (ACT) Devices:

We are engaged in an effort to develop a high-speed, high-resolution camera for HDTV. In our approach we collect photogenerated charge from an array of superlattice avalanche photodiodes (APD) and read this charge out using the ACT phenomena. In working towards this ultimate goal we have made and will continue to make significant strides in understanding surface acoustic wave (SAW) propagation in these photodiode array structures and in developing an optimal architecture. This has included an extensive study of the SAW properties of a ZnO on GaAs structure as well as an extensive study of the waveguide properties of structures which are similar to the ultimate imager array configuration. In addition, we have progressed well in our modeling of ACT devices and measurement of noise and transport properties.

Surface Acoustic Wave (SAW) Devices:

SAW devices are in widespread use as vital components in a variety of systems ranging from TV sets to communications systems to electronic test equipment. In this project we are working with SAW devices which are to be used for cellular telephone communications. In this research we are working closely with Bell Northern Research (BNR), the research arm of Northern Telecom. We have been doing theoretical and experimental work on the device physics of the relevant SAW components. Most of our efforts to date have been focused on waveguide

coupled resonators on STX-Quartz that are to be used for narrow band filters in cellular radios. In our work we use the laser probe measurements system we have in our laboratory for examining the surface acoustic wave beam profiles in the devices of interest.

Transducers for Biomedical Ultrasound:

For several years we have been working with Dr. David Connuck of the Pediatric Cardiology Group at the Medical College of Georgia to develop an ultrasound methodology which would allow physicians to make better diagnoses and hence better treat infants and children with congenital heart defects. Specifically, we are developing wideband catheter tip transducers and the attendant signal processing system to detect the degree of lamination in the pulmonary artery of patients with congenital heart defects. To achieve this we are exploiting microelectronic fabrication techniques to develop a wideband focusing transducer and have explored some non-standard signal processing techniques which have allowed us to demonstrate the validity of our approach.

I. Research Summary

The research conducted during the fourth year of the PYI included the projects described above. Graduate students who were at one time or another supported by this grant and their accomplishments during this past year are listed below. Two undergraduate students participated in this research.

1. Michael Z. Sleva (Ph.D.): Mr. Sleva is working on the transducers for the biomedical ultrasound project.

Research Accomplishments: Mr. Sleva continued his work on the development of wideband transducers for intravascular ultrasound. He completed an analysis of the transient response of the Fresnel zone plate (FZP) transducer and verified the analysis experimentally.

2. Steve Kenney (Ph.D.): Mr. Kenney is working on the noise and injection properties of ACT devices and is developing experimental and analytical techniques which will enable us to optimize the ACT device architecture.

Research Accomplishments: He has developed a small-signal model for ACT devices and has corroborated his theory with experiment. In addition, he has lent his considerable expertise in RF system design to the biomedical ultrasound project and has helped that effort considerably. He published two conference papers and published one journal paper.

4. Houston Irby (Ph.D.): Mr. Irby selected a thesis topic in the area of acoustooptic interactions in compound semiconductor waveguides.

Research Accomplishments: Mr. Irby began to investigate the above topic and determined, with my direction, that it would be a suitable Ph.D. topic. He has begun to determine both what

experiments will need to be done and what analytical tools will need to be developed to carry out the research.

5. Erol Yurtkuran (M.S.): Mr. Yurtkuran joined the group in the Winter of 1993 and is working on ACT devices. In addition, he assisted in the biomedical ultrasound project by designing some RF circuitry needed for our novel system approach to ultrasound data acquisition.

Research Accomplishments: Mr. Yurtkuran was most heavily involved in engineering tasks in the group. This has included the creation of macros for the EESof program environment which has allowed us to perform device mask layout in this RF simulation tool environment. Currently he is working on testing of ACT devices and the RF electronics for the biomedical ultrasound system.

II. Referred Journal Articles

1. Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Mode profiles in waveguide-coupled resonators," *Journal of Applied Physics*, vol. 74, no. 8, pp. 4886-4893, October 1993.

2. Kenney, J.S. and Hunt, W.D., "A physically-based small-signal circuit model for heterostructure acoustic charge transport devices," *IEEE Transactions on Microwave Theory and Techniques*, vol. 41, no. 12, pp. 2218-2226, December 1993.

3. Kim, Y., Hunt, W.D., Hickernell, F.S. and Higgins, R.J., "Surface acoustic wave properties of ZnO films on {100}-cut <110>-propagating GaAs substrates," *Journal of Applied Physics*, vol. 75, no. 11, pp. 7299-7303, June 1, 1994.

4. Silva, M.Z. and Hunt, W.D., "A transient model for wideband piezoelectric polymer Fresnel zone plate transducers," submitted for publication in the *Journal of the Acoustical Society of America.*

III. CONFERENCE PAPERS

1. Hunt, W.D., Cameron, T., Saw, J.C.B., Kim, Y. and Suthers, M.S., "Transverse and longitudinal modes in waveguide-coupled resonators," *1993 IEEE MTT Symposium Digest*, vol. 3, pp. 1509-1512, June 1993.

2. Kenney, J.S. and Hunt, W.D., "A physically-based small-signal circuit model for heterostructure acoustic charge transport devices," *1993 IEEE MTT Symposium Digest,* vol. 3, pp. 1513-1516, June 1993.

3. Kenney, J.S. , Hunt, W.D., and May, G.S., "Yield prediction of acoustic charge transport transversal filters," *Proceedings of the 1993 International Electronics Manufacturing Technology Symposium*, pp. 390-395, October 1993.

4. Kim, Y., Hunt, W.D., Liu,Y., Jen, C.K., "Velocity surface measurements for ZnO films over {001}-cut GaAs," *1993 IEEE Ultrasonics Symposium*, vol. 1, pp. 243-248, November 1993.

IV. Patents and Invention Disclosures

Sleva, M.Z., Hunt, W.D., Briggs, R.D., Connuck, D.M., "Wideband IV acoustic microscope," submitted to the U.S. Patent Office, June 1994.

E-21-615 #5

1994-1995 PRESIDENTIAL YOUNG INVESTIGATOR PROGRAM

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices and Transducers for Biomedical Ultrasound

Investigator: William D. Hunt

Organization: School of Electrical Engineering
Georgia Institute of Technology

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Funding: $62,500

Abstract

Acoustic Charge Transport (ACT) Devices:

We are engaged in an effort to develop a high-speed, high-resolution camera for HDTV. In our approach we will collect charge from an array of superlattice avalanche photodiodes (APD) and read this charge out using the ACT phenomena. In working towards this ultimate goal we have made and will continue to make significant strides in understanding surface acoustic wave (SAW) propagation in these photodiode array structures and in developing an optimal architecture. This has included an extensive study of the SAW properties of a ZnO on GaAs structure as well as an extensive study of the waveguide properties of structures which are similar to the ultimate imager array configuration. In addition, we have progressed well in our modeling of ACT devices and measurement of noise and transport properties. Several spin-offs of this work have gained considerable interest from industry. Our extensive work in ZnO thin films has led to funding from Texas Instruments to help them develop ZnO-based thin film bulk acoustic wave resonator filters for cellular radio. We have developed a new heterostructure ACT device structure which appears to be quite robust and is garnering considerable attention from BNR/Northern Telecom---again predominantly for cellular radio applications.

Surface Acoustic Wave (SAW) Devices:

SAW devices are in widespread use as vital components in a variety of systems ranging from TV sets to communications systems to electronic test equipment. In this project we are

working with SAW devices which are to be used for cellular telephone communications. In this research we are working closely with Bell Northern Research (BNR), the research arm of Northern Telecom. We have been doing theoretical and experimental work on the device physics of the relevant SAW components. Most of our efforts to date have been focused on waveguide coupled resonators on STX-Quartz that are to be used for narrow band filters in cellular radios. In our work we will use the laser probe measurements system we have in our laboratory for examining the surface acoustic wave beam profiles in the devices of interest. We have also been working to develop a new class of resonator filters on LST-Quartz which will have little variation in performance over a wide temperature range. This is needed as the requirements for cellular radio press for low power operation over a large temperature range.

Transducers for Biomedical Ultrasound:

For several years we have been working with Dr. David Connuck of the Pediatric Cardiology Group at the Medical College of Georgia to develop an ultrasound methodology which would allow physicians to make better diagnoses and hence better treat infants and children with congenital heart defects. Specifically, we are developing wideband catheter tip transducers and the attendant signal processing system to detect the degree of lamination in the pulmonary artery of patients with congenital heart defects. To achieve this we are exploiting microelectronic fabrication techniques to develop a wideband focusing transducer and have explored some non-standard signal processing techniques which have allowed us to demonstrate the validity of our approach. A patent on our device will be issued within 3 to 6 months.

I. Research Summary

The research conducted during the third year of the PYI included the projects described above. Graduate students who were at one time or another supported by this grant and their accomplishments during this past year are listed below. In all eight undergraduate students participated in the research.

1. Michael Z. Sleva (Ph.D.): Dr. Sleva worked on the development of transducers for the intravascular ultrasound project and received his doctorate during the Fall Quarter 1994.

Research Accomplishments: Mr. Sleva continued his work on the development of wideband transducers for intravascular ultrasound. He completed the development of a microelectronic fabrication procedure for spin-cast PVDF-TrFE transducers and successfully fabricated several devices. One of the principal problems with the procedure involves the fragile nature of the etched silicon membrane. Work has continued in this area to circumvent this problem. Dr. Sleva is now an Assistant Professor of Electrical Engineering at the University of North Carolina at Charlotte.

2. Steve Kenney (Ph.D.): Dr. Kenney worked on the development of a new class of manufacturable ACT devices and completed his doctorate during the Fall Quarter 1994. This work included a collaborative effort on the development of a new ACT architecture.

Research Accomplishments: He has developed a small-signal model for ACT devices and has corroborated his theory with experiment. In addition, he has lent his considerable expertise in RF system design to the biomedical ultrasound project and has helped that effort immensely. He helped to develop a novel ACT device architecture which is more robust and manufacturable. Dr. Kenney published two journal papers and one conference paper. Dr. Kenney is now with Pacific Monolithics.

3. Houston Irby (Ph.D.): Mr. Irby selected a thesis topic in the area of acoustooptic interactions in compound semiconductor waveguides.

Research Accomplishments: Mr. Irby spent part of the summer of 1994 at Sandia National Labs developing his thesis topic. He made some critical connections with researchers at one of the nation's premier semiconductor research facilities who are interested in his work . Mr. Irby will be presenting one conference paper and will submit one journal paper during the fall of 1995.

4. Bolaji Olutade (Ph.D.): Mr. Olutade joined the group and selected as his topic, research into ZnO thin film devices.

Research Accomplishments: Mr. Olutade's work will play a vital role in the development of the ACT devices and the intravascular ultrasound devices. He has developed some state of the art models for thin film bulk acoustic wave resonator devices and implemented these models on the EESof simulation platform. His experimental work has involved fabrication and testing of ZnO devices as well as some preliminary efforts to establish the capabilities within our group to RF sputter ZnO films. During the summer of 1995 Mr Olutade conducted research at Texas Instruments Central Research Labs and as a result of his stellar performance Texas Instruments has now given us a $20,000 grant for FY '96.

II. Referred Journal Articles

1. Kenney, J.S., May, G.S. and Hunt, W.D., "Yield modeling of acoustic charge transport transversal filters," *IEEE Transactions on Semiconductor Manufacturing*, vol. 8, no. 2, pp. 207-213, May 1995.

2. Sleva, M.Z., Hunt, W.D., and Briggs, R., "Focusing performance of epoxy- and air-backed PVDF Fresnel zone plates", *Journal of the Acoustical Society of America*, vol. 96, no. 3, pp. 1627-1633, September 1994.

3. Kim, Y., Hunt, W.D., Hickernell, F.S. and Higgins, R.J., "Surface acoustic wave properties of ZnO films on {100}-cut <110>-propagating GaA substrates," *Journal of Applied Physics*, vol. 75, no. 11, pp. 7299-7303, June 1, 1994.

5. Sleva, M.Z. and Hunt, W.D., "A transient model for wideband piezoelectric polymer Fresnel zone plate transducers," submitted for publication in the *Journal of the Acoustical Society of America.*

6. Kim, Y., Hunt, W.D., Liu,Y., Jen, C.K., "Velocity surface measurements for ZnO films over {001}-cut GaAs," *Journal of Applied Physics,* vol. 73, no. 3, pp. 1455-1461, August 1,1994.

7. Smith, A.W., Kenney, J.S., Hunt, W.D., Brennan, K.F., Benz, R. and Summers, C.J., "Theoretical Calculations of Charge Confinement in a pn'np Heterojunction Acoustic Charge Transport Device," *IEEE Transactions on Electron Devices*, vol. 42, no. 5, pp. 977-990, May 1995.

8. Kim, Y., Hunt, W.D., Hickernell, F.S., and Jen, C.K., "ZnO films on {001}-cut <110>-propagating GaAs substrates for surface acoustic wave device applications," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control,* vol. 42, no. 3, pp. 351-361, May 1995.

9. Sleva, M.Z., Briggs, R.D., and Hunt, W.D., "A micromachined polyvinylidene fluoride-trifluoroethylene transducer for pulse-echo ultrasound applications," accepted for publication in the *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control.*

III. Conference Papers

1. Kenney, J.S., Briggs, R.D., Smith, A.W., Yurtkuran, E.K., Irby, J.H., Hunt, W.D., Cameron, T.P., and Saw, J.C.B., "A heterostructure acoustic charge transport delay line for SONET radio adaptive multipath equalization," *1994 IEEE MTT Symposium Digest*, pp. 1213-16, June 1994.

2. Kim, Y., Hunt, W.D. and Hickernell, F.S., "Reflection properties of metallic gratings on ZnO films over GaAs substrates," *Proceedings of the 1994 IEEE Ultrasonics Symposium*, pp. 407-410, Cannes, France, November 1994.

3. Cameron, T.P., Hunt, W.D., Liaw, H.M., and Hickernell, F.S., "Waveguide coupled resonator filters on Aluminum Nitride-on-Silicon," *Proceedings of the 1994 IEEE Ultrasonics Symposium*, pp. 371-374, Cannes, France, November 1994.

OMB Number 3145-0058

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Georgia institute of Technology
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NATIONAL SCIENCE FOUNDATION
FINAL PROJECT REPORT

PART I - PROJECT IDENTIFICATION INFORMATION

1. Program Official/Org. Thomas Hsiang

2. Program Name Electrical and Communications Systems

3. Award Dates (MM/YY) **From:** 08/15/89 **To:** 01/31/96

4. Organization and Address
Georgia Institute of Technology
School of Electrical and Computer Engineering
Atlanta, Georgia 30332-0250

5. Award Number ECS-8957044

6. Project Title PYI Award

NSF Grant Conditions (Article 17, GC-1, and Article 8, FDP-11) require submission of a Final Project Report (NSF Form 98A) to the NSF Program Officer no later than 90 days after the expiration date of the award. Final Project Reports for expired awards must be received before new awards can be made (NSF Grants Policy Manual Section 340).

Below, or on a separate page attached to this form, provide a summary of the completed projects and technical information. Be sure to include your name and award number on each separate page. See below for more instructions.

PART II - SUMMARY OF COMPLETED PROJECT (for public use)

The summary (about 200 words) must be self-contained and intelligible to a scientifically or technically literate reader. Without restating the project title, it should begin with a topic sentence stating the project's major thesis. The summary should include, if pertinent to the project being described, the following items:

- The primary objectives and scope of the project
- The techniques or approaches used only to the degree necessary for comprehension
- The findings and implications stated as concisely and informatively as possible

PART III - TECHNICAL INFORMATION (for program management use)

List references to publications resulting from this award and briefly describe primary data, samples, physical collections, inventions, software, etc., created or gathered in the course of the research and, if appropriate, how they are being made available to the research community. Provide the NSF Invention Disclosure number for any invention.

I certify to the best of my knowledge (1) the statements herein (excluding scientific hypotheses and scientific opinion) are true and complete, and (2) the text and graphics in this report as well as any accompanying publications or other documents, unless otherwise indicated, are the original work of the signatories or of individuals working under their supervision. I understand that willfully making a false statement or concealing a material fact in this report or any other communication submitted to NSF is a criminal offense (U.S. Code, Title 18, Section 1001).

	10-7-96
Principal Investigator/Project Director Signature	Date

IMPORTANT:
MAILING INSTRUCTIONS
Return this *entire* packet plus all attachments in the envelope attached to the back of this form. Please copy the information from Part 1, Block I to the *Attention block* on the envelope.

PROJECT REPORT — SUMMARY DATA ON PROJECT PERSONNEL

(To be submitted to cognizant Program Officer upon completion of project)

The data requested below are important for the development of a statistical profile on the personnel supported by Federal grants. The information on this part is solicited in response to Public Law 99-383 and 42 USC 1885C. All information provided will be treated as confidential and will be safeguarded in accordance with the provisions of the Privacy Act of 1974. You should submit a single copy of this part with each final project report. However, submission of the requested information is not mandatory and is not a precondition of future award(s). Check the "Decline to Provide Information" box below if you do not wish to provide the information.

Please enter the numbers of individuals supported under this grant.
Do not enter information for individuals working less than 40 hours in any calendar year.

	Senior Staff		Post-Doctorals		Graduate Students		Under-Graduates		Other Participants[1]	
	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.	Male	Fem.
A. Total, U.S. Citizens										
B. Total, Permanent Residents										
U.S. Citizens or Permanent Residents[2]:										
American Indian or Alaskan Native										
Asian			1							
Black, Not of Hispanic Origin					1					
Hispanic										
Pacific Islander										
White, Not of Hispanic Origin	1				4		2	3		
C. Total, Other Non-U.S. Citizens										
Specify Country										
1. Korea			1							
2.										
3.										
D. Total, All participants (A + B + C)										

Disabled[3]

☐ Decline to Provide Information: Check box if you do not wish to provide this information (you are still required to return this page along with Parts I-III).

Category includes, for example, college and precollege teachers, conference and workshop participants.

Use the category that best describes the ethnic/racial status to all U.S. Citizens and Non-citizens with Permanent Residency. *(If more than one category applies, use the one category that most closely reflects the person's recognition in the community.)*

A person having a physical or mental impairment that substantially limits one or more major life activities; who has a record of such impairment; or who is regarded as having such impairment. *(Disabled individuals also should be counted under the appropriate ethnic/racial group unless they are classified as "Other Non-U.S. Citizens.")*

MERICAN INDIAN OR ALASKAN NATIVE: A person having origins in any of the original peoples of North America and who aintains cultural identification through tribal affiliation or community recognition.

SIAN: A person having origins in any of the original peoples of East Asia, Southeast Asia or the Indian subcontinent. This area ıdes, for example, China, India, Indonesia, Japan, Korea and Vietnam.

ACK, NOT OF HISPANIC ORIGIN: A person having origins in any of the black racial groups of Africa.

SPANIC: A person of Mexican, Puerto Rican, Cuban, Central or South American or other Spanish culture or origin, regardless of race.

CIFIC ISLANDER: A person having origins in any of the original peoples of Hawaii, the U.S. Pacific territories of Guam, American moa, and the Northern Marinas; the U.S. Trust Territory of Palau; the islands of Micronesia and Melanesia; or the Philippines.

ITE, NOT OF HISPANIC ORIGIN: A person having origins in any of the original peoples of Europe, North Africa, or the Middle East.

FINAL REPORT: PRESIDENTIAL YOUNG INVESTIGATOR PROGRAM

Title: Acoustic Charge Transport Devices, Surface Acoustic Wave Devices and Transducers for Biomedical Ultrasound

Investigator: Dr. William D. Hunt
Associate Professor

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Project Summary

During the course of this program a number of projects were undertaken, all of which had elements of acoustics and microelectronics. Specifically, we sought to advance the state-of-art in surface acoustic wave (SAW) devices, acoustic charge transport (ACT) devices, acoustoelectric amplifiers and transducers for intravascular ultrasound. The funding for this project has supported, all or in part, seven Ph.D. students, and fourteen undergraduate students. It has also spawned industrial funding from Nortel (formerly Northern Telecom) and Texas Instruments along with government funding from DARPA, NIH and US Customs and funding from the American Heart Association. The accomplishments associated with this project is summarized in this report.

I. INTELLECTUAL PRODUCTS

A. Most Significant Intellectual Products [1]

1. The extension of the Laguerre polynomial technique, first developed by Datta and Hunsinger, for the computation of the acoustic fields associated with a SAW propagating in a multilayer structure.[4] This provides us with the detailed information we need to compute the electrostatic potential propagating with the leaky wave in an arbitrary ACT architecture. We used this extensively in the evaluation of candidate ACT architectures and for the development of integrated acousto-optic devices in multilayered structures.

2. The introduction of the stack-matrix approach as an effective, efficient and accurate means of computing the mode profiles in SAW device architectures such as the waveguide-coupled resonator structures which utilize guided SAWs.[5] The paper describing this work includes both the stack matrix theory and the clear experimental demonstration of its accuracy.

3. The development of a robust ACT architecture which is relatively impervious to surface state concentration and is expected to prove to be more manufacturable than previous ACT architectures.[18] Preliminary experimental results (not yet published) indicate that device yields should be in excess of 50%.

4. The thorough investigation of the SAW properties of ZnO-on-GaAs structures.[9,12,13,16] This included the calculation of the ideal depth for the transport channel in ACT devices and the optimum ZnO thickness. It was found that the inclusion of ZnO results in a velocity surface which is concave upward and hence more diffractive than bare GaAs. The absolute importance of a protective layer, such as silicon nitride, was established to prevent doping of either the ZnO or the GaAs. Grating acoustic reflectivity studies were performed which demonstrated that it is possible to electrodes with zero reflectivity. Further, the Datta-Hunsinger technique for the calculation of electrode scattering parameters was extended to the case of an electrode on a multilayer substrate.

B. Published Books and Parts of Books

1. "Surface Acoustic Waves in AlGaAs," in *Properties of Aluminium Gallium Arsenide,* ed. S. Adachi, IEE Press; Stevenage, United Kingdom; 1993.

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[1] Superscript numbers refer to publications listed under **Journal Publications** in this vita

C. Refereed Publications

C.1. Journal Publications

1. Bright, V. M. and Hunt, W. D., "Bleustein-Gulyaev waves in gallium arsenide and other piezoelectric cubic crystals," *Journal of Applied Physics*, vol. 66, no. 4, pp. 1556-1564, August 1989.

2. Bright, V. M. and Hunt, W. D., "Acousto-optic interactions between optical waves and Bleustein-Gulyaev surface acoustic waves in gallium arsenide and other piezoelectric cubic crystals," *Journal of Applied Physics*, vol. 67, no. 2, pp. 654-662, January 1990.

3. Bright, V. M. and Hunt, W. D., "Light diffraction by Bleustein-Gulyaev surface acoustic waves in Gallium Arsenide and other piezoelectric cubic crystals," *Journal of Applied Physics,* vol. 68, no. 5, pp. 1985-1992, September 1990.

4. Kim, Y. and Hunt, W. D., "Acoustic fields and velocities for surface acoustic wave propagation in multilayered structures: An extension of the Laguerre polynomial approach," *Journal of Applied Physics*, vol. 68, no. 10, pp. 4993-4997, November 15, 1990.

5. Hunt, W. D., Kim, Y., and Fliegel, F. M., "A synopsis of surface acoustic wave propagation in {100}-cut <110>-propagating gallium arsenide," *Journal of Applied Physics,* vol. 69, no. 4, pp. 1936-1941, February 1991.

6. Kenney, J. S. and Hunt, W. D., "Synthesis of acoustic matching networks by discrete space Fourier transform method," *Journal of the Acoustical Society of America*, vol. 89, no. 5, pp. 2123-2130, May 1991.

7. Bright, V. M. and Hunt, W. D., "Analysis of Bleustein-Gulyaev wave propagation under thin periodic metal electrodes," *Journal of Applied Physics*, vol. 70, no. 2, pp. 594-602, July 1991.

8. Bright, V. M., Kim, Y., and Hunt, W. D., "Study of surface acoustic waves on the {110} plane of gallium arsenide," *Journal of Applied Physics,* vol. 71, no. 2, pp. 597-605, January 1992.

9. Kim, Y. and Hunt, W. D., "An analysis of surface acoustic wave propagation in a piezoelectric film over a GaAs/AlGaAs heterostructure," *Journal of Applied Physics*, vol. 71, no. 5, pp. 2136-2142, March 1992.

10. Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Mode profiles in waveguide-coupled resonators," *Journal of Applied Physics*, vol. 74, no. 8, pp. 4886-4893, October 1993.

11. Kenney, J.S. and Hunt, W.D., "A physically-based small-signal circuit model for heterostructure acoustic charge transport devices," *IEEE Transactions on Microwave Theory and Techniques*, vol. 41, no. 12, pp. 2218-2226, December 1993.

12. Kim, Y., Hunt, W.D., Hickernell, F.S. and Higgins, R.J., "Surface acoustic wave properties of ZnO films on {100}-cut <110>-propagating GaAs substrates," *Journal of Applied Physics*, vol. 75, no. 11, pp. 7299-7303, June 1994.

13. Kim, Y., Hunt, W.D., Liu,Y., Jen, C.K., "Velocity surface measurements for ZnO films over {001}-cut GaAs," *Journal of Applied Physics*, vol. 73, no. 3, pp. 1455-1461, August 1994.

14. Sleva, M.Z., Hunt, W.D., and Briggs, R., "Focusing performance of epoxy- and air-backed PVDF Fresnel zone plates", *Journal of the Acoustical Society of America*, vol. 96, no. 3, pp. 1627-1633, September 1994.

15. Smith, A.W., Kenney, J.S., Hunt, W.D., Brennan, K.F., Benz, R. and Summers, C.J., "Theoretical Calculations of Charge Confinement in a pnpnp Heterojunction Acoustic Charge Transport Device," *IEEE Transactions on Electron Devices*, vol. 42, no. 5, pp. 977-990, May 1995.

16. Kim, Y., Hunt, W.D., Hickernell, F.S., and Jen, C.K., "ZnO films on {001}-cut <110>-propagating GaAs substrates for surface acoustic wave device applications," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 42, no. 3, pp. 351-361, May 1995.

17. Kenney, J.S., May, G.S. and Hunt, W.D., "Yield modeling of acoustic charge transport transversal filters," *IEEE Transactions on Semiconductor Manufacturing*, vol. 8, no. 2, pp. 207-213, May 1995.

18. Danicki, E. and Hunt, W.D., "On spurious bulk wave excitation in SAW grating reflectors on GaAs (001) (110)," *Archives of Acoustics*, vol. 20, no. 2, pp. 171-175, 1995.

19. Sleva, M.Z., Briggs, R.D., and Hunt, W.D., "A micromachined polyvinylidene fluoride-trifluoroethylene transducer for pulse-echo ultrasound applications," *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 43, no. 2, pp. 257-262, March 1996.

20. Sleva, M.Z., Hunt, W.D. and Connuck, D.M., "A network analyzer-based tissue characterization system" *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, vol. 43, no. 4, pp. 626, July 1996.

C.2. Refereed Conference Proceedings

1. Bright, V. M. and Hunt, W. D., "Light diffraction by Bleustein-Gulyaev surface acoustic waves in Gallium Arsenide and other piezoelectric cubic crystals," *Proceedings of the 1989 IEEE Ultrasonics Symposium*, vol. 1, pp. 515-520, October 1989.

2. Tanski, W. J., Merritt, S. W., Cullen, D. E., Carroll, R. D., Branciforte, E. J., Sacks, R. N., and Hunt, W. D., "Heterostructure acoustic charge transport technology for programmable transversal filters," *1990 IEEE MTT Symposium Digest*, pp. 1107-1110, May 1990.

3. Kenney, J. S. and Hunt, W. D., "Synthesis of acoustic matching networks by discrete space Fourier transform method," *Proceedings of the 1990 IEEE Ultrasonics Symposium*, vol. 1, pp. 581-586, December 1990.

4. Kim, Y. and Hunt, W. D., "A Laguerre polynomial approach to surface acoustic wave propagation in multilayered structures," *Proceedings of the 1990 IEEE Ultrasonics Symposium*, vol. 1, pp. 171-183, December 1990.

5. Bright, V. M. and Hunt, W. D., "Bleustein-Gulyaev wave propagation under periodic metal gratings," *Proceedings of the 1990 IEEE Ultrasonics Symposium*, pp. 173-178, December 1990.

6. Sleva, M. Z. and Hunt, W. D., "A PVDF Fresnel Lens Transducer," *Proceedings of the 1990 IEEE Ultrasonics Symposium*, vol. 2, pp. 821-826, December 1990.

7. Bright, V. M., Kim, Y., and Hunt, W. D., "Surface acoustic waves on the {110}-cut of gallium arsenide," *Proceedings of the 1991 IEEE Ultrasonics Symposium*, vol. 1, pp. 419-424, December 1991.

8. Hunt, W.D., Cameron, T., Saw, J.C.B, Kim, Y. and Suthers, M., "Mode profiles in waveguide-coupled resonators," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, vol. 1, pp. 45-50, October 1992.

9. Kim, Y., Hunt, W.D., Hickernell, F.S. and Higgins, R.J., "Surface acoustic wave properties of ZnO films on {100}-cut <110>-propagating GaAs substrates," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, vol. 1, pp. 413-417, October 1992.

10. Sleva, M.Z. and Hunt, W.D., "Transient analysis of a PVDF Fresnel zone plate," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, vol. 1, pp. 593-598, October 1992.

11. Kenney, J.S. and Hunt, W.D., "A small-signal equivalent circuit model for heterostructure acoustic charge transport devices," *Proceedings of the 1992 IEEE Ultrasonics Symposium*, vol. 1, pp. 215-220, October 1992.

12. Hunt, W.D., Cameron, T., Saw, J.C.B., Kim, Y. and Suthers, M.S., "Transverse and longitudinal modes in waveguide-coupled resonators," *1993 IEEE MTT Symposium Digest*, vol. 3, pp. 1509-1512, June 1993.

13. Kenney, J.S. and Hunt, W.D., "A physically-based small-signal circuit model for heterostructure acoustic charge transport devices," *1993 IEEE MTT Symposium Digest*, vol. 3, pp. 1513-1516, June 1993.

14. Kenney, J.S. , Hunt, W.D., and May, G.S., "Yield prediction of acoustic charge transport transversal filters," *Proceedings of the 1993 International Electronics Manufacturing Technology Symposium*, pp. 390-395, October 1993.

15. Kim, Y., Hunt, W.D., Liu,Y., Jen, C.K., "Velocity surface measurements for ZnO films over {001}-cut GaAs," *1993 IEEE Ultrasonics Symposium*, vol. 1, pp. 243-248, November 1993.

16. Kenney, J.S., Briggs, R.D., Smith, A.W., Yurtkuran, E.K., Irby, J.H., Hunt, W.D., Cameron, T.P., and Saw, J.C.B., "A heterostructure acoustic charge transport delay line for SONET radio adaptive multipath equalization," *1994 IEEE MTT Symposium Digest*, pp. 1213-16, June 1994.

17. Kim, Y., Hunt, W.D. and Hickernell, F.S., "Reflection properties of metallic gratings on ZnO films over GaAs substrates," *Proceedings of the 1994 IEEE Ultrasonics Symposium*, pp. 407-410, Cannes, France, November 1994.

18. Cameron, T.P., Hunt, W.D., Liaw, H.M., and Hickernell, F.S., "Waveguide coupled resonator filters on Aluminum Nitride-on-Silicon," *Proceedings of the 1994 IEEE Ultrasonics Symposium*, pp. 371-374, Cannes, France, November 1994.

19. Cameron, T.P. and Hunt, W.D., "SAW Amplifiers on multilayer GaAs substrates," *Proceedings of the 1995 IEEE Ultrasonics Symposium*, pp. 349-352, Seattle, WA, November 1995.

20. Woodberry, M.E. and Hunt, W.D., "A comparison of temperature performance of SAW delay lines built on LST-cut Quartz," *Proceedings of the 1995 IEEE Ultrasonics Symposium*, pp. 375-378, Seattle, WA, November 1995.

21. Irby, J.H., Hunt, W.D., and Corless, R.F., "Characterization of SAW devices up to 2.6 GHz on GaAs and InP," *Proceedings of the 1995 IEEE Ultrasonics Symposium*, pp. 397-400, Seattle, WA, November 1995.

D. Presentations

1. "Acoustic aspects of acoustic charge transport devices," invited talk presented at the Fall 1990 meeting of the Acoustical Society of America in San Diego, California.

2. "An Acoustic Charge Transport Imager for HDTV Applications," Invited talk at the Fall 1995 meeting of the Society of Motion Picture and Television Engineers in New Orleans, Louisiana.

3. "A Review of Progress in Acoustic Charge Transport (ACT) Device Technology," invited talk presented at the Spring 1996 meeting of the Acoustical Society of America in Indianapolis, IN.

II. STUDENT INTERACTIONS

A. Postdoctoral Fellows

1. Dr. Yoonkee Kim, June 1993 to June 1994, worked on SAW propagation in ZnO-on-GaAs structures

B. Ph.D. Students

B.1. Graduated Students

1. Victor M. Bright, *Shear Horizontal Surface Acoustic Waves*, Spring 1992.
   Position: Associate Professor of Electrical Engineering; Air Force Institute of Technology

2. Yoonkee Kim, *Surface Acoustic Wave Propagation in Multilayered and Multichannel Waveguide Structures*, Spring 1993.
   Position: Research Scientist; Army Research Lab; Ft Monmouth, NJ

3. Michael Z. Sleva, *Toward Integrated, PVDF-TrFE Fresnel Zone Plate Transducers for Intravascular Pulse-Echo Applications*, Summer 1994.
   Position: Assistant Professor of Electrical Engineering; University of North Carolina at Charlotte

4. James S. Kenney, *Modeling Heterostructure Acoustic Charge Transport Devices for Performance and Manufacturability*, Fall 1994.
   Position: Manager of RF IC Product Engineering; RF Monolithics; Sunnyvale, CA

5. Thomas P. Cameron, *Low-Voltage SAW Amplifiers on Multilayer GaAs/ZnO Substrates*, Spring 1996.

Position: Manager, Filters and RF Packaging; Wireless Networks; Northern Telecom; Ottawa, Ontario; Canada

B.2. Current Students

1. J. Houston Irby, Acoustic Distributed Bragg Reflector Lasers,
   Degree expected: Fall 1997
   Began in group: Winter 1992
   Passed Preliminary Exam: Spring 1992
   Passed Qualifying Exam: Fall 1995

2. Bolaji Olutade, Integrated Bulk Acoustic Wave Resonator Filters for Wireless Communications.
   Degree expected: Winter 1998
   Began in group: Winter 1994
   Passed Preliminary Exam: Fall 1993

C. Undergraduate Students

1. Jeffrey Vetter, UROP[2] (Undergraduate Research Opportunities) student, November 1987 to June 1989, writing the software to control Professor Hunt's laboratory measurement system.

2. Sanjay Y. Mohan, UROP student, October 1988 to June 1989, designing and building electronics and enhancing Professor Hunt's laboratory system.

3. Charmen E. Warbington, UROP student, Summer 1989 to Summer 1991, microelectronic fabrication.

4. Terry J. Campbell, UROP student, Summer 1989 to June 1991, medical ultrasonics.

5. John Fava, UROP student, Summer 1990 to June 1991, CAD development for microelectronic mask layout and general computer assistance.

6. Mark Ewbank, UROP student, Fall 1990 to June 1991, development of an entrepreneur course in electrical engineering.

7. Cecilia Vinson, UROP student, Winter 1991 to Summer 1992, medical ultrasonics.

8. Steven Smith, UROP student, Summer 1991, software development.

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[2] I have classified all the undergraduates doing research in my lab as UROP students even though they may not have been enrolled in the School of ECE's formal UROP course sequence. Almost all of these students were paid out of my research grants.

9. Ron Briggs, UROP student, Fall 1991 to Spring 1993, laser probe laboratory development and microelectronic fabrication.

10. Jeff Bauch, UROP student, Fall 1993 to Summer 1994, development of software for automated testing.

11. Eric Hayes, UROP student; Winter 1993 to Spring 1994, ACT device design, fabrication and testing.

12. Acha Leke, UROP student, Fall 1993 to Spring 1994, RF signal processing applied to intravascular ultrasound.

13. Kym Olynger, UROP student, Fall 1993 to Summer 1994, microelectronic fabrication for intravascular ultrasound transducers.

14. Chris Fuller, UROP student, Fall 1994 to Spring 1996, testing of intravascular ultrasound transducers and some integrated optic device testing.

D. Other Teaching Activities

1. One of two Georgia Tech faculty members that were selected to participate in the "NSF Presidential Young Investigator Colloquium on U.S. Engineering, Mathematics and Science Education for the Year 2010 and Beyond," held November 1990 in Washington, D.C.

2. One of four Georgia Tech faculty members to participate in the National Research Council/National Science Foundation Convocation, "From Analysis to Action: Undergraduate Education in Science, Mathematics, Engineering, and Technology," March 1995 in Washington, D.C. Dr. Hunt was the only Georgia Tech faculty member in attendance at this meeting or the one described in C.1. who did not have an administrative title.

3. Founded the Undergraduate Research Opportunities Program (UROP) in the School of Electrical and Computer Engineering, 1988.

III. GRANTS AND CONTRACTS[3]

A. As Principal and Co-Principal Investigator

1. National Science Foundation
Engineering Research Equipment Grant: Network Analyzer for Laser Probe Measurement System

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[3] Except where otherwise stated, Professor Hunt was the PI for all of the grants and contracts listed

Amount funded: $33,219
Dates: (8/1/88 to 1/31/90)

2. DuPont Corporation
DuPont Young Faculty Award
Amount funded: $12,500
Dates: (7/1/88 to 6/30/89)

3. Motorola Inc. and the Georgia Tech Manufacturing Research Center
Flatness of Printed Circuit Boards
Amount funded: $15,000
Dates: (9/1/88 to 8/31/89)

4. National Science Foundation
Presidential Young Investigator Award
Amount funded: $312,500
Dates: (10/1/89 to 9/31/94)

5. Motorola, DEC, IBM, and the Georgia Tech Manufacturing Research Center
Advanced CAD Tools for Printed Circuit Board Design
Amount funded: $69,968
Dates: (3/1/89 to 2/28/90)

6. National Science Foundation
Research Experience for Undergraduates Supplement
Amount funded: $5,000
Dates: (6/89 to 5/90)

7. National Institutes of Health
Biomedical Research Support Grant (BRSG): A Novel Ultrasonic Scheme to Monitor Carotid Plaque Progression
Amount funded: $5,000
Dates: (6/1/89 to 3/31/89)

8. National Science Foundation
Research Experience for Undergraduates Supplement
Amount funded: $9,000
Dates: (4/1/90 to 4/1/91)

9. National Science Foundation
Instrumentation and Laboratory Improvement: Microelectronics Instructional; Processing Laboratory
Amount funded: $75,000
Dates: 3/15/91

10. American Heart Association--Georgia Affiliate
Ultrasonic Tissue Characterization of Carotid Plaque
Amount funded: $30,000
Dates: (7/1/90-6/30/90)

11. National Institutes of Health
NIH Small Instrumentation Program: Programmable Function Generator and Digital Oscilloscope
Amount funded: $21,539
Dates: (7/1/90-6/30/91)

12. NASA/ARPA
An Acoustic Charge Transport Imager for High Definition Television Applications
Amount funded: $4,628,000
Dates: (10/1/91 to 6/30/97)
Note: Professor Hunt was the Principal Investigator (PI) for this project. There are two co-PIs.

13. BNR, Inc.
Surface Acoustic Wave Devices for Telecommunication Systems
Amount funded: $262,500
Dates: (3/1/91 to 9/31/97)

14. Georgia Tech/Medical College of Georgia Biomedical Research and Education Program
Use of Intravascular Ultrasound in Congenital Heart Disease
Amount funded: $30,000
Dates: (8/1/92 to 6/30/93)

15. Advanced Technology Development Center
A Wideband Ultrasound Transducer Chip for an Intravascular Acoustic Microscope
Amount funded: 50,000
Dates: (9./1/94 to 6/30/95)

16. Texas Instruments
Integrated RF Filters for a Single-Chip RF Front-end
Amount funded: $20,000
Dates: (1/1/96 to 12/31/96)

18. Institute for Bioengineering and Biosciences
SAW Immunoassay Chemical Sensors
Amount funded: $9,000
Dates: (10/1/95 to 6/30/96)

19. U.S. Customs Service
SAW Chemical sensors for illicit materials
Amount funded: $25,000
Dates: (9/30/96 to 8/31/97)

Total Funding to Date: **$5,216,226**