RESUME: Professor A.G. Every

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Born: 22 November 1940, Germiston, South Africa
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Academic Qualifications:

- BSc, Majors in Physics, Mathematics and Applied Mathematics, University of the Witwatersrand, (1962).
- BSc (Hons) in Physics, University of the Witwatersrand, (1964).
- MSc in Physics, University of the Witwatersrand, (1965).
- PhD in Theoretical Solid State Physics, Reading University, UK, (1970).

Service to Profession and Awards:

- Fellow of the Royal Society of South Africa
- Member of the Academy of Science of South Africa
- Associate Editor of the international journal Ultrasonics
- An Associate of the CSIR (1998).
- Recipient of Reisner Award
- Member of the South African Institute of Physics.
- Session Chairman for numerous local and international conferences.
- Referee for numerour international journals.
- Member of the International Advisory Committees for the conferences Phonons'98 (Lancaster), Phonons'01 (Dartmouth College) and Phonons'04 (St Petersburg).
- Represented Wits at the Foundation Meeting of the World Federation of NDE Centers in Utah, July 1998.
- Played a driving role in the US-Africa Workshop on Materials Science, which took place in Pretoria in August 2000. The Workshop brought together representatives of the materials science communities and science funding agencies in the USA, South Africa and 14 other African countries. The purpose of

the Workshop was to recommend on mechanisms for enhanced international collaboration in materials research, and to identify areas in which collaboration could be profitably fostered.

- Member of the International Advisory Committee for the first meeting of the African MRS, Dakar, Senegal, Dec. 2002, of the Organising Committee for the Second Meeting of the African MRS, Johannesburg, Dec. 2003, and of the Scientific Committee of the Third International Conference of the African Materials Research Society, Marrakech, Morocco, December 2005.
- Member of the Organising Committee of the Euro-African Workshop on Acoustics, UCAM, Marrakech, Morocco, December 2005.
- Member of the Scientific Advisory Committees for the International Symposium on Mechanical Waves in Solids, Hangzhou, China, May 2006.

Research:

Most of my research falls within the broad field of acoustic wave propagation in elastically anisotropic solids. My researches are of a theoretical nature, and rely fairly heavily on computer simulations, not as an end in themselves, but as a way of gaining a deeper understanding of physical phenomena, and uncovering underlying regularities and patterns. Generally I find that the graphical results emerging from computer simulations direct one's attention to the salient features of a problem. I try to work on topics of current interest in my field, and wherever possible to collaborate with experimental groups, or at least work on problems that have a direct bearing on experiment. I know in broad outline what the general area of my research will be during the next few years, but cannot predict with any assurance the specific problems I will be working on. The projects I assign students to are more clear-cut, with reasonably well defined goals and a high probability of success, and are selected with an eye to developing their scientific skills. The main avenues of research I have been involved with in the past, and am likely to continue with in the immediate future are as follows:

Ballistic Phonon Transport

Prior to 1990 my research was mainly concerned with ballistic transport of high frequency thermal phonons, in particular with the phonon focusing patterns of crystals of cubic and lower symmetry, surface directivity effects and pseudo-surface wave structures in phonon imaging, the formation of caustics, acoustic symmetry in phonon imaging, phonon focusing in piezoelectric crystals, and the effects of first order spatial dispersion on phonon focusing. From the early 1990's, the emphasis of my research has shifted towards lower frequency phenomena, but I have kept a hand in phonon transport, for example, publishing with R. Raj et al. on thermal conductivity of diamond composites, with V. Neiman on electro-acoustic waves and phonon focusing in paratellurite, and A.A. Maznev on the focusing of surface acoustic waves. My results in the field of phonon transport have been reviewed in the monograph "Imaging Phonons" by J.P. Wolfe (CUP, 1998). At present I have a student, K. Jakata, working on the effects of spatial dispersion in phonon focusing. The interpretation of dispersive phonon images in the past has usually been based on lattice dynamical models. Since the phonons concerned do not extend very far from the centre of the Brillouin zone, we believe that the observations can equally well be explained by a modification of continuum elasticity incorporating second order spatial dispersion.

Lower Frequency Coherent Wave Phenomena; Laser Ultrasound

Since 1990 my interests have shifted towards lower frequency coherent phenomena encountered in ultrasonics, acoustics and elsewhere. I have found that many concepts developed within the context of phonon transport can be adapted for application in these areas. Thus, for instance, in phonon physics the wave surface represents the locus of points in a solid reached by phonons released in a pulse at the origin. In ultrasonics and seismology, it is the locus of singularities in transient waveforms generated by an impulsive or suddenly applied point force. Anisotropy focusing produces intense caustics in phonon focusing patterns, while for lower frequency coherent excitation these caustics unfold into Airy and higher order diffraction patterns. The polarization of modes has analogous effects at thermal phonon and ultrasonic frequencies. The main difference, at least in the problems I have studied, is that phonon transport is treated as an incoherent far-field effect, while coherence and diffraction are key issues in the acoustic phenomena. My interest in this area arose during a sabbatical I spent at Cornell University in 1990 with the Group of W. Sachse, during which I became involved in the field of laser ultrasound. The main outcomes during this and the early ensuing period were:

- The development of a technique called scan imaging of laser generated ultrasound of anisotropic solids, and the interpretation of the wave arrivals present in scan images on the basis of ultrasonic group velocities (with Sachse and Castagnede).
- The development of a method for determining the elastic constants of anisotropic solids from measured group velocity data, and an investigation of the sensitivity and numerical instabilities in the inversion algorithms used.
- Focusing of acoustic energy at the conical point in the wave surface of zinc, and the relationship of this to the phenomenon of external conical refraction (with Kim and Sachse).

Elastodynamic Green’s Functions and other Fundamental Studies

From the early 1990’s I have been engaged in the study of elastodynamic Green’s functions and other fundamental studies. Much of this work feeds directly into applications in the fields of acoustic microscopy and surface Brillouin scattering, and has been done in collaboration with K.Y. Kim (Cornell), A.A. Maznev (Phillips, USA), A.L. Shuvalov (Bordeaux), M. Deschamps (Bordeaux), G.A.D. Briggs (Oxford), P. Zinin (Hawaii), J. Kaplunov (Brunel), G. Rogerson (Keele) and others. Kim and I to start with treated the dynamic Greens functions of the infinite continuum, and later with Maznev we developed methods for calculating the interior and surface dynamic responses of an anisotropic elastic half-space to line and point dynamicsurface forces. We have applied these to interpreting capillary fracture and other experimental results of Kim, and to acoustic microscopy. I have extensively researched the spatial and temporal frequency domain dynamic Greens functions of anisotropic solids with and without surface layers, for application to surface Brillouin scattering.

Collaboration with Maznev: I have also completed a number of other related projects with Maznev, concerned with phonon focusing in surfaces and thin anisotropic plates, and secluded supersonic surface waves. These were initiated during a period of several months he spent with me at the University of the Witwatersrand (Wits).

Collaboration with A.L. Shuvalov: Dr A.L. Shuvalov has spent several periods of a few months each, working with me at Wits. We have published on the following fundamental issues concerned with wave propagation in elastically anisotropic solids:

- The evolution of phonon focusing caustics under linear spatial dispersion.
- The curvature of the acoustic slowness surface of anisotropic solids near symmetry axes and points of conical degeneracy
- How the change in sign of the curvature of the acoustic slowness surface in a symmetry plane is associated with phonon focusing cusps
- General features of the dispersion relations of surface acoustic waves in coated solids, studied by the impedance method

Collaboration with M. Deschamps: I have had an association lasting several years with M. Deschamps and his group at the University of Bordeaux. I have made several research visits to Bordeaux and M. Deschamps and O. Poncelet have visited me at Wits. We have worked on:

- Point focus acoustic microscopy of anisotropic solids
- The Green's function of a half space
- The diffraction extension to cuspidal edges in the wave surface of anisotropic solids

Effects of Spatial Dispersion on Wave Arrival Singularities in Anisotropic Solids: This project is being carried out in collaboration with J. Kaplunov (Brunel) and G. Rogerson (Keele), both of whom have visited Wits. I have recently spent a 2 month period at Brunel. Our primary objective, which we have made some progress towards, is to determine how wave arrival singularities in elastodynamic Green's functions of anisotropic solids unfold under the influence of spatial dispersion. We have a paper on this submitted for publication, which is an outgrowth of an earlier Phys. Rev paper of mine on the unfolding of wave arrivals in the point- and line-force Green's functions of isotropic solids.

Acoustic Microscopy

My contributions to acoustic microscopy have embraced several different aspects of the subject. A brief synopsis of these contributions, arranged more or less chronologically as they were done, is as follows:

- A detailed analysis of phase singularities in scanning acoustic microscopy, in collaboration with the group of W. Grill (Goethe University, Frankfurt). We have explored the various scenarios in which phase singularities can arise, and have studied the topology of phase jump lines and how they connect phase singularities of opposite signs, and how phase singularities can only emerge or disappear in opposite sign pairs.
- Study of the focusing of fast transverse modes in silicon at ultrasonic frequencies using focusing transducers (with K.Y. Kim and W. Sachse).

- Calculations carried out at Oxford University in collaboration with G.A.D. Briggs, that account for experimental results obtained by Wolfe et al. on a number of elastically anisotropic solids using a two focus probe technique. The one transducer excites the surface and the second transducer senses the dynamic response elsewhere on the surface. In our papers we explore in depth the damped Rayleigh wave, the Scholte wave and other surface excitations of water loaded solid surfaces.
- Analysis carried out at the University of Illinois in collaboration with the group of J.P. Wolfe, concerned with the excitation of Scholte waves at the fluid-loaded surfaces of solids with properties that vary periodically along the surface (phononic crystals). We have shown that when the liquid-loaded surface of a phononic crystal is insonified, Umklapp processes involving a change in the in-plane component of the wave vector by a reciprocal lattice vector of the phononic crystal, allow coupling into Scholte interfacial waves.
- A project with student G. Amulele, using the scanning probe equipment at the CSIR (Pretoria) to measure the wall thickness of single crystal superalloy jet engine turbine blades, and a specially cast test specimen. In the process of this study I developed a hybrid ray model, which he has applied with great success to his measurements. It is computationally simpler than detailed stationary phase calculations. The results have been presented at several NDT conferences, and culminated in a paper in the IEEE Trans. on UFFC.
- Point-focus acoustic microscopy (AM) modelling in collaboration with M. Deschamps (Bordeaux). We have explored in detail how the point focus acoustic materials signature V(z) of an anisotropic solid yields the extremal values of the directionally dependent SAW velocities. We have discussed the potential use of these findings for determining elastic constants, crystallographic orientation, residual stress and over-layer properties.
- Transmission acoustic microscopy (TAM) investigations of bulk acoustic wave fields in anisotropic solids: This project was initiated in 2003, and is a collaboration with W Grill (Leipzig) and M Pluta (Wroclaw). The project is concerned with the acoustic wave fields encountered in phase sensitive acoustic microscopy (PSAM) applied to anisotropic solids. We make extensive use of fast Fourier transforms to treat the forward and various inverse problems, and have considered monochromatic and also more general time dependent excitations, such as tone bursts and short pulses. One theme in our studies has been the caustics that occur in the phonon focusing patterns of crystals, and their diffraction broadening at finite frequencies, as observed in PSAM. Our emphasis has been on isolating the diffraction patterns of relatively simple caustic structures such as cusps and single and intersecting folds, which are normally observed interfering with each other in complex and incompletely resolved overlapping structures. With regard to inverse problems, we have shown how our methods, applied to complex wave field data, can be used to treat source reconstruction, image quality assessment and the determination of elastic constants.

Surface Brillouin scattering (SBS)

This has been a substantial part of my research activity during the last decade, and has mainly been conducted in collaboration with J.D. Comins at Wits and students Stoddart, Zhang, Crowhurst, Mathe and Kotane. The significance of SBS is that it is one of the few techniques available for determining the near-surface elastic properties of solids and of submicron coatings. It is applicable not only under ambient conditions, but also at high temperatures and, as we have established, at high pressures. SBS is of interest not only for the window it yields on fundamental physical processes in solids, but also for the technological value of the information it provides on solid surfaces and coatings. My main role in this activity has been the modelling of SBS for various situations involving generally anisotropic solids, including free and fluid loaded surfaces, interfaces between different solids, and scattering from any surface or interface of a solid with one or two over-layers. I have, for instance, helped in the clarification of the modes that evolve with increasing over-layer thickness in the two cases:

1. A fast layer on a slower substrate (such as TiN on steel or alumina on Al). The Rayleigh wave degenerates with the bulk wave continuum and various types of pseudo surface wave appear.
2. A slow layer on a faster substrate (such as amorphous Si on crystal Si). Here we have elucidated how additional surface modes, the so-called Sezawa modes, peel off the threshold of the bulk wave continuum.

The systems we have published on include:

- The elastic properties of TiN coatings on steel. These coatings are widely used for providing protection against abrasion and chemical attack.
- The high temperature elastic properties of the Ni-based superalloy CMSX-4, used extensively in gas turbine blades.
- The elastic behaviour of amorphous silicon on Si(001), and a structural transition in carbon ion bombarded Si during high temperature annealing.
- Vanadium carbide and the dependence of its elastic properties on stoichiometry.
- The first SBS measurements carried out at high pressure, by student J.C. Crowhurst.

I have also had a number of publications on SBS with

(a) M Mangnani and co-workers at the University of Hawaii on:

- Surface modes of SiN films on GaAs.
- A shear horizontal resonance in thin supported films.

(b) G A D Briggs and co-workers at Oxford University on:

- Determination of the elastic properties of a barrier oxide film on aluminium (important in the aircraft industry for the adhesive bonding of Al plates).
- Elastic measurements of layered nano-composite materials.

(c) C Prieto and co-workers at the Autonomous University of Madrid on:

- Elastic properties of Si/Ge superlattices (of importance in the electronics industry).
- Elastic properties of InGaP and InGaAs superlattices.

(d) R Sooryakumar and X Xhang of Ohio State University on:

- Observation of organ pipe acoustic excitations in supported thin films.

Interface between Acoustics and Seismology

This was a collaborative project with postdoc Dr Lin-ping Song, and C. Wright of the Bernard Price Institute of Geophysics (Wits). This work had two main thrusts. The first was establishing simple approximate formulae for the phase velocity and group slowness of acoustic waves in anisotropic solids, and applying these to elastic constants determination and other inverse problems. The second thrust was acoustic tomography with joint polarisation and arrival time data.

Books and Reviews in the past Decade

- I was co-editor (together with W Sachse) of "Dynamical Methods for Measuring the Elastic Properties of Solids", Vol. 1 of the four volume "Handbook of the Elastic Properties of Solids, Liquids and Gases" (Academic Press, 2001). It is the most extensive source book of information on elastic constant measurements. I also wrote the introductory chapter on the elastic properties of solids, and co-authored another chapter on point source-point receiver techniques.
- In 2002 I published a commissioned review article "Measurement of Near-surface Elastic Properties of Solids and Thin Supported Films" in the journal Measurement Science and Technology. It reviews the three principal surface wave methods for elastic properties characterisation, namely surface Brillouin scattering, laser generated SAW and acoustic microscopy.
- In 2004 M Beghi, P V Zinin and I published a 70 page review entitled "Brillouin Scattering Measurement of SAW Velocities for Determining Near-surface Elastic Properties" in a book published by CRC Press, titled "Ultrasonic Non-destructive Evaluation: Engineering and Biological Material Characterization"