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Mack Breazeale's contribution to Spring Schools on Acousto-optics and its Applications (1980 – 2008)

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ABSTRACT

Professor Mack A. Breazeale attended in few of Spring Schools on Acousto-optics and its Applications (organized every three years by the University of Gdansk since 1980) starting with the first one and participating last time in the 9th one in 2004). His original papers presented during these meetings had an evident importance for the development of this branch of physics and technology. Some recollections of the long cooperation of the authors with Mack Breazeale on the field of acousto-optics and some current results of experiments related to the Breazeale's description of a finite width ultrasonic beam reflection phenomena are presented in this paper. Particularly, some recent results of experiments on secondary interference in the near field of the ultrasonic light diffraction phenomena and of some schlieren pictures of the finite ultrasonic beam reflection including the Schoch shifted, null zone and leaky Rayleigh waves are demonstrated as well.

INTRODUCTION

Polish acousticians had opportunity to cooperate with Professor Mack Breazeale during last 30- ty years. He attended in few (starting in the 1st one in 1980) Schools on Acousto-optics and Applications organized every three years by the University of Gdańsk and in Symposia on Hydroacoustics organized every year by Polish Naval Academy and Gdańsk

Fig.1 Participants of the 1st School on Acousto-optics and Application, Gdansk-Wiezyca, 1980 [2]; from the left: dr J. Narkiewicz-Jodko, dr P. Kwiek, dr A. Markiewicz, dr S. Kryszewski, dr I. Wojciechowska, mgr K. Dałek and dr M. A. Breazeale.

University of Technology. In 1997 during the EAA Symposium on Hydroacoustics and Ultrasonics in Gdańsk he was awarded by the Polish Naval Academy Medal. Since 2004 he served as the member of the Advisory Editorial Board of Archives of Acoustics.

In the paper some Mack Breazeale's contributions to the Acousto-optical Schools are recalled and some current results related to his scientific interest are devoted by the authors to his memmory.

MACK BREAZEALE'S CONTRIBUTIONS TO ACOUSTO-OPTICAL SCHOOLS

A history of Spring Schools on Acousto-optics and Applications (regularly organized every three years) has been described in the review paper [1] published in the special issue of Applied Optics collecting some selected papers on acousto-optics presented in the 10th School in Sopot in 2008. In this review paper among others the Mack Breazeale's contributions to the Polish – American cooperation in acousto-optics were acknowledged.
As we already mentioned he participated the 1st School in 1980 (Fig.1) and then he presented the paper on Bragg imaging of finite amplitude ultrasonic waves. Fig. 2 and 3 show his historical photos of some examples of such Bragg images obtained in finite ultrasonic fields. The images of objects in higher diffraction orders obtained by Mack A. Breazeale had been for us a puzzle, however, at the same time they were an inspiration for studies the Bragg diffraction phenomenon within the so called intermediate range between the Ramann-Nath and the Bragg diffraction regimes. The phenomenon could only be understood in 1993. Together with Eric Blomme and Oswald Leroy we had examined theoretically and experimentally as well, the higher diffraction orders for light incident an ultrasonic wave at the Bragg angle in the range between the Raman-Nath type of diffraction and the Bragg one [3].

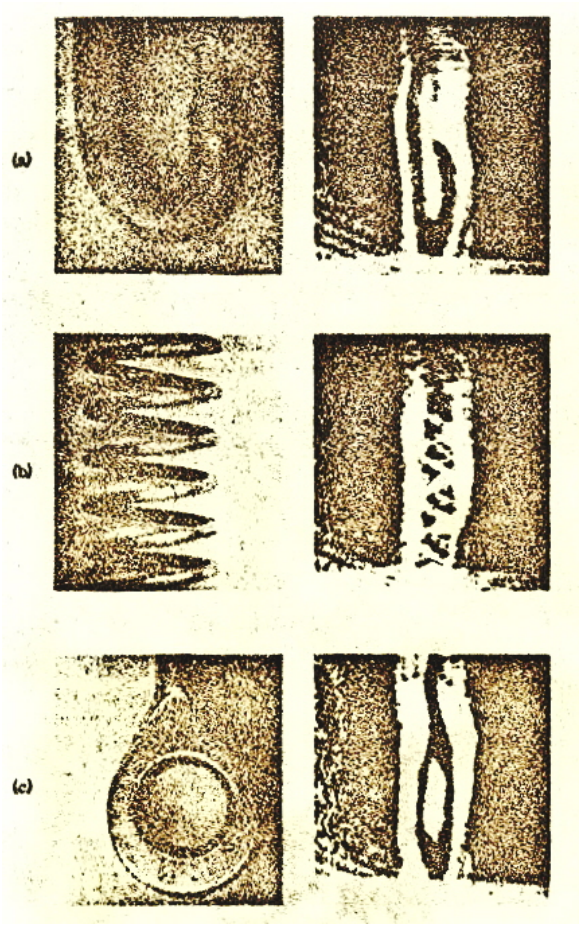


Fig. 2. A photograph of objects and their first- order Bragg images (frequency 18 MHz): a) a hook, b) a spring, c) a loop, after M.A.Breazeale from his presentation at the 1st School on Acousto-optics and Applications, Gdansk-Wieżyca, 1980 [2].

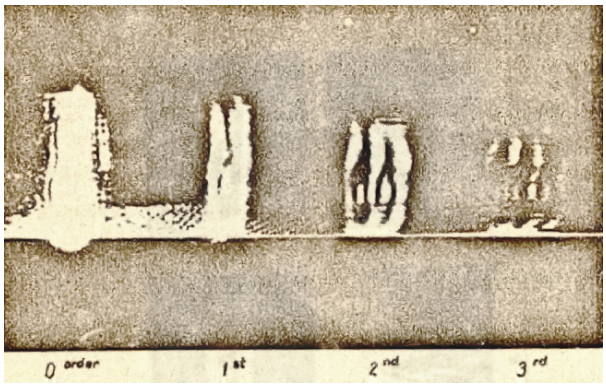


Fig. 3 A photograph of the first-, the second- and the third-order images for a loop, frequency 10 MHz; after M.A.Breazeale from his presentation at the 1st School on Acousto-optics and Applications, Gdansk-Wiezyca, 1980 [2].

During the 7th School dedicated to Bill Cook at the first plenary session in commemoration of Cook and chaired by A. Korpel several of Cook's friends delivered their commemoration words and among them was Mack Breazeale (Fig.4). Also, he gave a commemorative presentation on schlieren photography in physics [4]. Figs 5, 6 and 7 taken from his paper show two schlieren visualisation of the Schoch effects for the ultrasonic beam reflection at the liquid-solid and liquid – corrugated surface solid interfaces, respectively.

One of the first images of ultrasonic waves interacting with a liquid – solid interface was obtained by Schoch in 1952 [5]. Since that time many publications presenting images of waves reflected from the interface by using the schlieren method. A pretty big participation in imaging the phenomenon had Professor Mack Breazeale. The authors who used the schlieren method for imaging the ultrasonic wave reflection at the interface of two media had not taken into account the fact of the complex diffracted image structure occurring in the focus of the lens , in which the Foucoult's nife used to be situated. That can explain quality differences of schlieren images of various authors. In 1992 a space distribution of the ultrasonic light diffraction orders of the wave reflected at the liquid-solid interface was described [6]; consequently it was shown that taking a correspondent combination of diffracted orders one was able to obtain various images, for instance only the image of the incident wave or only reflected one together with reradiating one or all of them simultaneously. Reproducing all of the waves simultaneously one can observe a change of phase between the reflected wave and the leaky Rayleigh wave near the Rayleigh angle. Moreover, taking a corresponding combination of orders imaging only geometrically reflected wave and the leaky Rayleigh wave (without incident wave) one can very exactly examine the range of the so called null field.

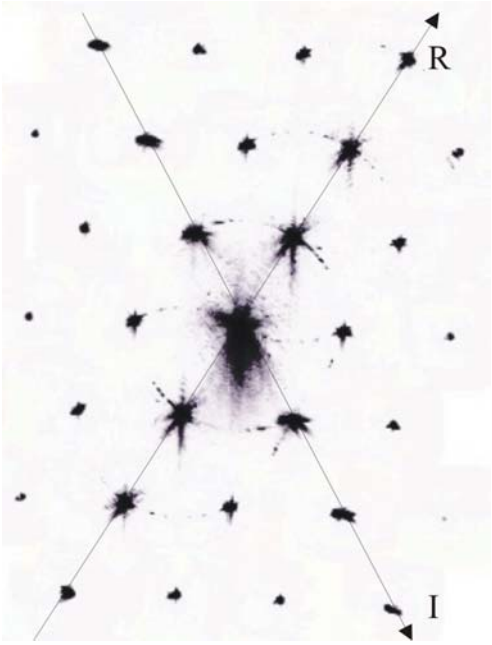
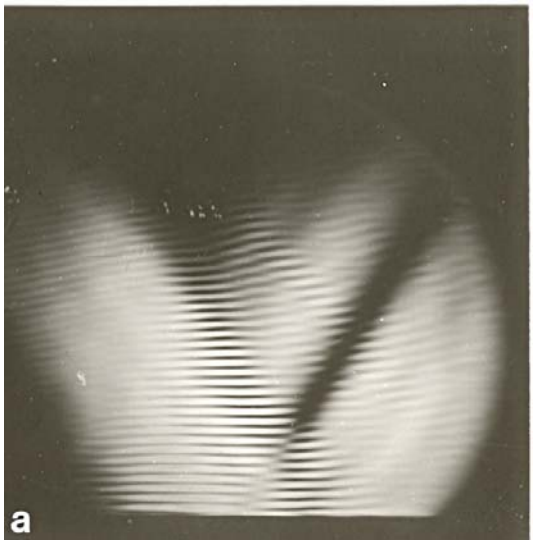


Fig. 4. The image of the diffraction orders. The arrows indicate the directions of: I - incident beam, R – reflected beam.

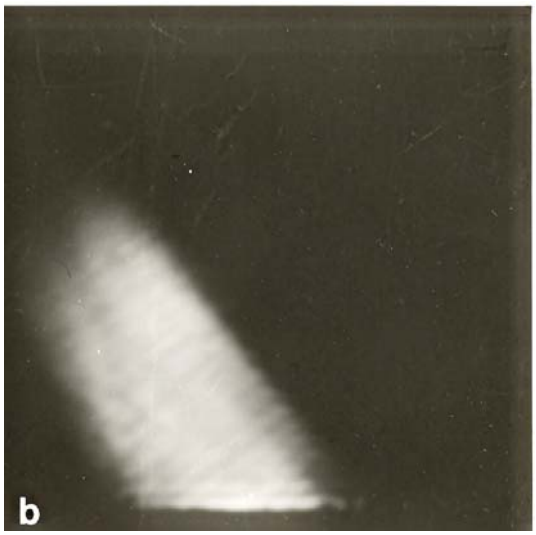
Comparing the results of imaging of the ultrasonic wave reflection from the liquid – solid interface by the schlieren method used by M. A. Breazeale with the imaging method by the selection of corresponding combination of diffraction orders, one is able to notice much greater possibilities of the second one in the case of examination of the phenomenon discussed above.

During the 8th School interesting paper was presented by M. A. Breazeale on visibility methods for convenient and accurate measurement of ultrasonic wave velocity [7] using secondary interference effects in the near field (Fresnel zone) of the ultrasonic light diffraction phenomenon. The near field of the ultrasonic light diffraction was an interest of professor Mack Breazeale since the beginning of 19-fifties [8] A problem which have not been solved by years of research was a

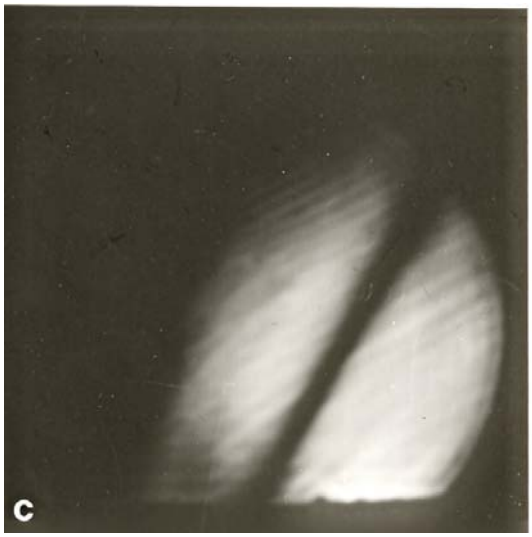
Fig.5.a, b, c. Illustration of the incident beam separation from reflected beam (liquid-solid boundary ↓). (phot. by P. Kwiek)



a) Both beams (the Rayleigh angle)



b) Incident beam



c) Reflected beam

Fig. 4. Professor M. A. Breazeale presenting commemoration lecture to Bill D. Cook during the 7th Spring School on Acousto-optics and Applications, Gdansk-Jurata, 1998; after [4].

Fig. 5. … and reading his scientific lecture.

localization of the secondary interference planes, also called Nomoto planes. It was not known from what place one should calculate the distance of localization of the secondary

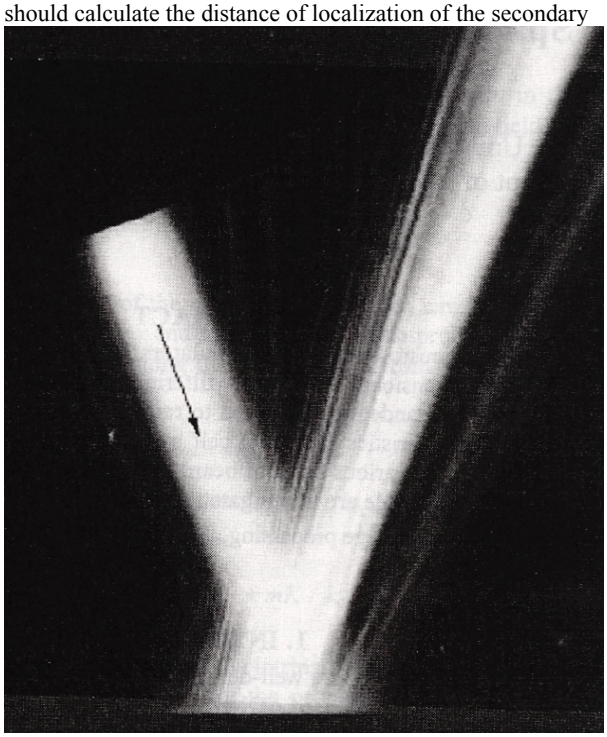


Fig. 5 Schlieren photograph showing "backward displacement" of an ultrasonic beam at a grating interface; after M. A. Breazeale [4]

interferences planes: from the beginning border of the ultrasonic wave or from the end or from its center? Also this question, which with Mack Breazeale was concerned, we were able to solve, with a considerable contributions of Eric Blomme, Oswald Leroy and Rainer Reibold, solving numerically the Raman-Nath equation system for the near field using the NOA (N-Order Approximation) method [9, 10]. In consequence of the research there was finding of the phase shifts in ultrasonic light diffraction orders depending on Klein-Cook and Raman-Nath parameters [11]. That's just the found phase shifts are responsible for the variation of the secondary interference planes localization.

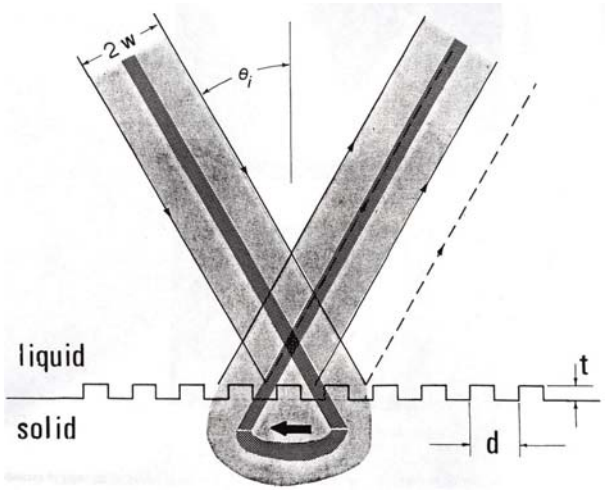


Fig. 6. Diagram of reflection expected at a grating interface after M. A. Breazeale [4]

CONCLUSIONS

Polish acousticians community and particularly the group of Mack Breazeale's friends in Poland working in the field of physical acoustics and applications of ultrasonics including hydroacoustics have been deeply upset of the loss of so outstanding scientist. He will long be remembered as the great person, tried friend and wonderful men.

REFERENCES

1. P. Kwiek, A. Sliwinski, Some recollections on acousto-optis research at the University of Gdansk in the light of international cooperation and of the history of Spring Schools on Acousto-Optics and Applications, Applied Optics, **48**, 7, C125-134, (2009).
2. M. A. Breazeale, Bragg imaging of finite amplitude ultrasonic waves, Proc. of the First Spring School on Acousto-Optics and Applications, Gdansk-Wiezyca, 1980, published by the Institute of Physics, University of Gdansk, 1 – 338, (1980).
3. E. Blomme, P. Kwiek, O. Leroy, A. Sliwinski, Higher order Bragg diffraction of light by ultrasound: theory and experiment., Proc. Ultrasonics Intern., Viena, Butterworth Heinemann, 69-72 (1993).
4. M. A. Breazeale, Schlieren photography in physics (Invited Paper); in: Proc. SPIE Vol. 3581 (SPIE Press), Acousto-Optics and Applications III, A. Śliwinski, B. B. J. Linde and P. Kwiek, eds, 41- 47, (1998).
5. A. Schoch, Seitliche Versezung eines total reflektierten Strahls bei Ultrashallwellen, Acustica 2, 1952, 18-19]
6. P. Kwiek, Phenomenon of light diffraction by two ultrasonic waves and its application for ultrasonic field imaging., Acustica, **77**, 201-207, (1992).
7. M. A. Breazeale, Visibility methods for convenient and accurate measurement of ultrasonic wave velocity (Invited Paper); Proc. SPIE Vol. 4514 (SPIE Press), Acousto-Optics and Applications IV, B. B. J. Linde and A. Sikorska, eds, 1 – 7, (2001).
8. E.A. Heidemann, M. Breazeale, Secondary interference in the Fresnel zone of gratings, JOSA, 49, 4, 372 – 376, (1959).
9. E. Blomme, P. Kwiek, O. Leroy, R. Reiboldt, On the near field of light diffraction by an ultransonic phase-amplitude grating: theory and experiment, Acustica, **73**, 134 – 143, (1991).
10. G. Gondek, T. Katkowski, P. Kwiek, The near field of the ultrasonically diffracted light beyond, the Raman-Nath regime, Acustica, **80**, 554 – 557, (1994).
11. P. Kwiek, R. Reibold, Additional phase shift in ultrasound light diffraction, Acustica, **80**, 294 – 299, (1994).