# Research cooperation between Catholic University Leuven Campus Kortrijk and University of Gdansk in acousto-optics a historical recollection*

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***) a tribute to Oswald Leroy for his significant contribution . Presented at the occasional session of ICU'2015 Metz, France**

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## 1. Introduction

During the **7th ICA Congress in Budapest in 1971 I met two interesting men from Belgium** who presented their papers on acousto – optic (AO) interaction, the field that I was interested, too (I presented a paper on that topic, there as well).

They were Professors:

**Robert Mertens (University of Gent)**

and **Oswald Leroy (Catholic University of Leuven - Campus Kortrijk (KULAK).**

I knew a few of their previous papers from the literature and we could have had a very fruitful discussion together. I was acquainted with AO achievements of the well known **R. Mertens' team in Gent** working on theoretical background of the ultrasonic light diffraction (ULD) phenomena since 1950 and **O. Leroy belonged to the Group**.

Later on, **since the Kortrijk–Campus of the Catholic University of Leuven was erected in 1965, Oswald Leroy created his own group** there and among others widely developed the theory of ULD by two adjacent ultrasonic beams studying that phenomena against the whole frequency and intensity range depending on the phase shift between them.

Already in Budapest, after our discussion in which I informed them about AO laboratory just being built at Gdansk University, we decided to exchange and share our knowledge and experience in the future and it was a starting point for a long cooperation for many years.

Four years later in 1975 at the Symposium on Acoustics and Spectroscopy which took place in Gdańsk for the Opening Day of New Physics Building at the University of Gdańsk Oswald Leroy presented the paper [1] on the theory of diffraction of light by adjacent ultrasonics.

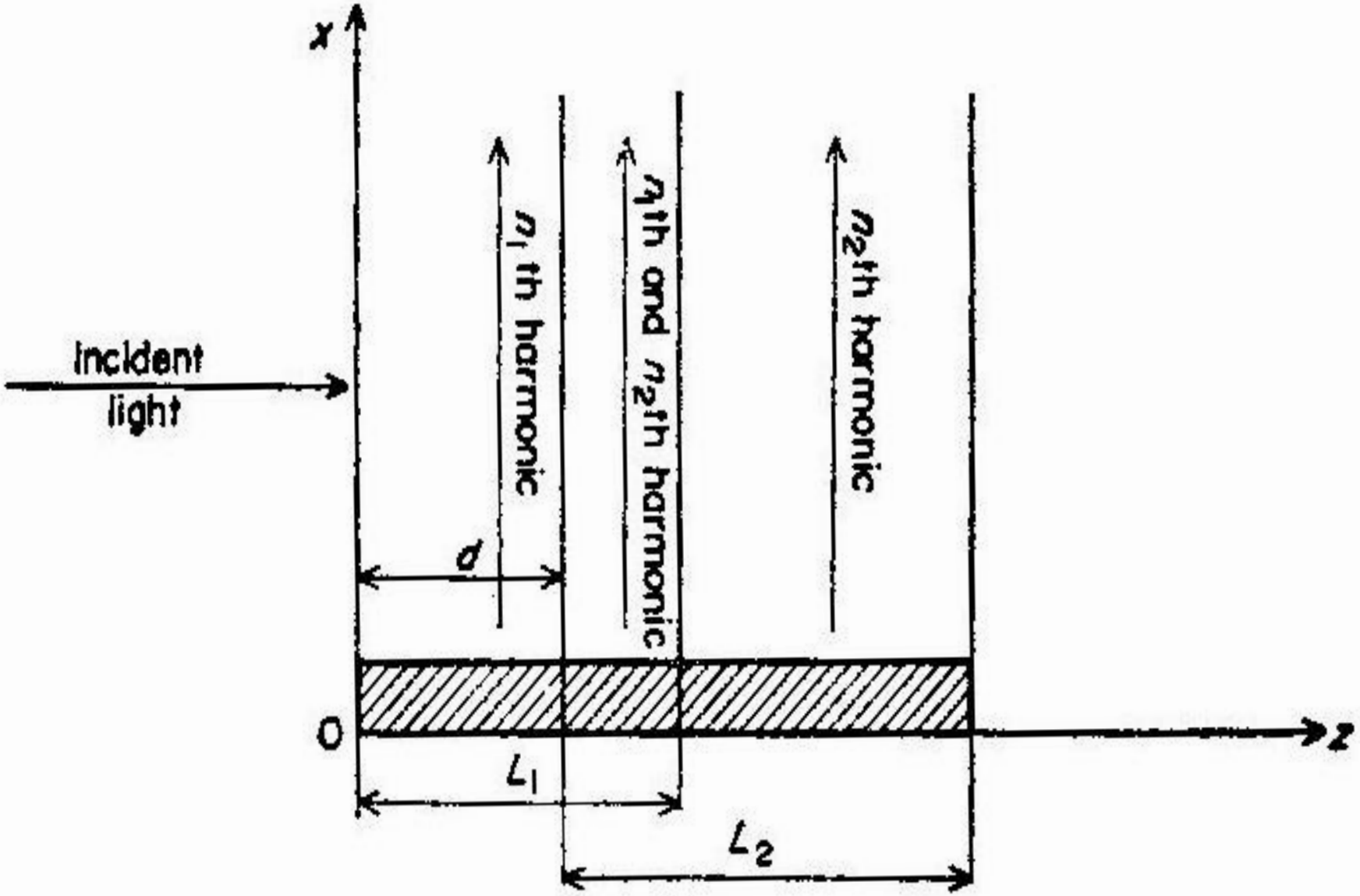



**Fig. 1 ULD by two parallel partly superposed partly adjacent ultrasoniscs** *(after [1])*

Predictions of his theory were very interesting and so far-sighted that our experimental AO group (P. Kwiek and co-workers) decided to start with adequate experiments to confirm the theory.

Since that time mutual cooperation was being continued and in the near future several common papers appeared confirming the theoretical results [2-9] and next ones followed [10-14].

## 2. Some historical results of the co-operation

- two adjacent beams in the same direction of propagation

- two adjacent beams in opposite dicections

- adjacent fundamental and second or forth harmonic ultrasound beams

- higher orders Bragg diffraction of light by ultrasound

**Theoretical Basis**

For $\rho > 1$, as shown in paper [1], one can expect the following light intensity distribution in the ±1 orders of diffraction lines:

$$J_{\pm 1}(\zeta) = I_{\pm 1}(\zeta)[1 \pm \cos\delta \sin\alpha_2(\zeta - \zeta_1)], \qquad (1)$$

where $I_{\pm 1}$ – are the intensities of the diffracted light caused by the first ultrasonic beam only,

$\zeta$ – coordinate axis normal to the incident light wavefronts,

$\delta$ – phase difference between the two adjacent ultrasonic beams;

$$\alpha_2 = \frac{\mu_2}{\mu_1} \text{ and } \rho = \frac{\lambda^2}{\mu_0 \mu_1 \Lambda^2},$$

where $\mu_0$ – light refractive index for undisturbed medium,

$\mu_1, \mu_2$ – maximum variations of refractive index caused by the first and the second ultrasonic beams,

$\lambda, \Lambda$ – wavelengths of the light and ultrasound beams respectively,

$\zeta_1$ – the width of the ultrasonic beam (equal for both beams): Fig. 1 describes the geometry of the physical problem.

***Fig. 1a. O. Leroy's theory on the ULD by two adjacent ultrasonic beams for the frequency ratio 1 : 2; theoretical formulas for the light intensity in +1 and -1 diffraction orders against the phase shift $\delta$ [2, 4].***

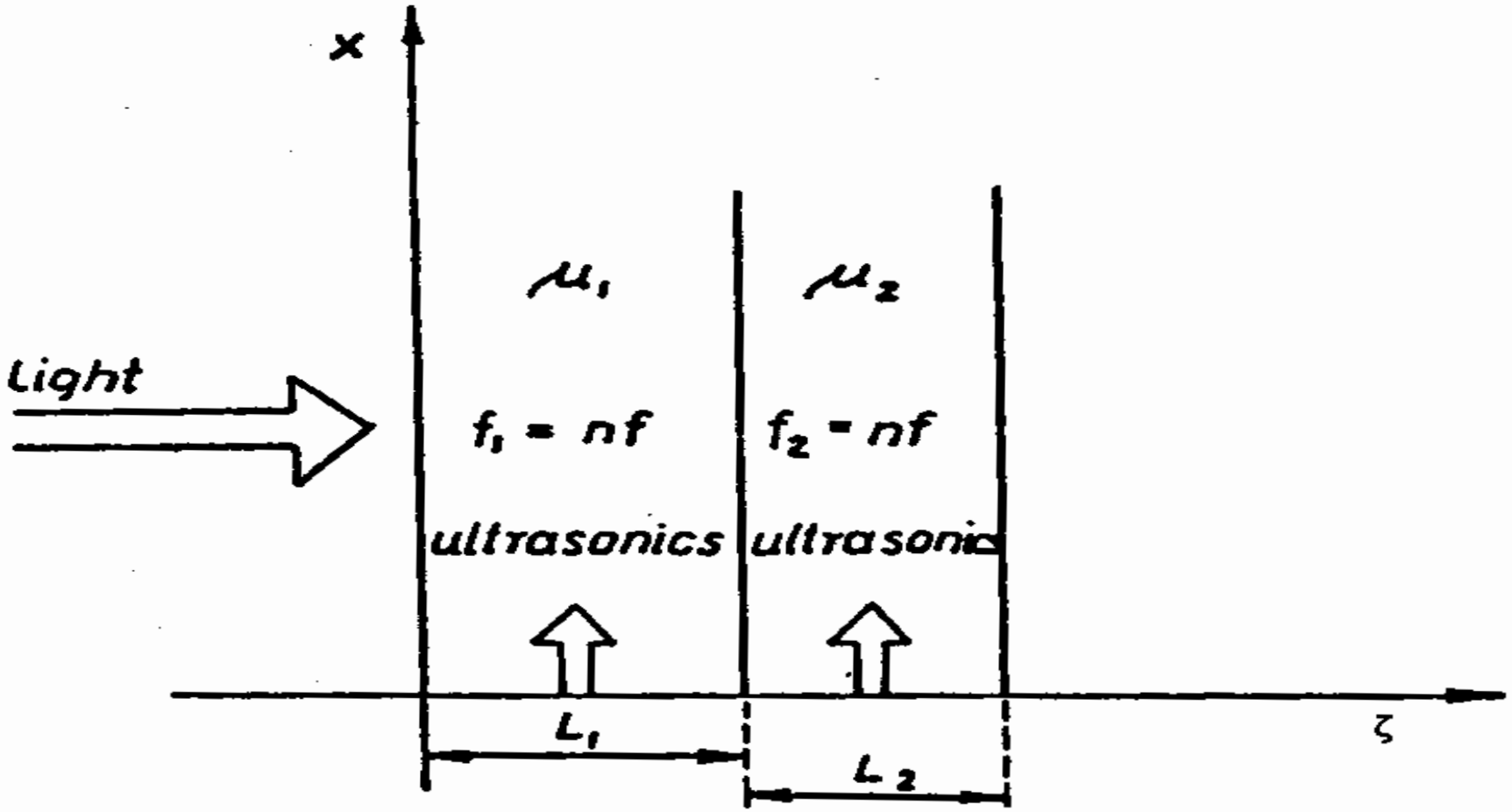



Fig. 1b. The first confirmation of the O. Leroy's theory on the ULD by two adjacent ultrasonic beams for the frequency ratio 1 : 2; experimental geometry;

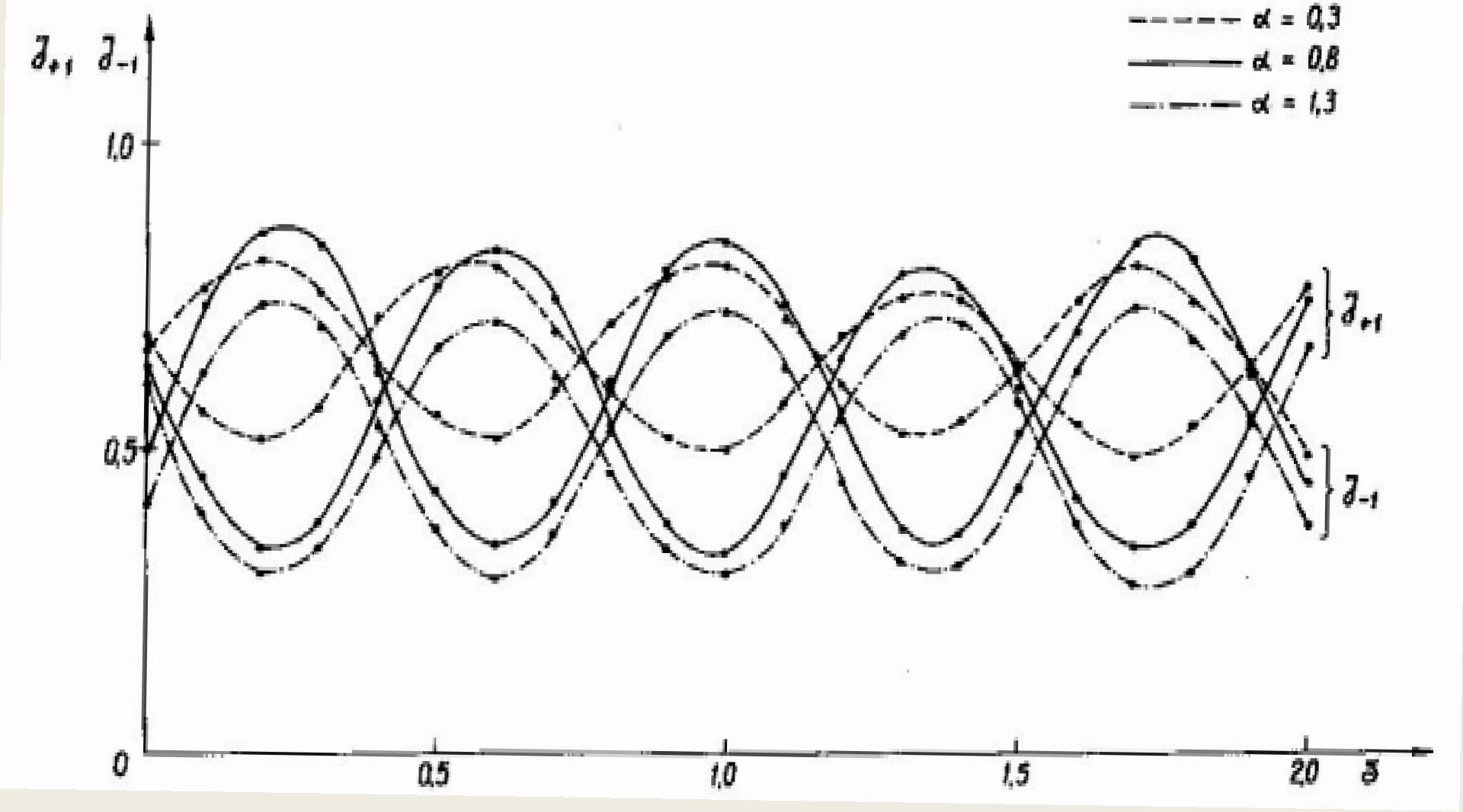



*Fig. 1c. The first confirmation of the O. Leroy's theory on the ULD by two adjacent ultrasonic beams for the frequency ratio 1 : 2; experimental results for the light intensity in +1 and -1 diffraction orders against the phase shift* $\delta$ *[2, 4].*

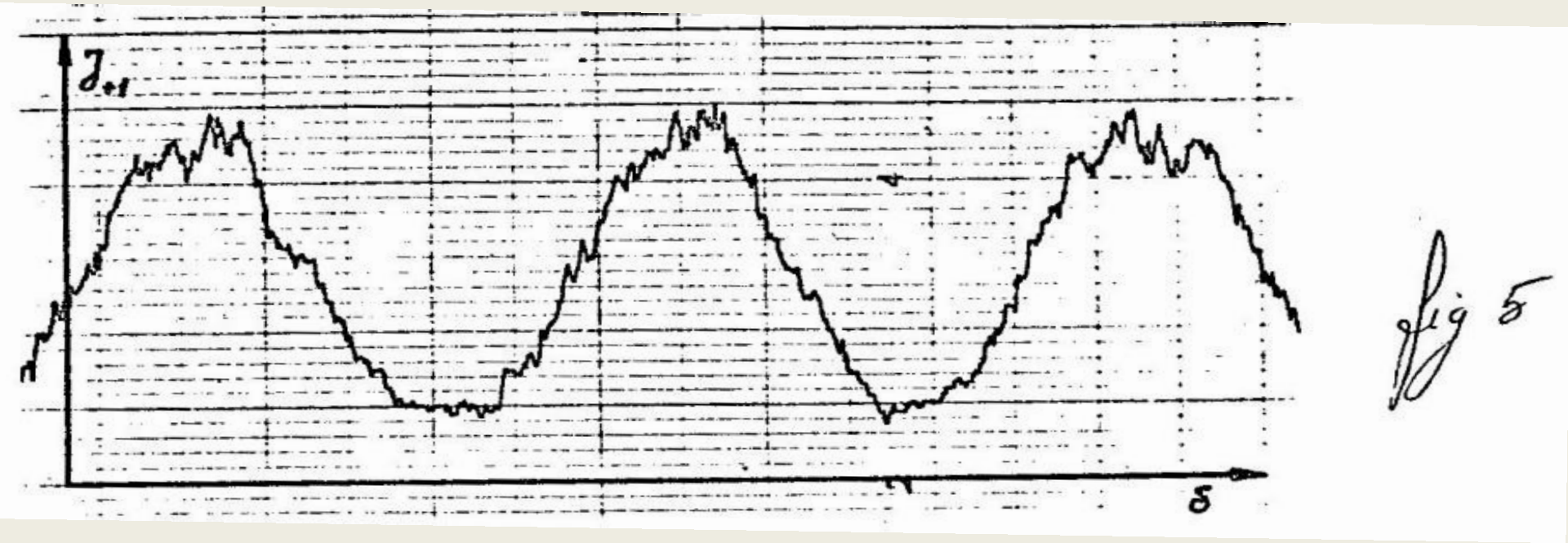



*Fig. 2 The original record of the light intensity in +1 diffraction order*

**- two adjacent ultrasonic beams in opposite dicections**

In next experiments the confirmation for the case of the two adjacent ultrasonic beams propagating in the opposite direction was verified [5]. In that case the effect of light intensity modulation in time takes place as illustrated in Fig. 3.

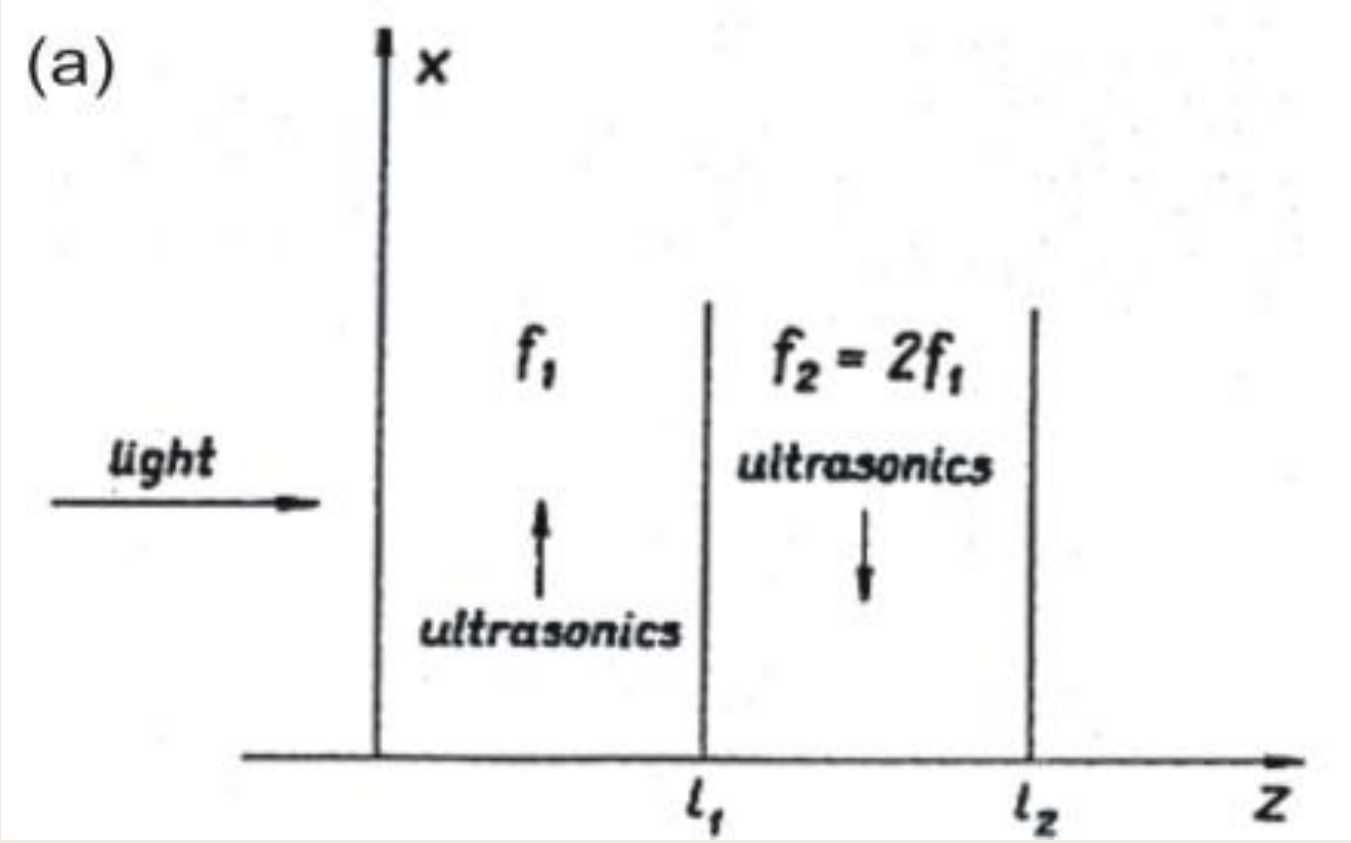
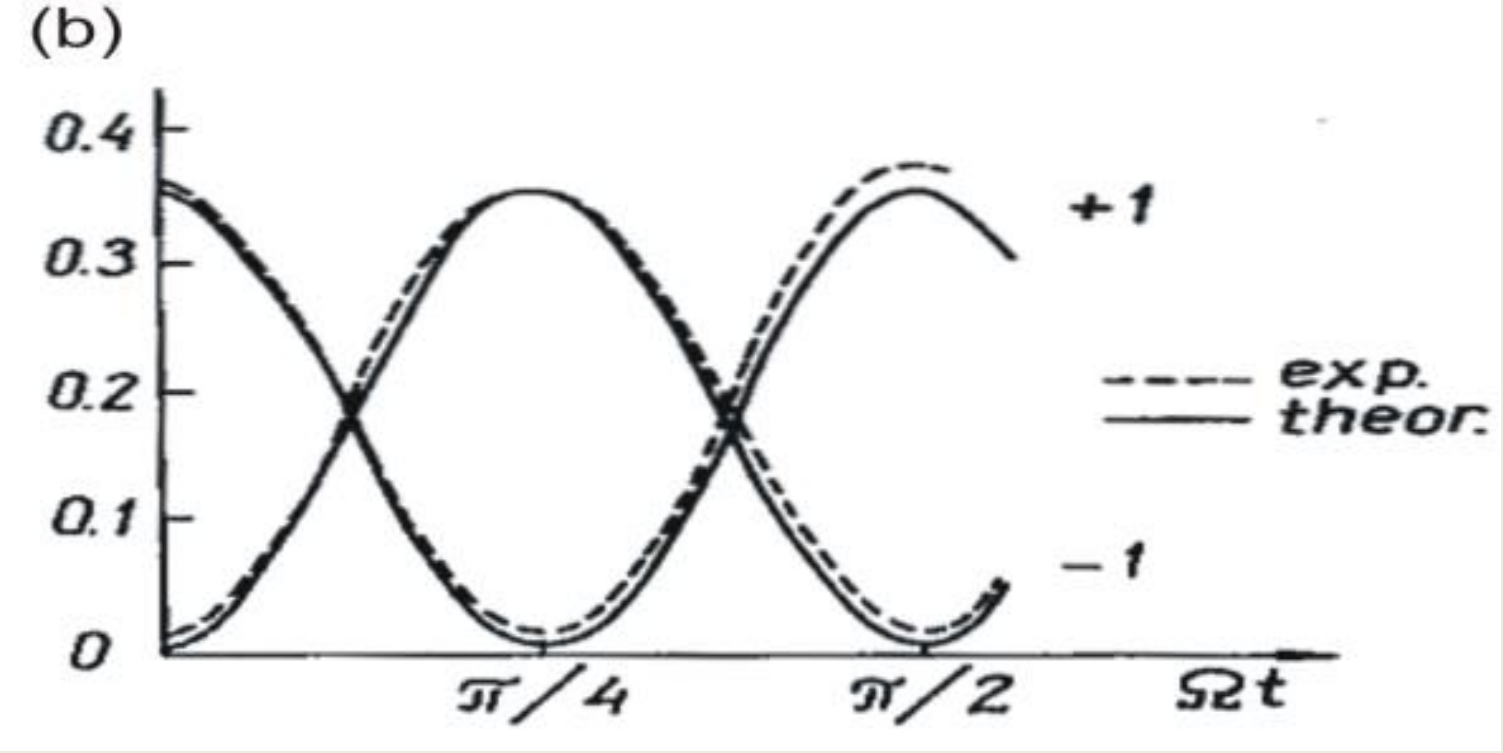



*Fig. 3a. Experimental verification of the theory for opposite adjacent ULD [5]; the scheme for frequency ratio 1 : 2.*




(c) $$I_r(\zeta, t) = \sum_{q=-\infty}^{+\infty} I_{rq}(\zeta) \cos q(2k\Omega t + \delta)$$

$\Omega = 2\pi f_1$ is the angular frequency of the first beam

*Fig. 3. Experimental verification of the theory for opposite adjacent ULD [5]; an example of results (b) and the theoretical formula (c) for frequency ratio 1 : 2.*

In the paper (O. Leroy, A. Śliwiński, P. Kwiek, A. Markiewicz) [4] very interesting results were obtained for ULD by **adjacent fundamental and second or forth harmonic ultrasound beams** and the comparison of exact and simplified formulae with experiment were examined.

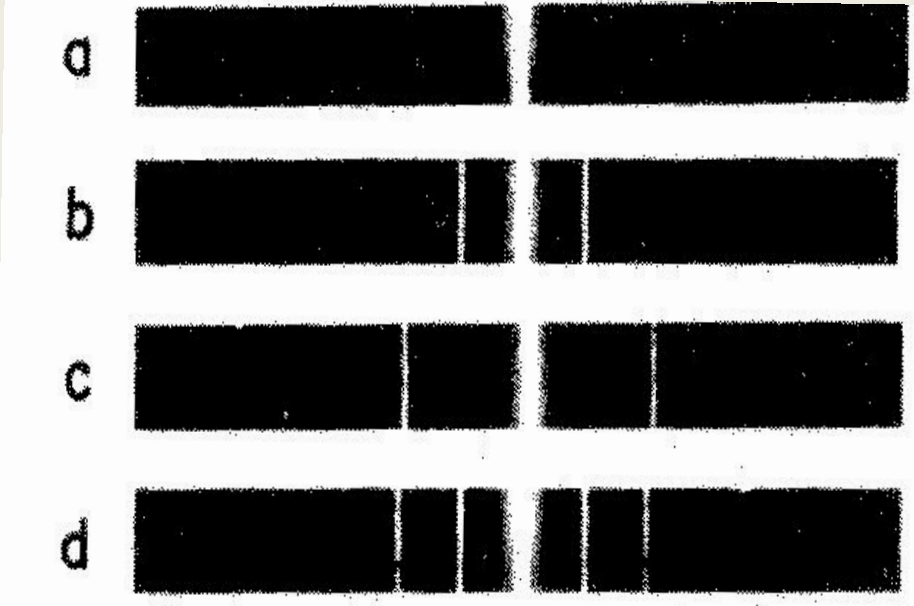



Fig. 3 Spectra of diffraction orders obtained in the experiment: a – without ultrasound; b – with only the first ultrasonic beam of frequency $\nu^*$; c – with only the second ultrasonic beam of frequency $2\nu^*$; d – with both ultrasonic beams $\nu^*$ and $2\nu^*$ operating adjacently

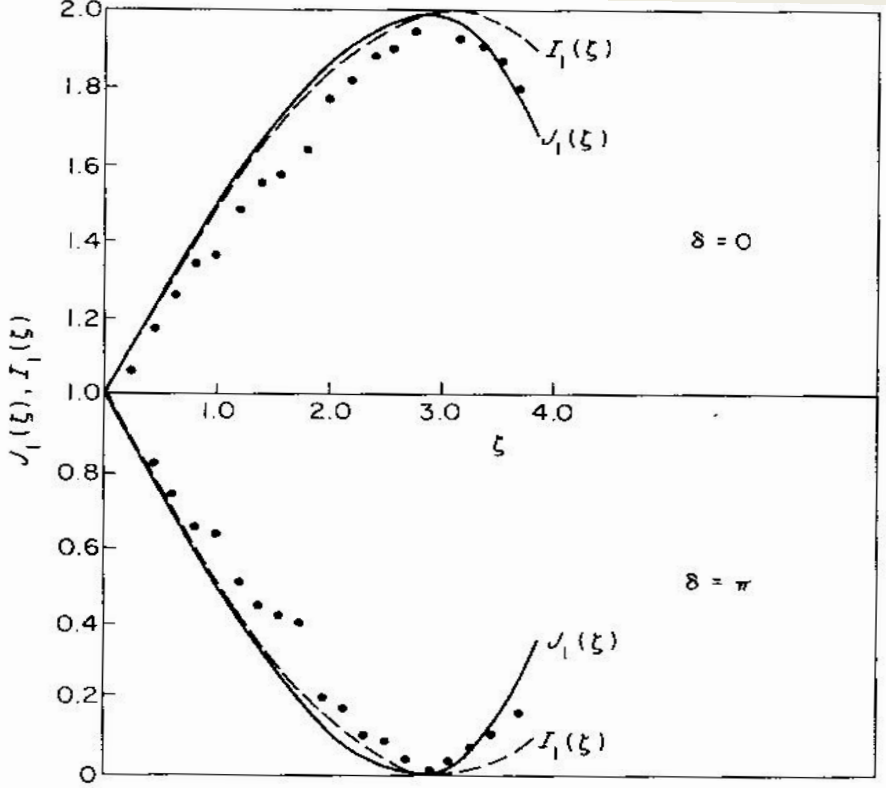



Fig. 5 Dependence of $I_{+1}, J_{+1}$ on $\xi$ in the case of $\nu^*$ and $2\nu^*$ in comparison with experimental data for $\alpha_2 = 0.8$ and $\delta = 0$ or $\delta = \pi$

Fig.4. An example of theoretical (–) and experimental (···) ULD for fundamental frequency ν* and its second harmonic 2ν*; experimental spectra of ±1 diffraction orders (left), light intensities in ±1 orders (right) against ξ for δ = 0 and δ = π [4].

Later on, the successful expeerimental confirmations of Oswald Leroy's theories have become inspiration for further fundamental search in acousto-optics.

At Gdansk University Ph.D. Thesis of P. Kwiek, I. Wojciechowska, M. Kosmol and later on D. Sc. Thesis (Habilitation) of P. Kwiek and Ph.D. of G. Gondek, T. Katkowski, I. Grulkowski under his promotion.

Members of Gdansk AO group many times visited Kortrijk to work together on ULD phenomena or attending seminars and symposia organized in Belgium and the Belgian group took part in the international Spring Schools and Applications systematically organized by Gdansk University as the triennial meetings since 1980. **Oswald Leroy's contribution** to the mutual co-operation has been recognized as so important and significant that **in 1991 he was honored with the Doctorate Honoris Causa of the University of Gdansk.**

**Oswald Leroy's** (central) **Doctor Honoris Causa of the Gdansk University, Gdansk , 9th February 1991**

Q.F.F F.Q.S.

Summis auspiciis serenissimae Rei Publicae Polonorum

Nos
Universitatis Gedanensis
Rector Magnificus
et
Mathematicae Physicae Chimiaeque Facultatis Decanus
et
Promotor rite constitutus
amplissimo Universitatis Gedanensis Senatu consentiente

in

Virum Clarissimum ac Doctissimum

O S V A L D U M L E R O Y

Universitatis Catholicae Lovaniensis

in Campo Cortraci

Professorem

qui in studiis ad quaestiones physicas acustico - opticas
pertinentibus maximam consecutus est gloriam
qui studia physica in Universitate Gedanensi promovenda
amicissime adiuvabat adiuvatque

HONORIS CAUSA DOCTORIS

Nomen honores iura et privilegia omnia contulimus
in eiusque rei fidem hasce litteras Universitatis
sigillo sanciendas curavimus

Datum Gedani die VIII mensis Februarii anno MCMXCI

Casimirus Gęba
H.T.Decanus

Sbigneus Grzonka
H.T.Rector

Antonius Śliwiński
Promotor

**The copy of Oswald Leroy's Doctorate Honoris Causa certification, University of Gdańsk,1991.**

Fig. 4 Oswald Leroy's Doctor Honoris Causa ceremony speech
University of Gdansk, 1991

It is worth to recollecting further common investigations in next years.

For instance, the results on higher orders Bragg diffraction of light by ultrasound in which theoretical results of E. Blomme and O. Leroy [6] were experimentally confirmed in Gdansk University laboratory in 1991-1993 .

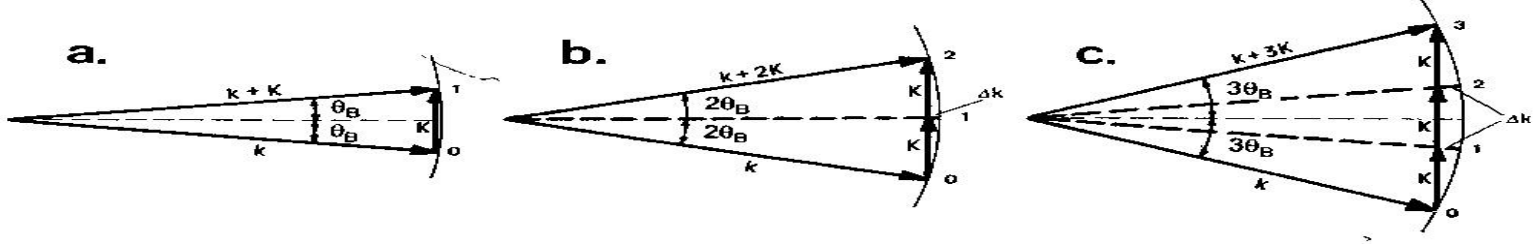



Figure 1 Wave vector diagram interpretation of Bragg diffraction of (a) order 1, (b) order 2, (c) order 3. **K** and **k** represent the wave vectors of resp. sound and light; **Δk** indicates the phase mismatch for the intermediate diffraction orders.

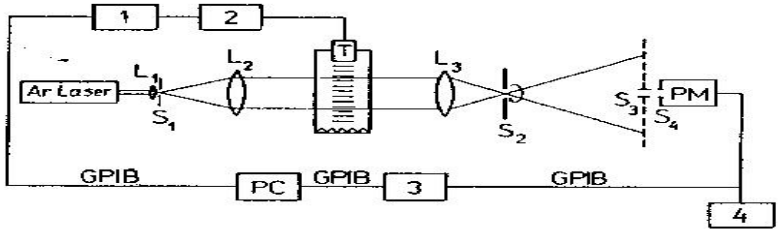



Figure 2 Scheme of the experimental set-up.
(1) frequency synthesizer Philips PM 5193
(2) power amplifier ENI 325 LA
(3) multimeter Philips PM 2525
(4) digital oscilloscope Philips PM 3323
(T) ultrasonic transducer
(PM) photomultiplier M12 FCC51
(PC) personal computer
($L_1$, $L_2$, $L_3$) lenses, ($S_1$, $S_2$, $S_3$, $S_4$) slits.

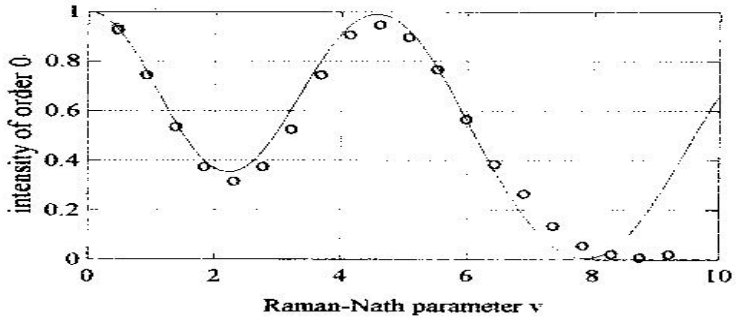



Figure 3 Calibration curve for the Raman-Nath parameter v, representing the light intensity in the zero diffraction order at normal light incidence and for Q = 4.42. The scale for v is chosen in function of the best fitting of the theoretical curve (——) to the experimental data (ooo).

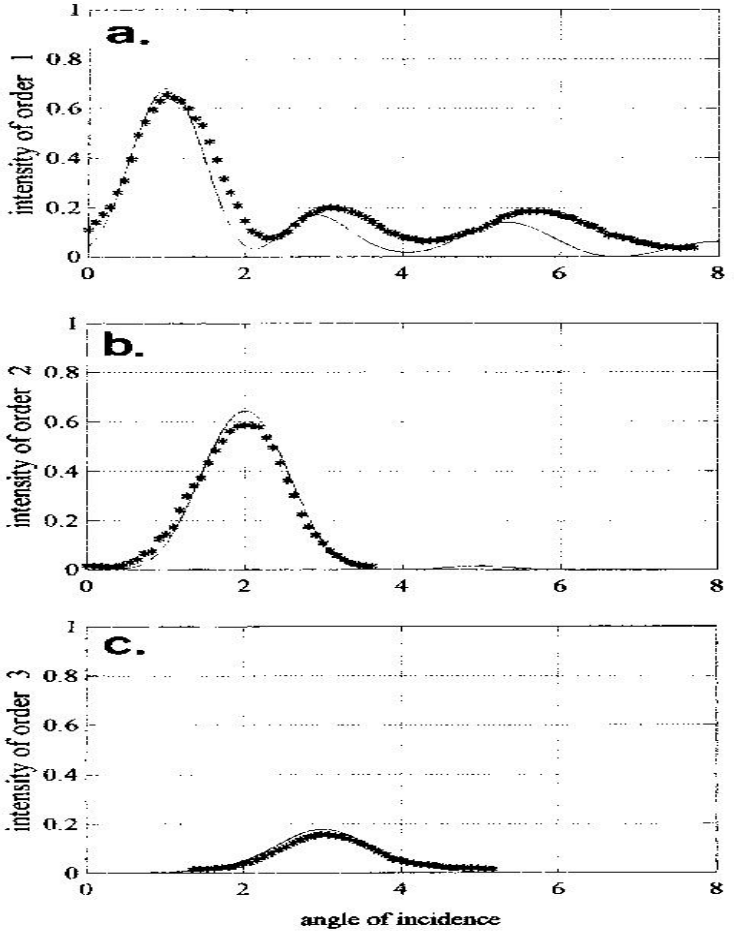



Figure 4 Theoretical (——) and experimental (***) diffracted light intensities as a function of the angle of incidence, expressed in units of the Bragg angle, for v = 4 and Q = 4.42; (a) order 1, (b) order 2, (c) order 3.

Next common research on light polarization effects in isotropic media with acoustically induced birefringence started and in the following years a series of common papers appeared: (E. Blomme, O. Leroy, A. Śliwinski, P. Kwiek, G. Gondek, T. Katkowski) [7-14].

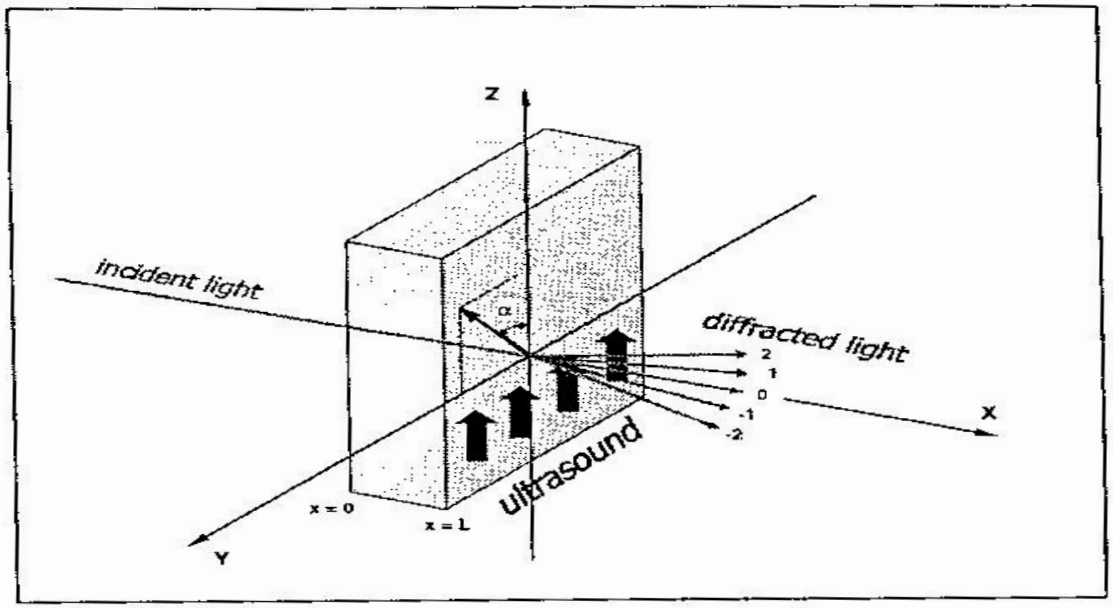



Figure 1. Geometry of the AO interaction.

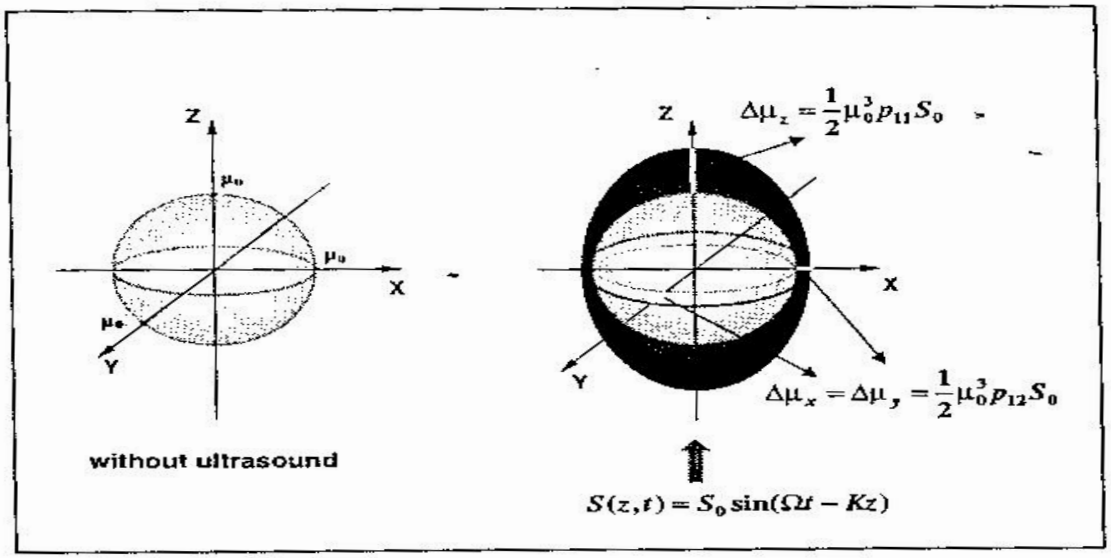



Figure 2. Ultrasonically induced anisotropy in an isotropic medium: changes of the optical indicatrix.

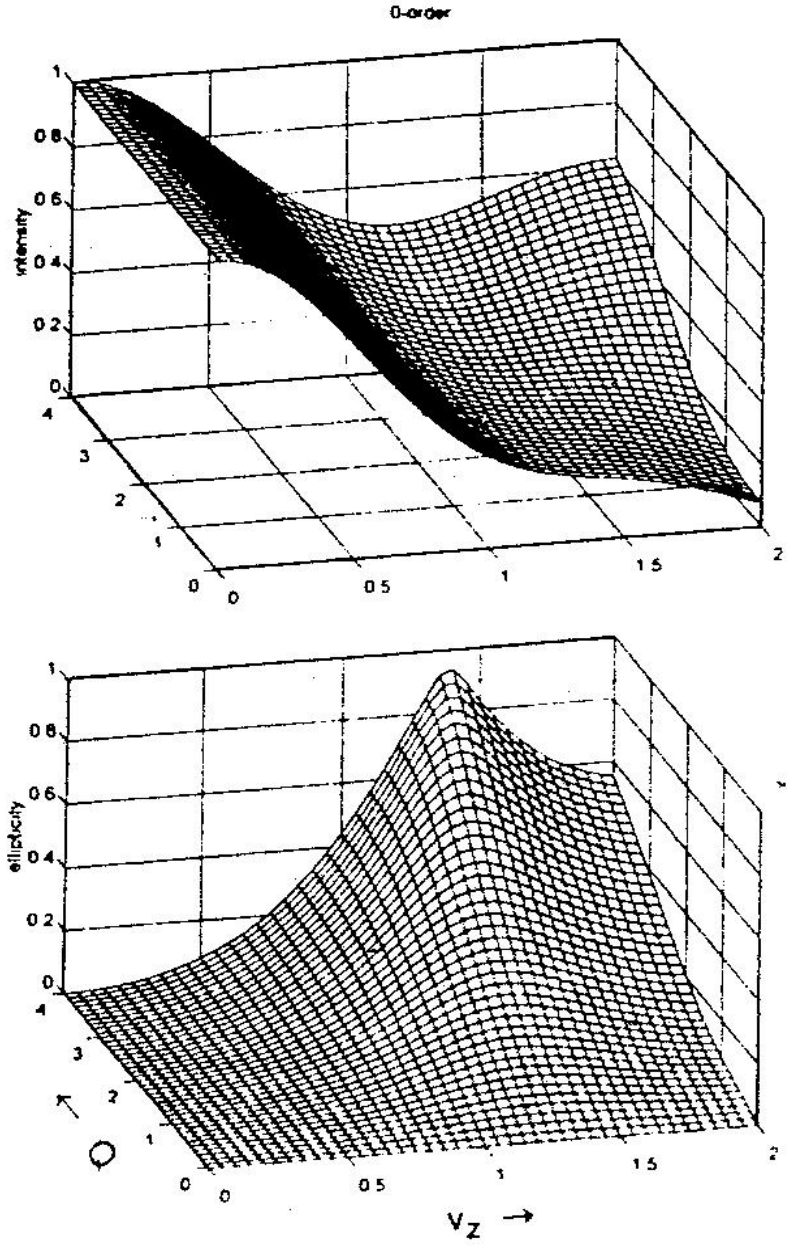



FIG. 3. 3D-plot of the 0-order intensity and ellipticity as a function of the RN-parameter $v_z$ and the KC-parameter Q.

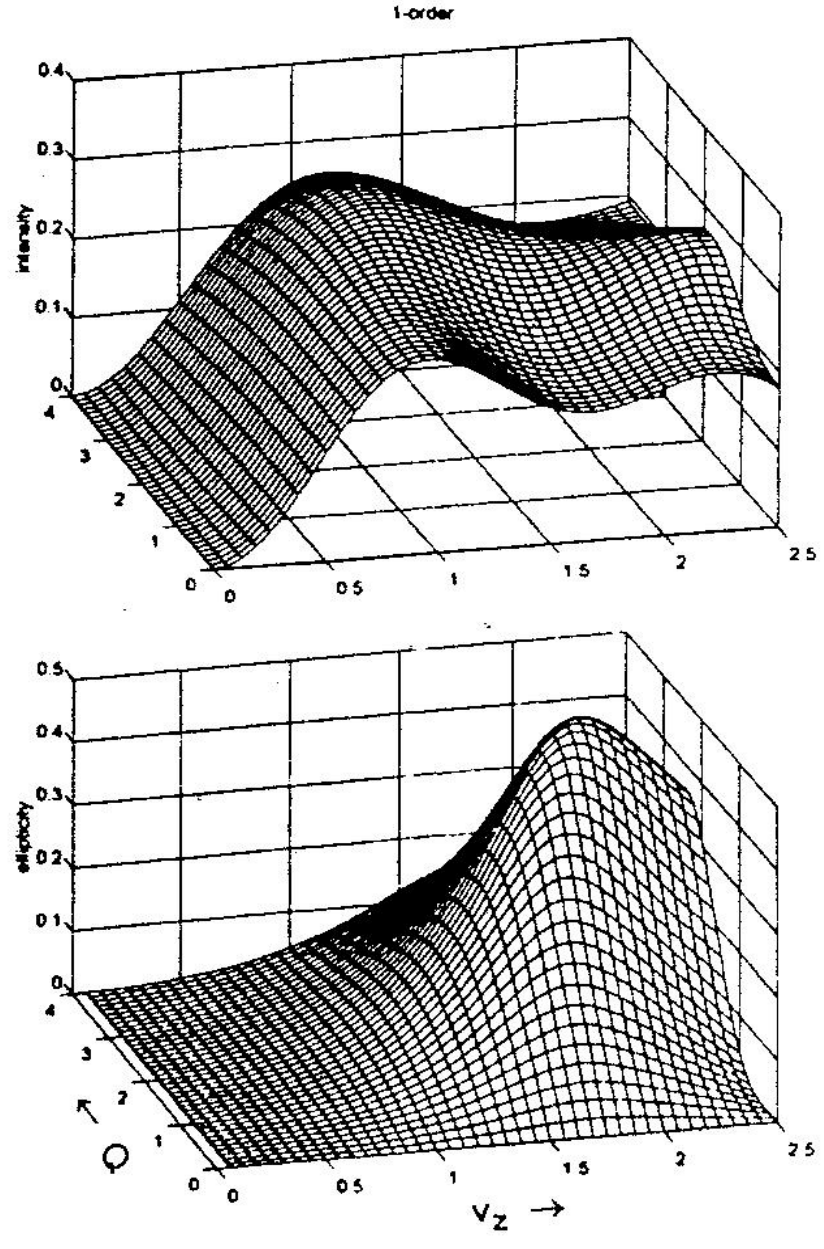
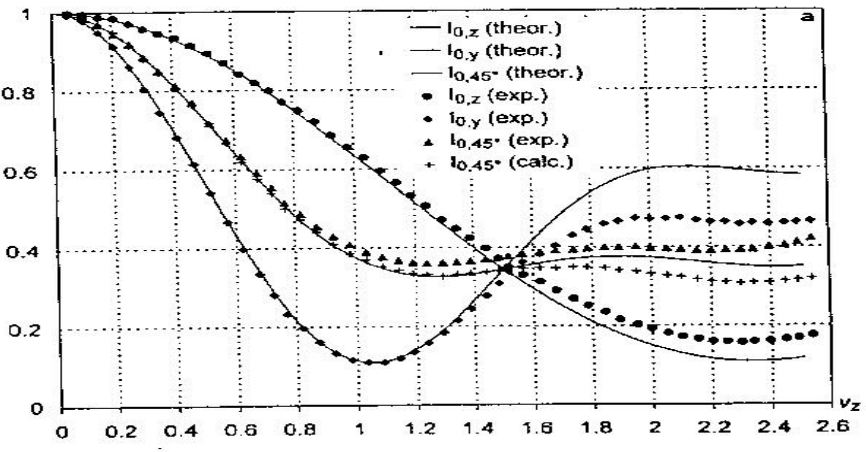
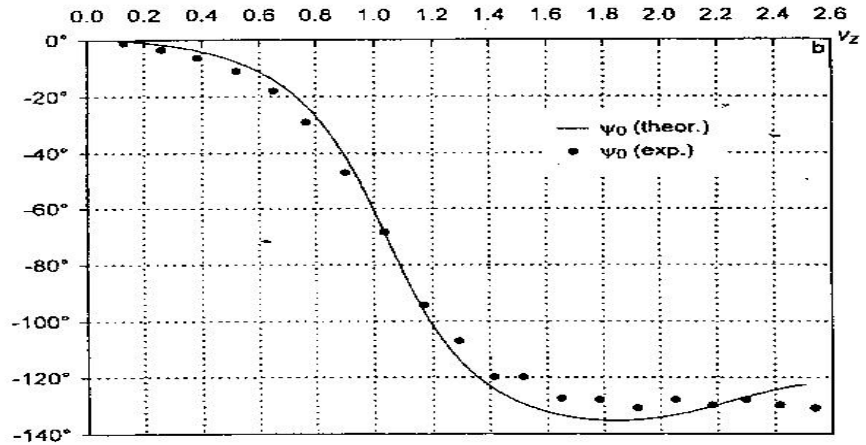
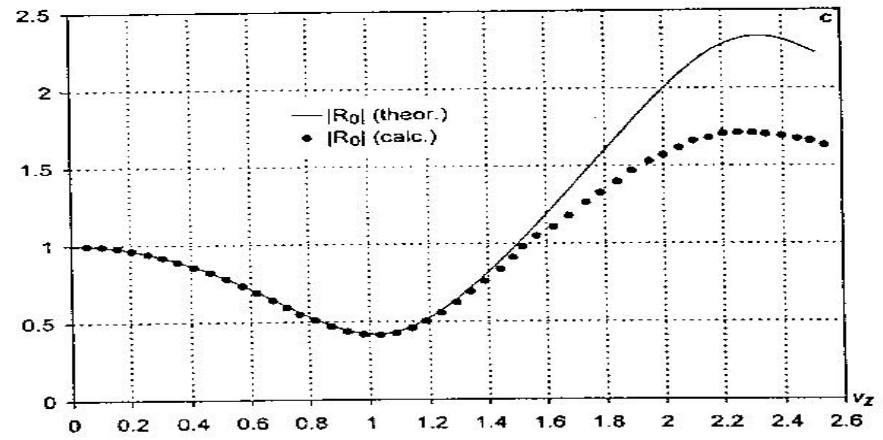
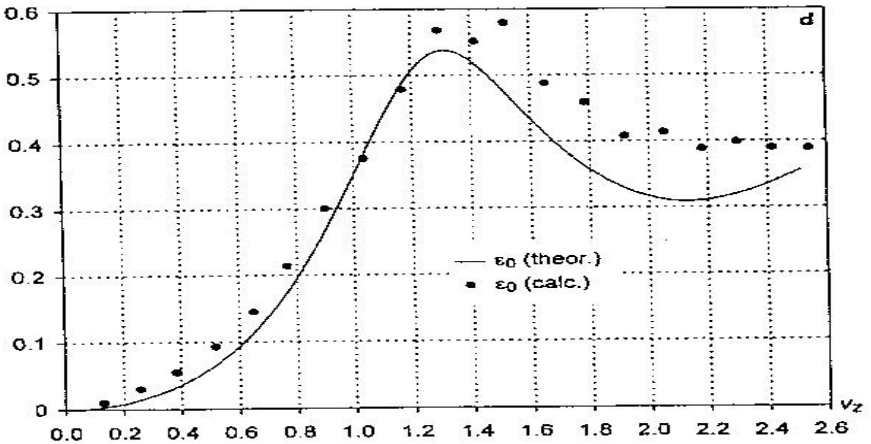



FIG. 4. 3D-plot of the 1-order intensity and ellipticity as a function of the RN-parameter $v_z$ and the KC-parameter Q.



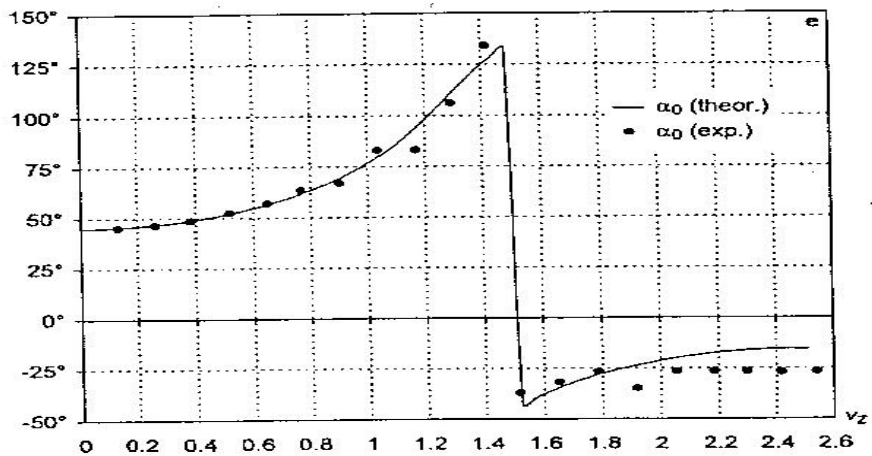




Figure 12. ULD in $SiO_2$ at normal light incidence. Experimental and theoretical dependencies in the zero order (a) intensities $I_{0,y}$, $I_{0,z}$, $I_0$ (corresponding to $\alpha = 45°$), (b) phase shift $\psi_0$, (c) modulus of the ratio of amplitudes $|R_0|$, (d) ellipticity $\varepsilon_0$ and (e) azimuth angle $\alpha_0$ against the RN-parameter $v_z$ for $Q = 2.6$. In (a), the calculated intensity refers to the average value of the experimental $I_{0,y}$ and $I_{0,z}$-data.

Many of common achievements of KULAK and UG were widely recognized in a few occasional review papers (R. Mertens, O.Leroy, A.Sliwinski) [15-20].

Now, let us go to a short history of

## 3. Spring Schools on Acousto-optics and its Applications.

**Spring Schools on Acousto-optics and its Applications**

have been organized by the University of Gdańsk

as triennale international meetings since 1980 .

The contribution of KULAK to scientific achievements of the Schools have been very efficient and highly acknowledged. O. Leroy and his coworkers presented many valuable papers during the Schools. It was our pleasure and privilege to host Oswald Leroy and his co-workers Erik Blomme and Nico Declercq during the 10th Jubilee School in Sopot in 2008 and Erik and Nico during the ICU'2011 in Gdansk.

The 12$^{th}$AO School took place in Druskininkai in 2014.

Many historical facts about AO School activities in acousto-optics and its applications were also reported in [16-20].

Representations of the Belgian AO group were always present at the Spring Schools on Acousto-optics and Applications since the 1st one at Gdańsk-Wieżyca in 1980. Fig. 4 presents a photo of that time. Professor R. Mertens (who passed away in 2007)) is seen there.

It is worth mentioning two publications, one by Mertens [17] on 50 years of AOs and one by Leroy and Mertens [18] on theoretical AOs achievements in Belgium, where one can also find information about our mutual cooperation.

**1st Spring School on Acousto-optics, Gdańsk-Wieżyca, May 26 -30, 1980**. – Proc. issued by the University of Gdansk, 1980. - a report published in **ULTRASONICS,** 1981,**19**, 44.

**5th Spring School on Acousto-optics and Applications,**

**Gdańsk-Jurata, May 25 – 29, 1992.**

**5th Spring School on Acousto-optics and Applications, Gdańsk-Jurata, May 25 – 29, 1992.**

# 5th Spring School on Acousto-optics and Applications, Excursion to Hel Gdańsk-Jurata, May 25 – 29, 1992.

Professor Oswald Leroy reminding his common work with Professor Bill D. Cook


Presentation at the
7th Spring School
Gdansk – Jurata, 1998

**10th Spring School on Acousto-optics and Applications, Gdańsk-Sopot, May 12 – 15, 2008.**

- Proceedings published in **Applied Optics, Feature Issue on Acousto-Optics,** 1st March, 2009, **C1 – C165.**

# 10th Spring School on Acousto-optics and Applications, Gdańsk - Sopot, May 12 – 15, 2008.

**Oswald Leroy** (siting), **Anna Markiewicz and Bogumil Linde during the 10th Shool on Acousto-Optics, Gdansk – Sopot 2008**

**Oswald Leroy and his wife Agnes** (sitting) , **Anna Markiewicz and Bogumil Linde during the 10th Shool on Acousto-Optics, Gdansk – Sopot 2008**

**Oswald Leroy** (on the right) **and Antoni Śliwinski** (on the left)
**with their wifes Agnes na Alina**
**during the 10th Shool on Acousto-Optics, Gdansk – Sopot 2008**

**11th School on Acousto-optics and its Applications (joined with ICU'2011) Gdansk, Sept. 5 - 6, 2011.**

- Proceedings are available at the AIP Proceedings Web site at the link:

***INTERNATIONAL CONGRESS ON ULTRASONICS: Gdansk 2011***

or ***http://proceedings.aip.org/browse/new_titles***

- a report on the 11th School published in

**Arch. Acoust., 37, 2012, 121-121**.

# 12th School on Acousto-optics and its Applications

(organized commonly by
the **University of Gdansk** and the **Vilnius University**)

**Druskininkai, Lithuania, 29 June - 3 July, 2014.**

Selected papers published in **Acta Physica Polonica A, 2014, Acousto-Optics and Applications,127,1,1-137**

## 4. Conclusions

It has been a fantastic opportunity to recall Oswald Leroy's essential contribution into the long cooperation between KULAK and UG during this special Session organized by ICU'2015 as the tribute to him for his achievements in physics, particularly in the field of light and ultrasound interactions . His merits have been highly acknowledged and I would like to express to him my cordial congratulations and the best wishes for the future.

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**I am very thankful to the Organizers of the ICU'2015 Congress in Metz for giving me the possibility to present at this occasional session the few recalls of the 45 years history of cooperation between the Belgian group of KULAK and the Polish group of Gdansk University (UG) as a tribute to Oswald Leroy for his significant contribution to acousto-optics;**

**Thank you for your attention .**