The Legacy of Prof. Gabriel Freire to Contemporary Research on Microwave Photonics at ITA

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***Abstract* – This paper highlights some of what, from the author's perspective, were notable contributions of Prof. Gabriel Freire to the advancement of microwave photonics at ITA, Brazil. For nearly three decades, beginning in the early 1960s when he completed Master's and PhD programs in Electrical Engineering at Stanford University, he was a driving force in the development of ITA's graduate studies program. He was without a doubt a very good researcher, a learned scholar, and an inspiring teacher who kindled the spirit of discovery in his students. The paper intersperses his academic achievements with a few personal reminiscences provided by his former students and attempts to review his notable legacy to microwave photonics.**

Keywords- electromagnetic waves; acoustooptic; electrooptic; laser; microwave; photonic.

I. INTRODUCTION

The primary purpose of this paper is to highlight some of what, from the author's perspective, were notable contributions of Prof. Gabriel Felisberto de Oliveira Freire, here after named Prof. Gabriel Freire, to the advancement of microwave photonics at Instituto Tecnológico de Aeronáutica (ITA), Brazil. He was very proud of his colleagues at ITA and of fellow researchers of the Brazilian Microwaves and Optoelectronics Society (SBMO), which he helped to found.

His career as a researcher on applied electromagnetism began at Instituto de Eletrotécnica of Universidade Federal do Rio de Janeiro (UFRJ), his "almamater", then Escola Nacional de Engenharia da Universidade do Brasil, where he was admitted as engineer trainee, in 1951. The following year, he resigned to take an engineering job with Centro Brasileiro de Pesquisas Físicas (CBF-Brazilian Center for Researcher on Physics) – RJ, to work on the Sincrociclotron Project sponsored by Conselho Nacional de Pesquisas (CNPq – National Research Council). At CBPF, then located in the city of Niterói, he had the opportunity to meet a few outstanding researchers, namely: César Lattes, José Leite Lopes, Jayme Tiomno and Roberto Salmeron. However, by late 1954, he was missing university life to such an extent that he decided to apply for a professorship position at ITA, in São José dos Campos, then a country town, in the state of São Paulo!

In order to better understand his decision, one first should recalls that ITA was created with assistance from the Massachusetts Institute of Technology (MIT) [1]. Hence, from the very beginning, ITA was seen as a direct offspring of MIT, therefore an institution patterned after some original concepts which would led to its growth as a special type of educational institution which can be defined as a university polarized around science and engineering. We might call such type of institution a university limited in its objectives but unlimited in the breadth and the thoroughness with which it pursues these objectives. These concepts explains why an institute of technology as ITA was created aiming at including an undergraduate school and a graduate school as coequal parts on a homogeneous faculty. Out of such conception plan one would expects the evolution of a school of engineering and applied science working in close association with a school of basic science, complementary and both enriched by the social and esthetic values of humanities.

An institution is often said to be the shadow of a man. ITA is the shadow of many men and women, but above all it is a tribute to both Casimiro Montenegro Filho, then a lieutenant-colonel from Brazilian Air Force (FAB), and Richard Habert Smith, a professor from MIT' Aero-astro Department. Montenegro was a very good administrator whose devotion to excellence and visionary leadership help to set ITA on the path towards greatness. Richard Smith, who was under contract with FAB, was author of a general plan aiming at the creation of a center in aeronautical engineering, the Centro Técnico Aeroespacial (CTA), known as Plano Smith. He later became the first Rector of ITA.

The institute aims, as stated above, appealed very much to scientific Gabriel Freire's ideals. He joined the ITA's Divisão de Engenharia Eletrônica in 1955. There, he happily shared duties with a group of experts from various nationalities, some of them holding a PhD degree from well known universities, which was performing research on microwave theory and applications on telecommunications. He also deeply appreciated the environmental beauty of the institute campus, of which one may catch a glimpse in Fig.1.

Figure 1. An Aero view of the ITA campus. Freire's office was in the second building seen at the far right hand side.

This work was sponsored in part by Brazilian Society of Microwaves and Optoelectronics (SBMO).

Prof. Gabriel Freire was determined to make a career at ITA. In the fall of 1957, he was awarded a CNPq fellowship which enabled him to undertake graduate studies at Stanford University. There he worked under Prof. Chodorow and obtained Master and PhD degrees in Electrical Engineering. His PhD program was concluded on April 6th, 1962.

It is opportune to recall that a few years earlier Prof. Senise, also from ITA had concluded Master and PhD programs, at Stanford, working under Ginzton and Chodorow, respectively, 1955 to 1958. As a matter of fact, for a short while Freire and Senise shared research facilities at Stanford. Saying it shortly, in the middle 1950 two ITA's electronic engineering faculty had graduated at Stanford under the same adviser! Naturally, their influential adviser, Prof. Chodorow, deserves further attention. As a matter of fact he graduated under Prof. John Slater, from MIT, in 1939, who a few years earlier had advised William Shockley, one of the co-inventors of the transistor. Him, Bardeen, and Brattain shared the 1956 Nobel prize in physics for their "investigation on semi-conductors and the discover of the transistor effect" [2]. Consequently, students under Chodorows, like Freire and Senise, would undertake challenging research while working for according to both the MIT's and Stanford's standard of values.

Moreover, finding out about sources of ITA's rather enduring affinity to Stanford University is relevant to this paper aims because it may help to understand way ever since his return from Stanford the number of former students from ITA who enrolled in graduate program at Stanford had became rather significant. Obviously, the assumption that ITA is a direct offspring of MIT is not questioned. To this aim one should recall that by the middle 1950s ITA's Electronic Engineering Division was headed by professor Spangenber, then on leaving of absence from Stanford University. He was a very good teacher preoccupied with institutional outcomes. His interest on such matters was powered by an effective and long standing collaboration with Frederick Terman, the legendary electrical engineer professor, known as "father of silicon valley", who was then the Provost and Vice President of Stanford University. At ITA, Spangenberg also encouraged advanced researcher on devices based on the interaction between electronic beams and electromagnetic fields. As a matter of fact both Senise and Freire developed their graduate studies working on Klystron, a microwave device based on the just mentioned kind of interaction [3].

Additional source for the affinity under examination may be found in the biographies of Aldo Vieira and Hélio Costa, both from Brazilian Air Force (FAB), who were students at Stanford during the World War II years [1]. For example, nearly ten years later, in 1956, Aldo Vieira became Director of CNPq. Beyond that, after retiring from FAB, he went back to Stanford, as graduate student, obtained a PhD degree, in 1965, and worked his way up as a faculty. Nowadays he is an emeritus professor at Stanford's electrical engineering department.

After these insightful historical notes, it is opportune look at ITA in the beginning of its second decade. The institute was recognized as an outstanding undergraduate school on aeronautics, electronics and mechanical engineering. Such remarkable achievement also indicated that ITA's ideal, which postulated both an undergraduate school and a graduate school as coequal parts of a homogeneous faculty, was still far from being completed. This perception explains why in the early 1960s, the creation of a graduate programs on engineering was a major concern to quite a few ITA's professors, specially to those who found inspirations on the vision of a former MIT's President, Karl Compton, which states the three most pertinent questions in evaluating: ""What is its purpose?", "What is its accomplishment?", "What is its future?"" [4].

A model for a graduate program on engineering aimed at fulfilling the so called "stricto sensu" requirements and tailored according to ITA's mission was created and adopted by ITA when Prof. Marco Antonio Guglielmo Cecchini was its 5th Rector, in1961. In its early stage, the program content on electronic engineering was very much based on the expertise and leadership of Prof. Richard Waullauschek.

When Prof. Gabriel Freire returned to ITA in early 1962, the institute was facing the challenge of pioneering graduate studies on engineering, in Brazil. He was eagle to undertake his share of duties, both teaching and researching on plasma and microwaves.

This paper comprises three more sections beyond this historical introduction. Section II highlights his research on plasma and microwaves, 1962 to 1975. Next, section III addresses his researches on photonics. It also points out reasons why his legacy has played so great a part in contemporary research on microwave photonics, at ITA, and even at other engineering schools across Brazil. The paper ends with section IV, where concluding remarks are given.

II. RESEARCH ON PLASMA AND MICROWAVES

As already mentioned, right after returning to ITA, Prof. Gabriel Freire undertook teaching on both the undergraduate and graduate levels. Simultaneously he began research on plasma and microwaves and also dealt with institute's research administrative matter. Nevertheless, he established his teaching and researcher interests and made a place among his academic colleagues.

His first graduate student at ITA was Aroldo Borges Diniz, a former ITA's student who was then beginning a career as a faculty at Electronic Division. Their joint work had a rather great impact on both graduate and undergraduate activities on the subject of electromagnetism at ITA. First, in order to fulfill the requirements for a master degree, Aroldo presented the thesis "Propagation of Electromagnetic Waves in Plasma", in 1963 (in Portuguese). His was the second graduate thesis presented at ITA. Next, he completed studies leading to the Doctorate degree, also under Prof. Gabriel Freire supervision and presented the first thesis of this kind at ITA, "Study of Microwave Oscillations by Gunn Effect", in 1970 (in Portuguese).

Their collaboration was crowned with the publication of a book "Electromagnetic Waves", EDUSP/Livros Técnicos e Científicos, in 1973 (in Portuguese), which became a

household item to many engineering students, across Brazil. A quick glance at its front cover, shown in Fig. 2, brings to life a joy of insight valuable to many SBMO's members who make their living out of Maxwell's equations and Smith's chart. The front cover was provided by Prof. José Antonio Justino Ribeiro, from Instituto Nacional de Telecomunicações (INATEL).

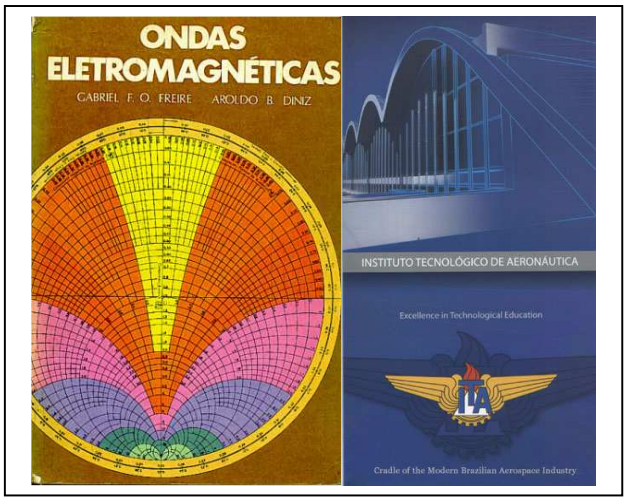

Figure 2. Front cover of Freires' s book, side by side to ITA logotype.

As a personal note, the author of this paper would like to mention that the aforementioned book was highly evaluated at Universidade de Brasilia (UnB), while he was doing undergraduate studies on electrical engineering there, from 1973 to 1976. A few years later, while undertaking graduate studies at ITA, he was honored by having Prof. Gabriel Freire as his adviser and had the opportunity to learn a great deal from the insightful author and his book as well.

Prof. Gabriel Freire's researches on microwave and plasma, mostly accomplished between 1962 and 1975, became quite well known and have been discussed by others. Therefore, this paper will present them in a rather descriptive fashion.

In the period under consideration his researches yielded ten publications on scientific international periodicals. Indeed, it was a very good outcome, specially when one takes into account the rather severe limitations which had to be overcome in order to be able to publish abroad. His publication appeared in the following scientific journals: Proceedings of IEEE (5), American Journal of Physics (1),

He also wrote a few very insightful internal reports based on researcher developed under the sponsorship of CNPq and Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP). Furthermore, his class's notes on plasma physics, microwave semiconductors, microwave devices, and magneto hydrodynamic were just wonderful. He also was very successful regarding to both undergraduate and graduate students advisement. Thirteen undergraduate students worked under his advisement, on subjects ranging from microwaves, semiconductor, plasma and ferrites.

Regarding graduate students advisement, beyond the already mentioned Aroldo's master degree, seven additional master degrees were completed. Among them, six were issued to junior professors affiliated to a few universities located at three different states of Brazil, whereas the seventh one was to an international student, from Peru. Their thesis subjects were very up to date research topics, such as: study of FM signal distortion on plasmas, electric dipole in anisotropic plasma, helicon waves in semiconductor, to name but just a few.

Regarding administrative duties Prof. Gabriel Freire also did his share. At ITA, where he was promoted to full professor in 1967, he was head of Electronic Engineering Division, from 1966 to 1967. Beyond that, he was one of founding fathers of "Faculdade de Engenharia de São José dos Campos" a private engineering school, of which he was the first Director, 1968-1971.

Concerning his contributions towards fostering research, is important to mention that he was keynote speaker at meetings such as: First Brazilian Congress on Electronic Engineering - ITA, 1965, and at Symposium of the Brazilian Society for the Advancement of Science (SBPC), held in Rio de Janeiro, in 1973, and Recife, in 1974. Naturally, he became friend to fellow researchers from a good many institutions such as: Universidade de São Paulo (USP), Instituto de Pesquisa Espaciais (INPE), Universidade de Campinas (Unicamp), Instituto Mauá de Tecnologia (IMT), Instituto Militar de Engenharia (IME), Instituto Nacional de Telecomunicaçoes (INATEL), to name but a few.

The achievement briefly highlighted in the previous paragraphs was a valuable academic asset which indicates Prof. Gabriel Freire's capability and leadership to carry on multidisciplinary research. Such qualities enabled him to obtain a rather strong institutional support, when he decided to undertake researcher on microwave photonics.

III RESEARCH ON MICROWAVE PHOTONICS

Looking backwards, one finds that by the middle 1970s the field of photonic had become a major subject in quite a few researcher groups throughout the world. Their aims were related to the generation, emission, transmission, modulation, signal processing, switching, amplification, detection, and sensing of light [8].

Prof. Gabriel Freire was very much aware of the trend driven by photonics and found stimulating appeals on branches dealing with modulation, switching, transmission, and signal processing, hence he decided to shift part of his research activities to the field of photonics. As far as frequency range was concerned, his interest was focused on the commonly called optical communication range, i.e. the range within the near infrared and the visible limits.

In order to better appreciate the effectiveness of Prof. Gabriel Freire's approach to research on the field of photonics

it is opportune to recall the topology of a standard fiber optical link, which is briefly illustrated in Fig.3.

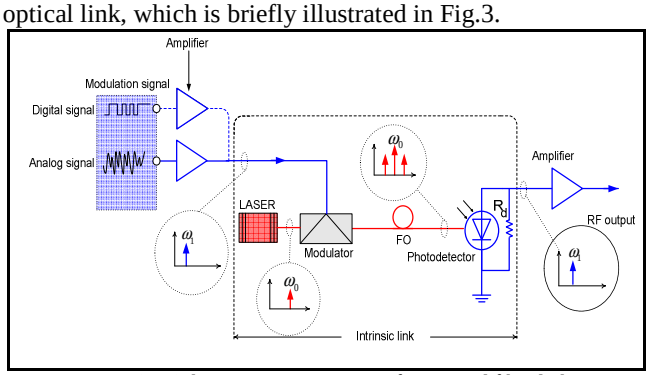

Figure 3. Schematic representation of an optical fiber link.

In the typical implementation of an optical fiber link, as shown in Fig.3, an analog or digital electrical signal at microwave frequency is transported over a certain length of optical fiber, with electrical-to-optical and optical-to-electrical conversion at transmitting and receiving sides. The illustration refers to a link based on external intensity modulation and direct detection (IMDD).

Since the very early stage of his interest on photonics, Prof. Gabriel Freire had decided to carry on experimental researcher and also take advantage of the laboratories facilities available at ITA and near by institutions. Based on such aim he decided to take on optical modulator, i.e. its design, fabrication and tests, as his main research topic. Fulfilling such aims would require quite a few graduate students with background ranging from physics (optics), electronic engineering (microwaves) and mathematics (analytical and numerical techniques). He had to sort out and trained the students aiming his research needs [9]

Coming back to the optical modulators matters, Prof. Gabriel Freire decided to investigate modulators which rely on the electrooptic and acoustooptic effects, irrespective of the their technology, i.e. bulk optic or integrated optic. These effects are rather intense in lithium niobate ($LiNbO_3$), therefore at ITA likewise in many researcher institution, it was recognized as enabling material by those who were working towards practical applications of photonics.

Recognizing the crucial role played by the interaction caused by the aforementioned effects in the modulator principle of operation, he worked out two insightful reports in which well ascertained scientific principles were applied in various ways to study the interactions between optical wave, acoustic wave, and microwave, namely: “Coupled Mode Theory for Acousto-optic Interactions”, ITA Physics Department, (in Portuguese), June, 1977, and “Coupled Mode Theory Applied to Optical Waveguides”, ITA Electronic Engineering Division, (in Portuguese), May, 1980.

Owing to the rather limited space available in this publication, let us apply his carefully built approach to anticipate some features of optical modulators based on the performance of a rather particular architecture, the so called Mach-Zehnder modulator (MZM), shown in Fig. 4.

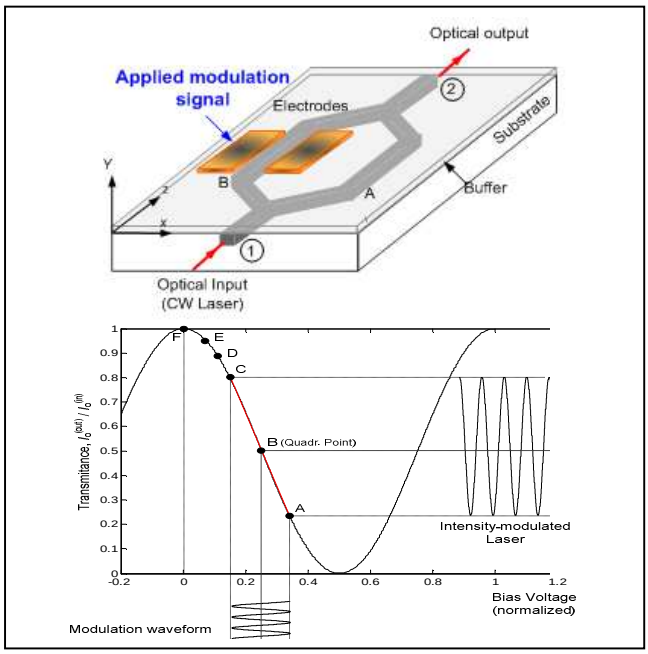

Figure 4. Integrated optical Mach-Zehnder amplitude modulator

The principle of operation of a standard Mach-Zehnder modulator and its non-linear transfer characteristic curve with a raised cosine like shape are well understood. At ITA such issues were studied by Claudio Kitano and José Antonio Justino Ribeiro, early on in the 1990s.

Research on acoustooptics devices also was being pursued at ITA, mainly aiming optical modulators based on the interaction between surface acoustic wave (SAW) and guided optic wave in $LiNbO_3$ substrates. In such type of modulator the acoustic wave is generated by an interdigital transducer (IDT), as illustrated in Fig. 5.

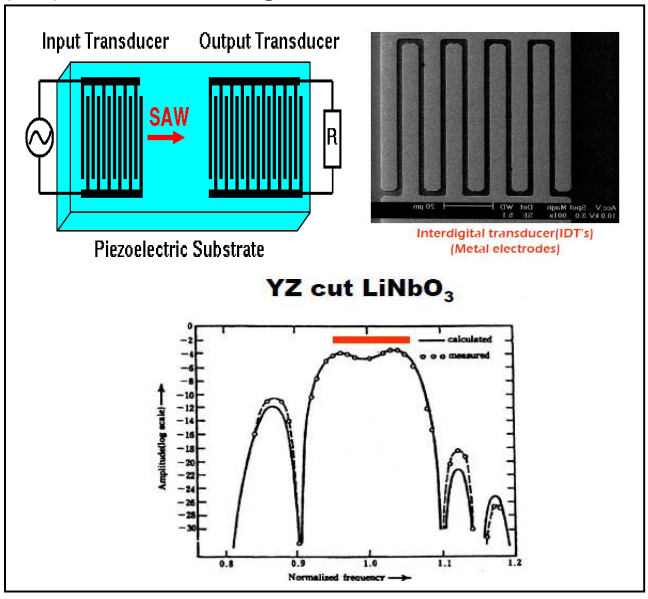

Figure 5. Surface Acoustic Wave (SAW) generation by Interdigital Transducer (IDT).

At this stage of the paper, the author would like to point out that Prof. Gabriel Freire's also introduced and thought advanced graduate courses related to the devices illustrated in Fig. 4 and Fig. 5, namely: FIS-292: " Introduction to Optical Waveguide Theory", 1976; FIS-280: "Optical Waveguide Theory", 1976; ELE-221:"Electrooptic Fundamentals", 1979, and EC-323: "Topics in Integrated Optics", 1980.

Quite a few students were attracted by Prof. Gabriel Freire's research area and enrolled at ITA as his graduate students. Let as nominate those who worked on photonics: José Antonio Justino Ribeiro, Avelino Marcante, Roberto Antonio Stempniak, Walter Winkel, Charles Arthur Santos Oliveira, André Côrtes, and José Edimar Barbosa Oliveira.

The research on bulk electrooptic modulator based on $LiNbO_3$ was undertaken by Justino, from Instituto Nacional de Telecomunicações (INATEL), while he was working towards a master degree. His thesis "The Dielectric Resonator in Microwaves and its Application in Electrooptic Modulation", (in Portuguese) was concluded in 1980. Later on he obtained a Doctorate, at ITA, working on integrated modulators.

The subject of SAW was undertaken by José Edimar while he was a master student. He presented the thesis "Study of the Generation of Rayleigh in Piezoelectric Crystals using Interdigital Transducers", (in Portuguese) in 1979. The assistance of Prof. José Kléber da Cunha Pinto, from LME/EPUSP, enabled the experiments.

Meanwhile, research on optical waveguide was well underway. For example, in 1982, Charles Arthur completed his master program presenting the thesis "Propagation Modes in Slab Optical Waveguides"; He went on and concluded a Doctorated in 1986 with the thesis "Design and Fabrication of an Integrated Optical Device Comprising a Thin Film Waveguide and a Periodic Structure" (in Portuguese)..

Insightful results on prism coupling of guided modes in slab type optical waveguide couplers also were reported in Stempniak's Doctorate thesis "Characterization of Fluoretos Thin Film Using Optical Methods" (in Portuguese), in 1984. His result on m-line spectroscopy for guided modes also appeared as front cover of ITA Engenharia - vol. 5, no. 1, pp. 57 - 65, March, 1984. Fig. 6 pictures a typical m-line result.

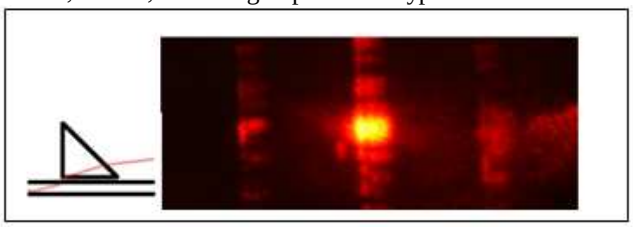

Figure 6. Prism Coupling of Optical Guided Modes.

Further results related to the propagation characteristics of slab type optical waveguides were obtained by Walter Winkel who completed the Doctorate degree with the thesis "Propagation Constants of Non-Homogeneous and Anisotropic Thin Film Optical Waveguides, (in Portuguese) in 1984.

The measurement of optical attenuation in waveguides was carried André Côrtes, who as a master student developed the thesis "Optical Attenuation in Slab Waveguide with Highly Conductive Substrate", (in Portuguese) in 1985.

The experimental results just mentioned enabled a rather challenging achievement on the subject of interaction between SAW and optical guided modes in $LiNbO_3$ slab waveguide. The experiment was carried out by Avelino Marcante, a very skilful Doctorate student. The device implemented by Avelino comprised a SAW transducer, like the one already shown in Fig. 5, and a planar optical waveguide obtained by in-diffusion of titanium. The optical source was a Helium-Neon (He-Ne) laser, which was coupled to the waveguide through a prism made of rutile (TiO_2). The prism was kindly donated by Dr. Zoraide Arguelo, from the physics department of Unicamp. The device performance was fully reported in Avelinos's thesis "Diffraction of Light via Acoustooptic Effect in Anisotropic and Non-Homogeneous Slab Waveguides", (in Portuguese) in 1984.

It is worthwhile to point out that in the early 1970s, when CTA was planning the creation of an Institute for Advanced Studies (IEAv), Prof. Gabriel Freire was very enthusiastic and contributed by addressing photonics potentiality in airspace application, For instance, on April 19^{th,}, he gave a talk on "Integrated Optics and New Wavelike Phenomena in Optical Waveguides". As a matter of fact, IEAv was inaugurated in 1982 having photonics is one of its primary goals.

Between 1982 and 1986, the author of this paper was at McGill University, in Montreal-Canada, working towards a PhD degree, under Prof. Eric Adler. Nevertheless, he was very much aware of the progress being made at ITA. His research on acoustooptic devices at McGill was also rather successful and he realized that the training at the time provided by Prof. Gabriel Freire, at ITA, was fully the equal of that in top ranked American Universities.

The state of the art of photonics technologies advanced so rapidly that by the middle 1980s worldwide researches were following new trends enabled by the interaction between microwave and optical signals, and aiming applications in radar, satellite communications, sensor networks, instrumentation, broadband wireless access networks, and warfare systems. Such subject was overall denominated as microwave photonics.

An examination of Prof. Gabriel Freire's achievements allows one to conclude that most of them were straightly related to the previously mentioned trends on microwave photonics. Indeed, at the span of time under consideration, quite a few of his eighteen former graduate students were undertaking researcher on such subject, either at ITA and any other CTA's institute or at some institutions scattered across Brazil. Such was the reality observed by the author of this paper when he returned to ITA, after completing his PhD studies at McGill, in early 1986. He was then rapidly enrolled on ongoing microwave photonics researcher, and in so doing he had the opportunity to share duties with Prof. Gabriel

Freire, always the ideal teacher, who by example provided an unequaled opportunity for his former student to practice and acquire some of the methods and the ideals which have made his former adviser a great researcher. Indications of the effectiveness of such learning can be found on the raising of the number of graduate students on microwave photonics, including those who enrolled in PhD studies abroad, as well as in the creation of a laboratory dedicated to microwave photonics, in 2001 [10].

So far, this publication has provided a rather broad view of Prof. Gabriel Freire's career at ITA. However it may be useful to attempt to sum up briefly some of what, from the author perspective, constitutes his legacy to contemporary researcher on microwave photonics at ITA.

In first place, stands up his teaching methodology ascertained in scientific principles which was applied in various ways for mentoring young researchers on the subject of interactions between microwave and optical signals, i.e. the area of microwave photonics, at ITA. As a second place we point out his approach to advisement which comprises envisaging and masterminding multidisciplinary issues through scientific seminars given by the students. Last but not least, stands enduring research on acoustic wave theory and techniques and electrooptics that he founded at ITA. These fields enabled relevant results in the late 1980s: Q switch for Nd-YAG laser and optical fiber frequency shift. Quite a few years later, in the early 2000s, experiments on laser ultrasound, sketched in Fig.7, were performed according to ITA's interest and in cooperation the National Research Council of Canada (NRC) [11]. At that time an enthusiastic ITA's former student, who had completed PhD at McGill University, was a research fellow at NRC.

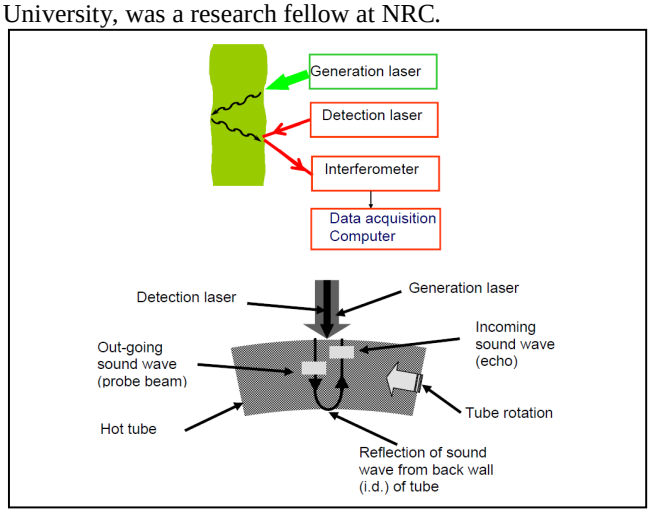

Figure 7. Laser ultrasound: On-line steel tub gauging [11].

As a personal note the author of this paper would like to nominate a few former ITA's graduate student whose achievement played so a great a part in the last mentioned experiments: Demartonne R. França (UnB), Claudio Kitano (UNESP) and Osni Lisbôa (IEAv). Moreover, stimulating experimental results on analog optical fiber links at microwave frequencies up to 18 GHz and microwave optical filters with center frequency about 2 GHz were recently reported by Vilson Rosa de Almeida (IEAv), Olympio Coutinho (ITA), Bráulio Sakamoto (CIGE), William Fegadolli (ITA), and Carla Martins (IPqM) [12], [13].

IV CONCLUDING REMARKS

This paper highlights some of what, from the author's perspective, were notable contributions of Prof. Gabriel Freire to the advancement of microwave photonics at ITA. The paper also intersperses his academic achievements with a few personal reminiscences provided by his former students and attempts to review his legacy to contemporary research on microwave photonics at ITA. He will remain in the hearts and minds of those many persons who were influenced by his teaching and his kind thoughts.

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REFERENCES

[1] A. J. J. Botelho, "Da Utopia Tecnológica aos Desafios da Política Científica e Tecnológica: O Instituto Tecnológico de Aeronáutica (1947 – 1967)". Revista Brasileira de Ciências Sociais, vol. 14, no. 39, São Paulo, pp. 139-154, Fev. 1999.

[2] C. S. Gillmor, " Fred Terman at Stanford – Building a Discipline, a University, and Sillicon Valley", Stanford University Press, Stanford, California 2004.

[3] G. F. Freire, "Interaction Effects Between a Plasma and a Velocity Modulated Electron Beam", Stanford University, Feb. 1962.

[4] K. T. Compton, "The Inaugural Address: 9th President of MIT", MIT *Technology Review* vol.32, pp. 436-438, 465, 466, July 1930.

[5] G. F. Freire, "The Effect of Ion Motion on Plasma Oscillation", Proceedings of IEEE, vol.51, no. 12, pp. 1970, Dec., 1963.

[6] G. F. Freire, "A Force-Free Magnetic Field Probem", American Journal of Physics, vol.34, no. 7, pp. 567-570, july 1966.

[7] G. F. Freire and A. Marcante, "Diffusion Effects on Space-Charge Waves in a Very Thin Semiconductor Layer", International Journal of Electronics, vol.38, no.4, pp. 443-453, 1975.

[8] K. Itoh at all, "Optics and Photonics for Security Defense", Proceedings of the IEEE-Special Issue, vol. 97, no.6, June 2009.

[9] E. C. Monteiro, G. J. Adabo, and J. E. B. Oliveira, "Fotônica e Optoeletrônica: Pesquisas Desenvolvidas na Divisão de Engenharia Eletrônica do ITA. Revista ITA Engenharia, pp. 13-17, Out. 1994.

[10] J. E. B. Oliveira, F. D. P. Alves, and A. L. P. Mattei, " Trends on Photonics Applied to Electronic Warfare at Braziian Airforce", SBMO/IEEE MTT-S, Rio de Janeiro, Aug. 1999, vol.2, pp. 599-602.

[11] D.R. França and A. Blouin, "All-Optical Measurement of In-Plane and Out-Of Plane Young's Modulus and Poison's Ration in Silicon Wafers by Means of Vibration Modes", Measurement Science and Technology, vol.15, no. 5, pp. 859-868, May 2004

[12] J. E. B. Oliveira, B. F. R. Sakamoto and W. S. Fegadolli, "Similarities between birefringent Gires-Tournois interferometer and double ring assisted Mach-Zehnder electrooptic modulator", European Microwave Conference, pp. 1330 – 1333, 9-12 Oct. 2007.

[13] O. L. Coutinho, V. R. Almeida, C. S. Martins and J. E. B. Oliveira, "Continuous Multiband Microwave Photonic Phase Shifter Based on Lightwave Polarization Control", International Conference on Fiber Optics and Photonics, Photonics 2008, New Delhi.