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## RESUME:

**Geraldo A Barbosa**

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### WORK: **Current:**

KeyBITS Encryption Technologies LLC

7309 Gardenview Drive, Elkridge MD USA 21075-5944

### EDUCATION

**PhD (Physics):** University of Southern California (1974), Los Angeles, CA,USA

**MA:** University of Southern California (1974), Los Angeles, CA,USA

**B.Sc:** Federal University of Minas Gerais (1968), Belo Horizonte, MG, Brazil

**High School:** Colegio Tiradentes (1963), Belo Horizonte, MG, Brazil

**CITIZENSHIP:** USA and Brazil.

**BIRTHDATE:** February 15, 1943.

### AREAS OF WORK

**Current:** *Quantum Optics* (1987-...): Coherence and Statistical Properties of Light, Photon Detection, Photon Correlation, Twin-Photons (Parametric Down-Conversion), Quantum Cryptography.

**Former:** *Light Scattering* (1974-87): Raman, Brillouin, and Quasi-Elastic Light Scattering from Ferroelectric Crystals and Phase Transitions.

## UNIVERSITY WORK

**Northwestern University**, 2000/2001: Eshbach Society Award from The McCormick School of Engineering and Applied Science. Until 2011: Adjunct Professor at the Electrical Engineering and Computer Science Department - Center for Photonic Communication and Computing, Evanston, Illinois, 60208.

Most recent activity at NU: Multidisciplinary University Research Initiative (MURI) on Quantum Imaging (DoD support/US Army). See

<http://www.optics.rochester.edu/workgroups/boyd/Quantum%20Imaging/index.htm>,

Several other projects supported by National Science Foundation (Parametric Down-Conversion), DARPA/Air Force (Cryptography with Light Noise).

Visiting Professor of Physics in **1999/2000** at the Physics Institute of the University of São Paulo (USP), Brazil, supported by FAPESP (Fundação do Estado de São Paulo para Amparo à Ciência) to Research on Parametric Down-Conversion Luminescence and Squeezed Semiconductor Lasers. Course taught: Quantum Optics.

Visiting Professor of Physics in **1996/1997** at University of Alagoas, Brazil, supported by CNPq (Conselho Nacional de Pesquisas) to Research on Parametric Down Conversion Luminescence and Quantum Cryptography. Course taught: Spontaneous Parametric Down-Conversion.

Visiting Professor of Physics in **1992/1993** at the University of Rochester, New York, USA: Department of Physics and Astronomy (Dr. Leonard Mandel's Laboratory).

**1982-1995**: Full Professor of Physics at **Federal University of Minas Gerais** (UFMG), Brazil; **1973-82**: Associate Professor; **1970-73**: Assistant Professor (leave of absence); **1968-69**: Teaching Assistant.

At UFMG, my duties and accomplishments included: Teaching, research, thesis advising, establishment and construction of laboratories in Optics for Light-Matter Interactions (Quantum Optics and nonlinear interactions, Raman and Rayleigh scattering, phase transitions, Brownian motion), including the First Quantum Optics Laboratory in Brazil.

### **Teaching Experience:**

Graduate Courses: Classical Electrodynamics (years 1974/75/85/86/ 87/88/89/90/91); Optics (1975/81); Quantum Optics (1985/96); Solid State Physics 1978/79/80/82); Quantum Mechanics (1980); Photon Correlation Spectroscopy (1978).

Undergraduate Courses: Introduction to Modern Physics (1975/76/77/89/90); Classical Mechanics (1974/82/86/88); General Physics (1968/69); Experimental Physics (1983/93/94).

*Summer courses of the Brazilian Physical Society: Photon statistics* (1986); *Parametric Down Conversion Luminescence: Principles and Applications* (1998); etc

### **Graduate Adviser:**

Carlos Henrique Monken (1993), Paulo Henrique Souto Ribeiro (1995) (Awarded "Best Experimental PhD Thesis in Brazil from 1994 to 1997, Brazilian Physical Society 1997"). // Oscar N. Mesquita (1979), José Inácio dos Santos (1979), Ricardo Russi (1980), Fábio João de Almeida (1982), Wagner Nunes Rodrigues (1982), Leonardo Fonseca (1982), Pedro Licínio de Miranda Barbosa (1983), Roberto Luiz Moreira (1984), Cláudio Antunes Siqueira (1987), Ana Maria de Paula (1987), Hugo Haele Arnaut (1998).

## OTHER INFORMATION

- **President** of the “Comitê Técnico e Científico da Rede Nacional em Segurança da Informação e Criptografia/RENASIC” – Centro de Defesa Cibernética/CDCiber – Exército Brasileiro (2015/2017).
- **Conference/school** (invited paper): WECIC2010/School of Computation and Quantum Information – Laboratório Nacional de Computação Científica – Petrópolis /Rio de Janeiro-Brazil, 13/15 October 2010.
- **President**, KeyBITS Encryption Technologies LLC, Elkridge MD;
- Consulting: QuantaSEC Ltd- Consulting, Projects and Research in Physical Cryptography – Brazil. Development with UFMG/Department of Defense: Physical Random Bit Generator (RENASIC/Brazilian National Network for Secure Information and Cryptography)
- **Head** of the Scientific Committee for Exact and Earth Sciences (1986-90) of the Foundation for Research Support of the State of Minas Gerais (FAPEMIG), Brazil.
- **Graduate Course Coordinator**, Physics (UFMG/Brazil, from 1986 to 1988),
- **Coordinator** of the FUNTEC 200 Project between the “National Bank for Economic Development” and UFMG (1974-76).
- Brazilian **Coordinator** of Scientific Bilateral Programs between UFMG/CNPq (*Brazil*) and CNRS (*France*), in 1981-83, 85-86, 88-91 on *Fluorperovskite crystals* (research on new crystals for laser operation), and DAAD (*Germany*) in 1981-83 on *Photo-refractive crystals* (research in LiNbO<sub>3</sub>:Fe crystals for 3D optical memories).
- PI in Research Grants from CNPq/Brazil (1974/1995).
- PI or coPI in NSF grants (2000/2010)
- Establishment of the first Quantum Optics Laboratory in Brazil.
- **Consultant** for FINEP-Brazil (e.g., Pronex) and other Brazilian agencies.
- **Chair/Member** of several organizing committees of Brazilian Meetings and Summer Schools (ENFMC, SLAF, J. A. Swieca).
- **Referee** for *The Physical Review* and other journals;
- Project **reviews** for National Science Foundation.
- **Patents in Cryptography: U.S.:** “Fast Multi-Photon Key Distribution Scheme Secured by Quantum Noise” (GA Barbosa - 2003) **US 7,831,050 B2 (2010)** and “Ultra-Secure, Ultra-Efficient Cryptographic System” (HP Yuen, P Kumar and GA Barbosa - 2003) **US 7,333,611 B1 (2008)**; **Brazil:** “Sistema para Distribuição de Chaves Criptográficas por Ruído Quântico” **PI 0405814-3 – INPI/Brazil (2017)**, 06/12/2004; “Quaternary Optical Emitter and Quantum Cryptographic System” (PI 9805314 – INPI/Brazil, 15/05/1998). INPI Journal1535, 06/06/2000. Brazilian government/UFMG.
- **Translator** (to Portuguese): *Physics*, F. J. Keller, W. E. Gettys and M.Skove (McGraw-Hill 1993).
- **Adviser** for the “Best Experimental PhD Thesis in Brazil from 1994 to 1997, Brazilian Physical Society 1997”, PhD student: Paulo H. Souto Ribeiro.
- **Membership:** Brazilian Physical Society, American Physical Society (formerly).
- **Conferences:** Scientific Presentations in several International Conferences (CLEO, QELS, CQO,...).
- **Languages:** English (Fluent), Portuguese (Fluent), Spanish (Read, Write-, Speak-), French (Read, Write-, Speak-).
- **User:** Wolfram’s Mathematica.

## Selected Publications

*A wireless secure key distribution system with no couriers: a One-Time-Pad Revival*

Geraldo A. Barbosa. arxiv.org 1901.05324 and

ENIGMA - Journal of Information Security and Cryptography, vol. 5, no. 1, pp 1-19 (2018).

*A Wireless Physically Secure Key Distribution System*

G. A. Barbosa, Enigma (Brazilian Journal of Information Security and Cryptography), Vol. 3, No. 1, 9 (2016).

*Untappable key distribution system: a one-time-pad booster*

G. A. Barbosa and J. van de Graaf, arXiv:1406.1543v2 [cs.CR] 8 July 2015;

Enigma (Brazilian Journal of Information Security and Cryptography), Vol. 1, No. 2, 16 (2015).

*A True Random Number Generator based on quantum-optical noise;*

A.A. Ruegger, G. A. Barbosa, J. van de Graaf, G. M. Ribeiro, J. C. de Melo, R. A. Nogueira, W. N. Rodrigues, F. S. Nunes,

XIV Simpósio Brasileiro em Segurança da Informação e de Sistemas Computacionais - SBSeg 2014, pg.334.

*Harnessing Nature's randomness: Physical Random Number Generator*, G. A. Barbosa, Invited paper, 2014: Enigma (Brazilian Journal of Information Security and Cryptography), Vol. 1, No. 1, 47 (2014).

*Can humans see beyond intensity images?*, G. A. Barbosa,

arXiv:1202.5434v1 [q-bio.NC] 24 Feb 2012

*Lossless single-photon shaping via heralding*, K. G. Köprülü, Y-P Huang, G. A. Barbosa, and P. Kumar, Optics Letters **36**, 1674 (2011).

*Wave function for spontaneous parametric down-conversion with orbital angular momentum*, G. A. Barbosa, Phys. Rev. A **80**, 063833 (2009).

*Comment on "Spatial Symmetry and Conservation of Orbital Angular Momentum in Spontaneous Parametric Down-Conversion"*, G. A. Barbosa, Phys. Rev. Lett. **103**, 149303, (2009).

*Indistinguishability of orbital angular momentum modes in spontaneous parametric down-conversion*, G. A. Barbosa, Phys. Rev. A **79**, 055805 (2009).

*On the distinguishability of downconverted modes with orbital angular momentum*; G. A. Barbosa, Optics Letters **33**, 2119-2121 (2008).

*Transverse coincidence-structures in spontaneous parametric down-conversion with orbital angular momentum: Theory*; G. A. Barbosa, Phys. Review A **76**, 033821 (2007).

[*Secure sharing of random bits over the Internet*; G. A. Barbosa, quant-ph/0705.2243 v2 17 May 2007]

[*One-time pad booster for Internet*; G. A. Barbosa, quant-ph/0704.1484 v1 11 Apr 2007]

*Quantum half-adder*, G. A. Barbosa, Phys. Rev. A **73**, 052321 (2006).  
(Also in Virtual Journal of Quantum Information -- June 2006, Volume 6, Issue 6)

[*Noise Secured Internet*; G. A. Barbosa, quant/ph0510011 (2005)]

*Information theory for key distribution systems secured by mesoscopic coherent states*;  
G. A. Barbosa, Phys. Review A **71**, 062333 (2005).

*Quantum imaging of nonlocal spatial correlation induced by orbital angular momentum*;  
Adam R. Altman, Kahraman G. Köprülü, Eric Corndorf, Prem Kumar, and Geraldo A. Barbosa,  
Phys. Rev. Letters **94**, 123601 (2005).  
(Also in Virtual Journal of Quantum Information -- April 2005 Volume 5, Issue 4, and quant-ph/0409180 (2004)).

*Fast and secure key distribution using mesoscopic coherent states of light*;  
G. A. Barbosa, Phys. Rev. A **68**, 052307 (2003).

*High-speed data encryption over 25km of fiber by two-mode coherent-state quantum cryptography*  
E. Corndorf, G.A. Barbosa, C. Liang, H.P. Yuen, and P. Kumar, Optics Letters **28**, 2040-2042 (2003).

*Secure communication using mesoscopic coherent states*;  
G. A. Barbosa, E. Corndorf, P. Kumar, and H. P. Yuen, Phys. Review. Letters **90**, 227901-1 (2003).

*Twin photons entangled in polarization and angular momentum*;  
G. A. Barbosa, The European Physical Journal D **22**, 433-440 (2003) [Invited paper].

*Quantum Cryptography with Coherent-state Light: Demonstration of a Secure Data Encryption Scheme Operating at 100kb/s*;  
G. A. Barbosa, E. Corndorf, and P. Kumar, Quantum Electronics and Laser Science Conference, OSA Technical Digest, Vol. 74, pp. 189-190 (2002).

*Secure Communication using Coherent States*;  
G. A. Barbosa, E. Corndorf, P. Kumar, H. P. Yuen, G. M. D'Ariano, M. G. A. Paris, and P. Perinotti in Proceedings of the Sixth International Conference on Quantum Communication, Measurement and Computing (Rinton Press, Princeton, NJ 2003)

*Twin Photons with Angular Momentum Entanglement: Phase Matching*;  
GA Barbosa and H. H. Arnaut, Phys. Rev. A **65**, 053801 (2002).  
Also selected for "Virtual Journal of Quantum Information", vol. 2, Issue 5, May 2002

*Transverse properties of squeezed light in diode lasers*;  
C. L. Garrido Alzar, S. M. de Paula, M. Martinelli, A. Z. Khoury, R. J. Horowicz and GA Barbosa, J. Opt. Soc. Am. B **18**, 1189 (2001).

*Orbital and Intrinsic Angular Momentum of single Photons and Entangled Pairs of Photons Generated by Parametric Down-Conversion*; H. H. Arnaut and GA Barbosa, Phys. Review Letters **85**, 286 (2000).

Reply to a comment on *Orbital and Intrinsic Angular Momentum of single Photons and Entangled Pairs of Photons Generated by Parametric Down-Conversion*; H. H. Arnaut and GA Barbosa, Phys. Review. Letters **86**, 5209 (2001).

*Transverse coherence length of down-converted light in the two-photon state*;  
E. J. S. Fonseca, C. H. Monken, S. Padua, GA Barbosa; Physical Review A **59**, 1608 (1999).

*Two Photon Pattern in a Second Order Interference*;  
H. H. Arnaut, and GA Barbosa, Phys. Rev. A **58**, 4163 (1998).

*Quantum Communication: tetra's coding*;  
GA Barbosa, Phys. Rev. A **58**, 3332 (1998).

*Mirror Effects and Induced Coherence in Parametric Down-Conversion*;  
P. H. Souto Ribeiro and GA Barbosa, Optical Comm. **139**, 139-147 (1997).

*Temporal Coherence Properties of Stimulated Down-Conversion*;  
P. H. Souto Ribeiro, S. Pádua, and GA Barbosa; Coherence and Quantum Optics VII,  
eds. J. Eberly, L. Mandel and E. Wolf, Plenum Press, NY (1996), pg. 721..

*Quantum Images in Double-Slit Experiments with Spontaneous Down-Conversion Light*;  
GA Barbosa; Phys. Rev. A **54**, 4473 (1996).

*Direct and Ghost Interference in Double-Slit Experiments with Coincidence Measurements*;  
P. H. Souto Ribeiro and GA Barbosa; Phys. Rev. A **54**, 3489 (1995).

*Parametric Down-Conversion Luminescence: A Fertile Ground in Quantum Optics*;  
GA Barbosa; (invited paper) Brazilian Journal of Physics **25**, 335 (1995).

*Control of Young's fringes visibility by stimulated downconversion*;  
P. H. Souto Ribeiro, S. Pádua, J. C. Machado da Silva, and GA Barbosa; Phys. Rev. A **51**, 1631 (1995).

*Controlling the degree of visibility of Young's fringes with photon coincidence measurements*;  
P.H.S. Ribeiro, S. Pádua, J.C. Machado da Silva, and GA Barbosa; Phys. Rev. A **49**, 4176 (1994).

*Spatial properties of spontaneous parametric down-conversion and their effect on induced coherence without induced emission*;  
T. Grayson and GA Barbosa; Phys. Rev. A **49**, 2948 (1994).

*Measurement of coherence area in parametric down conversion luminescence*;  
P. H. Souto Ribeiro, C. H. Monken, and GA Barbosa; Appl. Optics. **33**, 352 (1994).

*Forced indistinguishability in "induced coherence without induced emission"* ;  
GA Barbosa; Phys. Rev. A **50**, 3379 (1994).

*Observation of a non-local Pantcharatnam phase shift in the process of induced coherence without induced emission*;  
T. Grayson, J.R. Torgerson, and GA Barbosa; Phys. Rev A **49**, 626 (1994).

*Temporal response of a Fabry-Perót cavity to a single photon wavepacket;*  
C.H. Monken, GA Barbosa; Optics Commun. **99**, 152 (1993).

*Quasi-Elastic Light Scattering of Carnaúba Wax in the Liquid Phase: Dynamics II;*  
Fábio J. Almeida and GA Barbosa; Appl. Optics **22**, 3810 (1983).

*Vibronic contribution to the low temperature luminescence of  $KZnF_3:Ni$ . A quantitative approach;*  
R. Russi, GA Barbosa, M. Rousseau, J.Y. Gesland; J. Physique **45**, 1773 (1984).

*Quasi-Elastic Light Scattering Diffusion Measurements of  $FeCl_2 \cdot 4H_2O$  in Glycerol;*  
R.L. Moreira, A. Abras, and GA Barbosa; Chem. Phys. Lett. **112**, 456 (1984).

*Forced depolarized light scattering of Carnaúba wax in the liquid fase;*  
C. Monken and GA Barbosa; J.Phys.Chem. **92**, 4765 (1988).

*Dynamic light scattering at the non-equilibrium crystal melt interface in biphenyl and naphthalene;*  
O. N. Mesquita, L. O. Ladeira, I. Gontijo, A. G. Oliveira, and GA Barbosa; Phys. Rev. B **38**, 1550 (1988).

*Quasi-Elastic Light Scattering of Carnaúba Wax in the Liquid Phase: Dynamics I;*  
Leonardo Fonseca and GA Barbosa; Appl. Optics **22**, 1409 (1983).

*Cêra de Carnaúba: vale a pena estudar este eletreto natural?;*  
GA Barbosa; Ciência Hoje, Julho 1987.

*A semiconductor optical switch to generate sub-poissonian statistics in a light beam from the down-conversion luminescence;*  
GA Barbosa; J.Phys. Soc. Japan **58**, 2330 (1989).

*Raman Scattering Investigations of  $KY_3F_{10}$ ;*  
M. Mortier, J.Y. Gesland, M. Rousseau, M.A. Pimenta, L.O. Ladeira, J.C. Machado da Silva, and GA Barbosa; J. Raman Spectroscopy **22**, 393 (1991).

*Control of visibility in the interference of signal photons by delays imposed on the idlers;*  
X. Y. Zou, T. Grayson, GA Barbosa, and L. Mandel; Phys. Rev. A **47**, 2293 (1993).

*Enhancing the sub-Poissonian character of a light beam from the down-conversion luminescence;*  
GA Barbosa, C.H. Monken; Phys. Rev. Letters **67**, 3372 (1991).

*Aplicação do Conceito de Área de Coerência Óptica: Sistema Óptico para Espectroscopia Rayleigh;*  
GA Barbosa; Revista Brasileira de Física **1**, 533 (1980).

*Photon Correlation Spectroscopic Analysis of a Natural Electret Material: Carnaúba Wax;*  
GA Barbosa, Ricardo Russi, A. S.T. Pires, O. N. Mesquita; Appl. Phys. Letters **38**, 236 (1981).

*Relaxation Mode in  $SrTiO_3$  ;*  
GA Barbosa; Lasers and Applications, Edited by W.O.N. Guimarães, C.T. Lin, A. Mooradian;

Springer-Verlag - 1981, pg. 41.

*Relaxation Mode in SrTiO<sub>3</sub>: A mode to test Melting Models?*;

GA Barbosa, J. I. dos Santos; Journal of Raman Spectroscopy **10**, 100 (1981).

*Disorder Manifestations in the Light Scattering Spectra of SrTiO<sub>3</sub> at High Temperatures*;

J. I. dos Santos, and GA Barbosa; Ferroelectrics **25**, 625 (1980).

*Effects of Polarized Impurity Clusters in KDP Crystals*;

GA Barbosa and A. S. T. Pires; Ferroelectrics **26**, 733 (1980).

*Effects of Polarized Impurity Clusters in Light Scattering Experiments with Potassium Dihydrogen Phosphate Crystals*;

GA Barbosa and A. S. T. Pires; Phys. Review B **20**, 4321 (1979).

*Optical Properties of SrTiO<sub>3</sub> at High Temperatures*;

GA Barbosa, K. S. Katiyar, S. P. S. Porto; J. Opt. Soc. Am. **68**, 610 (1978).

*Linear response function for tunneling systems in the polariton region*;

GA Barbosa; Ferroelectrics **17**, 537 (1978).

*Response function of the proton-phonon system describing ferroelectricity in the KDP-family in the polariton region*;

GA Barbosa, F. C. S. Barreto, A. S. Chaves, R. Gazzinelli, N.P. Silva;

5<sup>th</sup> International Conference on Raman Spectroscopy, Freiburg, Germany. Verlag (1976) 596.

*Combined Raman-Brillouin scattering in SrTiO<sub>3</sub> near 110 K phase transition*;

L. Firstein, GA Barbosa, and S. P. S. Porto;

3<sup>rd</sup> International Conference on Light Scattering in Solids, 866-871, Flammarion (1975).

*A Raman study of the soft-optical and acoustic modes at the 110 K phase transition in SrTiO<sub>3</sub>*;

L. Firstein, GA Barbosa, and S. P. S. Porto;

4<sup>th</sup> International Conference on Raman Scattering, Maine - USA (1974).

[*Optical studies of the crystals KH<sub>2</sub>PO<sub>4</sub> and SrTiO<sub>3</sub>*;

GA Barbosa; Ph.D. Thesis, University of Southern California (1973).]

*Temperature dependence of the Raman cross-section in BaTiO<sub>3</sub> and SrTiO<sub>3</sub>*;

GA Barbosa, A. S. Chaves, and S. P. S. Porto; Sol. Stat. Comm. **11**, 1053 (1972).

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