

## Wooram Lee

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<b>Contact Information</b>	Central Engineering Broadcom Corporation 5300 California Avenue, Irvine, CA 92617, USA	<i>Phone:</i> (607) 227-3943 <i>E-mail:</i> wooram@cornell.edu
<b>Research Specialization</b>	High performance analog/RF integrated circuits and systems for high-speed communication, biomedical sensing, imaging and radar applications  - Low-noise signal generation and processing exploiting nonlinear circuits. - Millimeter-wave and terahertz circuits and systems. - High-speed electrical/optical inter- and intra-chip communications and networking. - Nonlinear wave propagation and interaction.	
<b>Education</b>	Cornell University, Ithaca, NY USA  <b>Ph.D.</b> , Electrical and Computer Engineering Sep. 2007–Aug. 2012 - <b>Dissertation Topic:</b> <i>Nonlinear circuits for signal generation and processing</i> - <b>Adviser:</b> Professor Ehsan Afshari - Minor in Applied and Engineering Physics  Korea Advanced Institute of Science and Technology (KAIST), Daejeon, Korea  <b>M.S.</b> , Electrical Engineering with the highest honors Feb. 2003 - <b>Thesis Topic:</b> <i>Injection-Locked Fabry-Perot Laser for WDM-PON</i> - <b>Adviser:</b> Professor Y.C. Chung  <b>B.S.</b> , Electrical Engineering, <i>Magna Cum Laude</i> Feb. 2001	
<b>Honors and Awards</b>	Broadcom Corporation - SPOT Award, recognition for contribution to 20-nm CMOS serial link project 2013  IEEE Solid State Circuits Society (SSCS) - Predoctoral Fellowship, the sole winner for 2010-2011 2010 - \$23,000 for tuition+stipend and \$2,000 for department  IEEE Workshop on Passive Microwave Circuits 2010 - Best Paper Award, given to the top three presentations 2010  IEEE RadarCon 2009 - Best Student Paper Award and Travel Grant Award 2009  The Samsung Scholarship Foundation - Predoctoral Fellowship 2007–2012 - \$50,000 per year for tuition+stipend, five-year full scholarship for Ph.D study  Korean Government Overseas Scholarship [declined to avoid duplicate support] - \$38,000 per year for tuition+stipend, three-year scholarship for Ph.D study 2006 - one of two awardees selected in electrical engineering  Electronics and Telecommunications Research Institute (ETRI) - Best Paper Award, given to the top three journal papers published in 2006 2007 - Rookie of the Year, awarded to the best new employee in 2003 2004  Korean Ministry of Education, Science and Technology and the daily <i>JoongAng</i> - Silver Medalist in National Physics Competition 1996 - First prize in Incheon Physics Competition 1996	

**Research  
Experience**

Cornell University, Ithaca, NY USA

**Research Assistant**, UNIC Group

September 2007 to May 2012

Studied nonlinear processes in integrated circuit design to go beyond the transistor limits of noise, speed, and efficiency:

- **Noise squeezing for ultra-low noise amplification and oscillation**

Achieved sensitivity close to the thermal noise limit in one quadrature phase using a 10-GHz low-noise amplifier in a 0.13- $\mu\text{m}$  CMOS process: the first demonstration of noise squeezing in electrical circuits.

- **Picosecond pulse generation in a nonlinear electrical medium**

Demonstrated an integrated nonlinear 2-D LC lattice that generates pulses as narrow as 6 psec with amplitude higher than 2.7 V in a 0.13- $\mu\text{m}$  CMOS process: the narrowest pulse width achieved for high-amplitude pulses ( $>1$  V) reported in any CMOS processes.

- **Electrical parametric oscillator for frequency synthesis**

Demonstrated the first CMOS passive frequency divider based on electrical parametric oscillator, operating at 20 GHz with low phase noise in a 0.13- $\mu\text{m}$  CMOS process.

- **Nonlinear delay-locked loop for high-speed interconnects**

Designed a delay-locked nonlinear transmission line for high frequency interconnects in a 0.13- $\mu\text{m}$  CMOS process. This structure effectively compensates the loss and dispersion in electrical interconnects using a delay-controlled soliton.

**Teaching  
Experience**

Cornell University, Ithaca, NY USA

**Teaching Assistant**, ECE department

Fall 2010

- **ECE 4530, Analog Integrated Circuits Design**

Conducted office hours and supervised a 4-hour lab in which senior undergraduate students learn design and layout of advanced analog circuits (43 students)

**Professional  
Experience**

Broadcom Corporation, Irvine, CA

**Scientist**, Analog and Mixed Signal Group, Central Engineering July 2012-Present

- Designing analog/mixed-signal circuits for high-speed serial link operating at data rates up to 100 Gbps in optical, copper and backplane applications.
- Designed low power, high-speed CMOS data converters for millimeter wave transceivers.

IBM T.J. Watson Research Center, Yorktown Heights, NY

**Research intern**, RF Circuits and Systems

Summer 2011

- Designed a high-conversion-gain, power-efficient 90-GHz bipolar frequency multiplier for millimeter-wave phase array system in a 90-nm SiGe process.
- Designed a high-power 240-GHz frequency quadrupler in a 90-nm SiGe process.

Electronics and Telecommunications Research Institute, Daejeon, Korea

**Research staff**, Optical Communications Research Center Feb 2003 to July 2007

Developed optical links and transceivers for wavelength-division multiplexed (WDM) passive optical network (PON):

- Developed wavelength-independent optical network terminals using reflective semiconductor optical amplifier.
- Proposed 1) gain-saturation, 2) wavelength detuning, and 3) feed-forward current injection techniques for optical wavelength reuse.
- Succeeded in developing the first 1.25-Gb/s WDM-PON for commercialization.

**Mentoring and Supervising** **Tumay Kanar**, Undergrad student, ECE, Cornell University. 2009-2010  
 Project: Nonlinear transmission line for sharp pulse generation in a CMOS process.  
**Pervaze Humayun**, Master's student, ECE, Cornell University. 2010-2011  
 Project: Nonlinear CMOS delay-locked loop for high-speed interconnects.

**Journal Publications**

**J.1** Wooram Lee and Ehsan Afshari, "Fundamental Limits of Harmonic Generation Using Passive Nonlinear Devices," to be submitted.

**J.2** Wooram Lee and Alberto Vales-Garcia, "A High Conversion Gain, Power-Efficient Millimeter-Wave Frequency Doubler in a 90-nm SiGe Process," submitted to *IEEE Transactions on Microwave Theory and Techniques*.

**J.3** Wooram Lee, Muhammad Adnan, Omeed Momeni, and Ehsan Afshari, "A Nonlinear Lattice for High-Amplitude Picosecond Pulse Generation in CMOS," *IEEE Transactions on Microwave Theory and Techniques*, vol. 60, no. 2, pp.370-380, Feb. 2012.

**J.4** Wooram Lee and Ehsan Afshari, "A CMOS Noise-Squeezing Amplifier," *IEEE Transactions on Microwave Theory and Techniques*, vol. 60, no. 2, pp.329-339, Feb. 2012.

**J.5** Wooram Lee and Ehsan Afshari, "Low Noise Resonant Parametric Amplifier," *IEEE Transactions on Circuits and Systems-I*, vol. 58, no. 3, pp.479-492, Mar. 2011.

**J.6** Wooram Lee and Ehsan Afshari, "Parametric Distributed Resonator: a Passive Frequency Divider," *IEEE Journal of Solid States Circuits*, vol. 45, no. 9, pp.1834-1844, Sep. 2010.

**J.7** Harish S. Bhat, Wooram Lee, Georgios N. Lilis, and Ehsan Afshari, "Steady-State Perturbative Theory for Nonlinear Circuits," *Journal of Physics A: Math. Theor.*, vol. 43, no. 20, May 2010.

**J.8** Georgis N. Lilis, Jihyuck Park, Wooram Lee, Guansheng Li, Harish S. Bhat, and Ehsan Afshari, "Harmonic Generation Using Nonlinear LC Lattices," *IEEE Transactions on Microwave Theory and Techniques*, vol. 58, no. 7, pp.1713-1723, July 2010.

**J.9** Paul K. J. Park, S. B. Jun, Hoon Kim, D. K. Jung, W.R. Lee, and Y. C. Chung, "Reduction of polarization-induced performance degradation in WDM PON utilizing MQW-SLD-based broadband source," *Optics Express*, vol. 15, issue 21, pp. 14228-14233, 2007.

**J.10** Wooram Lee, Seung Hyun Cho, Mahn Young Park, Jie hyun Lee, Chulyoung Kim, Geon Jeong, and Byoung Whi Kim, "Frequency Detuning Effects in the Loop-Back WDM-PON Employing Gain-Saturated RSOAs," *IEEE Photon. Technol. Lett.*, vol. 18, pp.1436-1438, 2006. **(Best paper award in 2007 ETRI annual meeting)**

**J.11** Wooram Lee, Seung Hyun Cho, Mahn Young Park, Jie hyun Lee, Chulyoung Kim, Geon Jeong, and Byoung Whi Kim, "Wavelength Filter Detuning for Improved Carrier Reuse in Loop-Back WDM-PON," *IEE Electron. Lett.*, vol. 42, pp. 596-597, 2006.

**J.12** Geon Jeong, Jie Hyun Lee, Mahn Young Park, Cheol Young Kim, Seung Hyun Cho, Wooram Lee, and Byoung Whi Kim, "Over 26 nm Wavelength Tunable External Cavity Laser Based on Polymer Waveguide Platforms for WDM Access Networks," *IEEE Photon. Technol. Lett.*, vol. 18, pp. 2102-2104, 2006.

**J.13** Wooram Lee, Mahn Young Park, Seung Hyun Cho, Jihyun Lee, Chulyoung Kim, Geon Jeong, and Byoung Whi Kim, "Bidirectional WDM-PON Based on Gain-Saturated Reflective Semiconductor Optical Amplifiers," *IEEE Photon. Technol. Lett.*, vol. 17, pp. 2460-2462, 2005 **(Cited 207 times)**

**J.14** Jie Hyun Lee, Mahn Young Park, Cheol Young Kim, Seung Hyun Cho, Wooram Lee, Geon Jeong, and Byoung Whi Kim, "Tunable External Cavity Laser Based on Polymer Waveguide Platform for WDM Access Network," *IEEE Photon. Technol. Lett.*, vol. 17, pp. 1956-1958, 2005.

**Conference Proceedings**

- C.1** Wooram Lee and Ehsan Afshari, “An 8 GHz, 0.45-dB NF CMOS LNA Employing Noise Squeezing,” *Proc. of IEEE RFIC Symposium 2011*, Baltimore, Maryland, USA.
- C.2** Wooram Lee, Farid Amoozegar, and Ehsan Afshari, “Picosecond Pulse Generation on CMOS: Design Beyond Transistor Limits,” *Proc. of IEEE Radar Conference 2009*, Pasadena, California, USA (**Best Student Paper Award and Travel Grant Award**).
- C.3** Wooram Lee, Seung Hyun Cho, Mahn Young Park, , Jie Hyun Lee, Chulyoung Kim, Geon Jeong, and Byoung Whi Kim, “Optical Transceiver employing an RSOA with Feed-Forward Current Injection,” *OFC2007*, Anaheim, California, USA.
- C.4** Seung Hyun Cho, Wooram Lee, Mahn Young Park, Jie Hyun Lee, Chulyoung Kim, Geon Jeong, and Byoung Whi Kim, “Demonstration of Burst Amplified Uplink for RSOA-based WDM/TDM Hybrid PON Systems Using SOA as a Multi-Channel Preamplifier,” *ECOC 2006*, Cannes, France.
- C.5** Wooram Lee, Jaedong Park, and Byoung Whi Kim, “The Performance Analysis of ASE Injection-Locked FP-LD Over Injected Light Wavelengths,” *OECC 2004*, Yokohama, Japan.

**Selected Invited Talks**

- S.1** “A New Circuit Design Paradigm Exploiting Nonlinear Phenomena”, Qualcomm (Santa Clara, CA), Intel (Hillsboro, OR), Broadcom (San Diego, CA), Cornell University, University of Utah, Johns Hopkins University, and Boston University, 2012-2013
- S.2** “Novel Nonlinear Circuits for Signal Generation and Processing in CMOS”, Center for Circuits & System Solutions (C2S2) and IBM T.J. Watson Research Center (Yorktown Heights, NY), Sep. 2011

**Patents**

- P.1** Wooram Lee and Alberto Valdes-Garcia, “Method and Circuits for Bipolar Transistor Frequency Doublers at Millimeter-Wave Frequencies,” U.S patents pending (IBM research).
- P.2** Wooram Lee and Alberto Valdes-Garcia, “Method and Circuits for Frequency Quadruplers at Millimeter-Wave Frequencies,” U.S patents pending (IBM research).
- P.3** Ehsan Afshari and Wooram Lee, “Nonlinear Lattice for Picosecond Pulse Generation in CMOS and Methods of Use Thereof,” U.S patents pending.
- P.4** Ehsan Afshari and Wooram Lee, “Distributed Electrical Parametric Oscillator in CMOS Process and Methods of Use Thereof,” U.S Patent 61/351,964, filed 06/07/2010.
- P.5** Jie Hyun Lee, Mahn Young Park, Geon Jeong, Seung Hyun Cho, Wooram Lee, and Byoung Whi Kim, “Athermal External Cavity Laser,” U.S. Patent 2010/0014545, Jan. 21, 2010.
- P.6** Byoung Whi Kim, Wooram Lee, Yun Chur Chung, Eui Seung Son, and Jang Won Chae, “Wavelength Tracking Apparatus and Method in WDM-PON System,” U.S. Patent 2007/0154216, Jul. 5, 2007.
- P.7** Byoung Whi Kim, Mahn Yong Park, Wooram Lee, and Tae Yeon Kim, “Reflective Semiconductor Optical Amplifier(RSOA), RSOA Module Having the Same, and Passive Optical Network Using the Same,” U.S. Patent 2007/0133990, June. 14, 2007.
- P.8** Seung Hyun Cho, Wooram Lee, Jae Dong Park, and Byoung Whi Kim, “Method for Fabricating Laser Diode Having Optical Fiber Bragg Grating as Front Mirror of External Resonator and Laser Diode Fabricated Thereby,” U.S. Patent 2006/0133729, June. 22, 2006.
- P.9** Byoung Whi Kim, Wooram Lee, and Jae Dong Park, “Wavelength Tunable Light Source Module for Wavelength Division Multiplexing Passive Optical Network System,” U.S. Patent 2006/0098697, May. 11, 2006.