Guest Editorial Special Issue on Vacuum Electronic Devices, ”From Mega to nano: Beyond one Century of Vacuum Electronics”

I am delighted and honoured to open the sixth Special Issue on vacuum electronics published by the IEEE Transactions on Electron Devices “From Mega to nano: Beyond one Century of Vacuum Electronics”, following the successful Special Issues published in January 2001, May 2005, May 2009, June 2014 and June 2018.

The wonderful response of the outstanding colleagues in vacuum electronics, both as authors and reviewers, has permitted to offer an exciting overview of the state of the art in the field and a seminal source of knowledge for the whole scientific community.

I do not have enough words to thank the immense work and dedication of the fellow Guest Editors, Dr. Monica Blank from CPI, Dr. Jeffrey Calame from Naval Research Laboratory, Prof. Yubin Gong from University of Science and Technology of China and Prof. Manfred Thumm from Karlsruhe Institute of Technology. Their expertise has been invaluable in leading a rigorous peer-review process to ensure the highest quality of the papers of this issue.

Vacuum electron devices were born more than one century ago and were, until the discovery of the transistor, the only existing electronic devices. From the first valve, “tubes” evolved over years and years of development into a variety of devices with specific purposes (e.g. magnetrons, klystrons, TWTs, gyrotrons) but a common unique feature, high output power to enable fundamental applications, from space communications to medical instruments to nuclear fusion, particles accelerators, radars, and many others. After one century, vacuum electronic devices have evolved with the use of new materials, microfabrication processes, simulation tools. New frontiers are explored in the millimeter wave and THz range and in the nanometric domain. Vacuum electron devices are the only family of devices with size ranging from a few meters, such as Megawatt klystrons for particle accelerators, to nanometers, such as new nano vacuum transistors, spanning eight orders of magnitude in size. This Special Issue aims to showcase the great diversity in this family of devices by reporting the state of the art in the field of Vacuum Electronic Devices both to inform the scientific community and to stimulate the interest of brilliant young minds for ensuring a healthy future of vacuum electronics.

Five invited review papers offer an overview to specialist and general public over key topics, highlighting the scientific and societal importance and impact of vacuum electronics.

Dr. Carter Armstrong, that was with L3Harris Electron Devices, has led a review paper titled “Frontiers in the Application of RF Vacuum Electronics”, where the vast variety of fields of use of “tubes” is thoroughly described by the most relevant experts in the fields, with an enjoyable and accessible narrative for general public.

Dr. Lawrence Ives of Calabazas Creek, has offered an update of his seminal paper published in 2001 on Advanced Fabrication of Vacuum Electron Devices, with a review of the most recent fabrication processes and technologies.

Prof. Yaogen Ding, from Chinese Academy of Sciences, has led a review paper on multi-beam klystrons, devices fundamental for extreme high power required in particle accelerators and other fields of application, titled “An Overview of Multi-beam Klystron Technology”.

Prof. Thomas Antonsen, from the University of Maryland, has led two review papers on the complex field of modelling and simulations of vacuum electronic devices “First Principles Codes and Analysis Environments for Vacuum Electronics Simulation” and “Advances in the Theory and Modeling of Linear Beam VE Amplifiers”.

The majority of the excellent papers in the Special Issue are on millimeter waves and THz vacuum electronic devices, following a natural evolution of traveling wave tubes sustained by new fabrication technology to provide high power for applications in wireless communications, radar, imaging at high frequency, beyond the traditional helix microwave TWTs. Gyro devices is the second topics in terms of number of papers representing the importance of this family of devices for nuclear fusion, electron paramagnetic resonance (EPR) and other applications requiring extreme power. A variety of topics spanning from cathodes and carbon nanotubes to physics of vacuum electronic devices provide an overview of the worldwide research in the field.

We would like to express our gratitude to the over 100 reviewers who generously contributed with their time, expertise and advices for ensuring the highest quality and rigor of the published papers.

The T-ED Editorial Staff deserves our deep gratitude, with a special mention to Mrs Marlene James, for the outstanding and expert support that has made possible the publication of this Special Issue.

We are also grateful to members of the IEEE Electron Devices Society Vacuum Electronics Technical Committee (EDS VETC) for advice and support (the website of EDS VETC is http://vacuumelectronics.org).

Finally, we wish to thank Prof. Giovanni Ghione, IEEE T-ED’s former Editor-in-Chief for the guidance and encouragement to prepare this Special Issue and Professor Patrick Fay, IEEE T-ED’s Editor-in-Chief, for the continued support.

Claudio Paoloni
Guest Editor in Chief

Claudio Paoloni Claudio Paoloni is Professor of Electronics and Cockcroft Chair. He has been the Head of Engineering Department and first Head of School of Engineering at Lancaster University in the period July 2015 - July 2022. He is Senior Fellow of the Higher Education Academy in the UK. He is Distinguished Lecturer and was member at large of the Board of Governors of the IEEE Electron Device Society. He is Associate Editor of the IEEE Transaction on Microwave Theory and Technology. He is author of more than 240 articles in international journals and conference proceedings in the field of high frequency electronics. He holds three patents. He is Lead Guest Editor of the Special issue “From Mega to nano: Beyond one Century of Vacuum Electronics” of IEEE Transaction on Electron Devices (June 2013). He has been Coordinator of the Horizon 2020 project TWEETHER ”Travelling wave tube based w-band wireless networks with high data rate distribution, spectrum energy efficiency” (€3.3M) and of the Horizon 2020 ULTRAWAVE ”Ultra capacity wireless layer beyond 100 GHz based on millimeter wave Traveling Wave Tubes” (€3M). He was Chair of the IEEE Electron Devices Society Vacuum Electronics Technical Committee. He was Guest Editor for the Special Issue of IEEE Transaction on Electron Devices on Vacuum Electronics (June 2014). He is IEEE Senior member. He established the TWT Fab, unique distributed laboratory in Europe for fabrication of sub-THz Traveling Wave Tubes. He served in the organization of many conferences and workshops. In particular, he served as Local Organisation Chair of IEEE International Vacuum Electronic Conference 2009 (IVEC 2009), Conference Chair of UK/Europe China Millimeter Wave and THz Technology Workshop 2013 (UCMMT2013) held in Rome, Technical Programme Committee Chair of UK/Europe China Millimeter Wave and THz Technology Workshop UCMMT 2021 and Chair of the Technical Programme Committee of the International Vacuum Electronics Conference 2017 (IVEC) held in London, 24-26 April 2017.

Jeoffrey Calame Jeffrey Calame received the B.S. (1985), the M.S. (1986), and the Ph.D. (1991) degrees in electrical engineering from the University of Maryland, College Park. His graduate research form 1985-1991 involved the development of a high peak power gyroklystron amplifier for accelerator applications. From 1992-1997 he performed postdoctoral research at the University of Maryland on microwave amplifiers, the microwave processing of materials, and the dielectric properties of ceramics. In 1997 he joined the Naval Research Laboratory (NRL) as an Electronics Engineer in the Vacuum Electronics Branch, and during 1997-2003 he developed high average power, wideband millimeter-wave amplifiers for radar applications. He is presently a Section Head in the Electromagnetics Technology Branch at NRL, where he performs and supervises research on millimeter-wave amplifiers and components for electronic warfare, communications, and radar applications. He also performs research on related advanced materials and microfabrication technologies, including ceramic microwave absorbing materials, high heat flux cooling, additive manufacturing, nonlinear dielectrics, and high-peak-power energy storage. Dr. Calame received the 1991 APS Award for Outstanding Doctoral Thesis Research in Beam Physics and was a co-recipient of the 1999 Robert L. Woods Award for Excellence in Vacuum Electronics Technology. He was elected to IEEE Fellow in 2018.

Monica Blank Monica Blank received the B.S. degree (Electrical Engineering) from the Catholic University of America, Washington, D.C. in 1988, and the M.S. and Ph.D. degrees (Electrical Engineering) in 1991 and 1994, respectively, from the Massachusetts Institute of Technology, Cambridge, MA. In 1994 she joined the Vacuum Electronics Branch of the Naval Research Laboratory, where she was responsible for the design and demonstration of high-power millimeter wave vacuum electronic devices for radar applications. In 1999 she joined the gyrotron team at Communications and Power Industries (formerly Varian) where she continues her work on high-power millimeter wave gyrotron amplifiers and oscillators. Dr. Blank has received several professional awards, including the 1998 Alan Berman Publication Award at Naval Research Laboratory, the Robert L. Woods Award for Excellence Vacuum Electronics Technology in 1999, and an RD 100 Award in 2015. Dr. Blank has previously served several terms on IEEE Plasma Science and Applications Executive Committee, one term on the IEEE Nuclear and Plasma Sciences Society Administrative Committee and was a Senior Editor for the IEEE Transactions on Plasma Science from 2009 – 2015.

Yubin Gong Yubin Gong Graduated from Changchun University of Science and Technology in 1989, got his bachelor degree in applied optics. Then, he entered to University of Electronic Science and Technology of China (UESTC) to study continuously, and got his master and Ph.D degrees of physical electronics in 1992 and 1998, respectively. He was ever a visiting scholar in City University of Hong Kong from July of 1997 to August of 1998. And now he is the Yangzi scholarship distinguished professor in the major of physical electronics in UESTC. In the past 30 years, Prof. Gong devoted himself to the scientific research a9d teaching in the field of vacuum electronics and other related areas. He focused his main research interests on millimeter wave and terahertz electronics, high power microwave technology, plasma electronics, electromagnetic biological effects and so on. He was the authors and coauthors of more than 200 referenced journal papers and conference papers in the field of microwave, milimeter wave and THz vacuum devices. Prof. Gong won 8 science and technology awards due to his contributions in the field of vacuum electronics and he is also the winner of the national natural science foundation of china for the distinguished young scientists. In addition to the scientific research, Prof. Gong also gives lectures to under- and post-graduate students on five subjects of microwave elecrtronics, electromagnetic field and waves, relativistic electrodynamics, principle and application of the accelerators, principle and application of electromagnetic radiation of the charged particles.

Manfred Thumm (M'76–SM'11) Manfred Thumm (SM92, F02, LF19) received the Dipl. Phys. and Dr. rer. nat. degrees in physics from University of Tübingen, Germany, in 1972 and 1976, respectively, when he was involved in the investigation of spin-dependent nuclear forces in inelastic neutron scattering. From 1972 to 1975 he was Doctoral Fellow of the Studienstiftung des Deutschen Volkes. In 1976, he joined the Institute for Plasma Research of the University of Stuttgart, Germany, where he worked on RF production and RF heating of toroidal pinch plasmas for thermonuclear fusion research. From 1982 to 1990 his research activities were mainly devoted to electromagnetic theory and experimental verification in the areas of component development for transmission of very high power millimeter waves through oversized waveguides and of antenna structures for RF plasma heating with microwaves. In June 1990 he became a Full Professor at the Institute for Microwaves and Electronics of the University of Karlsruhe, Germany, and Head of the Gyrotron Development and Microwave Technology Division, Institute for Technical Physics, Research Center Karlsruhe (Forschungszentrum Karlsruhe: FZK). From April 1999 to September 2011, he was the Director of the Institute for Pulsed Power and Microwave Technology, FZK, where his current research projects have been the development of high power gyrotrons, dielectric vacuum windows, transmission lines and antennas for nuclear fusion plasma heating, and industrial material processing. On October 1, 2009, the University of Karlsruhe and the FZK have merged to the Karlsruhe Institute of Technology (KIT). M. Thumm has authored/co-authored 8 books, 21 book chapters, 620 research papers in refereed scientific journals, and around 1690 conference proceedings articles. He holds 14 patents on active and passive microwave devices. He was for 6 years member of the IEEE NPSS PSAC Executive Committee and is member of the IEEE EDS Vacuum Devices Technical Committee, the Chapter MN6 Committee Vacuum Electronics and Displays of the Information Technical Society in German VDE (Chairman from 1996 to 1999) and of the German Physical Society. From 2007 to 2008 he was the vice chair of the Scientific-Technical Council of the FZK and the vice chair of the Founding Senate of the KIT. From 2008 to 2010 he was the deputy head of the Topic Fusion Technology of the KIT Energy. He was the General Chair of the IRMMW-THz 2004 and IEEE ICOPS 2008 Conferences in Karlsruhe, Germany. From 2012 to 2021 he served as Editor for Vacuum Electron Devices of IEEE Trans. on Electron Devices. Sine 2012 he has been Distinguished Lecturer of IEEE NPSS and KIT Distinguished Senior Fellow. Since 2016 he serves as member of the Scientific Advisory Council of the Leibniz Institute for Plasma Science and Technology Greifswald and since 2020 in the International Steering Committee of the International Vacuum Electronic Sources Conference Series. He was awarded with the Kenneth John Button Medal and Prize 2000, received in 2001 the title of Honorary Doctor by the Peter the Great St. Petersburg Polytechnic University and in 2008 the EEE-EDS IVEC Award for Excellence in Vacuum Electronics. In 2010, he was awarded with the IEEE-NPSS Plasma Science and Applications Award. He is a winner of the 2010 open grant competition of the Government of the Russian Federation to support scientific research projects implemented under supervision of Leading Scientists at Russian institutions of higher education (with Novosibirsk State University). Together with A. Litvak and K. Sakamoto he was the recipient of the EPS Plasma Physics Innovation Prize 2011. In 2012 he was awarded with the Heinrich Hertz Prize of the EnBW Foundation and the KIT and with the HECTOR School Teaching Award in Embedded Systems Engineering. In 2017 he received the Exceptional Service Award of the IRMMW-THz Society and in 2018 the IEEE NPSS Merit Award. In 2022, he was awarded with the title of Honorary Doctor by the V. N. Karazin Kharkiv National University.