Guest Editorial
The Tenth Special Issue on High-Power Microwave Generation

THE publication of this Special Issue of the IEEE TRANSACTIONS ON PLASMA SCIENCE devoted to advances in high-power microwave (HPM) generation marks the tenth volume in the series. Beginning with the initial volume published in December 1985, the Special Issues have documented the tremendous advances in the performance and physical understanding of high-power vacuum electronic devices ranging in frequency from the hundreds of megahertz to above a terahertz. Looking back, the first Special Issue contained 27 papers describing devices that spanned the frequency range from 3 to 200 GHz. At that time, the state-of-the-art in continuous-wave (CW) and long-pulse gyrotron oscillators produced power levels on the order of 200 kW at frequencies ranging from 28 to 84 GHz; papers such as the one by Kreischer, *et al.* [1] were just beginning to address the issues related to the design of megawatt-class devices. Fast-forwarding to today, the 56 papers in the current Special Issue span the frequency range from 1 GHz to above 1 THz. Long-pulse gyrotron oscillators that operate reliably at megawatt power levels are a reality, and operational frequencies up to 170 GHz have been demonstrated by several groups. Indeed, recent successes with short-pulse coaxial gyrotrons suggest that power levels up to 2 MW are achievable [2].

The papers in this current Special Issue are representative of the breadth and depth of the field, and describe the recent progress of a technology that continues to produce devices with unsurpassed performance in power, efficiency, and reliability. The many outstanding contributed papers reflect the wide range of electron beam-electromagnetic wave interaction mechanisms available to designers and include fast-wave, slow-wave, crossed-field, and plasma devices and the related component and supporting technologies that are critical to their success. Advances in the development of analytic theory and the speed and accuracy of computational design tools continue to be key factors that drive device performance improvement.

There is a continuing trend toward higher-frequency and higher-power density applications. In addition to the more traditional application areas such as nuclear fusion, high-energy RF accelerators for particle physics, high-resolution radar, and electronic defense, emerging applications include submillimeter wave spectroscopy, biomedical research, and high-data-rate wireless communications. Of the papers contributed to this issue, over a third of them deal with device technologies with operating frequencies above 100 GHz. To reflect the growing content, perhaps it is time to amend the title of future Special Issues to include frequencies extending into the millimeter and submillimeter wavelength bands.

The three excellent invited review articles highlight advances in gyrotron theory, multiple-beam device design and performance, and the future challenges facing the creation of terahertz-class devices. Nusinovich *et al.*describe the detailed modeling of startup scenarios in a highly overmoded megawatt power level gyrotron oscillator operating at 140 GHz. As discussed in the paper, a correct analysis of the startup is a necessary step in the design of any gyrotron operating in a very high-order mode. The paper presents a strong case for the critical need for sophisticated and well-benchmarked design tools in the development of the next generation of fast-wave devices.

Multiple electron beam devices have demonstrated impressive power-bandwidth performance at reduced size and voltages relative to single-beam devices. In their paper, Korolyov *et al.* provide scaling laws and discuss the details of several classes of multiple-beam klystrons developed in the Russian Federation. The authors describe devices that range from high-gain, high-peak power amplifiers producing 800 kW in S-band with 10% 1-dB bandwidths to miniaturized K_u-band amplifiers with extremely high power densities (up to 330 W/kg, including the weight of the magnet).

In the third invited paper, Ives describes new opportunities for high-power density vacuum electronic devices at submillimeter wavelength frequencies brought about by advances in microfabrication technology. In this paper, several microfabrication techniques are reviewed, including lithographic process techniques, deep-reactive ion etching, electrical discharge machining, and ion beam milling. In addition, the application of these processes to the fabrication of vacuum electronic devices is discussed. Examples of several specific devices which would not have been feasible without advanced microfabrication techniques are described.

Topical, author affiliation, and sponsoring organization trends for the past nine Special Issues are summarized in Tables I–III, respectively. Table I indicates that the level of activity in the field remains relatively flat with topical interests evenly divided between gyro-devices on the one hand, and slow-wave and crossed-field devices on the other hand. From Table II, we see that while university research remains strong,

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TABLE I
PAPERS IN THE SPECIAL ISSUES ON HPM GENERATION BY SUBJECT

	1988	*1990*	*1992*	*1994*	*1996*	*1998*	*2000*	*2002*	*2004*
Gyro Devices	12	14	15	27	23	27	21	18	18
Free Electron Lasers	3	11	3	7	8	5	2	--	--
BWOs and TWTs	4	7	4	11	7	9	7	17	11
Klystrons and Variants	2	1	3	9	7	3	6	3	4
Crossed-Field	2	5	3	2	--	7	5	7	4
Plasma Devices	2	--	1	3	3	9	2	2	1
Vircators	3	2	1	2	1	1	1	2	2
Impulse	--	--	1	--	--	2	--	--	--
Supporting Technology	2	3	1	2	6	8	6	4	6
Applications	--	--	--	--	4	2	1	1	--
Pulse Shortening	--	--	--	--	--	4	--	2	--
Computational Techniques	--	--	--	--	--	6	2	5	3
Beam/Diode/Cathode	--	--	--	--	--	-	7	2	7
TOTAL	29	43	31	55	59	83	60	63	56

TABLE II
PAPERS IN THE SPECIAL ISSUES ON HPM GENERATION BY AUTHOR AFFILIATION

	1988	*1990*	*1992*	*1994*	*1996*	*1998*	*2000*	*2002*	*2004**
University	15	26	21	31	30	26	34	40	39
Industry	9	12	12	6	5	18	13	7	21
USDOE	42	14	6	7	2	2	3	--	5
USDOD	27	14	6	8	11	4	20	7	9
Non-US National Labs	--	--	--	4	13	12	12	9	12

*Author affiliations were counted once per category per paper.

TABLE III
PAPERS IN THE SPECIAL ISSUES ON HPM GENERATION BY SPONSORING ORGANIZATION

	1988	*1990*	*1992*	*1994*	*1996*	*1998*	*2000*	*2002*	*2004*
USDOD	26	23	20	32	32	51	36	27	23
USDOE	5	13	12	19	16	5	6	7	6
USNSF	4	--	1	2	--	--	--	--	--
USNIH	--	--	--	--	--	--	2	--	--
Industry	--	6	1	3	3	7	4	3	4
Non-US Government	4	4	4	10	15	20	18	26	23

there is an increase in industrially sponsored research relative to 2002. In addition, as was first seen in 2002, the sponsorship of vacuum electronics research continues to be more or less evenly distributed between organizations within the U.S. and organizations outside of the U.S.

The continued high quality of the Special Issues on HPM generation is truly the result of a community effort. The Guest Editors would like to thank all of the contributors to this Special Issue as well as those individuals who generously gave their time and expertise to review the submitted manuscripts. The professionalism and cooperative spirit of both authors and referees alike have made the editorial process a rewarding experience. The Guest Editors would also like to express their thanks to Dr. Steven J. Gitomer for his advice and support.

In conclusion, we note with sorrow the passing of Dr. Georges Mourier, one of the pioneers in the field of vacuum electronics. Dr. Mourier's professional life and numerous contributions are memorialized in this issue by G. Faillon, H. Jory, and G. S. Nusinovich.

DAVID K. ABE, *Guest Editor*
U.S. Naval Research Laboratory
Vacuum Electronics Branch
Washington, DC 20375 USA

MONICA BLANK, *Guest Editor*
Communications and Power Industries
Palo Alto, CA 94303 USA

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[1] K. E. Kreischer, B. G. Danly, J. B. Schutkeker, and R. J. Temkin, "The design of megawatt gyrotrons," *IEEE Trans. Plasma Sci.*, vol. PS-13, pp. 364–373, Dec 1985.

[2] B. Piosczyk, G. Dammertz, O. Dumbrajs, M. V. Kartikeyan, M. Thumm, and X. Yang, "165 GHz coaxial cavity gyrotron—Last results," *IEEE Trans. Plasma Sci.*, vol. 32, pp. 853–860, June 2004.

David K. Abe (M'92) received the B.S. degree (with honors) in engineering from Harvey Mudd College, Claremont, CA, in 1981, the M.S.E.E. degree from the University of California, Davis, in 1988, and the Ph.D. degree in electrical engineering from the University of Maryland, College Park, in 1992.

From 1982 to 1988, he was a Member of the Technical Staff at the Lawrence Livermore National Laboratory, Livermore, CA, supporting the nuclear design program. After receiving the Ph.D. degree, he joined Berkeley Research Associates, Springfield, VA, where, from 1992 to 1994, he worked on pulsed-power and high-power microwave projects. He joined the Army Research Laboratory, Adelphi, MD, in 1994, where he pursued projects in electromagnetic effects and high-power microwave generation. In 1997, he joined the Vacuum Electronics Branch, Naval Research Laboratory, Washington, DC, where he is currently pursuing research projects involving microwave and millimeter-wave vacuum electronic devices using both single and multiple electron beams and high data rate communications.

Dr. Abe is a member of the American Physical Society.

Monica Blank (M'95) received the B.S. degree from the Catholic University of America, Washington, DC, in 1988, and the M.S. and Ph.D. degrees from the Massachusetts Institute of Technology, Cambridge, in 1991 and 1994, respectively, all in electrical engineering.

In 1994, she joined the Vacuum Electronics Branch, 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), Palo Alto, CA, where she continues her work on high-power millimeter-wave gyrotron amplifiers and oscillators.

Dr. Blank is a member of the American Physical Society. In 1999, she received the Robert L. Woods Award for achievements in the field of vacuum electronics.