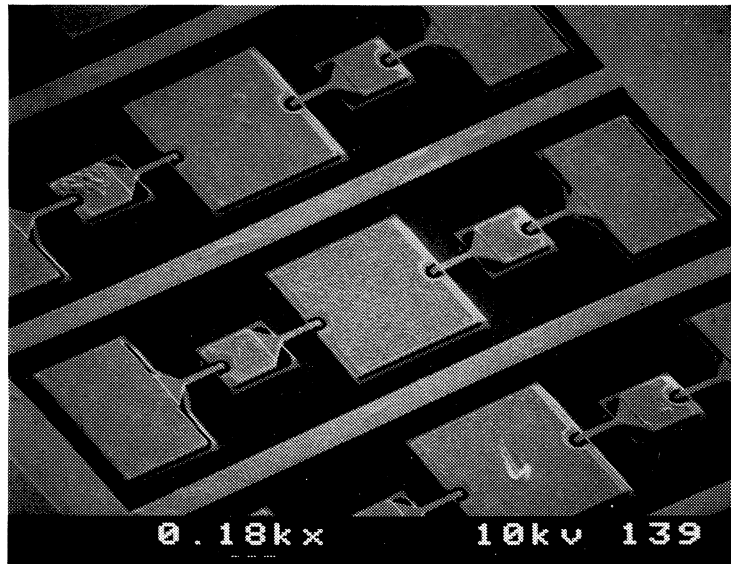


# Seventh International Symposium on Space Terahertz Technology

March 12-14, 1996

On the Grounds of the  
University of Virginia  
Charlottesville, Virginia

## PROCEEDINGS



**Planar Schottky Varactor Diodes**

**Sponsored by:** JPL Center for Space Microelectronics Technology, (CSMT) NASA Office of Space Access and Technology (OSAT)

**Organized Jointly by:** The University of Virginia Semiconductor Device Laboratory and The University of Michigan NASA Center for Space Terahertz Technology.

# PROCEEDINGS

of the

## SEVENTH INTERNATIONAL SYMPOSIUM ON SPACE TERAHERTZ TECHNOLOGY

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### Organizing Committee

Robert M. Weikle, University of Virginia  
Gabriel M. Rebeiz, University of Michigan  
Thomas W. Crowe, University of Virginia

## PREFACE

The Seventh International Symposium on Space Terahertz Technology was held on the Grounds of the University of Virginia, Charlottesville, Virginia, on March 12-14, 1996. Fifty-three technical papers were presented covering all aspects of terahertz technology, but with emphasis on mixer technology (Schottky, SIS and Hot electron Bolometric) and sources (Multipliers, Oscillators and Lasers). There were two invited plenary speakers. Dr. Hans-Peter Röser described the plans for the new DLR Institute for Space Sensor Research in Berlin, Germany and Dr. John Carlstrom gave an update on the Millimeter Array. There was also a special session on Dielectric Lens Antennas which was organized by Dr. Gabriel Rebeiz and chaired by Dr. Robert Mattauch.

The symposium papers were contributed by authors from ten of the United States and eleven countries. Of the fifty-three papers, the primary author on twenty-five came from overseas. Of the one hundred and twenty registered participants, roughly twenty-five percent were from outside the US. Thus, this remains a very "international" symposium.

The Eighth International Symposium on Space Terahertz Technology will be hosted by the Harvard-Smithsonian Center for Astrophysics. For further information, please contact:

Dr. Raymond Blundell  
Harvard-Smithsonian Center for Astrophysics  
60 Garden Street  
Cambridge, MA 02138  
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The organizing committee would like to thank all of the symposium participants, especially the authors and session chairs. The papers were very exciting and well presented and the sessions ran very smoothly. This is a truly exciting and dynamic field and the caliber and friendliness of the international group of researchers is unmatched. We look forward to seeing you all next year in Massachusetts.

*Robert M. Weikle  
Gabriel M. Rebeiz  
Thomas W. Crowe*

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## DAY 1 - TUESDAY, MARCH 12

### Opening Session - Rotunda Dome Room

**Chair: Bobby Weikle**

Welcoming Remarks	Carl Kukkonen	JPL	(8)
THz Research at the DLR Institute for Space Sensor Research	H.-P. Röser	DLR-Berlin, GERMANY	(*)
The Millimeter Array	J. Carlstrom	U. Chicago	(17)

### Session 1: SIS Mixers I - Rotunda Dome Room

**Chair: Pete Smith**

Low-Noise Micromachined SIS-Mixers for Millimeter-Wave Imaging Arrays	G. de Lange, B.R. Jacobson, A. Rahman, E. Duerr and Q. Hu	MIT	29
Quasi-Optical Submillimeter Wave SIS Mixers with NbN/AlN/NbN Tunnel Junctions	Y. Uzawa, Z. Wang, A. Kawakami	Kansai Advanced Research Center, Kobe, JAPAN	37
Sub-Millimeter Distributed Quasiparticle Receiver Employing A Non-Linear Transmission Line	C.-Y.E. Tong, R. Blundell, B. Bumble, J.A. Stern, H.G. LeDuc	Harvard-CfA; JPL	47
Fixed Tuned Waveguide Mixers Around 450 GHz, 670 GHz and 810 GHz for a Dual Channel Receiver	C.E. Honingh, S. Haas, D. Hottgenroth, K. Jacobs, J. Stutzki	U. Köln, GERMANY	63
A 665 GHz Waveguide Receiver Using a Tuned $0.5 \mu\text{m}^2$ Nb/AlO <sub>x</sub> /Nb SIS Tunnel Junction	J.W. Kooi, M.S. Chan, H.G. LeDuc, T.G. Phillips	CSO; JPL	76
An 850 GHz Waveguide Receiver Using a Tuned Nb SIS Tunnel Junction Fabricated on a $1\mu\text{m}$ Si <sub>3</sub> N <sub>4</sub> Membrane	J.W. Kooi, M.S. Chan, P. Schaffer, B. Bumble, H.G. LeDuc, C.K. Walker, T.G. Phillips	CSO; JPL; U.AZ.	86

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**Session 2: Multipliers and Sources** **Chair: Rich Bradley**

Thermal Considerations in the Design of D-Band InP Gunn Devices	R. Kamoua	SUNY-SB	103
High Frequency Limitations of Diode Frequency Multipliers	J. East	U. Michigan	116
Tripling to 250 GHz with Planar, Multiple Barrier Heterostructure Barrier Varactors	J.R. Jones, S.H. Jones, W.L. Bishop	UVA	125
Novel Planar Varactor Diodes	P.J. Koh, W.C.B. Peatman, T.W. Crowe, N.R. Erickson	UVA; U. Mass-Amherst	143
Design and Analysis of Broad-Band Fixed-Tuned Submillimeter-Waveguide Multipliers Using MMIC Style Circuit Topology	J. Bruston, M. Kim, S.C. Martin, I. Mehdi, R.P. Smith, P.H. Siegel	JPL	157
An Integrated 435 GHz Quasi-Optical Frequency Tripler	M. Shaalan, D. Steup, A. Grüb, A. Simon, C.I. Lin, A. Vogt, V. Krozer, H. Brand, H.L. Hartnagel	T.H. Darmstadt & U. Erlangen-Nürnberg, GERMANY	176
Miniaturization of p-Ge Lasers: Progress Toward a Tunable, CW THz Laser	E. Bruendermann, A.M. Linhart, H.P. Röser, O.D. Dubon, W.L. Hansen, E.E. Haller	DLR-Berlin, GERMANY; LBNL; UCB	187

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**Session 3: THz Materials, Components & Circuits I** **Chair: Jack East**

SIS Mixer Analysis with Non-Zero Intermediate Frequencies	S.-K. Pan and A.R. Kerr	NRAO	195
Design of Planar Image Separating and Balanced SIS Mixers	A.R. Kerr and S.-K. Pan	NRAO	207
Performance of Micromechanical Tuning Elements in a 620 GHz Monolithic Integrated Circuit	V.M. Lubecke, W.R. McGrath, P.A. Stimson, D.B. Rutledge	JPL, CalTech	220
Tuning Circuit for NbN SIS Mixer	V. Belitsky and E. Kollberg	Chalmers, SWEDEN; IREE, RUSSIA	234

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## DAY 2 - WEDNESDAY, MARCH 13

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### Special Session: Dielectric Lens Antennas

Chair: Bob Mattauch

The Dielectric-Filled Parabola: Concept and Applications Review	P.H. Siegel, R. Dengler, M. Kim and P. Stimson	JPL	251
Internal Reflections of, and Matching Layers for, Integrated Lens Antennas	P.J.I. de Maagt, M.J.M. van der Vorst, M.H.A.J. Herben	ESTEC & Eindhoven U. Tech., NETHERLANDS	282
Off-Axis Performance of Dielectric Lens Antennas	D.F. Filipovic and G.M. Rebeiz	U. Mich	288
Antireflection-Coated Silicon Lenses for Low-Noise 400-1040 GHz Quasioptical SIS Mixers	M. Bin, M. Gaidis, H.G. LeDuc, D. Miller, J. Zmuidzinas	Caltech; JPL	289

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### Session 4: HEB Mixers I

Chair: Mark Lee

The Bandwidth of HEB Mixers Employing Ultrathin NbN Films on Sapphire Substrate	P. Yagoubov, G.N. Gol'tsman, B. Voronov, L. Seidman, V. Siomash, S. Cherednichenko, E. Gershenson	Moscow State Pedagogical U., RUSSIA	290
Quasioptical Phonon-Cooled NbN Hot-Electron Bolometer Mixer at THz Frequencies	P. Yagoubov, G. Gol'tsman, B. Voronov, S. Svechnikov, S. Cherednichenko, E. Gershenson, V. Belitsky, H. Ekström, E. Kollberg, A.D. Semenov, Yu.P. Gousev, K.F. Renk	Moscow State Pedagogical U., RUSSIA; Chalmers, SWEDEN; U. Regensburg, GERMANY	303
Spectrum of Output Noise in Diffusion and Phonon Cooled Hot Electron Superconducting Mixers	R.J. Schoelkopf, P.J. Burke, D.E. Prober, A. Skalare, W.R. McGrath, B. Bumble, H.G. LeDuc	Yale; JPL	318
Superconductive NbN Hot-Electron Bolometric Mixer Performance at 250 GHz	J. Kawamura, R. Blundell, C.-Y.E. Tong, G. Gol'tsman, E. Gershenson, B. Voronov	Harvard-CfA; Moscow State Pedagogical U., RUSSIA	331
9.6 $\mu\text{m}$ Wavelength Mixing in a Patterned $\text{YBa}^2\text{Cu}_3\text{O}_{7-\delta}$ Thin Film	V.A. Trifonov, B.S. Karasik, M.A. Zorin, G.N. Gol'tsman, E.M. Gershenson, M. Lindgren, M. Danerud, D. Winkler	Moscow State Pedagogical U., RUSSIA; Chalmers, SWEDEN	337

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**Session 5: THz Materials Components and Circuits II** **Chair: Stephen Jones**

Spectroscopic Measurements of Optical Elements for Submillimeter Receivers	J. Kawamura, S. Paine, D.C. Papa	Harvard-CfA	349
Progress on Characterization with Integrated Test Structures of Dielectric and Superconducting Films for SIS Mixer Circuits	D. M. Lea and A.W. Lichtenberger	UVA	356
Full-Wave Numerical Modeling of Near-Field Beam Profiles at 200 and 700 GHz	M.T. Chen, C.E. Tong, L. Chen, S. Paine, R. Blundell	Academia Sinica, TAIWAN; Harvard-CfA; Harvard U.	369
Theoretical Analysis of Superconducting Submillimetre Wave Microstrip Transmission Line	S. Withington and G. Yassin	U. Cambridge, UK	379
A Horn-Reflector Antenna for High Performance Submillimetre Wave Applications	S. Withington, G. Yassin, M. Buffey, C. Norden	U. Cambridge, UK	389

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**Session 6: THz Materials, Components & Circuits III** **Chair: Chris Mann**

THz Signal Generators Based on Lift-Off LT-GaAs on Transparent Substrates	H.-M. Heiliger, M. Vossebürger, H.G. Roskos, R. Hey, K. Ploog, H. Kurz	Rheinisch-Westfälische T.H., Aachen, GERMANY; Paul-Drude Institute, Berlin, GERMANY	400
A Broad-Band 230 GHz Antipodal Finline Mixer for Array Receivers	G. Yassin, S. Withington, R. Padman, M.S. Goodchild, M.G. Blamire	U. Cambridge, UK; U. Köln, GERMANY	409
Development of a Superconducting Integrated Receiver for Application in Imaging Arrays	S.V. Shitov, V.P. Koshelets, A.M. Baryshev, L.V. Filippenko, Th. de Graauw, J.-R. Gao, W. Luinge, H. van de Stadt, N.D. Whyborn, P. Lehikoinen	IREE, RUSSIA; SRON & U. Groningen, NL	417
A Submillimeter High Angular Resolution Bolometer Array Camera for the Caltech Submillimeter Observatory	N. Wang, T.R. Hunter, D.J. Benford, E. Serabyn, D.C. Lis, T.G. Phillips, S.H. Moseley, K. Boyce, A. Szymkowiak, C. Allen, B. Mott, J. Gygas	CSO; NASA/GSFC	426

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## DAY 3 - THURSDAY, MARCH 14

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### Session 7: Schottky Mixers I

Chair: Victor Lubecke

A Quasi-Optical, Subharmonically Pumped Double Slot Mixer	J.P. DeLap, T.M. Cunningham, R.M. Weikle, T.W. Crowe	UVA	442
200 GHz Waveguide Based Subharmonically Pumped Mixers with Planar Schottky Diodes	I. Mehdi, T. Lee, R. Dengler, A. Pease, J. Oswald, D. Humphrey, S. Martin, R.P. Smith, P.H. Siegel	JPL	450
Submillimeter Wavelength Waveguide Mixers using Planar Schottky Barrier Diodes	J.L. Hesler, W.R. Hall, T.W. Crowe, R.M. Weikle, B.S. Deaver, R.F. Bradley, S.-K. Pan	UVA; NRAO	462
A Mixer up to 300 GHz with Whiskerless Schottky Diodes for Spaceborne Radiometers	I. Galin	Gencorp-Aerojet	474
A Design Approach for Planar Waveguide Launching Structures	J. Thornton and C.M. Mann	RAL, UK	477

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### Session 8: Schottky Mixers II: THz

Chair: Israel Galin

Quasi-Planar Schottky Diode Design	R. Nitsche, R.U. Titz, E.M. Biebl	DLR-Oberpfaffenhofen and T.U. Munich, GERMANY	488
First Results for a 2.5 THz Schottky Diode Waveguide Mixer	B.N. Ellison, B.J. Maddison, C.M. Mann, D.N. Matheson, M.L. Oldfield, S.M. Marazita, T.W. Crowe, P. Maaskant, W.M. Kelly	RAL & U. Kent; UK, UVA; U. College, Cork, Ireland	494
A Practical Schottky Mixer for 5 THz (Part II)	A. Betz and R. Boreiko	U. Colorado	503
A Novel Structure and Fabrication Process for Sub-Quarter-Micron THz Diodes	W.L. Bishop, S.M. Marazita, P.A.D. Wood, T.W. Crowe	UVA	511

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<b>Session 9: SIS Mixers II: THz</b>			<b>Chair: Tony Kerr</b>
Wide-Band Quasi-Optical SIS Mixers for Integrated Receivers up to 1200 GHz	S.V. Shitov, A.M. Baryshev, V.P. Koshelets, J.-R. Gao, J. Jegers, W. Luinge, H. van de Stadt, Th. de Graauw	IREE, RUSSIA; U. Groningen & SRON, NL	525
An Improved 1 THz Waveguide Mixer	H. van de Stadt, A. Baryshev, J.-R. Gao, H. Golstein, Th. de Graauw, W. Hulshoff, S. Kovtonyuk, H. Schaeffer, N.D. Whyborn	SRON & U. Groningen, NL; IREE, RUSSIA	536
Fabrication of Nb-SIS Mixers with UHV Evaporated Al Striplines	J.R. Gao, S. Kovtonyuk, J.B.M. Jegers, P. Dieleman, T.M. Klapwijk, H. van de Stadt	U. Groningen & SRON, NL; IREE, RUSSIA	538
Design and Characterization of a Quasi-Optical SIS Receiver for the 1 THz Band	M. Bin, M.C. Gaidis, D. Miller, J. Zmuidzinias, T.G. Phillips, H.G. LeDuc	Caltech; JPL	549
<b>Session 10: HEB Mixers II: THz</b>			<b>Chair: Tom Crowe</b>
Niobium Superconducting Diffusion-Cooled Hot-Electron Bolometer Mixers Above 1 THz	A. Skalare, W.R. McGrath, B. Bumble, H.G. LeDuc, P.J. Burke, R.J. Schoelkopf, D.E. Prober	JPL; Yale	561
Modeling and Optimization of a High-T <sub>c</sub> Hot-Electron Superconducting Mixer for Terahertz Applications	B. Karasik, W.R. McGrath, M.C. Gaidis, M.J. Burns, A.W. Kleinsasser, K.A. Delin, R.P. Vasquez	JPL	565
Optimization of Hot Electron Bolometer Mixing Efficiency in NbN at 119 Micrometer Wavelength	E. Gerecht, C.F. Musante, Z. Wang, K.S. Yngvesson, E.R. Mueller, J. Waldman, G.N. Gol'tsman, B.M. Voronov, S.I. Cherednichenko, S.I. Svechnikov, P.A. Yagoubov, E.M. Gershenson	UM-Amherst; UM-Lowell; Moscow State Pedagogical U., RUSSIA	584
Rigorous Analysis of a Superconducting Hot-Electron Bolometer Mixer: Theory and Comparison with Experiment	R.S. Nebosis, A.D. Semenov, Yu. P. Gousev, K.F. Renk	U. Regensburg, GERMANY	601
Submillimeter Waveguide SIS Mixer with Full NbN Circuit (Late News Paper)	A. Karpov, B. Plathner, J. Blondel, M. Schicke, K.H. Gundlach	IRAM	614
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