IVEC EVENTS OCTOBER 21, 2020

- **Opening Remarks**
- **Plenary Session II**

  Srabanti Chowdhury: Advances in Wide Bandgap, High Power Density Semiconductor Devices

  Shannon Rodriguez: The Use of Vacuum Electronic Devices in NASA Missions

- **Technical Sessions**
- **Poster Sessions**

Technical Sessions

Session 10:
Cathode Processing & Gun Development

Chair: Russell Martin, L3Harris EDD

10.1 - Preparation of the Tungsten Matrices of Dispenser Cathodes by Selective Laser Melting - keynote

- *Kaijie Luo, Yunfei Yang, Xuanming Liang, Jie Ma, Jinshu Wang*
  Beijing University of Technology

  In this study, the porous tungsten matrices of dispenser cathodes were prepared by a new method of three-dimensional selective laser melting, and the relationship between 3D printing process and porosity of matrix was studied. The emission performance of the cathodes impregnated with barium aluminates with and without addition of Scandia, have been measured. It was found that the emission property of the cathodes with machined and W-coated surface is similar to that of traditional B-type cathodes, and the addition of Sc2O3 in the impregnations improved the emission capability of cathode significantly.

10.2 - Electron Beam Melting of Pure Copper – From Research to Industrialization - keynote

- *Ralf Guschlbauer, Pär Arumskog, Simon Eichler*
  Arcam EBM Center of Excellence, GE Additive

  The Additive Manufacturing technology Electron Beam Melting shows high potential in processing pure copper for high conductivity applications. Pure copper powder was

consolidated, and process parameters were optimized. It is feasible to manufacture components with a relative density >99.5 %, an electrical conductivity > 57 MS/m, an ultimate tensile strength >175 MPa and with an elongation at fraction of >35 %. With those physical properties, high performance applications like heat exchangers, induction coils and electrification components can be additively manufactured with EBM.

10.3 - Practical and Technical Challenges of TWT Grid Spherical Radius Characterization

- *Timothy Scott Dyer*
  Elcon Precision LLC

This paper examines the capability of advanced optical CMMs to measure both the height profile and the spherical radius (SR) of titanium hemispheres with variable surface finish. Using precision manufactured hemispheres as a proxy for TWT control and focus grids, we can simulate characterizing grids of variable Measurement Difficulty Factor (MDF). MDF is the ratio of the spherical radius of the TWT grid divided by the grid chord length. The Z-axis or height determination for grid dimensional characterization is primarily influenced by surface finish and by the measurements taken furthest out on the diameter from the apex of the part. The outside diameter of a TWT grid is challenging to characterize since the grid spherical radius changes from target value to infinity at the grid flange. We investigated SR characterization using multiple measurement patterns, number of locations, the pattern type and MDF. The results from the pattern examination show that there is no significant relationship between pattern type and SR accuracy. The results also show that a dull surface gives a smaller deviation (difference between true value and measurement) on the height measurement compared to the shiny surface. The results also show a larger SR gives a smaller deviation for the Z-axis measurement. Measurements taken too far along the grid radius are less accurate since the optical CMM is not measuring height orthogonal to the grid surface.

10.4 - Characterization of a W-band TWT Electron Gun

- *Reginald Jaynes, Alan Cook, Colin Joye, John Rodgers*
  U.S. Naval Research Laboratory

- *Edward Wright, Khanh Nguyen*
  Beam-Wave Research, Inc.,

- *John Atkinson, Takuji Kimura, Galen Aymar*
  Communications & Power Industries LLC

We present experimental characterization of a 20 kV, 130 mA thermionic electron gun in a W-band TWT. The gun heater voltage, focus electrode voltage, and modulating anode voltage are swept to characterize the performance of the emitted cathode current and beam transport through the RF circuit. We observe variation of the cathode current from 107 to 155 mA and

peak beam transmission of 95% at the collector. Experimental results are compared to 2D MICHELLE simulations.

10.5 - Barium Dispenser Cathode Operation in a Cesium Vapor Environment for Applications in Thermionic Converters

- *Daniel Velazquez*
  Modern Electron, LLC

Thermionic converters are devices that convert heat directly into electricity with no moving parts. Thermionics require a high current density emission source. Historically, Ba dispenser cathodes have not been used in thermionic converters due to practical limitations surrounding poor background pressure in thermionics. Here we measure the impact of cesium exposure on the performance of a Ba dispenser cathode that that had previously been exposed to air. Measurements indicate that cesium exposure accelerates cathode activation and increases current density, even in the case of unconventionally high base pressures (>10-7 Torr).

Session 11:
High Power Microwaves II

Chair: Dev Palmer, DARPA

11.1 - First Experiments and Diagnosis of Multipactor in Planar Microstripline Platform

- *Eric David Weber, Mirhamed Mirmozafari, Nader Behdad, John Booske*
  University of Wisconsin-Madison

We have designed, constructed, and started initial operation of a microstripline testbed for studying onset and suppression of multipactor (MP). Its characteristics include exceptional impedance match (|S11| < -10 dB) to 50 ohms over the extremely wide bandwidth from DC – 1.2 GHz, ability to substitute different materials for the conductive strip, ability to operate in ultra-high-vacuum or various gas fills (up to atmospheric pressure), and ability to operate with arbitrary waveforms, pulsed, or CW. Diagnostics include RF wave perturbations (reflection or transmitted phase shifts), and a local electron probe. The probe signal is fed to a shut-down circuit to keep MP events short. Simluations with CST predicts a MP susceptibility window that we should be able to access over the entire band. The simulated susceptibility window has been determined to be in good agreement with previously published theoretical model predictions. First experimental results will be reported at the conference, including validation of the predicted susceptibility window, as well as initial experiments to suppress using either waveform control or modifications to the conducting strip surface.

11.2 - Higher Harmonics in Multipactor-Induced Gas Ionization Breakdown near a Microwave Window

- *De-Qi Wen, Janez Krek, John P Verboncoeur*
  Michigan State University

- *Peng Zhang*
  Michigan State Unversity

- *Yangyang Fu*
  Michigan State Unveirsity

Multipactor and gaseous ionization breakdown can exist on the upstream and downstream side of a dielectric window in high power microwave devices. In this work, we report excited higher harmonics of the electric field normal to window surface in multipactor-induced argon ionization breakdown by particle-in-cell (PIC) simulations. The observed harmonic frequency of the normal electric field is ten to twenty times of the fundamental microwave frequency (1GHz), but lower than the electron plasma frequency. It is found that multipactor dominates at the beginning of the discharge. The ionization collisions and electron density significantly increase in time, and higher harmonics are gradually generated after the fifth rf period. In our simulation, argon background gas is considered to simplify the chemical reactions, and a large number of charged particles are traced under self-consistently charging electric field. A theoretical model based on streaming instability is built to describe higher harmonics and their damping of oscillated amplitude in the collisional regime. The theoretically resulting spectral components generally agrees with the PIC simulation. Our research brings new insights to understand the regime of multipactor-induced ionization breakdown in high power microwave systems.

11.3 - Experimental Hot Test Results of a Metamaterial-Enhanced Resistive Wall Amplifier Prototype

- *Patrick Forbes, John Booske, Nader Behdad*
  University of Wisconsin-Madison

The Metamaterial-Enhanced Resistive Wall Amplifier (MERWA) is theoretically predicted to offer high gain rates with a modest bandwidth. The MERWA operates via space charge wave growth due to interaction with a metamaterial that has been engineered to provide an inductive-resistive admittance to the edge of beam. Previous work has shown that an inductive-resistive metamaterial could be implemented using a periodic array of thin lossy wires. We have implemented and tested an experimental low-power prototype to validate the theory. This work details experimental hot test results.

11.4 - A 3D-Printed Metamaterial Slow-Wave Structure for High-Power Microwave Generation

- *Antonio Breno de Alleluia, Artem Kuskov, Dmitrii Andreev, Edl Schamiloglu*
  University of New Mexico

- *Ahmed F. Abdelshafy, Mohamed A.K. Othman, Alex Figotin, Filippo Capolino*
  University of California, Irvine

  We present a high power microwave (HPM) source based on a metamaterial slow wave structure (MSWS). The MSWS is composed of a circular waveguide with periodic loading of two complementary split-ring resonator disks and was designed at the University of California, Irvine (UCI). This SWS has been studied and simulated to quantify its cold structure properties. Moreover, a backward wave oscillator (BWO) using the proposed SWS has been simulated using a particle-in-cell solver to evaluate its performance. In simulations this BWO has generated 88 MW peak power in a pulse duration on the order of 15 ns with frequency about 2.9 GHz. This SWS was fabricated using 3D printing and copper plating technology and was tested using the SINUS-6 pulsed electron beam accelerator at the University of New Mexico (UNM). This paper presents the results.

Session 12:
Gyrotrons / Magnetrons

Chair: Mikhail Glyavin, IAP RAS, Nizhny Novgorod

12.1 - Phase Measurements of a 140 GHz Confocal Gyro-Amplifier - keynote

- *Guy Rosenzweig, Sudheer K. Jawla, Julian F. Picard, Michael A. Shapiro, Richard J. Temkin*
  Massachusetts Institute of Technology

  The phase stability of a 140 GHz, 1 kW pulsed gyro-amplifier system and its dependence on the cathode voltage were experimentally measured. The phase was determined to be stable both pulse-to-pulse and during each pulse. The phase shift with voltage was measured and found to be ~130°/kV, in agreement with simulated results.

12.2 - Upgrades of W-Band Gyro-TWA System for High-PRF Operation

- *Craig R Donaldson, Liang Zhang, Adrian W Cross, Colin G Whyte*
  University of Strathclyde

  A broadband, high-power gyrotron traveling wave amplifier (gyro-TWA) was demonstrated to show single-shot millimeter wave output over a 3 dB bandwidth of 91-96.5 GHz, with maximum power of 3.4 kW and gain of 36-38 dB. Following on from this, the system will be upgraded for high, Pulse Repetition Frequency (PRF) output, suitable to be employed in radar applications. Amongst the changes required is the design and construction of a modulated anode electron gun and water cooled collector system to be installed with a cryogenic liquid free, up to 5.5 T, superconducting magnet to replace a conventional solenoid.

12.3 - Direct Coupled Gyrotrons for Plasma Heating

- *Robert Lawrence Ives, George Collins*
  Calabazas Creek Research, Inc.

- *Jeffrey Neilson*
  Lexam Research

- *David Marsden*
  Calabazas Creek Research, Inc.

High power gyrotrons typically produce RF power in a Gaussian free-space mode. An internal converter transforms the whispering gallery mode produced in the cavity to the Gaussian beam using a quasi-optical launcher and a series of mirrors. Transmission of this power typically requires transformation into an HE11 mode in corrugated waveguide. This conversion is achieved using a Mirror Optical Unit, which uses a second series of mirrors. The transformation of the whispering gallery mode to a Gaussian beam and then to an HE11 mode requires a complexity of RF structures, increasing cost and RF losses. This program is developing a coupler that transforms the whispering gallery mode directly into an HE11 mode inside the gyrotron. This results in significant reduction in gyrotron cost and RF losses and completely eliminates the Mirror Optical Unit.

12.4 - Design of TE_{01} to HE_{11} Mode Converter at 35GHz

- *Ling Gu*
  Southwest minzu University

- *Yinghui Liu*
  University of Electronic Science and Technology of China

Mode conversion is hugely vital for the transmission and measurement of high power microwaves. In this paper, the TE01-HE11 high-efficiency high-power mode converter with TM11 as the intermediate mode is designed by numerical simulation, and the operating frequency is 35GHz. In the calculation process, in order to solve the problem of the ohmic losses caused by the metal wall, we used the rematch phase technique to improve the conversion efficiency. We then used the Commercial Microwave Studio software for modeling analysis. Finally, experimental tests were performed on the processed TE01-TM11 and TM11-HE11 mode converters. Experimental results verify the accuracy of numerical simulation.

12.5 - The Effect of Absorbers on the Operation of a Coaxial Magnetron

- *Dmitry A. Komarov, Yury N. Paramonov, Denis A. Kalashnikov, Oleg V. Yakovlev, Sergey V. Surkov*
  JSC "RPE "Toriy"

  The results of calculating the S-parameters of a coaxial magnetron are presented. The results of modeling the dynamic mode of interaction of the electron beam with the RF field are presented. The effect of surface and volume absorbers on the operation of a coaxial magnetron is estimated. The simulation results are compared with experimental data.

12.6 - Simulation of an Industrial Magnetron Using Cathode Modulation

- *Andong Yue, Jim Browning*
  Boise State University

- *Mike Worthington, John Cipolla*
  L3Harris Technologies

  Results of a simulation study of the L3Harris CWM75KW industrial strapped magnetron is presented. This study is part of a larger project which studies the feasibility of achieving phase control and faster startup in the magnetron via controlled electron injection by using gated field emission arrays (GFEAs). The device was simulated by using the 3-D PIC code VSim at its typical operating conditions (18kV, 5A, 1900G, 896-929MHz). The startup behavior was examined with 1) no priming of any kind, 2) RF Priming, and 3) cathode modulation. With no priming, no oscillations were seen up to 300 ns; with RF priming for the first 50 ns, oscillations were then observed at 150 ns; and with cathode modulation to create electron spokes, RF oscillation was observed at 130 ns.

Session 13:
Klystron Frontiers

Chair: Takuji Kimura, CPI Microwave Power Products Division

13.1 - Experimental Demonstration of a W-band Photonic Bandgap Klystron - keynote

- *JACOB STEPHENS*
  Center for Pulsed Power and Power Electronics

- *Guy Rosenzweig, Michael Shapiro, Richard Temkin*
  MIT Plasma Science and Fusion Center

- *John Tucek*
  Northrop Grumman Systems Corp

- *Kenneth Kreischer*
  Northrop Grumman Systems Corp.

  This paper details recent progress on the experimental demonstration of a W-band klystron amplifier completed at the MIT. The amplifier utilizes a square lattice photonic bandgap (PBG) structure that permits the use of a highly oversized beam tunnel of diameter $simlambda$/4. Cold test measurements of the PBG klystron cavities revealed successful fabrication of the device. In hot test, a small-signal gain of 26 dB was measured at 93.7 GHz, with a saturated output power of 30 W.

13.2 - Experimental Demonstration of a W-Band Sheet-Beam Klystron - keynote

- *Ding Zhao, Wei Gu, Qingsheng Li, Shuzhong Wang, Zhiqiang Zhang*
  Institute of Electronics, Chinese Academy of Sciences

  As an important proving experiment for further developing a compact sheet beam klystron with the multi-cavity, multi-gap interaction circuit, we have designed and built a uniform magnetic focusing prototype tube, where a simulated 55 kV, 2.2 A sheet beam transports an interaction length of about 100 mm. A water-cooled solenoid is used to produce the field with a maximum value of 4,000 Gauss. To improve the characteristic impedance and efficiency, the HF circuit is composed of four multi-gap cavities, and each cavity includes a multi-layered membrane to finely tune its working frequency. Meanwhile, to simplify the structure, a single-port scheme is applied in the input and output cavities, the adverse influence of which on the field uniformity is reduced to a minimum level. The latest hot test shows the maximum output power attains to 2.5 kW at 94.025 GHz and the bandwidth is about 100 MHz when the output is over 1 kW. The self-oscillation has not been observed in this experiment.

13.3 - High-Efficiency, High-Average-Power, Multiple Beam Inductive Output Tubes

- *Henry Freund*
  Calabazas Creek Research

- *Robert Lawrence Ives, Thuc Bui*
  Calabazas Creek Research, Inc.

- *Walter Sessions*
  Georgia Tech Research Institute

  The development of high efficiency, Multiple Beam Inductive Output Tubes (IOTs) with efficiencies greater than 80% would substantially reduce the operating costs of next-generation particle accelerators. We discuss the development of a multiple-beam IOT that employs a third harmonic drive component on the grid to achieve efficiencies greater than 80%. We discuss a

novel input coupler, grid design, and simulation of the output cavity. This presents a path forward to the design and production of such high efficiency IOTs.

13.4 - A 1.3-GHz 100-kW Ultra-High Efficiency Klystron

- *Michael Read, Robert Lawrence Ives, Thuc Bui, David Marsden, George Collins*
  Calabazas Creek Research Inc.

- *Aaron Jensen*
  Leidos

Calabazas Creek Research, Inc. is developing a high efficiency, 1.3 GHz, 100 kW klystron for driving accelerators. A design with an efficiency of 79% has been realized and a device is being fabricated. Details of the design and available test results will be presented.

13.5 - Design Study of X-Band High Efficiency Klystrons for CLIC

- *Jinchi Cai*
  Lancaster University & CERN

- *Igor Syratchev*
  CERN

The design of two X-band high efficiency (HE) Klystrons are presented in this paper. Based on Core Oscillation Method (COM) and coupled-cell output structure topology, 8MW Klystron for Xbox test stand can yield 58% output efficiency with beam perveance of 1.6uP. Scaling and post-optimization method is used for 50MW Klystron for CLIC accelerating structures design, which can provide 65% output efficiency with beam perveance of 0.75 uP. The peak electric field is lower than 100kV/mm for both cases, which is purposely optimized to avoid RF breakdown. The parameter optimization is done with KlyC1.5D simulation and results are verified by CST PIC simulations.

13.6 - A Multi-Beam Terahertz Coaxial Cavity Reflex Klystron

- *Hongyang Guo, Zhanliang Wang, Huarong Gong, Zhigang Lu, Zhaoyun Duan, Yubin Gong*
  University of Electronic Science and Technology of China

- *Jinjun Feng*
  Beijing Vacuum Electronics Research Institute

A multi-beam (6 beams) terahertz reflex klystron based on a coaxial cavity is presented. 6 beams instead of 1 beam are used to increase the total direct current and output power. When the beam voltage is 2000V, the single beam current is 5.7mA and the reflection voltage is 2235V, the electromagnetic field of TM110 mode with frequency of 316.54GHz is excited and the output power and electron efficiency are 832mW and 1.2%, respectively.

Poster Sessions

Poster Session
TWT/Linear Beam

P1.1 - Design of a Source for Millimeter-Wave Ultra-Wide Bandwidth Applications Using the Two-Stream Instability

- *Derek Neben, Kip Bishofberger, Vitaly Pavlenko, Nikolai Yampolsky*
  Los Alamos National Laboratory

A novel source for millimeter-wave RF is being designed at Los Alamos National Laboratory (LANL) utilizing the two stream instability, offering the potential for consistent output power over a large bandwidth on a single device. The characteristic length of longitudinal bunching due to the two stream instability is dependent, along with current, on the energy difference of the two beams. The design of a source using co-axial electron beams coupled into a solenoid is presented. The electron beam energy from the innermost cathode will fall in the range between 16-20 keV with the beam energy from the outer cathode 75-95% the inner beam energy. In order to efficiently match the beam from the outer cathode into the solenoid, heat shields are used to shape the electric field in the gun region to minimize the total beam radius in the solenoid. The source will be used to evaluate the longitudinal bunching of the electron beams at millimeter wavelengths.

P1.2 - The Verification of the Expression of the Interaction Impedance and Ohmic Losses of the Nonuniform-Grating-Based Slow Wave Structure

- *Fengzhen Zhang, Xiaoyan Wang*
  Aerospace Information Research Institute, Chinese Academy of Sciences & University of Chinese Academy of Sciences

- *Zhaochuan Zhang, Dongping Gao*
  Aerospace Information Research Institute, Chinese Academy of Sciences

The expression of the interaction impedance of the nonuniform-grating-based slow wave structure (SWS) is given in this paper. The verification of the expression of the interaction

impedance and Ohmic losses of the non-dielectric-loaded (NDL) SWS and partially dielectric-loaded (PDL) SWS is verified by simulations.

P1.3 - The Hot Dispersion Equation of the Backward Wave Oscillator with the Nonuniform Grating

- *Fengzhen Zhang, Xiaoyan Wang*
  Aerospace Information Research Institute, Chinese Academy of Sciences & University of Chinese Academy of Sciences

- *Zhaochuan Zhang, Dongping Gao*
  Aerospace Information Research Institute, Chinese Academy of Sciences

The hot dispersion equation of the backward wave oscillator (BWO) with the partially dielectric-loaded (PDL) nonuniform grating is proposed in this paper. The expression of the hot dispersion equation is given and the resonant growth rate is verified by the Pierce small signal gain of a BWO with the PDL nonuniform grating.

P1.4 - Analysis of High Frequency Characteristics for a Meander Line Slow-wave Structure

- *Zheng Wen, Jirun Luo, Yu Fan, Chen Yang*
  Institute of Electronics, Chinese Academy of Sciences & University of Chinese Academy of Sciences

- *Fang Zhu, Min Zhu, Wei Guo*
  Institute of Electronics, Chinese Academy of Sciences

- *Yubin Gong*
  University of Electronic Science and Technology of China

- *Jinjun Feng*
  Beijing Vacuum Electronics Research Institute

Analysis of high frequency characteristics for a meander line slow-wave structure (ML-SWS) has been carried out by field-matching methods with the dyadic Green's function. The effect from thickness of the meander line was considered and the theoretical results had been compared with the simulation ones

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P1.5 - Design of Ridge-Loaded Slow-Wave System in Terahertz Band

- *Xiaohan Zhang*
  Aerospace Information Research Institute, Chinese Academy of Sciences & University of Chinese Academy of Sciences

- *Linlin Cao, Jun He, Mingguang Huang*
  Aerospace Information Research Institute, Chinese Academy of Sciences

- *Fei Li*
  Aerospace Information Research Institute,Chinese Academy of Sciences

In this paper, a ridge-loaded waveguide structure working at terahertz band is established, and the high frequency characteristics are calculated by HFSS. Based on the ridge-loaded structure, a multi-section slow wave system is designed, and the MTSS is used to calculate the beam-wave interaction. The results show that the slow wave system designed in this paper has a great improvement in performance.

P1.6 - Research on Vacuum Test of Sealed TWT

- *Feng Zou, Gang Wang*
  Institute of Electronics, Chinese Academic of Sciences & University of Chinese Academy of Sciences

- *Xin'ai Liu, Kangsong Tang*
  Institute of Electronics, Chinese Academic of Sciences

- *Fangfang Song*
  Science and Technology on Reliability Physics and Application Technology of Electronic Component Laboratory

Vacuum is an important parameter which is related to TWTs' long term operation and reliability. Vacuum deteriorate rate in tuning, vibration, thermal and vacuum thermal tests can be used to evaluate a TWT functional quality in a short-term way. By using TWT electrodes and cathode, an ion current test system is applied to scale vacuum status. After calibration, ion current and vacuum are matched in pairs. We tested a TWT's vacuum over a long term of tuning and environmental tests.

P1.7 - Thermal Analysis of Slow-Wave Structure of a Medium-Power Helix Traveling-Wave Tube

- *Srikrishna , RAJA RAMANA RAO, TALUR CHANAKYA TALUR, K VENKATESWARA RAO, SUBRATA KUMAR DATTA*
  MTRDC

Thermal analysis of slow-wave structure, window and waveguide coupler of a medium power helix TWT has been carried out using ANSYS. The thermal simulation using ANSYS has been carried out for estimating the maximum temperature and the temperature distribution in a medium average power broadband helix traveling wave tube (TWT). The simulation was first carried out independently for the sub-assemblies like the slow-wave structure and the output waveguide coupler; and the combined effect on the overall temperature inside the TWT was estimated subsequently

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P1.8 - Simulations of a Coaxial Multipactor Testbed

- *Rajani Budha, Salvador Portillo, Edl Schamiloglu*
  The University of New Mexico

The harsh radiation environment in orbit leads to electrons avalanche in Traveling Wave Tubes (TWTs) affecting the Satellites communication. To this end, researchers at the University of New Mexico (UNM) are developing particle-in-cell (PIC) models of a coaxial geometry testbed as a first step in developing complex models of TWTs with different emission properties as well as different modulated tonal inputs.

P1.9 - Application of Filter in TWT Energy Transmission Coupler

- *Lianbing Li, Liu Xiao, Linlin Cao, Shirui Miao*
  University of Chinese Academy of Sciences & Chinese Academy of Sciences

- *Hongxia Yi*
  Chinese Academy of Sciences

The coupler is an important part of the input and output structure of Traveling Wave Tube (TWT). Its performance directly affects the working bandwidth and efficiency of the tube. It is significant to design a coupler with wide bandwidth and compact structure for the miniaturization of TWT. In this paper, the design idea of filter is applied to the design of TWT energy transmission coupler. A stepped impedance transformer composed of seven transmission lines of different sizes is designed. Compared with the traditional quarter-wavelength impedance transformer, it achieves better performance with shorter length. The voltage standing wave ratio (VSWR) of the impedance transformer is lower than 1.1 in the frequency band of 11.9-13.2GHz, and it presents similar characteristic of bandpass filter.

P1.10 - S Band Miniaturized Reversed Cherenkov Oscillator with Uniform Axial Magnetic Field

- *Hengyu Luo, Shengkun Jiang, Xin Wang, Tao Tang, Yubin Gong, Zhaoyun Duan*
  University of Electronic Science and Technology of China

Based on the reversed Cherenkov radiation of metamaterials (MTMs) which is not found in naturally occurring materials, an S band Reversed Cherenkov Oscillator (RCO) is designed. In order to make it practical, coaxial coupling output structure and uniform magnetic field permanent magnet focusing system are used. The simulation shows that at the beam voltage of 29 kV and the beam current of 6.8 A, 55 kW of average output power at 2.219 GHz with 27.8% electronic efficiency is generated under the uniform axial magnetic field of 1300 G. The diameter of the MTM slow-wave structure (MSWS) is ~1/6-1/2 of the conventional backward wave oscillators (BWOs). A step has been taken in the practical process of RCO.

P1.11 - Enhance the Efficiency of Sheet Beam TWT with Advanced Optimization Algorithm

- *Zeng Liu, Jianxun Wang, Yixin Wan, Qiang Liu, Yong Luo*
  University of Electronic Science and Technology of China

The sheet beam traveling-wave tube (SBTWT) with staggered double vane (SDV) structure has attracted much attention as a board band and powerful terahertz and millimeter-wave source. In this paper, the velocity taper for SDV structure is optimized with a recently proposed swarm-intelligence (SI) based optimization algorithm named dragonfly algorithm (DA) in order to enhance the beam-wave interaction efficiency in sheet beam TWT. The optimization result of this algorithm is compared with other commonly used algorithms. The taper optimized with DA is verified with CST particle in cell (PIC) simulations. The efficiency of the optimized structure has been greatly increased in both optimization and PIC simulations.

P1.12 - Effect of Noisy Input Signal and Electron Beam Velocity Nonuniform on Helix TWT Output Performance

- *Changsheng Shen, Jin Zhang, Hehong Fan, Ningfeng Bai, Xiaohan Sun*
  Southeast University

Due to the complex electromagnetic environment in the helix TWT, the input signal is noisy, and the velocity magnitude and direction of electron beam from the electron gun to the slow wave structure are nonuniform. A simulation model for helix TWT output performance with different noisy input signal and velocity of electron beam is established and the results show that signal-to-noise ratio (SNR) of the output signal is affected by noisy input signal, the velocity magnitude and direction. SNR decreases obviously when signal-to-noise ratio of input signal decreases.

P1.13 - Simulation Design of TWT Based on CNT Cold Cathode

- *Yanan Liu, Xiaotao Xu, Xuesong Yuan, Rui Wang, Hailong Li, Bin Wang, Yong Yin, Lin Meng, Yang Yan*
  University of Electronic Science and Technology of China

Beam-wave interaction system of a Ka-Band traveling wave tube (TWT) based on carbon nanotube (CNT) cold cathode is theoretically researched in this paper. Based on the electron beam parameters of a truncated-cone carbon nanotube cold-cathode electron gun, a high-frequency system for coupled-cavity TWT is designed. Simulation results show that the maximum output power of the TWT can reach 313 W at 33.5 GHz with an input power of 500mW, corresponding to the maximum gain of 28 dB, when the electron beam voltage and current are 28 kV and 300 mA. The 3dB bandwidth of the TWT is about 0.6 GHz.

P1.14 - Broad bandwidth Suspending Conformal Angular Meander Line Slow Wave Structure

- *Tenglong He, Duo Xu, Hexin Wang, Wei Shao, Zhanliang Wang, Zhigang Lu, Huarong Gong, Zhaoyun Duan, Yubin Gong*
  University of Electronic Science and Technology of China

- *Jinjun Feng*
  Beijing Vacuum Electronics Research Institute

In this paper, a wide bandwidth suspending conformal angular meander line slow wave structure (ML SWS) is proposed. By suspending the dielectric substrate, this SWS changes the e-field of microstrip that its lower sur-face of dielectric substrate does not connect with ground. So, it has wide bandwidth and high impedance. The simu-lation results show suspending conformal ML SWS has a low voltage 3800V at Ka-band. The maximum output power can reach 104W at 34GHz. The 3-dB bandwidth is7GHz that is from 32GHz to 39GHz and the maximum electron efficiency is 14%.

P1.15 - A Low-Voltage Backward Wave Oscillator Operating at THz Band

- *Wei Shao, Duo Xu, Zhanliang Wang, Huarong Gong, Tao Tang, Zhaoyun Duan, Zhigang Lu, Yanyu Wei, Yubin Gong*
  University of Electronic Science and Technology of China

- *Jinjun Feng*
  Beijing Vacuum Electronics Research Institute

A low-voltage backward wave oscillator based on staggered double vane structure is designed in this paper and a novel straight-waveguide input/output coupler is also proposed. The high-frequency characteristics and transmission characteristics of the structure are calculated and the results of the circuit show that the reflection coefficient is below -10dB in the frequency range of 250-300GHz. The beam-wave interaction is also carried out and the output power is greater than 20mW within the frequency range of 290GHz to 300GHz, which the corresponding operating voltage is 3800V to 4500V. And a maximum output power of 2W is reached at 300GHz.

P1.16 - Ka-Band Plane Suspension Line Slow-Wave Structure and Its Integrated Design

- *Ludi Song, J Xu, R.C Yang, L.N Yue, H.R Yin, G.Q Zhao, Z.G Lu, W.X Wang, T Tao, Z.L Wang, Z.Y Duan, H.R Gong, M.Z Huang, Y.B Gong, Y.Y Wei*
  University of Electronic Science and Technology of China

In this paper, a suspension line slow-wave structure and its integration scheme for Ka band traveling wave tube are proposed. The beam-wave interaction of the structure is calculated by particle simulation. The results show that the output power of the one-channel slow-wave structure can reach 71.9 W when the frequency is 30GHz, the banded electron beam voltage is 4700V and the current is 0.15A, and the corresponding maximum gain and electron efficiency are 21.58dB and 10.2%, respectively. When the frequency of the two-channel integrated slow-wave structure is 30GHz and the banded electron beam voltage is 5000V, the output power can reach 168.5W. The corresponding maximum gain and electronic efficiency are 22.27dB and 11.23%, respectively.

P1.17 - A Novel Feedback Circuit of Beam-Wave Interaction for THz Amplifier

- *Luanfeng Gao, Yulu Hu, Quan Hu, Xiaofang Zhu, Jianqing Li, Bin Li, Tao Huang, Wenkai Deng, Xiaobing Wang*
  University of Electronic Science and Technology of China

- This paper describes the working and dispersion synchronization condition of the novel beam-wave interaction to develop a watts-level, tunable THz amplifier, which can enhance the gain and reduce the starting current. In the feedback circuit, two beams can be possibly coupled with HOM as their beam position has a strong coupling with the modes. Thus, the HOM is analyzed. Simulation results show that the high order mode excitation cannot become dominant in the feedback circuit.

P1.18 - Thermal Impact on Metamaterial Absorber in Traveling-Wave Tube

- *Fuxian Zhong, Ningfeng Bai, Changsheng Shen, Xiaohan Sun*
  Southeast University

- *Pan Pan, Jun Cai, Jinjun Feng*
  Beijing Vacuum Electronics Institution

In this paper, the thermal impact on a metamaterial absorber (MMA) used in traveling-wave tube is investigated. This MMA has three layers, where the dielectric layer, SiC, is middle layer with metallic layers, copper, are top layer and bottom layer. The thermal impact on this MMA is studied with a comprehensive consideration of all thermal-sensitive parameter of MMA

structure. The simulation results reveal the performance of MMA in high temperature circumstances. When temperature rising from 300 K to 600 K, the absorbing frequency of the proposed MMA shifts from 27.60 GHz to 26.79 GHz. These results indicate the MMA has a potential application in TWT.

P1.19 - A 0.67-THz Sheet Electron-Beam TWT Based upon Sine Waveguide

- *Wuyang Fan, Shuanzhu Fang, Jin Xu, Lingna Yue, Hairong Yin, Guoqing Zhao, Wenxiang Wang, Yanyu Wei*
  University of Electronic Science and Technology of China

- *Wenxin Liu*
  Chinese Academy of Science

- *Luwei Liu*
  Anhui East China Photoelectric Technology Research Institute Co., Ltd

- *Dazhi Li*
  Neubrex.Ltd

A 0.67THz sheet electron beam traveling-wave tube based upon sine waveguide slow-wave structure is studied. In this paper, the high frequency characteristics and transmission characteristics are calculated by a 3-D high frequency simulation software. The beam-wave interaction is also simulated. From the simulation results, the peak output power is 1.7W ranging from 0.65THz to 0.69THz with synchronous voltage of 17kV, operation current of 10mA and input power of 3.2mW.

P1.20 - Development of an X-Band 600-W Pulsed Mini-TWT

- *Linlin Cao, Liu Xiao, Lianbing Li, Xiaohan Zhang, Xinwen Shang, Yanwei Li, Ning Li, Mingguang Huang*
  Aerospace Information Research Institute, Chinese Academy of Sciences

This paper describes the development of an X-band pulsed miniature traveling-wave tube (mini-TWT) at the Aerospace Information Research Institute, Chinese Academy of Sciences (AIRCAS). This mini-TWT can produce more than 600-W peak output power and 47.5% minimum overall efficiency over the frequency range of 9 to 10 GHz. It achieves a compact size less than 180mm (L) × 30mm (W) × 20mm (H) and weighs less than 0.3kg.

P1.21 - PIC Simulation in the Reversed Magnetic Field of MW-DC Cyclotron Wave Converter

- *Maho Matsukura, Kohei Shimamura, Yokota Shigeru*
  University of Tsukuba

- *Masafumi Fukunari, Yoshinori Tatematsu*
  University of Fukui

To develop the vacuum-type microwave DC converter for high frequency, in a region of the whole converter where the z-axial magnetic field was reserved, the motion and z-axial velocity of the electron were simulated. The results showed that the increment of z-axial velocity in the region was 3.8 x 10^7 m/s. Moreover, conversion efficiency in conversion region that is the kinetic energy transfer from transverse direction to z-axial one was 94%.

P1.22 - W-Band Multi-Beam Sine Waveguide Traveling-Wave Tube with Low Current Density

- *Shuanzhu Fang, Jin Xu, Xia Lei, Gangxiong Wu, Ruichao Yang, Pengcheng Yin, Hairong Yin, Lingna Yue, Guoqing Zhao, Wei Yang, Zhigang Lu, Yubin Gong, Wenxiang Wang, Yanyu Wei*
  University of Electronic Science and Technology of China

A W-band multi-beam traveling-wave tube (TWT) based on sine slow-wave structure is designed. The cold bandwidths of the fundamental and higher-order modes in the slow-wave circuit are analyzed using HFSS software. Through reasonable structural design, the fundamental mode and low-order mode are suppressed. The beam-wave interaction capability of the multi-beam TWT is analyzed based on the high-order mode transmission design. At the voltage of 11.7 kV, the current density of the sheet electron beam is 96 A/cm2 which can be produced by the non-convergent electron gun, and the output power is over 150 W in the operating frequency 90 GHz-100 GHz.

P1.23 - A New Type of 0.34-THz Sine Waveguide Slow-Wave Structure

- *Zhang Xue heng, Xu Jin, Fang Shuan zhu, Jiang Xuebing , Yin Pengcheng, Hairong Yin, Yue Lingna, Zhao Guoqing, Wang W.X., Gong Y.B., Wei Y.Y.*
  University of Electronic Science and Technology of China

- *Liu W.X.*
  Chinese Academy of Science

- *Li D.Z.*
  Neubrex.Ltd

A new type sine waveguide slow wave structure (SWS) is proposed in this paper considering fabrication feasibility. Unlike the conventional sine waveguide SWS, a round beam tunnel is adopted in this modified structure. The simulation results show that the new structure has the advantages of wide bandwidth and low loss which are important in millimeter-wave and THz

TWT. A 3dB band-width of 25 GHz and a maximum gain of 27 dB were predicted by PIC simulation for a 40 mm-long slow wave circuit.

P1.24 - Analytical Analysis of Saturation Output Power for Traveling-Wave Tube

- *Zhang Shen, Hairong Yin, ShiRong Wang, DongDong Jia, Jun Cheng, Yue Zhao, Jin Xun, Lingna Yue, Guoqing Zhao, WenXiang Wang, Y.Y Wei*
  University of Electronic Science and Technology of China

- *L.W. Liu*
  Anhui East China Photoelectric Technology Research Institute Co

In order to predict the saturation output power of traveling wave tubes rapidly, analytical expression has been worked out. This theory is verified by comparison with two of large signal theory.

P1.25 - Joint Simulation of Electron Optical System and Beam-wave Interaction of V Band Folded Waveguide TWT

- *Xiuling Ge, Jin Xu, Lingna Yue, Hairong Yin, Guoqing Zhao, Wenxiang Wang, Z.G Lu, T. Tao, H.R. Gong, Y.B Gong, Yanyu Wei*
  University of Electronic Science and Technology of China

In order to make the design results of the traveling wave tube (TWT) coincide with the experiments very well, we need to build a bridge between the actual electron situation and the beam-wave interaction. In this paper, considering the actual magnetic field distribution, the macro particle data at the waist position is processed by MATLAB to meet the needs of the interaction calculation model, so as to realize the integrated design of electron gun, magnetic system and interaction calculation using CST studio suite.interaction calculation using CST studio suite.

P1.26 - Dielectric Loss Analysis of Anisotropically Conducting Tape Helix Slow-Wave Structure in Traveling-Wave Tube

- *NAVEEN BABU GNANAMOORTHI*
  SHIV NADAR UNIVERSITY

- *Richards Joe Stanislaus*
  CEERI

This paper presents the analysis of dielectric losses obtained through the coldwave field analysis of anisotropically conducting tape helix supported by lossy dielectric rods in travelling wave tubes (TWT). The electromagnetic field expressions are derived through field approach using Maxwell's equations and vector Helmholtz's equations through boundary conditions. Through the application of lossy dielectric permittivity in the resultant axial electric field, the shunt capacitance and the shunt conductance per unit length are obtained. The lossy dielectric support rods result in attenuation in the electromagnetic wave propagation. The attenuation constant obtained through current analysis has been compared with the published models and experimental results. The effect of the frequency and temperature is also studied for X-Ku band and Q- band travelling wave tube amplifiers.

P1.27 - Study of a Ka-Band Helix TWT with Semi-Metallic Rod

- *Xiaoxia Hu, Lingna Yue, Kai Chen, Shirong Wang, Maosong Gou, Guoqing Zhao, Jin Xu, Baorong Qiu, Li Huang, Wenxiang Wang, Hairong Yin, Wei Yang, Yanyu Wei*
  University of Electronic Science and Technology of China

The high frequency characteristics and beam wave interaction characteristics of a Ka-band (26-40GHz) helix traveling wave tube (TWT) with rectangular semi-metallic rod are presented. The design results show that the TWT has the gain of more than 42dB, the output power of more than 220W and the electronic efficiency of more than 19% in the working bandwidth. Now the high frequency structure of the TWT are manufactured, the preparation for the transmission test is in progress.

P1.28 - Design and Cold Test of a Ka-band Fan-Shaped Metal Loaded Helix Traveling Wave Tube

- *Yixin Li, Lingna Yue, Shirong Wang, Guoqing Zhao, Jin Xu, Hairong Yin, Zhaoyun Duan, Mingzhi Huang, Yubin Gong, Wenxiang Wang, Yanyu Wei*
  University of Electronic Science and Technology of China

- *Baorong Qiu, Huaying Gao*
  Guoguang Elecric Co., Ltd.

This paper describs a fan-shaped metal loaded helix traveling wave tube working at Ka-band. It has the gain of 37.3-48.7dB, electronic efficiency of 15.18%-19.42% and output power is greater than 286W when it works at a voltage of 9KV and a current of 210mA. The simulation results of VSWR for its coaxial energy coupler are below 1.35, and the test results of it is below 2.1 at the working frequency range.

Poster Session
Components

P2.1 - Design and Experiment Test of an L-Band RF Window

- *Xiudong Yang, Rui Zhang*
Key Laboratory of High Power Microwave Sources and Technologies

  This paper describes the design and experiment test of an pill-box RF window for L-band klystron test application. A piece of alumina ceramic with a diameter of 220 mm and a thickness of 8.1 mm is used in the pill-box RF window to divide the microwave transmission channel into two regions, one region close to klystron, another one close to high power water load. In case the water load breaks, the RF window protects the klystron from the impact of water. Test result shows that the VSWR is 1.07 and the S21 is -0.11dB with the microwave frequency of 1300MHz.

P2.2 - Design and Test of a C-Band Water Load

- *Rui Zhang, Xiudong Yang*
Key Laboratory of High Power Microwave Sources and Technologies

  This paper describes the design and experiment test of a C-band water load developed for high power klystron test application. In order to reduce reflection microwave and expand the bandwidth, a structure with multi-level gradual change was adopted. In this load, a piece of alumina ceramic with a thickness of 3 mm was metalized and brazed on one cooper ring, two O-rings were used for sealing water. Finally, two water loads were fabricated and tested. Test result shows that the VSWR is 1.07 with a frequency of 1300 MHz, the VSWR is less than 1.2 with the frequency band of 5659MHz to 5746MHz. These two loads were mounted in the C-band klystron test system.

P2.3 - Design of 94GHz TE_{11}-HE_{11} Mode Converter

- *Wei Zhang, Qian Wang, Xinjian Niu*
University of Electronic Science and Technology of China

  Based on the coupled wave theory, a corresponding parameter optimization program was compiled. In order to achieve mode conversion and phase matching in the shortest length, a two-stage structure is adopted. Optimized by a numerical calculation program, the TE11-HE11 mode converter with a working frequency of 94GHz and the port diameter from 4mm to 18mm was designed. Its conversion efficiency reached 99% while its length was only 69mm.

P2.4 - Investigation on a Gyrotron Quasi-Optical Mode Converter for Imaging

- *Xiaolei Zheng, Wenjie Fu, Xiaotong Guan, Chengxin Zhang, Tongbin Yang, Yang Yan*
  University of Electronic Science and Technology of China

  In gyrotron devices, the mode of operation usually adopts the high-order cavity mode which could get high power capability and low loss. However, high-order cavity mode cannot be directly used in applications, and it must be converted into the fundamental mode Gaussian beam which is suitable for free space propagation. In the high frequency band, the conventional waveguide mode converter is too small in the inner diameter of the waveguide, difficult to fabricate and assemble with the gyrotron, thus the quasi-optical mode converter is proposed and investigated for gyrotron. Additionally, the quasi-optical mode converter can reduce the reflection of the output window and prevent the reflection wave from heating the electron beam, thus improving the stability of the beam-wave interaction. In this paper, the design and cold test experiment of a 220GHz gyrotron quasi-optical mode converter for imaging are reported.

P2.6 - Analysis of Contact Effect on Collector Interface of High-Power TWT

- *Gao Cha CHa, Tang kang song, Wang Jin tian, Su Xiao bao, Zang Hai liang*
  Institute of Electronics, Chinese Academy of Sciences

  This paper mainly analyzes the temperature of collector with the changes of the thermal resistance between the ceramic plate and the electrode. The results show that the maximum temperature of the collector electrode (Electrode2) increases slowly at first and then rapidly with the increase of thermal resistance, and the temperature on Electrode3 increases relatively evenly, the temperature on the pole piece and the ceramic column varies little.

P2.6 - An Innovative Metal/Insulator/Metal Structure for Application of Damping Oscillator within One-Selector-One-Resistance

- *Chih-Yang Lin*
  Department of Physics, National Sun Yat-sen University

- *Ting-Chang Chang*
  National Sun Yat-Sen University

- *Po-Hsun Chen*
  Department of Applied Science, Chinese Naval Academy

  This paper presents a comprehensive study of oxide-based selector characteristics with universal model for interface-type threshold switching (TS) phenomena. The thermal-induced TS transition and electrical-induced TS transition at interface have been confirmed by versatile material and structure systems. The physical understanding of evolution in energy barrier and MIT metallic state modulation have been studied with proposed innovative vanadium electrode.

The selector with vanadium electrode owns better characteristic, after series to a resistance, it shows the damping characteristic which can be applied to be a promising oscillator.

P2.7 - Dynamics Analysis of Particles in Coaxial Lines Loaded by Dielectrics

- *Yao Long, Wang Yong*
  Institute of Electronics, Chinese Academy & University of Chinese Academy of Sciences

- *Zhang Rui*
  Institute of Electronics, Chinese Academy

- *Zhang Xue*
  Xiang tan University

Multipacting is electron discharge that occurs in components where operate with RF high-power electromagnetic fields. In this paper, we will study the motion characteristics of particles in the coaxial structure with a ceramic window. A Monte Carlo algorithm is used to track the secondary electron trajectories and study the multipactor scenario on the surface of a ceramic window by using 2-D particles trajectory code. By studying the motion of particles, we can provide guidance for suppressing secondary electron multiplication in coaxial waveguide loaded ceramic.

P2.8 - Compact Oversized TE01-to-TE11 Mode Converter Based on Deformed Waveguide

- *Zewei Wu, Xiaoyi Liao, Minxing Wang, Ding Li, Jianxun Wang, Yong Luo*
  University of Electronic Science and Technology of China

A Q-band oversized TE01-to-TE11 mode converter is designed for high power transmission line of gyro-TWTs. To obtain a compact and broadband structure, the deformed circular waveguide, named quad-polar waveguide, which can improve the conversion capacity of between TE01 mode and TE11 mode is introduced. The axis perturbation is synthesized by iteration method. Validated by simulation software, the designed mode converter has the efficiency over 95% in the range of 46.9 GHz to 49 GHz.

Poster Session
Gyrotrons

P3.1 - Influence of Linear Magnetic Field Taper on 394-GHz Gyrotron

- *Xuewei Wang, Qianzhong Xue*
  Key Laboratory of Science and Technology on High Power Microwave Sources and Technologies, Institute of Electronics, Chinese Ac

The influence of magnetic field taper on gyrotron operation is studied by generalizing the well-known (? F) plot, which just discussed the transverse efficiency using Gaussian field profile and not took the self-consistent non-stationary codes or ohmic dissipation into consideration. In this paper, linear and self-consistent nonlinear codes are used to investigate influences of magnetic field taper on start current and output parameters of a 394 GHz gyrotron.

P3.2 - Design on a 100-kW-level Gyrotron Operating at 30 GHz

- *Yanyan Zhang*
  Science and Technology on Electronic information Control Laboratory

- *QIAO LIU, Rutai Chen, Zhipeng Wang, Lina Wang*
  University of Electronic Science and Technology of China

In this paper, we present a design on a 30 GHz 100 kW-level gyrotron. The cold-cavity of the gyrotron has been studied by using an in-house gyrotron simulation code and CST microwave studio, respectively. Meanwhile, in the hot-cavity analyses, the behavior of multi-mode beam-wave interaction has been studied in detail by using PIC simulation with the help of CST particle studio. The results present that the gyrotron can operate at TE0.3 mode stably with the output power of 150 kW under the operating conditions: beam voltage of 50 kV, beam current of 10 A, magnetic field of 1.14 T, and pitch factor of 1.3.

P3.3 - Electron Beam Defocusing for the Collector of W-band large power Gyrotron

- *Guo Guo, Jianwei Liu, Xinjian Niu, Yinghui Liu, Hui Wang*
  University of Electronic Science and Technology of China

The power dissipation of the collector is based on the theory by adding the external coils outside the collector which generates vertical or transverse magnetic field to modify the trajectory of electrons on the collector. In this paper, three power dissipation methods of the thermal loading on the collector for a 94GHz large power gyrotron are described and simulated the trajectory of electrons with CST Particle Studio. The approaches described are the vertical field sweeping system(VFSS), the transverse field sweeping system(TFSS), and the method of synthesis combine VFSS with TFSS, respectively. The results are revealed and discussed though modeling and simulation.

P3.4 - Simulation of Transverse Field Sweeping System with Different Modulation Waves for MW-Class Gyrotron

- *Kai Wang, Qianzhong Xue*
  Aerospace Information Research Institute, Chinese Academy of Sciences & University of Chinese Academy of Sciences

  The transverse field sweeping system is capable of spreading electron deposited areas and reducing peak power density efficiently. In order to obtain lower peak power density further, the means of modulation wave has been employed. The effect of different modulation waves have been investigated using CST code in this paper. The simulated results indicate the triangular wave has the best performance among rectangular wave, triangular wave and cosine wave. Finally, the optimal peak power density 106.2 W/cm^2 has been obtained.

P3.5 - Design and Study of W-band Gyrotron with Output Power of 150 kW Level

- *Yujie Zhang, Qiao Liu, Yinghui Liu, Xinjian Niu, Jianwei Liu*
  University of Electronic Science and Technology of China

  Based on the linear theory and the self-consistent nonlinear theory, a 94 GHz complex cavity gyrotron is designed with the pair of TE7.2/TE7.3 operating mode in this paper. Through operating at the high-order mode and second harmonic, the gyrotron can output hundred-kilowatt power at low magnetic field. Furthermore, the influences of electron beam parameters on interaction efficiency are analyzed in detail. As a result, the output power of 173 kW, corresponding to 34.83% efficiency, has been achieved with the beam voltage 71 kV, the beam current 7 A, the pitch factor 1.3 at the DC-magnetic field of 1.83 T.

P3.6 - Investigation on a 170-GHz/230-GHz Dual-Mode Megawatt-Class Gyrotron for CFETR

- *QIAO LIU, Yinghui Liu, Xinjian Niu, Jianwei LIU, Lina Wang, Jie Qing*
  Univesity of electronic science and technology of China

  In this paper, we present an investigation on a dual-frequency dual-mode megawatt-class gyrotron. The gyrotron can operate at frequencies of 170 GHz and 240 GH with the corresponding operating modes TE33.12 and TE44.16, respectively. In the analyses, the startup scenarios for the operating modes have been investigated by an in-house, developed, multi-mode, time-dependent code. The simulations result show that the output power of the gyrotron can reach about 1 MW at two operating frequencies with corresponding operating conditions.

P3.7 - Design and Simulation of a 140GHz Gyro-TWT with Dielectric Loaded Waveguide

- *Rutai Chen, Sheng Yu, Zhipeng Wang, Tianzhing Zhang, Weihua Ge*
  University of Electronic Science and Technology of China

In this paper, a 140GHz gyro-TWT uniform dielectric loaded waveguide operating in the low loss TE01 mode is presented. By adopting a low DC driver of 50kV, 1A to satisfy the power capacity of small dimension structure. The loaded dielectric is used to suppress the potential backward wave oscillation. This gyro-TWT is designed and simulated by a particle-in-cell (PIC) software. The optimized simulation results indicate the designed gyro-TWT can operate at the desired mode TE01 with the output power of 12.85kW. The corresponding saturated gain and -3dB bandwidth are 39.3dB and 7.5GHz, respectively

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P3.8 - A Study on Instabilities of 220 GHz Confocal Waveguide Gyro-TWT

- *Jie Yang, Yong Wang, Xiaoyan Wang*
  Aerospace Information Research Institute, Chinese Academy & University of Chinese Academy of Sciences

- *Shouxi Xu, Lianzheng Zhang*
  Aerospace Information Research Institute, Chinese Academy

Instability problem is one of the most significant limits for high power gyro-TWTs. In this paper, the absolute instabilities and backward wave oscillation (BWO) instabilities of a 220 GHz confocal waveguide gyro-TWT are discussed. The results show that the starting current of absolute instabilities is much higher than the operating current 5A, and the critical interaction length of HE05 mode backward wave oscillation is about 10mm.

P3.9 - Simulation of a 0.33-THz Second Harmonic Gyrotron Based on Double Confocal Cavity

- *Xiaotong Guan, Wenjie Fu, Jiayi Zhang, Dun Lu, Xiaolei Zheng, Yang Yan*
  University of Electronic Science and Technology of China

Confocal cylindrical waveguide performs many good characters, such as big power capacity and low mode density, which are good for designing high harmonic terahertz gyrotron. Motivated by improving beam-wave interaction efficiency of quasi-optical gyrotron, a novel gyrotron beam-wave interaction structure based on double confocal waveguide has been proposed and theoretically analyzed in this paper. A 0.33 THz second harmonic gyrotron oscillator based on double confocal cavity has been designed and simulated by PIC code. It is indicated that double confocal cavity is able to enhance the output power and the interaction efficiency of quasi-optical gyrotron. Besides, the mode characteristic of double confocal waveguide is investigated with the simulation results.

P3.10 - A Preliminary Theoretical Study on Double-Confocal Gyrotron Traveling-Wave Amplifier

- *Chen Zhang, Wei Wang, Jie Huang, Tao Song, Diwei Liu*
  University of Electronic Science and Technology of China

  To suppress parasitic oscillation in a gyro-TWT, the gyro-TWT with a quasi-optical confocal waveguide is proposed. Theoretical and experimental investigations demonstrate that the confocal waveguide has good-mode selection and is suitable for gyro-TWT. However, due to the transverse non-uniformity of the radio frequency field, the beam–wave interaction efficiency is low in the confocal waveguide. To mitigate this drawback, the double confocal gyro-TWT is investigated in this study.

P3.11 - Study and Design of Twin-Beam Magnetron Injection Gun

- *Bukya Bharat Kumar*
  Mtrdc

  The paper describes the detailed design of double anode double-beam magnetron injection gun with two beams operating in the harmonic mode. The operating voltage is 65kV with a total current of 15A, which is divided in to beam lets. Twin beams with voltage 65kV and current 10A and 5A are generated simultaneously with average velocity ratio of 1.4. The emitter operates under temperature limited regime. Computer simulation technology (CST) which is based on finite integration technique is the primary computation tool used for particle tracking simulations.

P3.12 - Formation of Electron Flows for Diagnostic Gyrotrons by Electron-Optical Systems with Multi-Tip Field Emitters

- *Gennadii Sominskii, Evgeny Taradaev*
  Peter the Great St.Petersburg Polytechnic University

- *Vladimir Manuilov, Mikhail Glyavin*
  Insitute of Applied Physics RAS

  The authors have developed silicon multi-tip field emitters with two-layer metal - fullerene coatings suitable for use in miniature high-voltage electronic devices operating in a technical vacuum. Currently, methods are being developed for creating electron flows for diagnostic gyrotrons by electronoptical systems (EOS) with such emitters. The report describes the developed methods for studying the spatial structure and velocity spectrum of the electron flow formed by the EOS. In addition, the first data on characteristics of the flows generated by the EOS is reported.

P3.13 - Some Advantages of the Gyrotrons with Width Emitters

- *Mikhail Proyavin, Mikhail Glyavin*
  Institute of Applied Physics RAS

- *Gregory Nusinovich*
  University of Maryland

- *Olgierd Dumbrajs*
  University of Latvia

The main trends in gyrotron development are escalation of the radiated power and increasing the frequency of coherent radiation. For both trends it is beneficial to develop gyrotrons with wide emitters because this allows one to use cryomagnets with smaller inner bore sizes. For analyzing and optimizing the operation of gyrotrons with wide emitters it is proposed to represent such emitters as a superposition of thin rings and analyze the properties of electron beams emitted by each of these rings. The analysis of electron beam properties, for electron optical systems with different emitters is presented. The possibility to reduce velocity spread by anode profiling is discussed. The dynamics of electron beam and interaction efficiency for different emitters are calculated.

P3.14 - Design of Coaxial Resonator in $TE_{28,8}$ Mode Generator

- *Shuang Chen, Yinghui Liu, Jianwei Liu, Lina Wang, Xinjian Niu*
  University of Electronic Science and Technology of China

- *Liwei Wang*
  Beijing Jiaotong University

In this paper, a three-stage coaxial cavity mode generator for the cold measurement of gyrotron is studied in detail, which uses the mode selection characteristics of the coaxial cavity to convert the input 140 GHz Gaussian mode into the high purity TE28, 8 mode. Based on the first-order transmission line equation and its boundary conditions, we describe the design the structural parameters of the coaxial cavity and verify it by simulation. The TE28, 8 mode generator consists of a Gaussian horn, a convex lens, a quasi-parabolic cylindrical lens, and a coaxial cavity. After numerical programming, the diffraction quality factor of the resonator is 872, and the mode purity is 93.2%.

P3.15 - Study on Beam Phase Correcting for Gyrotron Quasi-optical Mode Converter

- *Guohui Zhao*
  College of Physics and Electronic Engineering Taishan University

- *Qianzhong Xue, Yong Wang*
  Institute of Electronics, Chinese Academy & University of Chinese Academy of Sciences

In this paper, the Katsenelenbaum–Semenov Algorithm(KSA) of beam phase correcting for gyrotron quasi-optical mode converter is introduced. Based on KSA, two models with one phase-correcting mirror and two phase-correcting morrors are designed respectively. Five Gaussian beams at 170GHz with different ellipticity and astigmatism are studied base on above two models. A phase correcting mirror is designed for 170GHz, TE32,9-mode gyrotron quasi-optical mode converter by using KSA. After adding phase correcting mirror into the mirror system, the scalar and vector correlation coefficient on the output window increased by 1.02% and 9.72% respectively.

P3.16 - Study on Beam-Shaping Mirrors Based on Gaussian Beam Propagation Theory

- *Guohui Zhao*
  Taishan University

- *Yong Wang, Qianzhong Xue*
  Institute of Electronics, Chinese Academy & University of Chinese Academy of Sciences

Based on the Gaussian beam propagation theory, the phase correcting of five Gaussian beams with different parameters is studied. A numerical model including two phase correcting mirrors is established to correct the phase of incident beam. The purpose of thses mirrors is to eliminate the astigmatism and ellipticity of the incident Gaussian beams, compensate the phase of the Gaussian beams on the correcting mirror, and obtain the ideal Gaussian beam on the ouput window. After correcting, the vector correlation coefficient between the output Gaussian beams and the ideal Gaussian beams are above 99.1%.

P3.17 - Design Studies of Quasi-Optical Mode Converter for 105 GHz High-Power Gyrotron

- *Debasish Mondal, Surbhi Adya, Aditya Singh Thakur, M.V. Kartikeyan*
  Indian Institute of Technology Roorkee

- *S. Yuvaraj*
  National Institute of Technology Andhra Pradesh

In this paper, the design aspects of the quasi-optical launcher (QOL) and matching optics unit (MOU) are performed for 105 GHz gyrotron. After the interaction cavity and nonlinear taper section, high power RF wave with the cavity mode of TE17,6 need to be converted to Gaussian like mode which can be obtained from a dimpled wall QOL. The Gaussian content of the converted beam is achieved by 99% using commercially available launcher optimization tool (LOT) & Surf3D. Besides, design of a matching optics unit (includes a set of phase correcting mirrors) is carried out using in-house code Gyrotron Design Studio (GDS.V.1.2019) to correct the phase of the off-axis Gaussian beam.

P3.18 - Effect of the Position Variation of the Launcher Cut on the Conversion Efficiency of the Gaussian Beam in a Denisov-type Mode Converter

- *Chen Yang, Wenqi Li, Zhiqiang Zhang, ZhiXian Li, Menglong Jiao, Jirun Luo*
  Institute of Electronics, Chinese Academy of Sciences & University of Chinese Academy of Sciences

- *Min Zhu, Wei Guo*
  Institute of Electronics, Chinese Academy of Sciences

In this abstract, the position variation of the launcher cut was slightly adjusted for decreasing the effect of the diffraction on the launcher conversion efficiency of the Gaussian beam from the TE28,8 mode in Denisov converter, which shows that the Gaussian beam content can be improved indeed.

P3.19 - Design of Mode Converter Based on Genetic Algorithm

- *Qian Wang, Yinghui Liu, Jianwei Liu, Lina Wang*
  University of Electronic Science and Technology of China

As a high-power power source, the output mode of the gyrotron is usually TE0n mode. As a part of high power output system, modal converter plays a very important role. This paper mainly introduces the method of converting TE01 mode to TE11 mode. The traditional TE01-TE11 analog converter is calculated by coupling wave theory and designed by axis function. In this paper, based on the iterative method, genetic algorithm is used to optimize the parameters of the axis function to obtain a more efficient modal converter. The genetic algorithm can optimize the function in the global scope, and the result is more accurate and effective.

P3.20 - End-to-End Design and Thermal Simulation of Energy Recovery Section of Gyrotron

- *Nalini Pareek, Anirban Bera, Hasina Khatun*
  CSIR CEERI

In this work, a single stage, depressed, energy- recovery section has been designed for a 170 GHz, 100kW Gyrotron. The design has been thermally analyzed, using the CST Multiphysics tool, results of which are validated with analytical calculations. The analytical results show good match with the ones generated using CST Multiphysics Software. The design of magnet field profile in the energy-recovery section has also been done, using the Magneto static solver of CST. The electron beam flare length of 100 mm was achieved in the collector. The collector efficiency of 60 % was achieved at a voltage depression of 25kV.

P3.21 - Time Domain Multimode Analysis of a 394-GHz Gyrotron

- *Xuewei Wang, Qianzhong Xue*
  Key Laboratory of Science and Technology on High Power Microwave Sources and Technologies, Institute of Electronics, Chinese Ac

This paper presents the time domain multimode analysis of a 394 GHz gyrotron designed for DNP-NMR. The calculation results show that the gyrotron reached a steady state where both TE261+ and TE261? modes oscillate at 393.87 GHz in time domain and the TE261+ mode dominated the final oscillation,which output power and efficiency are 136.8 W and 3.6%,respectively.

P3.22 - Numerical Investigation on Beam-Wave Interactions of the Resonator in a W-Band Gyrotron

- *Ying-hui Liu, Jian-wei Liu, Xin-jian Niu, Hui Wang, Guo Guo, Lin Xu, Qiao Liu, Yu-jie Zhang, Kai Jia, Hong-fu Li*
  University of Electronics Science and Technology of China

- *Chaojun Lei*
  The Chinese People's Armed Police Force Academy

- *Shuangshi Zhang*
  The Chinese People's Armed Police Force Academy

A W-band high power gyrotron with a gradually tapered cavity has been developed at the University of Electronic Science and Technology of China recently. The TE22,6 mode is selected as an operating mode of the desired gyrotron. The startup-scenario of the electron beam interaction with RF fields under different conditions has been studied with a code, which is based on the quasi-self-consistent nonlinear theory for gyrotrons. Then, a gyrotron with optimized parameters has been designed and constructed. An output pulse power above 300 kW is obtained in the preliminary tests.

P3.23 - Stabilization of Phase and Frequency of an S-Band Magnetron by Injection Locking

- *Seong-Tae Han, Dokyun Kim*
  Korea Electrotechnology Research Institute & University of Science and Technology

- *Jong-Soo Kim*
  Korea Electrotechnology Research Institute

- *Jong-Ryul Yang*
  Yeungnam University

We demonstrated feasibility of magnetron as a promising candidate for the microwave power units constituting a phased array system which enables long distance wireless power transfer, by stabilizing phase and frequency of an S-band magnetron.

Poster Session
Klystrons

P4.1 - Design of a Double-Gap Hughes-Type Coupled-Cavity as a Beam-Wave Interaction Structure for a Ka-Band Extended Interaction Klystron Amplifier

- *Vincenzo A. Zito, Antonino Muratore, Patrizia Livreri*
  University of Palermo

In this paper, the design of a three-cavity interaction structure for a Ka-band Extended-Interaction Klystron (EIK) working at 2? mode is presented. The beam-wave interaction structure is composed of two single-gap cavities followed by a double-gap Hughes-type coupled-cavity to maximize the output power in a wider band. Based on the results obtained with the 3D model developed by CST Studio, the “cold electrical parameters”, necessary to measure the interaction with the electron beam, have been calculated. The structure stability and the synchronization with the electron beam are analyzed. A large-signal analysis is performed by 1D software AJDISK. Under the beam voltage and current of 19.55 kV and 0.95 A, respectively, an RF output power value of 3.8 6 kW and a bandwidth gain value of 37.06 dB have been obtained.

P4.2 - Radial Multigap Resonant Cavity for W-Band High Power EIK

- *Shaomeng Wang, Yuanjin Zheng, Sheel Aditya*
  Nanyang Technological University

A novel angular radial multigap resonant cavity (ARMRC) is proposed for W-band high power extended interaction klystron (EIK). The proposed cavity can operation with an angular radial sheet electron beam (ARSEB), which has larger space-charge limited current than conventional sheet electron beam. As a result, the angular radial EIK based on the proposed ARMRC is supposed to provide higher output power than the conventional sheet beam EIK with the same operation voltage. The high frequency characteristics of the proposed ARMC have been investigated by using high frequency simulation software. The 2?-mode resonant frequencies of the ARMC with different radii, angles and cavity heights have been obtained and discussed. The study provides guideline for the design of a high power angular radial EIK at W-band.

P4.3 - Research on the Competition Mode Suppression in Coaxial Extended Interaction Structure

- *Zhang Xu, Zhang Rui, Wang Yong*
  Aerospace Information Research Institute Chinese Academy & University of Chinese Academy of Sciences

  Extended interaction klystrons operating in high-order mode can establish more sufficient axial electric field than the fundamental mode in a large size cavity. However, this structure suffers greatly from the mode competition because of the combination of axial and transverse modes. This paper presents the mode competition analysis of a coaxial extended cavity operating in TM31 mode through particle-in-cell (PIC) simulation. Meanwhile, applying dielectric loads in the proper position can effectively suppress the mode competition of this structure, while the TM31¬ mode has little interaction with the dielectric loads.

P4.4 - Characteristics of Electric Field Distribution in a G-band Overmoded Extended Interaction Oscillator

- *Che Xu, Lin Meng, Liangjie Bi, Zhiwei Chang, Bin Wang, Hailong Li, Yong Yin*
  University of Electronic Science and Technology of China

  One kind of G-band extended interaction oscillator (EIO) with rectangle cavity model which works on 220 GHz is simulated with CST Eigenmode Solver. The influences of the structural parameters of the cavity on the electric field characteristics, including the gap length and the extension length of the coupling cavity, were simulated and analyzed. In addition, the field distribution, coupling impedance and beam-loaded conductance of the EIO are derived.

P4.5 - Analysis on Resonant Cavities of 231GHz EIA with Trapezoid Subwavelength Holes

- *Yu Ji, Zongjun Shi, Ziqiang Yang, Feng Lan*
  University of Electronic Science and Technology of China

  A novel resonant cavity of extended interaction amplifier (EIA) is designed, combined with a double-grating structure and trapezoid subwavelength holes array structure. The resonant cavity is analyzed when operating at the TM31-2? mode in millimeter-wave band. The electric field distributions, dispersion, Q, and R/Q characteristics are simulated with the different parameter trapezoid subwavelength holes. Compared to the EIA which adopts the resonant cavity with rectangular holes?the one with trapezoid-hole resonant cavity may have a higher gain and wider bandwidth.

P4.6 - Development of a Powerful Small-Sized Continuous Mode Klystron for Communication Systems

- *Dmitriy Komarov, Evgeniy Yakushkin, Alexandr Darmaev, Yuriy Paramonov, Mikhail Kravchenko*
  JSC "RPC "Toriy"

JSC Research and Production Corporation “Toriy” developed and manufactured continuous mode C-band klystron KU-409. The device has small dimensions and light weight and provides a continuous output power of 10 kW and gain of 35 dB

P4.7 - Design of X-Band 20-MW Klystron

- *Toshiro Anno, Yoshihisa Okubo*
  Canon Electron Tubes & Devices co., ltd.

The market of the high power X-band klystron is expanding these days. CETD (Canon Electron Tubes & Devices co., ltd.) is developing a new X-band 20-MW klystron for industrial and scientific applications. The output power of 20 MW covers the gap between about 10 and 50 MW, which gives klystron users new choice. The klystron was designed based on our experience of the existing X-band 6-MW klystron. The electron gun and the electromagnet were newly designed. To decrease the electric field strength in the output section, the 3-cell output cavity was used. In this report, we show the specifications and design details of the klystron.

P4.8 - Numerical Simulation of Electron Bunching Characteristics of Inductive Output Tube

- *Zhi-Hui Geng, Rui Zhang*
  Institute of Electronics,Chinese Academy of Sciences

In this paper, in order to study 650MHz inductive output tube, according to the basic principles of electrodynamics, the influence of the gap and field strength between the cathode and grid, the bias voltage of grid and frequency offset on the modulation density of electron beam is simulated and analyzed, and the verification is carried out by using the three-dimensional electronic optics software.